# PROCEEDINGS OF THE SIXTH CONFERENCE OF THE INTERNATIONAL INSTITUTE OF FISHERIES ECONOMICS AND TRADE




Edited by

Martine ANTONA
Joseph CATANZANO
John G. SUTINEN

TOME I

INTERNATIONAL INSTITUTE
OF FISHERIES ECONOMICS
AND TRADE

ORGANIZED BY
IFREMER

# CONFÉRENCE INTERNATIONALE DE L'IIFET
# 6-9 JUILLET — PARIS

# ACTES DE LA SIXIÈME CONFÉRENCE DE L'ASSOCIATION INTERNATIONALE D'ÉCONOMIE DES PÊCHES

*PROCEEDINGS OF THE SIXTH CONFERENCE OF THE INTERNATIONAL INSTITUTE OF FISHERIES ECONOMICS AND TRADE*

TOME I

Publié par / Edited by :
**M. ANTONA, J. CATANZANO, J.G. SUTINEN**

Institut Français de Recherche pour l'Exploitation de la Mer

COPYRIGHT 1994 ©
IFREMER
155, rue Jean-Jacques ROUSSEAU
99138 Issy-les-Moulineaux
France

## COMITE SCIENTIFIQUE – SCIENTIFIC COMMITTEE

Max Aguero, ICLARM, Santiago, Chili.
Peder Andersen, Ministère des Pêches, Copenhague, Danemark.
Denis Bailly, IFREMER/SEM, France.
Jean Pierre Bertrand, INRA, Paris France.
Joseph Catanzano, Chairman, IFREMER/SEM, France.
Christian Chaboud, ORSTOM, Dakar, Sénégal.
Steve Cunningham, Porstmouth Polytechnic, Royaume Uni.
Artes Ramon Franquesa, Université de Barcelone, Espagne.
Chris Ioannidis, Cardiff Business School, Royaume Uni.
Richard S.Johnston, Oregon State University, Corvallis, USA.
Mustapha Kebe, CRODT/ISRA, Dakar, Sénégal.
Alan Kirman, Institut Européen de Florence, Italie.
Rebecca J.Lent, Université de Laval, Canada.
Susan A.Shaw, Université de Strathclyde, Royaume Uni.
Nana Sinkan, ONU/FAO-CEA, Addis Abeba, Ethiopie.
Massimo Spagnolo, IREPA, Salerne, Italie.
Jon G. Sutinen, IIFET, Chaiman of the Executive Committee,
Université de Rhode Island, Kingston, USA.

## COMITE D'ORGANISATION

Wilem Brugge, CEE DG XIV Programme FAR
Claude Bernet, Secrétariat d'Etat à la Mer, DPMCM
Monsieur le Président du CCPM
Jacques Chabanne, ORSTOM
Daniel Dreumont, Bertrand Tison, Crédit Maritime Mutuel
Michel Laneret, Frédéric Gueudar-Delahaye, FIOM
Joseph Legall, Loïc Jagot, FEDOPA
Alain Parrés, Françoise Bastien, UAPF
Maurice Benoish, Jean-Luc Defeuardent, CCMCM
Jean-ClaudeDetilleux, Crédit Coopératif
Jean Ayral, Joëlle Dari, CFCE-DPA
Pierre Heumann, ORMES

Ann Shriver, IIFET, Executive Director
Joseph Catanzano, Maryline Champin, Yves Henocque,
Philippe Paquotte, Claire Pistor, IFREMER

**Remerciements,**

En tant qu'éditeurs scientifiques, nos remerciements vont tout particulièrement à Philippe Paquotte, du Service d'Economie Maritime de l'IFREMER, pour l'attention qu'il a portée au suivi de ce travail et pour la qualité de son aide.

Session 1 : Fisheries Common Policy
A : Plenary Session ..... 11
B : Institutions and Fisheries Common Policy ..... 29
C : Evaluating the Socio-Economic Impact of the E.E.C. Fishery Policy ..... 53

Session 2 : Aquaculture Sectoral Dynamics
A : General Session ..... 73
B : Panel Session - Salmon Price and Market ..... 119

Session 3 : Fisheries Modelling
A : Multi-objectives Modelling ..... 139
B : Fishermen Behaviour ..... 197
C : Others ..... 223

Session 4 : Aquaculture Enterprise Management
A : General Session ..... 311
B : Panel Session ..... 355

Session 5 : Consumption and Demand
A : Consumption and Demand ..... 413
B : Food Safety ..... 463

Session 6 : International Exchange
A : International Trade Policy and Competition ..... 485

Session 7 : Fishing Enterprise Management
A : Academic ..... 635
B : Fishing Enterprise Mangement ..... 693

Session 8 : Fishing Regulatory Tools ..... 781

Session 9 : Distribution and Processing ..... 949

Session 10 : Market, Price and Production Systems
A : General Session ..... 1047
B : Market Organization and Fisheries Statistics in Japan ..... 1115

Session 11 : Resources Value and Conflicts
A : Resource Valuation and Conflicts ..... 1159
B : Information ..... 1223

Session 12 : Fishing and Development ..... 1269

Session Poster ..... 1367

# Pierre Papon
# Chairman and Chief Executive Officer
# IFREMER

Monsieur le Chairman, Messieurs les Directeurs, Mesdames et Messieurs, je suis heureux de vous accueillir à Paris, au nom de l'IFREMER, à l'occasion des travaux de la VIème Conférence internationale de l'IIFET. Cette Conférence coïncide avec le dixième anniversaire de l'IIFET et je voudrais en profiter pour rappeler brièvement quelques unes des missions de cette institution.

Créée en 1982, sa vocation première aura été de promouvoir le développement d'échanges internationaux en matière de recherche et de coopération dans le monde du commerce des produits de la mer et des politiques de pêche. Ces dix premières années d'existence ont suffi à générer des dynamiques internationales et les 50 pays représentés à l'IIFET en témoignent aujourd'hui. Ce sont en réalité plus de 300 personnes, représentants d'organismes internationaux gouvernementaux, universitaires et professionnels des secteurs public et privé qui se retrouvent associés à l'IIFET. A partir de ces motivations, l'IIFET a su proposer tous les deux ans dans un lieu différent l'un des forums internationaux les plus attendu sur les questions relatives à l'économie des pêches et de l'aquaculture. Veillant à permettre la confrontation des recherches, des expériences de régulation, des pratiques professionnelles, l'IIFET a misé sur l'analyse économique pour prolonger l'analyse des questions de gestion des ressources renouvelables en essayant de susciter chez les autres disciplines des sciences sociales une motivation à venir s'atteler à ces problématiques. J'y vois pour ma part une rigueur certaine sur le chemin de la multi-disciplinarité. L'IIFET a donc joué un rôle important pour stimuler les recherches en sciences sociales qui doivent être un maillon essentiel du processus de prise de décision.

Mais l'IIFET ne s'est pas limité à cela. Trois pôles d'intérêt ont donné lieu à ce jour à la constitution de groupes ou de réseaux qui ont vocation à fonctionner en continu, bénéficiant tous les deux ans de l'opportunité de

Mr. Chairman, Fellow Directors, Ladies and Gentlemen, I am very pleased to welcome you to Paris, on behalf of IFREMER, for the Sixth International Conference of the IIFET. This Conference coincides with the tenth anniversary of the IIFET and I would like to take the opportunity to briefly recall some of the missions which have been entrusted to this institution.

At the time of its creation in 1982, IIFET's primary vocation was to promote international exchange in research and co-operation in the field of fisheries and the trade of sea production. The preceding decade has provided opportunities to generate dynamic international relations and the presence of 50 countries here today is living proof of this reality. In point of fact, more than 300 individuals, representing international government agencies, universities and professional entities from both the public and private sectors are currently associated to the IIFET. Taking into account these different concerns, IIFET has shown itself capable of organizing international forums every two years in different locations, each dealing with pertinent questions related to fisheries and aquaculture economics. Through the encouragement of comparative approaches to research, regulation and professional practises, IIFET has concentrated on economic analysis as a means for assessing the management of renewable resources and has sought to elicit the other disciplines of the social sciences to focus upon this domain. For my part, I believe this rigorous process has been a key to paving the way for more multi-disciplinarity. IIFET has thus played an important role in stimulating research in the social sciences as an essential element in the decision-making process.

However, IIFET has not limited itself to these concerns. Permanent groups or networks have focused on three major topics, acting as bridges and taking advantage of the possibility of meeting every other year within the framework of the Conference. The world market for

rencontres offerte par la Conférence. Le marché mondial des poissons de fond, la salmoniculture et les statistiques des échanges internationaux sont en effet traités au sein de groupes de travail avec des rythmes de publications et de fonctionnement distincts sous un principe commun de large ouverture. Cette Conférence marquera peut-être la naissance d'un sous groupe thématique nouveau qui pourrrait faire de la question des relations Nord-Sud ou encore de la Politique Commune des Pêches des axes de réflexion et de recherche complémentaires. D'autres thèmes encore mériteront certainement au terme de vos débats la poursuite d'une action commune pour laquelle l'IIFET pourrait tenir lieu de fédérateur. Je ne veux pour autant anticiper sur les conclusions de vos travaux. Je resterai attentif, sachez le, à vos propositions dans ce sens.

L'IIFET a encore ceci de particulier, que sa création est intervenue à un moment où les concepts d'aménagement des pêches entraient dans une phase nouvelle. La Convention des Nations Unies sur le Droit de la Mer allait marquer définitivement la reconnaissance à l'échelle internationale de zones d'appropriation de l'espace marin. A un moment où la pleine exploitation générale du potentiel halieutique mondial était admise, cette réforme majeure du Droit International allait poser avec davantage d'acuité encore la question de la gestion des pêcheries, du partage des espaces, des ressources et des richesses qui en découlent. Les récents arbitrages internationaux que la France a connus et le souhait de certains états côtiers de s'approprier des zones maritimes au delà de leurs 200 milles montrent à quel point encore la question de l'appropriation des espaces et des ressources marines reste d'actualité. L'ensemble des questions a fait évoluer la problématique de la gestion des ressources dès la seconde moitié de ce siècle d'un primat de la biologie marine à la pleine reconnaissance des dimensions sociales et politiques de cette question. L'écologie viendra dans le même temps prendre une place nouvelle dans l'explication des causes de diminution des stocks. Plus généralement les relations entre l'exploitation des ressources marines (la pêche et l'aquaculture) et l'environnement marin posent des problèmes nouveaux comme l'ont montré les travaux du CIEM lors de la dernière Conférence de la Rochelle en 1991 et bien sûr les débats de la Conférence de Rio sur l'environnement et le développement. Ces problèmes ne peuvent laisser les sciences sociales indifférentes.

Comme vous l'aurez compris, cette Conférence témoigne de l'importance qu'accorde l'IFREMER aux questions d'économie liées non seulement à l'exploitation des ressources marines vivantes mais aussi, et vous le savez, à leur valorisation, aux marchés qui en dépendent, aux espaces qui les contiennent. C'est cet attachement

deep-sea fishing, salmon farming and statistics dealing with international exchange are thus treated within these work groups, with specific publication and organizational time frames, all operating with the same open-minded principle. This Conference will perhaps spawn a new sub-group which will concentrate on North-South relations or Common Fisheries Policies as a focus for reflection and complementary research. Other subjects may, at the conclusion of your debates, appear as worthy of your attention, with IIFET acting as the federating force. I do not want to anticipate on the conclusions which will result from your work. Allow me simply to say that I will remain open to your proposals in this spirit.

IIFET benefits from another specific advantage since it was created at a time when the organizational and management concepts relating to fisheries were entering a new phase of development. The United Nations Convention on Maritime Law was a decisive step in the recognition, at an international level, of appropriation zones for the maritime environment. At a time when the full general exploitation of the world's fisheries resources became an accepted principle, this major reform of International Law was a determining factor in accurately posing the fundamental question of the management of fisheries and the ensuing share of space, resources and wealth. Recent international arbitration involving France and the desire of certain coastal countries to appropriate maritime zones beyond their 200-mile limits demonstrate that the questions of space and resource appropriations remain critical issues. These questions taken as a whole have influenced the management of resources in this second half of the century to evolve and, what were previously preoccupations limited to the field of marine biology, have now been recognized in terms of their overall social and political impact. Ecological concerns have simultaneously contributed to the explanation of the reduction of stocks. On a more general basis, the relation between the exploitation of maritime resources (fisheries and aquaculture) and the maritime environment poses new questions, as demonstrated by the discussions of the ICES during their last Conference in La Rochelle in 1991 and, of course, the debates of the Rio de Janeiro Conference on Development and the Environment. These questions cannot be ignored by the social sciences.

You are certainly aware of the fact that IFREMER, as this Conference demonstrates, is not only sensitive to questions linked to the exploitation of living marine resources, but also, as you know, to what we term their value enhancement and derivative industrial applications in the markets and the zones involved. This involvement was in fact the reason why IFREMER, from its very

qui avait d'ailleurs conduit l'IFREMER à se doter, dès sa création, d'une équipe d'économistes spécialisés sur ces questions. Sans cette initiative, cette VIème Conférence ne se déroulerait certainement pas en France aujourd'hui.

Lorsque l'IFREMER s'est porté candidat dès 1988 à l'organisation de cette sixième Conférence, nous savions que ce rendez-vous se ferait à un moment où l'Europe des pêches s'avance vers des étapes majeures de sa construction. Nous ne pouvions prévoir par contre qu'entre temps, d'autres événements ajouteraient à l'opportunité de vos travaux en ce lieu, à cette date.

Pour n'en retenir que quelques uns, j'évoquerai tout d'abord les évolutions historiques que connaissent les pays de l'Est. Le redécoupage des anciennes Républiques Soviétiques et l'unification de l'Allemagne s'accompagnent en effet de la remise en cause des fondements économiques internes à partir desquels se déterminaient les choix et les modes de production tout autant que les flux d'approvisionnement et d'échanges de ces pays. Lorsque l'on sait le poids de ces pays dans l'exploitation des ressources marines vivantes, le volume de la demande potentielle qu'ils représentent, leur position dominante sur certains marchés, les zones d'activité de leurs flottilles dans certains PED, on entrevoit aisément l'ampleur des ajustements à attendre. Un pas définitif est franchi qui rapproche maintenant l'ensemble des pays producteurs face à des principes de régulation et de partage identiques. Il est intéressant de noter à ce propos que là où les pays à économie planifiée avaient intégré les mécanismes de marché pour accéder à des droits de pêche, les pays à économie capitaliste, et c'est notamment le cas dans la C.E.E., se sont engagés eux dans la voie de l'interventionnisme public pour contraindre les mécanismes de marché.

Un autre événement sur lequel l'actualité récente nous interpelle ces jours ci, est le processus de ratification du Traité sur l'Union Européenne. On savait, et vous aborderez cet aspect de la Politique Communautaire lors de vos débats, que le calendrier européen pour les Pêches marquait en cette fin d'année 1992 l'entrée dans la préparation de 1996 et 2002. Le rapport intermédiaire de 1991 sur la Politique des Pêches en est le trait d'union. Le traité de Maastricht en toile de fond vient ajouter une dimension à certaines interrogations que soulevaient déjà avec acuité les questions de gestion des ressources marines. La subsidiarité telle qu'elle est définie dans le texte du Traité ainsi que le principe de précaution de l'article 130R (Titre XVI sur l'environnement) ne manquent pas de nous interpeller dans ces temps où la place de l'avis scientifique et l'avis des économistes sont de plus en plus sollicités et où chacun des Etats, chacune des structures professionnelles du secteur s'interroge sur

creation, included a team of specialized economists working on these questions. Without this initiative, this Sixth Conference would certainly not be taking place in France today.

When IFREMER submitted its candidacy as of 1998, to organize this Sixth Conference, we knew then that this meeting would occur at a time when European fisheries would advance toward major stages in its construction. We could not however foresee at the time that other events would take place which would add to the significance of our work at this time and in this place.

Without being exhaustive, it is important to mention major events such as the historic changes that have taken place in the countries of Central and Eastern Europe. The redefinition of the former Soviet Republics and the reunification of Germany have occurred at the same time as the reassessment of internal economic foundations which determine both the modes of production and the supply and exchange flows between these countries.

When we consider the weight of these countries in the exploitation of living marine resources, the potential volume of demand that they represent, their dominant position on certain markets and the activity zones of their fishing fleets in certain developing countries, it is possible to have an idea of the necessary adjustments that will have to be made. A decisive step has been taken in that all producing countries have operated a rapprochement in applying identical regulatory and sharing principles. It is interesting to note in this respect that the countries with planned economies had integrated certain market mechanisms to gain fishing rights while capitalist countries, and notably the EEC, committed themselves to interventionist policies to constrain the effects of the market.

The process of ratification of the Single European Treaty is another major event which will have impact in our field. It is a known fact that in terms of Community Policy, which you will deal with in your discussions, the European fisheries calendar at the end of 1992 is leading toward the preparation of 1996 and 2002. The 1991 intermediate report on Fisheries Policy is a stepping stone in this direction. In the background, the Maastricht Treaty adds another dimension to certain pertinent questions concerning the management of marine resources which were in the process of being examined. Subsidiarity, as defined in the Treaty, as well as the principle of precaution in Article 130R (Heading XVI on the environment) continue to solicit our interest at a time when scientists and economists are increasingly called upon to express their points of view and where States and professional bodies are questioning themselves on the role they will play in the preparation and orientation of

la place qu'ils vont devoir tenir dans la préparation et l'orientation du secteur. Nul doute que tous les acteurs du secteur porteront la plus grande attention à vos conclusions sur ces points.

Enfin, et les professionnels français le savent déjà, si l'actualité mondiale a porté la Conférence de Rio en tête d'affiche durant quelques mois, c'est davantage la revendication écologiste qui va vous conduire en tant qu'économistes des ressources et des espaces marins à prendre de plus en plus en compte de nouvelles options d'usage, de nouvelles revendications sociales. A bien des égards, les questions environnementales portées par de larges effets médiatiques trouvent dans vos acquis et réflexions déjà anciennes des réponses adaptables pour la gestion d'autres ressources communes. Aider à définir des règles de régulation, s'interroger sur les interactions entre politiques publiques et choix individuels, déterminer la valeur de ressources patrimoniales marines... autant de questions pour lesquelles l'ensemble des pays et des décideurs sont en attente de réponses. Les sciences sociales, je le soulignais il y a quelques instants, ont là un vaste champ soumis à leurs investigations. Gageons que vous saurez prolonger vos travaux dans l'avenir pour faciliter leur choix.

Bien d'autres questions encore, j'en suis certain, viendront animer vos débats : le devenir et les potentiels promis par l'aquaculture, le rôle des ressources marines vivantes dans le développement des PED, la place enfin de ces ressources face à la gravité du paradoxe mondial de la malnutrition... Là encore l'avantage et l'intérêt que représente ce forum international doivent porter des fruits.

Je voudrais pour conclure affirmer à nouveau toute l'importance d'une recherche construite sur la plus large coopération internationale et très largement pluridisciplinaire, bénéficiant à tous (pays du Nord et du Sud) et nourrie du plus grand nombre de références face à un monde politique et économique dont les événements récents et les déséquilibres pérennes nous laissent entrevoir encore quelques écueils sérieux sur la route de la compréhension et de la prédiction. Je souhaite, pour finir, un plein succès à vos travaux qui porteront, j'en suis certain, encore plus en avant nos possibilités de coopération.

our sector of activities. There is no question that the actors in our field will be highly attentive to your conclusions on this point.

Finally, it is important to mention a point which French professionals today are aware of and that the Rio de Janeiro Conference brought to the forefront in the last few months: i.e. the increased pressure of ecologists which will lead you as economists dealing with resources and the management of the marine environment, to increasingly take into account new operational options and heightened social demands. In large part, the environmental issues which have been amplified by spectacular media effects are mere reflections of adaptations which you have been carrying out for a long time in the management of other common resources. In helping to define the rules for regulation, in asking questions on the interaction between public policies and individual choices and in determining the value of our marine resource heritage, you are dealing with questions for which all countries and their decision-makers are seeking responses. The social sciences, as I mentioned earlier, are a vast domain which can benefit from your investigations. I am willing to wager that you will be capable of extending your work in the future to facilitate their choices.

I am convinced that there are many other questions, which will enliven your debates: the future and potential of aquaculture, the role of living marine resources in the developing countries and finally the influence of resources in the grave and paradoxical problem of malnutrition in the world. In this regard, the advantages and interest of this international Forum should bear its fruits.

I would like to conclude by affirming once again the importance of research built upon the widest degree of international co-operation, as multi-disciplinary as possible, benefiting all countries in both the North and the South and enhanced by the greatest number of references in a highly political and economic world where recent events and lasting imbalances continue to demonstrate that there are serious shortcomings in our attempts at comprehension and prediction. I would like to wish you, finally, great success in your work which, I am convinced, will further contribute to our possibilities for co-operation.

# Joseph Catanzano
# Chairman Scientific Committee VI Conference, 1992 Paris

En préparant cette Conférence, lors de voyages dans des pays extérieurs à la Communauté Européenne, j'ai pu constater avec satisfaction mais aussi avec étonnement en quelques cas, toute l'attention que portaient les économistes et les responsables nationaux des ressources marines au fabuleux chantier et défi que représente la Politique Commune des Pêches. Pour ceux qui sont le plus souvent affairés au cœur même de la construction ou de l'application de cette politique commune, cet intérêt extérieur a permis de mieux prendre conscience de l'ampleur de ce projet au plan international.

Mais cet intérêt particulier ne se limitait pas exclusivement à la question de la gestion des ressources marines vivantes. Il révélait également, à la veille des changements importants placés dans l'agenda communautaire pour 1993, quelques inquiétudes quant au devenir des marchés internationaux, aux évolutions des activités aquacoles et aux étapes de développement des pays les moins avancés.

Pour le Comité Scientifique œuvrant à la préparation et au suivi de cette Conférence, il est apparu très vite que l'Europe Bleue allait nous permettre de décliner la plupart des thèmes de l'économie des pêches et de l'aquaculture ; depuis le fonctionnement des entreprises jusqu'aux politiques publiques de régulation. Ainsi fut-il décidé de consacrer l'ouverture de la Conférence à l'évocation de cette Politique Européenne Commune donnant ainsi aux responsables politiques nationaux, responsables européens et économistes des pêches, l'occasion de débattre de quelques éléments clefs de cette initiative internationale unique.

Au delà de ce thème, le Comité Scientifique a voulu au terme de l'évaluation des propositions d'intervention offrir au plus grand nombre de candidats l'occasion de présenter et discuter leurs travaux de recherche. Il faut dire que la qualité des textes proposés nous a fait rapidement oublier la difficulté qu'allait représenter,

As I was working on this conference, during the trips I have made to non-EC member states, I was pleased and sometimes amazed to note the great attention that economists and national representatives of marine resources were focusing on the Common Fisheries Policy. For those who are busy trying to build or apply this common policy, this external interest has increased awareness of the importance of this project at an international scale.

However, this particular interest went far beyond the question of the management of living marine resources. It has also revealed, on the eve of the important changes occuring in the 1993 EC agenda, some concerns as to the future of international markets, the development of aquaculture activities and the development of the least advanced countries.

For the Scientific Committee which was preparing this conference, it soon became apparent that the "Blue Europe" would enable us to include most of the subjects regarding the economics of fisheries and aquaculture : from the functioning of companies to public regulation policies. Therefore, it was decided to focus the opening of this conference, on CFP thus enabling national political officials, european representatives and fisheries economists to debate of some of the key elements of this unique international initiative.

Apart from this subject, the Scientific Committee intended, at the end of the evaluation of propositions, to give the opportunity to most of the candidates to present and discuss their research work. It is necessary to mention that the quality of the texts proposed made us easily forget the difficulties inherent in programming 115 communications. You can imagine the intellectual enrichment from this, equalled only, I think, by the anxiety at the time of organizers.

As a follow-up step for the conference, the publication of the proceedings has occupied us for more than a year now giving us the opportunity to reinforce the links that we have established with most of you.

inévitablement, la programmation de 115 communications. Vous pouvez imaginer l'enrichissement intellectuel que l'on en a retiré et qui n'a eu d'égal à l'époque, je crois, que l'angoisse des organisateurs.

Prévue dans la continuité de la Conférence, l'édition scientifique des actes nous a occupé plus d'un an nous offrant l'occasion de poursuivre avec la plupart d'entre vous de multiples échanges.

Aujourd'hui, l'ensemble de ces communications est contenu dans deux tomes qui s'organisent en référence au déroulement réel de la Conférence, selon douze sessions distinctes.

Ces deux tomes qui regroupent les textes exposés à Paris, fournissent une revue exceptionnelle en économie à propos des questions d'aquaculture, de consommation, de demande, de valorisation, de distribution et d'échanges internationaux des produits de la mer, d'outils de régulation pour les systèmes pêche (production et marchés). Y sont traitées également les questions de modélisation des pêches, de conflits d'usage ou d'appropriation, les méthodes de mesure de la valeur des ressources, les questions enfin du développement et celles de la Politique Commune des Pêches.

Ils sont enrichis d'une grande diversité de cas qui vous permettront sur chacune des questions de mettre en comparaison vos propres références et les situations rencontrées sur les divers Océans pour l'ensemble des continents de la Planète.

Afin de disposer d'une présentation sommaire du contenu des sessions, nous avons retenu le principe de livrer avant chacune d'entre elles, un texte introductif court, destiné à vous renseigner brièvement sur l'état de l'art à propos de ces sujets mais aussi sur les questions spécifiques abordées par chacun des auteurs.

Ainsi, vous pourrez disposer à ce niveau d'une vision synthétique de chacune des sessions. Je suis convaincu que celle-ci vous engagera très vite à la lecture des textes rassemblés, vous facilitant par la suite l'utilisation continue de ces documents.

Participant à ces rédactions, des chercheurs ont bien voulu prolonger à nos côtés leur engagement initial et je pense que l'usage que vous saurez faire de ces deux tomes durant les années à venir, sera, pour eux, à côté des remerciements que nous leur renouvelons ici, la meilleure des reconnaissances.

Now, the complete set of papers as been compiled into 2 volumes which have been organized into 12 distinct sessions, according to the presentation of the conference.

These 2 volumes give an exceptionnal economic review regarding the questions of aquaculture, consumption, demand, marketing, distribution and international exchange of maritime products and methods of regulation of the fisheries systems (production and distribution). They also deal with the issues of modelling of fisheries, use and appropriation conflicts, methods of resource valuation and finally with the questions of development and the CFP.

They are enhanced by a wide variety of case-studies which will enable comparisons to be made between the situation in your aera and that in other aeras of the world.

In order to give a summary presentation of the content, we present before every session, a brief introductory text giving you concise information about the state of art and the specific questions dealt with by each authors.

This will give you a overview of each session which, I am convinced, will help you read the texts, thus facilitating at a later stage the regular utilization of these documents.

By contributing to these volumes, researchers have continued their initial engagement with us and I think that your best vote of thanks for their efforts will be the use that you will make of their work now and in the future.

# Intervention de Monsieur Charles Josselin Secrétaire d'Etat à la Mer, France

Monsieur le Président, Mesdames, Messieurs

Je suis particulièrement heureux de pouvoir faire part de réflexions qu'inspirent, à l'homme politique que je suis, les principaux enjeux de l'économie des pêches maritimes mondiales, devant une assemblée d'experts de toutes les régions du globe.

Des économistes du monde entier sont en effet venus ici confronter leurs expériences, informer de l'état d'avancement de leurs travaux théoriques et rechercher ensemble les solutions au problème majeur de la pêche mondiale : la gestion de la ressource. Il s'agit d'un patrimoine collectif commun, heureusement renouvelable. Le bilan établi en septembre 1991 à la Toja près de Vigo par les Ministres des pays les plus concernés par la pêche, avait déjà mis en évidence deux conclusions essentielles en ce domaine :

d'une part, l'économie des pêches maritimes s'est mondialisée depuis dix ans,

d'autre part, la production s'est considérablement accrue depuis quarante ans : elle était de 15 millions de tonnes en 1950 ; elle avoisine les cent millions de tonnes en 1990.

L'afflux constant des nouvelles capacités de capture et le progrès spectaculaire des technologies donc de la productivité, expliquent cette évolution. Mais – et c'est un signal pour nous tous – la production mondiale a, pour la première fois, régressée en 1990, le mouvement se confirmant en 1991. Je suis pourtant convaincu que ni le développement des initiatives, ni la modernisation des technologies ne constituent en eux-mêmes un danger. Ils ne le deviennent que si le mouvement est incontrôlé, si les captures deviennent excessives au regard du potentiel offert par la biomasse – et le problème est loin d'être seulement européen – !

La nouvelle donne de la pêche mondiale dans les années 1990 doit par conséquent être dominée par la maîtrise équilibrée entre les capacités de capture et les stocks. Pour cela il est clair qu'on ne peut s'en remettre uniquement au jeu du marché. Il doit donc y avoir des règles et des normes. Il doit donc y avoir des outils de régulation de la ressource. Ces constatations valent pour l'ensemble des pêches du globe et c'est dans cet esprit que le principe d'une Conférence Mondiale de la Ressource en 1993 en Inde a été retenu. Mais elles valent aussi en Europe, dont la politique commune des pêches constitue pour vous un laboratoire de ce que peut être un régime de gestion et de conservation des ressources halieutiques. C'est dans ce cadre que je voudrais inscrire mes réflexions. Même si l'importance de la pêche dans l'économie européenne peut paraître réduite son poids relatif est en fait beaucoup plus important. L'activité de pêche se concentre en effet dans des zones littorales et insulaires dont elle est le support principal pour le maintien du tissu économique et social.

Toute stratégie de régulation de la ressource se heurte ainsi dès l'abord, et parce que son impact est considérable, à cette redoutable gageure de la nécessité de préserver une activité économique, tout en assurant la bonne gestion d'une ressource halieutique dont la principale caractéristique est d'être limitée.

En d'autres termes, la pêche est constituée d'hommes et d'entreprises qui ont des aspirations, des ressorts psychologiques et économiques : gagner de l'argent pour investir, préserver l'emploi, vivre décemment de leur travail, innover. En outre l'économie des pêches maritimes doit également prendre en considération des aspects périphériques mais essentiels liés par exemple à l'environnement et à l'aménagement du territoire. Sans même parler à ce stade d'outils techniques, toute régulation de la ressource qui ne s'appuierait pas sur ces motivations, ou pire encore irait à leur encontre, ne peut courir qu'à l'échec. Ce sont ces aspects, qui donnent une dimension politique à ces problèmes et qui sensibilisent fortement le Ministre de la Mer. Dès lors, nous ne pourrons avancer en ce domaine qu'à deux conditions :

1. que toutes les décisions publiques soient fondées sur des données scientifiques incontestables. Ouvrir trop grand le parapluie de la prudence pour masquer l'ignorance de phénomènes mal maîtrisés ou sacrifier à des théories insuffisamment fondées n'est pas acceptable. Il serait d'ailleurs souhaitable que les associations qui se donnent la juste cause de la défense de l'environnement se dotent dans le domaine des pêches d'un solide appareil scientifique ;

2. que les professionnels de la pêche soient associés, au préalable, aux décisions.

D'abord parce que leur point de vue complète souvent très utilement celui des scientifiques, ensuite parce qu'aucune décision ne peut être sérieusement appliquée si elle n'est pas perçue comme nécessaire et génératrice de progrès à terme. Il est par conséquent de la responsabilité des décideurs, comme de celle des scientifiques, de faire preuve de la plus grande pédagogie afin que le message, quel qu'il soit, pour être reçu, soit clair, simple et incontestable. C'est dans cet esprit que je n'ai pas hésité à reprendre à mon compte l'initiative de mon prédécesseur Jean Yves Le Drian, de réunir des Etats Régionaux de la Ressource.

Ces Assemblées, qui associent au niveau régional l'ensemble des parties prenantes – professionnels, scientifiques, élus, administration – dans le domaine de la pêche, devront d'ici l'automne prochain dresser le bilan des difficultés de gestion de la ressource – côtière ou communautaire – auxquelles elles se trouvent confrontées, et formuler des propositions d'amélioration.

Je tenais avant d'évoquer les thèmes qui sont l'objet de votre débat, à poser les principes qu'il me paraît essentiel de conserver à l'esprit.

La réflexion proprement dite sur les modalités de gestion des pêcheries me semble comporter au moins trois volets :

une réflexion sur les outils de régulation de la ressource ;

une réflexion sur les institutions le plus aptes à les mettre en œuvre ;

une réflexion sur les moyens de contrôle nécessaires à leur efficacité.

Les réflexions qui sont les miennes sur ces différents sujets seront nécessairement marquées par l'exemple européen, que je vis tous les jours, de la politique commune des pêches.

Les outils de régulation actuellement en usage peuvent se décomposer en deux familles :

les outils de gestion de la ressource (Tacs, quotas, mesures techniques...) ;

les outils d'accès à la ressource et de maîtrise de l'effort de pêche (permis de mise en exploitation, licences, quotas individuels, quotas individuels transférables).

Le système des Tacs et des quotas, ainsi que les mesures techniques de conservation de la ressource – maillages notamment – représentent les mécanismes les plus traditionnels qui ont fait leurs preuves, même s'il est possible d'améliorer leur efficacité.

De ce point de vue, la réflexion actuellement engagée en Europe porte sur la fixation de quotas sur une base pluriannuelle et non plus annuelle et sur les quotas multispécifiques. Cette idée semble répondre à une nécessité pour le pêcheur, dont l'entreprise a besoin de perspectives de fonctionnement sur une durée suffisamment longue. Il convient toutefois qu'une analyse et une expérimentation suffisamment approfondies d'un tel mécanisme confirment ou infirment sa validité. La détermination des mesures techniques quant à elle, pour être comprise donc admise par le pêcheur, doit reposer sur des données scientifiques incontestables. Mais la rigueur, la souplesse, la progressivité doivent aussi présider à leur fixation, par exemple lorsqu'il s'agit des problèmes de maillage.

Il est indispensable en second lieu, pour adapter les capacités de capture aux stocks disponibles, de contrôler l'accès à la ressource.

Les programmes d'orientation pluriannuels définissent ainsi, pour chaque Etat-membre de la C.E.E. et sur une période de cinq ans, le taux de réduction des flottilles.

C'est dans le même ordre d'idée que la France a, au titre des mécanismes d'entrée en flotte, mis en œuvre depuis plusieurs années un permis de mise en exploitation. Les critères retenus à cet effet combinent les indications liées à l'état

de la ressource et la productivité des différents types de navires. La segmentation peut en effet paraître une solution opportune, dans la mesure où elle différencie l'évolution nécessaire des flottilles s'adressant à des ressources dont l'état n'est pas uniforme. Il convient toutefois de prendre garde aux limites d'une telle approche :

la première pourrait être l'incertitude relative des connaissances scientifiques. Jusqu'ici l'évaluation des stocks déterminait seulement la fixation des prises maximales. Avec la segmentation prenons garde à ne pas figer la maquette d'évolution de différentes flottilles pour de nombreuses années, les investissements conduits, compte tenu de leur importance, engageant le long terme. Est-on sûr que les connaissances scientifiques soient assez précises pour fonder des conséquences aussi lourdes?

La seconde limite à respecter est l'indispensable souplesse de l'activité de pêche : une segmentation trop détaillée peut bloquer le redéploiement des entreprises vers de nouveaux métiers, de nouvelles ressources. On voit bien que par ce biais nous atteignons déjà un niveau plus grand de contraintes qui est celui des licences dont l'objet n'est plus seulement de contrôler les entrées en flotte mais l'ensemble des navires en flotte. Un troisième et un quatrième degré en la matière est constitué par l'instauration de quotas individuels voire de quotas individuels transférables qui en établissant une forme d'appropriation de la ressource, rompent avec la tradition qui en fait une "res communis" et posent la redoutable question de sa patrimonialisation. Prenons garde au risque majeur que constitue la fixation étroite de situations acquises : toutes les sociétés européennes souffrent encore de l'existence de secteurs économiques où, généralement sur la base des meilleures intentions – éviter une surproduction, protéger les consommateurs ou les producteurs – on a artificiellement créé des droits d'exploitation exclusifs.

L'initiative et la compétition deviennent impossibles, l'accès à la profession est mis aux enchères. Demeurons attentifs également aux difficultés de gestion et aux incohérences économiques qui résulteraient d'une régulation des captures par les temps de pêche. Comment imaginer en effet qu'une entreprise ne s'efforce pas d'utiliser à plein l'instrument dans lequel elle a investi, et dont le coût — en termes de fonctionnement et d'amortissement – oblige au contraire à optimiser son activité. Doit-on s'orienter dans cette voie ou au contraire privilégier pour l'adaptation durable des capacités de capture le strict contrôle des entrées en flotte, et quand c'est nécessaire, l'incitation à l'arrêt définitif, gérée aussi bien que possible du point de vue économique et social ? Ces questions font actuellement l'objet de débats dans bien des enceintes scientifiques et politiques. Je souhaite que vos travaux d'aujourd'hui permettent d'avancer dans la connaissance et l'analyse de ces mécanismes et de leurs effets afin d'éclairer les décisions que les politiques ont (ou auront) à prendre en ces matières. Les responsables politiques doivent pour leur part faire prévaloir une organisation à l'accès à la profession et à la ressource, qui s'appuie sur les capacités professionnelles et la formation des pêcheurs, sur la qualité de leurs projets, du point de vue de la ressource et des perspectives économiques, et sur l'équilibre des entreprises existantes.

Vos travaux portent également sur les institutions les plus aptes à mettre en œuvre ces outils.

De ce point de vue, il semble préférable que leur gestion obéisse au principe de subsidiarité récemment affirmé au niveau communautaire, qui consiste à en attribuer la responsabilité à l'échelon de compétence – communautaire, national ou régional – le plus adapté.

S'il existe une responsabilité qui, à l'évidence relève du niveau national, c'est le contrôle.

Mais l'enjeu du contrôle, déterminant pour le succès de toute politique de régulation de la ressource, lui aussi doit au préalable et dans l'esprit que j'évoquais tout à l'heure, être compris de tous, qu'il s'agisse du professionnel, pêcheur ou partenaire de la filière, du consommateur, voire du juge.

En clair il est nécessaire que l'opinion publique prenne conscience du préjudice que causent les infractions à l'économie des pêches, et par là même à la collectivité toute entière. Il faut aussi que le contrôle soit crédible et donc réellement dissuasif. Il convient enfin que soit respecté le grand principe des libertés publiques selon lequel toute limitation d'une liberté doit être strictement proportionnée à son objectif. Les nouvelles technologies de contrôle – satellite notamment – ne peuvent éluder les questions relatives à leur bilan coûts-résultats, ou celles qui se posent en termes de coût social – liberté individuelle, protection du savoir-faire –.

Je ne voudrais pas terminer mon propos sans évoquer une question qui, tout en étant à la périphérie de la régulation de la ressource, en constitue pourtant un point central, tant il est vrai que la gestion de la ressource doit être conçue en synergie avec les aspects liés au marché. Il est en effet tout à fait essentiel, au moment où la situation de la ressource et l'adaptation des capacités contractent les débarquements en volume, de rechercher, sans relâche, la valorisation.

Celle-ci passe à l'évidence par une meilleure connaissance des marchés alimentaires des produits de la mer, et par une action cohérente de tous les acteurs de la filière, pour y adapter les processus de production et de commercialisation. Elle suppose également :

> une politique d'adaptation des captures et de programmation des débarquements que peuvent soutenir des mécanismes comme ceux qui sont en vigueur au titre de l'organisation commune des marchés ;
>
> une politique de qualité à bord, en criée et dans les circuits de commercialisation : les techniques de conservation, de débarquement, de vente, de transformation doivent assurer à cet effet le consommateur d'une qualité régulière, qui peut d'ailleurs faire l'objet d'une certification, comme on commence à le voir dans certains ports de Bretagne et de Méditerranée. Les règles sanitaires européennes comme la politique de qualité récemment initiée au niveau communautaire, participent de cette logique. On l'a vu, le défi est majeur, les solutions nombreuses mais difficiles à mettre en œuvre et s'adressent le plus souvent à une population dont le maintien de l'activité de pêche est une condition de survie économique. Il est de notre responsabilité de décideurs de concilier le souhaitable et le possible en appréciant au préalable l'impact économique et social des mesures prises, quel que soit leur bien-fondé.

Vos travaux constituent à cet égard une base indispensable à la prise de décision. Je suis convaincu qu'une telle conférence peut largement contribuer à cet objectif. Je tenais en concluant mon propos à vous en remercier. Je souhaite une pleine réussite à vos travaux.

# The Common Fishery Policy
# by
# J. Catanzano

La Politique Commune des Pêches (PCP), s'impose au plan international comme l'un des exemples majeurs sur la voie de la recherche de modalités fonctionnelles viables, équitables et communes à plusieurs pays dont la finalité globale s'expose en termes de recherche d'adéquation entre système de production, dynamique des ressources halieutiques et dynamiques des marchés.

Trouvant son autonomie de définition et de mise en œuvre à partir de la Politique Agricole Commune et sur les fondements du Traité de Rome, la PCP représente aujourd'hui l'un des projets les plus ambitieux de la construction européenne, étant à certains moments de l'élargissement de la Communauté l'un des dossiers les plus sensibles (Espagne et Portugal hier, Islande et Norvège demain). Sorte de « mal nécessaire » aux dires de certains, il n'est aucun des pays qui puisse aujourd'hui renoncer à ce cadre de traitement des problèmes de la pêche tant il est vrai que les changements du contexte juridique international (Nouveau Droit de la Mer), ont forcé définitivement à la mise en commun des ressources européennes contraignant encore davantage les possibilités de redéploiement de flottilles excédentaires des pays membres.

Sur cette voie d'une politique commune, les difficultés que rencontrent les institutions européennes tiennent :

1 - d'une part aux embûches inhérentes à la complexité du projet - qui vise à mettre en commun pour gérer, des ressources non appropriées -,

2 - et d'autre part aux effets multiplicateurs qui tendent à rendre encore plus complexes, variés et étendus, les problèmes afférents aux modes de production, aux marchés, aux institutions, aux stocks, aux contextes socio-politico-économique... Là où déjà, classiquement, sur le cas de simples pêcheries

The Common Fisheries Policy is seen, at an international scale, as one of the major examples in the search for functional methods that are viable, impartial and common to many countries whose general purpose is to balance production systems, dynamics of fisheries resources and markets.

Deriving its definition and implementation from the Common Agricultural Policy and the foundations of the Treaty of Rome, the CFP represents one of the most ambitious projects of European construction: it is one of the most delicate items at a time when the community is extending (first the adhesion of Spain and Portugal and, in the future, Iceland and Norway). None of the countries is able nowadays to avoid dealing with fisheries problems in such a context which is considered by some as a "necessary evil". Besides, the changes which have occurred in the international judicial context (New Law of the Sea) have compelled the sharing of European resources, thus limiting further the possibility of redeploying the surplus of member states fleets.

In their objective to reach a common policy, European institutions are encountering two major difficulties:

1 - obstacles inherent to the complexity of the project which aims at sharing non appropriated resources in order to manage them;

2 - multiplying effects which tend to increase the complexity, variety and range of problems relative to productive means, markets, institutions, stocks, socieconomic and political context... In the classical case of national fisheries, we find it hard to deal with complex systems subject to intense variabilities and to situations managed with great uncertainty; but in the CFP, we have a case study which is extraordinarily developed in the process of multiplying complex phenomena.

nationales on souffre d'avoir à traiter de systèmes complexes soumis à de fortes variabilités, à des situations régies sous incertitude, on trouve au travers de la PCP un cas d'observation extraordinairement avancé sur la voie de la démultiplication de phénomènes complexes.

A la fin de sa deuxième décennie d'existence et à la veille de l'entrée en vigueur du grand marché européen (1er janvier 93), il apparaissait opportun de profiter de cette conférence pour mettre en auscultation la PCP. L'occasion offerte allait trouver son originalité dans la confrontation directe de responsables européens (Directeurs des volets Structures, Marché et Ressources Internes de la Direction Générale des Pêches de la Communauté Européenne), les responsables nationaux chargés de sa préparation et de sa mise en œuvre (Direction des Pêches en France), les acteurs professionnels du secteur et enfin les économistes des pêches intéressés, ici ou ailleurs, aux problèmes de la gestion des pêches.

Au travers de cette session il nous est donné de mieux comprendre les critiques adressées à la PCP par chacun des observateurs, acteur du système ou extérieur totalement à ses institutions. Ces propos rejoignent souvent le rapport 1991 de la Commission, sorte d'introspection à partir de laquelle P. Andersen mettra en exergue les voies d'évolution proposées pour améliorer globalement l'efficience des mécanismes européens. On y retrouve posé comme principe de réforme :

(i) la mise en œuvre effective de la subsidiarité dont on sait qu'elle renvoie en préalable à l'identification d'unités d'aménagement et à une meilleure connaissance des institutions et des mécanismes qui sous-tendent leurs actions,

(ii) la reconnaissance d'un *numerus clausus* concrétisé au travers d'une licence européenne, supposant en préalable une amélioration des modes de contrôle, de plus fortes incitations au respect des règles existantes, une meilleure programmation de la politique structurelle placée dans le cadre général des Fonds Structurels européens et enfin une réflexion sur les effets nés de la combinaison de licences et de quotas.

On peut imaginer à l'énoncé de ces seuls principes et à l'inventaire des préalables qui s'y rattachent, les nombreux chantiers qui s'ouvrent aux économistes. De part les questions posées, on prend conscience des imbrications qui existent entre mécanismes décisionnels avec les présupposés politiques qui les accompagnent, et recommandations d'experts économistes. P. Andersen s'interroge à ce propos sur les faibles échos donnés à ces recommandations. S'il semble que la réponse se trouve

At the end of the second decade of the existence of the CFP and on the eve of the implementation of the European Market (January 1st, 1993), this conference provided the opportunity to examine the CFP in depth. One original aspect of the conference consisted in the direct confrontation of European officials (Directors for Structures, Market and Internal Resources of the General Department of Fisheries of the European Community), national officials in charge of its preparation and implementation (Fisheries Department in France), professionals of the sector and fisheries economists involved, here and elsewhere, in the problems of the management of fisheries.

As a result of this session, we are able to understand much better the criticisms of the CFP by observers, both internal or external to the system's institutions. These observations often agree with the 1991 report of the Commission, and led P. Andersen to emphasize the ways in which the efficiency of European mechanisms might be improved. Two principles were proposed as a basis for reform:

(i) the effective implementation of subsidiarity which, as we know, requires the identification of management units and a better understanding of the institutions and mechanisms which underpin management;

(ii) the recognition of a *numerus clausus* in the form of a European licence. It implies, as a prerequisite:

- an improvement in enforcement,
- stricter inducements to respect existing regulations,
- better planning of the structural policy placed in the general context of European Structural Funds,
- finally, a discussion of the effects of combining licences and quotas.

Even with such a small number of principles and their prerequisites, we can imagine the numerous fields opened to economists. By taking into account the questions stated, we become aware of the linkages which exist between decision mechanisms including their political presuppositions and the recommendations of economists. P. Andersen notes the lack of attention paid to such recommendations. If the reason is to be found in the complexity of the institutional road which leads from the opinion to the decision, it is important to note that, this raises an obscure question often ignored because it is difficult to fit in the formal representation preferred by economists. The contribution of other disciplines may clarify this question which is at the heart of the decision process.

dans la complexité du chemin institutionnel qui conduit de l'avis à la décision, il est plus important de noter que du même coup se trouve révélée une zone d'ombre fondamentale souvent ignorée des observateurs car de nature peu propice à la réprésentation formelle des économistes. Le regard d'autres disciplines pourrait éclairer en partie cette zone au cœur même des processus de décision.

En pensant à cela et toujours dans cette sorte d'introspection, des responsables nationaux et européens s'expriment sur les mécanismes, les enjeux, les dysfonctionnements de la PCP nous permettant ainsi de conforter sous un autre angle les points de réforme envisagés face à un constat relativement critique des mécanimes en œuvre (C. Bernet, E. Mastracchio, D. I A Steel). Si on retrouve bien en toîle de fond les principes premiers de la PCP, on perçoit les limites d'application à partir desquelles se greffent les propositions des auteurs ; qu'il s'agisse de la réduction de l'effort, de la segmentation et du maintien de la flexibilité ou des enjeux de pouvoir entre Parlement et Commission. Le point commun de ces avis se trouve certainement dans une remise en cause d'une vision par trop mécaniste des solutions à opposer à la dynamique de surpêche. On pressent mieux la prise de conscience générale qui s'exprime par la nécessité de trouver et de mettre en œuvre des processus plus participatifs, mieux localisés institutionnellement au plus près des acteurs professionnels, plus incitatifs du respect des règles, davantage fondés sur une co-responsabilisation voire une autorégulation de sous-ensembles homogènes participant de la définition du secteur soumis à la PCP. Les travaux des économistes présentés dans ce cadre vont permettre d'illustrer ce mouvement de pensée s'agissant du rôle des organisations de producteurs (CEMARE), de la compréhension des stratégies des pêcheurs au travers d'une recherche sur les liens entre capacité de capture et effort (SFIA), ou encore des impacts socio-économiques de la PCP (IREPA), dans un souci de différenciation d'espaces fortement dépendant de la pêche. A partir de ces travaux quelques idées fortes se trouvent énoncées qui confortent en bien des cas les problématiques privilégiées.

La première de ces idées concerne le comportement du producteur qui apparait plus distant du cadre de rationalité stéréotypé par lequel trop souvent on réduit la fonction d'objectif des individus à une recherche de maximisation du profit. Comme le confirme les travaux de G. Valatin, il est en fait plus difficile de déterminer après intégration de paramètres qualitatifs (en rapport par exemple au patron de pêche ou aux équipages), une mesure de la capacité d'utilisation de chaque unité de pêche donc, de la capacité de capture et par voie de conséquence de l'effort. A cela s'oppose dans les faits un

Within the same theme, national and European leaders spoke about the mechanisms, the stakes and dysfunctions of the CFP. This enables us to confirm, from a different viewpoint, envisaged points of reform, given a relatively critical assessment of the mechanisms in use (C. Bernet, E. Mastracchio, D I A Steel). While the major principles of the CFP remain in the background, we can perceive the problems that lead to the authors' propositions: for instance, effort reduction, segmentation, maintainance of flexibility or the power struggle between the Parliament and the Commission. What these opinions have in common is to warn against a too mechanistic vision of the solutions to the dynamics of overfishing. We can clearly see a general awareness expressed by the necessity to find and bring into play processes with (i) more "involvement", (ii) better institutional localization close to the professional actors, (iii) better incentives to compliance, more based upon a co-responsibility or even on autoregulation of homogeneous sub-groups in accordance with the definition of the sector submitted to the CFP. The economists' works presented in this context illustrate the trend of opinion concerning the role of producers'organizations (CEMARE), the understanding of fishermen' strategies by trying to find the links existing between fishing capacity and effort (SFIA), or even the socioeconomic impacts of the CFP (IREPA). These works put forward some important ideas which in most cases relate to the main problem areas.

The first idea refers to producer's behaviour which moves away from the stereotyped vision of rationality wherein the objective function of individuals is limited to profit maximization. As shown by the paper of G. Valatin, it is difficult, after taking into account qualitative parameters (concerning the skipper or the crew for instance), to determine a measure of the capacity of each fishing unit relating to fishing capacity and thence to effort. This goes against the aggregative statutory principle which produces a uniform measure of effort (combination of technical parameters) in the search for a solution to the overfishing problem.

The results presented by CEMARE reinforce the second idea which shows that fishing activity depends on the institutional structure, especially in the European case, where producers' organizations appear to be the key to a system of management naturally divided in territories (fishing zone), biological characteristics (stock and quota) and socially defined (members).

The third fundamental idea brought out by the different attempts to measure the effects of the CFP implies that fishing represents, in some areas, the "source" of a social network which generates important economic and political effects in a context where existing opportunities are

principe agrégatif simple à visée réglementaire qui, dans la recherche de solution à la surpêche, produit une mesure uniforme de l'effort (combinaison de paramètres techniques).

Une seconde idée se trouve confortée à partir des résultats présentés par le CEMARE qui tend à montrer que la pêche ressort d'une logique de structuration institutionnelle de proximité où, dans le cas européen notamment, les organisations de producteurs apparaissent de plus en plus comme la clef de voûte d'un système de gestion naturellement territorialisé (zone de pêche), biologiquement inventorié (stock et quota) et socialement défini (statut d'adhérent).

La troisième idée centrale que l'on peut retenir à l'énoncé des tentatives de mesure des effets de la PCP (IREPA), tient au fait que la pêche constitue en quelques endroits le ferment d'un tissu social dense, diffuseur d'effets économiques et politiques non négligeables dans des contextes d'opportunités souvent peu favorables à des reconversions ou restructurations massives. Cette perception sociale du secteur des pêches, plus courante dans les économies en développement, semble reprendre aujourd'hui d'autant plus de légitimé que les espaces économiques et sociaux se trouvent de plus en plus fortement contraints.

Cette lecture croisée de la PCP dans la préparation de sa prochaine étape d'évolution à l'horizon 2002 permet de mettre en conformité d'un côté les conclusions des débats théoriques de l'économie des pêches, qui incitent globalement à une révision des paradigmes et des concepts, avec d'un autre côté les souhaits d'évolution des pratiques de la régulation qui émanent des responsables politiques.

unfavorable to major change. This social perception of the fisheries sector, more common in the developing economies, seems to be all the more reasonable today as the social and economic environment is increasingly subject to constraints.

This review of the CFP which is preparing for its next evolutionary phase in 2002 enables us to bring together the conclusions of theoretical debates on fisheries economics which generally encourage a revision of paradigms and concepts and the wish for the development of regulatory practice expressed by political leaders.

# The EEC-Common Fisheries Policy and the 1991-Report

**Peder Andersen**

Head of Secretariat, The Danish Economic Council

ABSTRACT

*The paper gives an overview of the EEC-Common Fisheries Policy and of the 1991-report from the EEC-Commission. Furthermore, the paper contains an evaluation of the 1991-report. The conclusion is that the implementation of several of the proposals will improve the exploitation pattern and improve the profitability of the fishing fleet. However the idea of segmentation of the fleet will result in an inoptimal use of the fleet.*

## 1. INTRODUCTION

The fisheries policy in the EEC involves many countries, many fleets, many stocks, many markets, many regional areas and different political systems. Furthermore the policy has developed over more than 20 years and many problems are still unsolved. The fact is that several of the todays problems in the fisheries are worse than 10 or 20 years ago. After more than a decade with extensive regulations we are facing the fundamental problem why more and more regulations does not improve the economic performance of the fishing industry.

The Common Fisheries Policy is one of world largest experiments in international coorporation of managing renewable and common property resources.

The EEC is now in the very middle of changing the fisheries policy. It is therefore of great interest for all of us to learn more about the EEC-fisheries policy experiment. In the following I will give a short introduction to the past and the future of the Common Fisheries Policy.

## 2. BASIC ELEMENTS IN CFP

The basic elements in the EEC-fisheries policy (CFP) are :

i) market organization, the first component of the CFP set in place by the Council in 1970, based on the same principles and presenting many similarities with the Common Agricultural Policy ;

ii) structural policy, also in place since 1970, with the objective of rational development of the fishing industry to ensure a fair standard of living for fishermen ;

iii) conservation and management of resources, involving - in the interests of fishermen and consumers alike - rules on the use and allocation of resources, technical conservation measures, special measures for inshore fishing and supervisory measures ;

iv) relation with non-Community countries and international organizations. Fishing agreements with non-Community countries have enabled the essential interests of the Community and its Member States to be safeguarded, restored or developed in the waters of non-Community countries and certain international waters covered by international organizations.

In January 1983 the EEC adopted a package of rules on conservation and management based on the following principles :

i) equal access to fishing grounds ;

ii) the use of total allowable catches (TACs) and allocation of TACs into national quotas. TACs are fixed in the light of scientific advice ;

iii) the principle of relative stability. The rule of fixed percentage per stock for each member was established in the 1983 agrement ;

iv) various technical conservation measures ;

v) Multiannual Guidance Programs (MGP). The idea behind this was to adjust fleet capacity to available resources.

## 3. THE LAST 10 YEARS

The major findings according to the management of the exploitation of the fish resources in EEC-waters during the last 10 years can be summarized as follows :

i) most species are overexploited from a biological as well as an economic point of view ;

ii) the ecomomic net return from the fishery is very low. In many fisheries the resource rent is negative ;

iii) the fleet capacity is too high and has been increasing during the last 10 years in spite of the fact that significant financial resources have been used on fleet capacity reduction programs.

## 4. THE 1991-REPORT FROM THE EEC-COMMISSION

The purpose of this report is to stimulate a debate about changes in the fisheries policy. First of all I would like to use this opportunity to gratulate the authors of the 1991-report. It is a report with many new ideas - a least in a EEC-context. Even a fisheries economist can be optimistic by reading the report from the EEC-Commission.

The report states the facts :

- that we have overfishing and a latent sectoral crisis

and concludes

- that present mechanisms are incomplete

and recommends

- regulation and limitation of access to resources.

In the report the list of ideas for the new common fisheries policy are summarized as follows :

i) distribution of responsibility at all levels, in accordance with the subsidiarity principle, conferring responsibility on the parties concerned, in particular the fishermen's organizations which could be given the task of implementing the management measures at the appropriate level ;

ii) more stringent regulation of access to resources by a system of licenses to rationalize fishing effort (by zone, species, fisheries, etc.), cutting back excess capacity and improving the planning of fishing so as to reduce over-investment and economic inefficiency ;

iii) a new classification of fishing activities (multiannual, multispecies, and analytical TACs, as appropriate), definitions being based on existing rights and the economic and social characteristics of each fishery ;

iv) more stringent control mechanisms, using modern technologies for vessel location and communication of information, in order to monitor the movements of certain vessels and inform the authorities concerned, while coordinating the information obtained ;

v) enforcement of compliance with rules which are in the common interest, ideally through economic incentives encouraging good behaviour by fishermen (use of selective gear, compliance with landing standards), and deterrent sanctions at Community level (penalty quotas, withdrawal of licenses, withholding of aid, fines) ;

vi) stronger structural management, by segmentation of the fleet, on the basis of new parameters, providing a basis for the assessment and control of fishing effort, and inclusion of structural measures under the umbrella of the reform of the structural Funds ;

vii) greater synergy between management of internal and external resources, other sources of supply and market management.

## 5. VIEWS ON THE 1991-REPORT

I strongly believe that implementation of several of the ideas presented in the report would significantly improve the exploitation of the EEC-fishery resources - the fish stocks, as well as the capital and human resources.

I do look at the suggestions as an economist, not as an observer of political processes within the EEC.

A ranking of the suggestions would give the idea of using economic incentives the highest priority. In many years several of the incentives in the Common Fisheries Policy have pushed fishermen as well as member states to fish and regulate in such a way that the misuse of the fish stocks is now obvious to all of us and the catch capacity is high above optimal. On that background I wellcome the ideas of positive economic incentives.

The introduction of economic incentives to improve gear selectivity as well as fishing pattern, including a reduction in fishing mortality on juveniles could be a revolution of the Common Fisheries Policy.

The report does not present examples of economic incentives. Let me give some :

i) Catches of small fish should count by a factor larger than one in the catch figures (TAC-figures). Catches of larger fish should count by a factor smaller than one in the catch figures (TAC-figures).

ii) Fishermen should be given a premium for moving their fishery towards larger fish. One way would be to increase trip quotas, monthly vessels quotas and/or to give a price premium.

iii) If a specific gear is proved to be more selective than others fishermen could be given a premium to switch to this type of gear. This idea also applies to specific gear construction.

iv) Economic support could be given to some directed fisheries in a predefined way.

Also the idea of a new classification of fishing activities is of great importance. The implementation of multiannual quotas and multispecies quotas would enforce managers to have a more broad and longer perspective. An direct benefit of multispecies and multiannual quotas is the reduction in discard. There are technical difficulties related to these measures but it is my belief that the introduction of these measures will improve the exploitation.

The third new idea of importance is the principle of subsidiarity. This implies that fishermen's organizations will be much more involved in the management process and hopefully results in decisions which are understand and accepted by the fishermen. This would also reduce the pressure on the enforcement system and increase selfregulation among fishermen.

The idea of using a system of licenses to cut back excess capacity and to improve the use of fleet capacity is unclear presented. If we are talking only about the right to fish, the system will not improve the current system. If it is a individual quote system at EEC-level it could be a violation of the principle of subsidiarity. Also the introduction of an individual quota system can only be succesful if it is an integrated part of the regulation system of the single member state. But EEC could support the implementation of individual quota systems in member states.

Finally, a warning. The report strongly states that the reduction of the fleet capacity and segmentation of the fleet are of great importance in solving the crisis in the fishery. It may be a wrong recommendation as a general fleet reduction may create undercapacity in some fisheries. On the other hand a segmentation of the fleet reduces the flexibility of the fleet. Along with fleet reduction there will be a need for other measures but segmentation is in my view a wrong measure, as it will give an inoptimal use of the fleet.

An economist will always suggest economic measures.

Finally, the report emphasizes the important of increasing use of biological, technical and economic research as the basis for management. I'm sure all of us working in fisheries economics can support that proposal but also that we feel that economic analyses in the past have played a second role and that this could be one of the reasons for the insufficient management over the last decade. Of course, reasons for not having used fisheries economics can be many but perhaps the results have not been applicable or have been to close to the political circle.

However the use of basic bioeconomic findings on management will significantly change the explotation pattern, improve the profitability of the fleet and reduce the need for EEC and/or govermental financial support.

## REFERENCES

**Anderson L.G.** (1986). *The Economics of Fisheries Management,* The Johns Hopkins University Press. Baltimore.

**Clark C.W.** (1985). *Bioeconomic Modelling and Fisheries Management.* John Wiley. New York.

**Clark C.W.** (1976). *Mathematical Bioeconomics : The Optimal Management of Renewable Resources.* John Wiley. New York.

**Commission of the European Communities** (1991). *Report 1991 from the Commission to the Council and the European Parliament on the Common Fisheries Policy.* Brussels.

**Hannesson R.** (1978). *Economics of Fisheries : An Introduction.* Universitetsforlaget, Bergen.

**Sutinen J.G. and P. Andersen** (1985). The Economics of Fisheries Law Enforcement. Land Economics **61,** pp. 387-397.

# The Fisheries Structural Policy on the Horizon of the Year "2000"

**Emilio Mastracchio**

Commission of the European Communities, Director Directorate-General for Fisheries,
rue de la Loi 2000, B-1049 Bruxelles, Belgique

## 1. INTRODUCTION

My purpose today is to address you on structures within the common fisheries policy.

I propose to present an outline of the policy under the following headings :

i) role and evolution of structures policy,

ii) new concepts and approaches to :

- the fishing fleet,
- aquaculture,
- processing and marketing of the fish,
- the role of fisheries in regional development.

## 2. ROLE AND EVOLUTION OF STRUCTURAL POLICY

Structural policy in the fisheries sector is an integral part of the common fisheries policy. Its main aim is to promote the maintenance of a community fishing fleet which is in equilibrium with available fish resources thereby ensuring that the industry can :

- face up to international competition,
- provide the standard of living for those dependant on fishing,
- guarantee reasonable prices for customer

The institutional objectives are consistant with those laid down in the article 39 of the treaty and establish the basis for policy objectives which are fixed from time to time.

The specific objectives for structural policy now are to :

- control fishing effort,
- ensure maximum financial support for the various measures in operation and particularly those aimed at achieving effort reduction,
- increase the contribution of the fishing industry to the integrated development of regions dependent on the fisheries.

When the common fisheries policy was introduced in 1983, a more comprehensive structural policy was also adopted in parallel [1]. This included the introduction of multiannual guidance programmes which created a framework within which the capacity targets for restructuring the fleet were fixed and the development of aqualculture took place.

Structural policy was extended in a revised Regulation in 1986[2] and multiannual guidance programmes for the fishing fleet in particular were improved by fixing annual targets for fleet capacity reduction to be achieved by 1991 in an atttempt to reverse a trend towards overcapacity in the Community fleet.

The council adopted further amendments to the regulation in 1990 [3] in order to extend certain structural measures to small-scale fisheries and to introduce measures to support the reorientation of fishing activities. These measures reinforced the existing arrangements for permanent cessation of fishing and joint ventures. Two new measures were introduced to accomodate redeployment of vessels outside the Community and for the arrangement of joint entreprises.

The purpose of these amendement was mainly to facilitate an appreciable reduction in fishing effort more rapidly than previously envisaged by supplementing and improving existing measures.

Despite the emphasis on the fishing fleet which was necessary due to the emerging problem of overcapicity and excessive fishing effort, the processing and marketing of fish continued to be supported from 1977 to 1989 under Reg (EEC) n° 355/77 [4]. The main aim of this regulation was to rationalize and develop the sector. It was replaced in 1990 by Reg (EEC) n° 4042/89 [5] which has the same objectives as the previous Regulation, but stresses more modernization and innovation.

## 3. THE FISHING FLEET

### *3.1 Fleet overcapacity*

Nothwithstanding the comprehensive range of measures introduced, fleet overcapacity remains one of the main obstacles to the rational development of the common fisheries policy and represents a threat to the economic welfare of fishing communities. It forces fishing activity to unsustainable levels also and makes it difficult to carry out the stock management objectives of the CFP.

In reporting to the Council in December 1990 [6], the Commission underlined, once again, the problem of overcapacity in the community fleet and stressed the importance of taking initiatives to solve the problems. This gave rise to a debate on the ways and means of improving policy, and arising from this debate new approaches and concepts have been introduced to improve the situation as rapidly as possible.

1. OJ N° L 290, 22.10.1983, p. 1.
2. OJ N° L 376, 31.12.1986, p. 7.
3. OJ N° L 380, 31.12.1990, p. 1.
4. OJ N° L 51, 23.02.1977, p. 1.
5. OJ N° L 388, 30.12.1989, p. 1.
6. SEC (90) 2244 final of december 1990.

*3.2 Measurement of fishing effort and segmentation of the fleet*

The Commision was particularly anxious to move toward the measurement of the fishing effort. Reporting again to the council in December 1991 in the so called "1991-Report"[7] , the Commision underlined further the potential crisis arising from overfishing.

After benefiting from these discussions a new generation of multiannual guidance programmes are being developed. These new programmes will be innovative and involve segmentation of the fleets and a framework within which the fishing effort of the different fleets must envolve over the period of the programmes in relation to the state of the fish stocks. The objectives will allow the adjustment of the size of the fishing fleets in every Member State to levels compatible with those of the fish stocks they exploit. A further new element will be the level of reduction required.

The objectives can be achieved by reductions in both capacity and activity, but the reduction in capacity must be predominant.

*3.3 The fishing vessel register of the Community*

Concurrent with these developments, the commission has also been engaged with the Member States in the establishment of a Community register of fishing vessels [8], which will be in the future the main instrument for monitoring the progress of multinannual guidance programmes.

It was established in 1989 and includes details of fishing vessels provided by Member Sates. It provides a description of the vessels and a history of events in relation to each vessel.

It is up-dated continously to reflect changes in the status of individual vessels Member States. At present, a programme is being implemented ; it aims at developing a procedure to permit the monitoring of fishing effort. The system also porvides for Member States to have access to their own data ; this facility is already available to certain Member States and will be shortly in operation in all Member States.

*3.4 Financial support for measures in force*

Despite serious problems of overcapacity in the fishing fleet, the Commission has continued to provide finance, within the framework of Reg (EEC) n° 4028/86, principally for measures aimed at reducing capacity and improving shore and fleet infrastructure.

The measures aimed at directly reducing fleet capacity in Community waters are adjustment of capacity, exploratory fishing, joint ventures, redeployment of vessels and joint entreprises. Fleet improvement is mainly affected by financing modernization and construction projects to a limited extent only.

The financial provisions for these measures show a substantial increase in the overall budget from 178.6 MECU in 1990 to 241.0 MECU in 1991. This demonstrates the importance which the commission places on achieving progress in this sector.

Further, the importance placed on reducing fleet capacity is demonstrated by the increase in the proportion of the total provision on adjustment of capacity and reorientation measures which accounted for 30 % of the total in 1990 while this increased to 63 % in 1991. During the same period, the provision for construction as a proportion of the total provision fell from 24,7 % in 1990 to 3,2 % in 1991.

Modernization projects accounted for 14,7 % of total provision in 1990, 8,8 % in 1991 and 5,3 % in 1992.

The actual budget allocated to the various measures is indicated in the table 1.

7. SEC (91) 2288 final of 18 december 1991.
8. OJ N° L 20, 25.01.1989, p. 5.

## 4. AQUACULTURE STRUCTURAL POLICY

Aquaculture development is also financed under Reg (EEC) n° 4028/86. This sector has grown rapidly in recent years and marine aquaculture is the sector which offers the best prospects for substantial healthy growth in the future. Aquaculture is helping to reduce the Community's trade deficit in fisheries products, and offers a means of stimulating economic development in coastal and rural areas, often in areas where other alternatives are lacking.

The community has played a key role in the process of the development of marine aqualculture through its structural instruments. This instrument provides aid for construction and modernization projects in aquaculture.

Public support for aquaculture is not entering a new phase and the attention should be focused not only on more increases in production. In the future, due to the increasing concern for environment, aquaculture will form an integral part of the economic development of coastal areas.

## 5. PROCESSING AND MARKETING OF FISHERIES PRODUCTS

Improving processing and marketing of fishery and aquaculture products is also an important component of structural policy. It is, up to now, the only element of structural policy in the fisheries sector which is included in the structural funds.

This measure was included in the new framework of the structural funds in 1989 and is operational since the begining of January 1991. It is, in common with Agriculture, included in objectives 5a. The aim is to spend up the adjusment of structures in order to create a viable industry able to compete in an open market inside the Community and with third countries.

The regulation provides financial assistance in the form of capital grants (roughly 220 MIO Ecus for three years (1991-1993) to promote and encourage investments in processing and marketing of fishery and aquaculture products from landing to wholesale markets.

Processing on board of fishing vessels, the retail sector and the fishemeal sector are excluded.

The main priorities are :

- improve hygiene conditions in order to reach the standards established by the hygiene directives adopted by the Council in July 1991,
- improve product quality,
- encourage innovation, new processing techniques.

The mechanism of this financial assistance is the same as that applied in the framework of other structural funds : (Regional Fund, FEOGA, Social Fund). That is to say they are based on subsidiarity, partnership and programming.

There are three stages :

i) Each Member State is required to establish and submit a sectoral plan indicating the strength and weakness of the sector. The programme for investment promoting is outlined and the level of finance required is indicated.

ii) The commission prepares a reply to each plan (a Community support framework), in collaboration with the Member State. In the CSF, the priorities for intervention and the level of financial assistance (Community and national) are fixed for three years. It is a System of co-financing.

iii) Based on the content of the CSF, the Member States establish operational programmes made up of the different individual investment projects. These programmes are adopted by the commission after checking that the projects are in conformity with the priorities and the financial allocations of the CSF.

The implementation of the programme is the task of monitoring Committees chaired by the Member States and, of course, the Commission participants. Decisions are taken by Member States and the Commission

## 6. INTEGRATION OF FISHERIES INTO STRUCTURAL POLICY

The integration of fisheries into structural policy has two objectives :

i) The rationalization of structural measures, which are at present partly outside and partly inside of the structural funds. In 1993, 83 % of the fisheries structural budget will continue to be managed like the Regional Fund and the Social Fund were before 1988. By the beginning of 1994, however, all of the fisheries structural measures will be subject to the rules of operation of the structural funds. By way of analogy with agricultural measures, fisheries structural measures will be included in objectives 5a which will have two distinct aspects :

- agricultural (FEOGA)
- fisheries (FIGF)

The rationalization will have both a legal and financial basis. A draft Regulation has been prepared corresponding to the regulations for the Regional Fund, Social Fund and FEOGA orientation and the fusion of existing financial instrument for guidance of fisheries is proposed (FIGF) so that the Community can serve better the integrated development of coastal regions.

ii) The financing of accompanying socio-economic measures in order to compensate for the negative effects, in coastal regions, of restructuring of the fisheries sector is typically a matter for the regional Fund and the Social Fund. The Edinburgh Council did not support the proposition of a new objective 6 and considered that it was more appropriate to give all the attention needed to regions dependent on fisheries within the framework of the relevent existing objectives. A limited number of areas dependent on fisheries do not as yet have access to structural funds through objectives 1, 2 and 5b. To fill this gap, the Commission has proposed to make the eligibility criteria for objectives 2 and 5b more flexible.

This outline indicates the direction and the achievements today of structural policy, within the framework of the overall objectives of the Common Fisheries Policy (CFP), should be to :

- contribute to the rationalization and the economic soundness of the sector,
- promote investments in the areas of quality product, harbour infrastructure, etc..
- smooth out the effects of the restructuring of the fishing sector,
- decrease the socio-economic costs of the necessary adjustments,
- contribute to the development of the fishing dependent regions.

With respect to the general trend granting of aid of the various structural measures the following can be said :

- With regard to the granting of aid for new constructions of fishing vessels, there is a strong decrease.
- Parallel to this, there is a considerable increase in the amounts for adjustments of capacity.

These two developments reflect the Commision's attitude to continue and to accentuate its policy of decreasing further more the fishing capacity by giving priority to the adjustment of capacity, and definitive withdrawal has been supplemented in 1991 and 1992 by putting the emphasis of the reorientation measures on the establishment of joint entreprises ("sociétés mixtes").

**TABLE 1**
**BUDGETARY COMMITMENTS 1990–1991.**

| MEASURE | 1990 | 1991 |
|---|---|---|
| REG - 4028/86 | | |
| Reorientation | 4,9 | 31,5 |
| - *exploratory fishing* | *3,5* | *1,8* |
| - *redeployment* | - | *0,5* |
| - *associations temporaires* | *1,4* | *1,7* |
| - *sociétés mixtes* | - | *27,5* |
| Modernization | 26,2 | 21,4 |
| Construction | 44,2 | 7,8 |
| Adjustment of capacity | 49,8 | 120,4 |
| - *Definite* | *32,0* | *119,6* |
| - *Temporary* | *17,8* | *0,8* |
| Adjustment of capacity for ex-GDR | - | 5,7 |
| Fishing port equipment | 4,8 | 7,0 |
| Special measures | 1,2 | 2,5 |
| Market research | 0,5 | 0,4 |
| Aquaculture | 47,0 | 39,3 |
| Petite pêche | - | 5,0 |
| TOTAL R. 4028/86 | 178,6 | 241,0 |

In summarizing the above figures, it can be noted that there has been a considerable increase of the yearly budgetary amounts from 178,6 MIO (1990) to 241 MIO Ecu in 1991 and further to 278,5 MIO Ecu in 1992.

# Définition et mise en œuvre de la Politique Commune des Pêches de la CEE : le point de vue d'un Etat membre

**Claude Bernet**

Directeur des Pêches Maritimes et des Cultures Marines, 3 place de Fontenoy, 75007 Paris, France.

## 1. INTRODUCTION

En m'efforçant d'échapper à la subjectivité, qui consisterait à développer seulement le point de vue français, je traiterai successivement :

i) des modes d'élaboration de la PCP

ii) des critiques auxquelles elle est confrontée

iii) des attentes essentielles des Etats membres

## 2. LA PCP (COMME TOUTE POLITIQUE COMMUNAUTAIRE) EST L'OEUVRE CONJOINTE DE LA COMMISSION ET DES ETATS MEMBRES, ET LE RÉSULTAT D'UN PERMANENT COMPROMIS.

### *2.1 L'articulation des compétences au sein de la CEE*

La Commission a le monopole de la proposition,

Les Etats ont le monopole de la décision (en Conseil),

Toutes les autres institutions (dont le Parlement) ont un rôle consultatif.

### *2.2 Toute décision est donc le fruit de négociations et de compromis*

Rien ne peut se faire sans une initiative de la Commission, précédée ou suivie de contacts entre les Etats et la Commission sur les projets initiaux et des versions amendées.

Toute décision exige une majorité qualifiée, difficile à atteindre (53 voix sur 76), d'où des négociations entre Etats membres et Commission.

*2.3 La PCP est-elle marquée par cette nécessité de compromis ?*

Evidemment oui, ce dont témoigne :

- la longueur du processus de décision (ex. Règlement Mesures Techniques de 1991).
- la nécessaire "modération" des mesures finalement adoptées,
- leur "lisibilité" parfois insuffisante,

mais il faut nuancer ces aspects critiques :

- quand on regarde, à travers le monde, les politiques des pêches mises en oeuvre par des Etats qui décident seuls, on n'a pas toujours l'impression qu'elles sont plus efficaces,
- la construction européenne repose sur l'idée de patiente conciliation des intérêts nationaux pour dégager un intérêt général européen. Chaque fois que l'on veut aller trop vite, on risque un dérapage.

## 3. CRITIQUER LA PCP EST FACILE, LA CONDUIRE EST PLUS DIFFICILE

*3.1 On trouve plus facilement des critiques que des éloges*

Les avantages apportés par la PCP sont considérés comme des acquis, dont la valeur n'est pas réellement estimée et ressentie :

- ouverture mutuelle des zones de pêche (mer communautaire),
- grand marché : pour les producteurs, de plus larges perspectives de commercialisation,
- pour les consommateurs, l'accès à des produits diversifiés et de qualité,
- interventions financières européennes.

Les contraintes sont, au contraire, très sensibles, notamment toutes celles qui visent à résoudre le problème de l'excès de capacité par rapport à la ressource.

*3.2 La construction de la PCP est rendue difficile par des raisons structurelles et conjoncturelles, et aussi par le contexte international.*

Des raisons structurelles, que l'on retrouve dans d'autres politiques communautaires :

- diversité et même rivalité des pêches européennes. Même si ce n'est pas exprimé aussi crûment, les pêcheurs rêvent de conquérir l'espace et les marchés des autres, en défendant leur espace et leur marché.
- diversité des structures et des cultures, qui rend malaisée l'application de mesures uniformes quelques exemples : diversité des systèmes juridiques (ex : sanctions administratives et judiciaires), caractère fédéral de certains Etats membres, structures économiques diverses des secteurs de pêche (ex : pê che industrielle/artisanale ; pêche pour la consommation humaine/pêche minotière).

Une raison conjoncturelle : la crise de la pêche

Une politique des pêches, il y a 10 ou 20 ans, consistait à allouer généreusement des moyens publics au secteur des pêches, pour favoriser son développement.

Partout dans le Monde développé, elle consiste aujourd'hui à limiter l'effort de pêche pour éviter que le progrès technologique ne compromette la ressource, ce qui entraîne une inévitable impopularité, encore accrue par le sentiment d'inégalité dans les efforts.

Enfin le contexte international ne contribue pas à faciliter la PCP :

- accès aux ressources : un monde de plus en plus fermé (les Accords de pêche).
- accès aux marchés : une Communauté de plus en plus ouverte, et marquée par le déclin de la notion de préférence communautaire.

## 4. LES ATTENTES DES ETATS MEMBRES À L'ÉGARD DE LA PCP

L'attente principale est évidemment l'efficacité au meilleur coût : encore faut-il analyser comment les Etats membres apprécient efficacité et coût.

### *4.1 L'efficacité*

C'est d'abord le rétablissement de la santé économique des entreprises, par l'équilibre ressource/capacité (certes il y a d'autres critères, mais celui-ci est primordial).

### *4.2 Au meilleur coût*

- coût financier, bien sûr : le budget de la Communauté n'est autre que le produit des contributions des Etats membres (d'où des différences d'appréciation entre Etats selon leurs contributions)

- coût humain et social

Les Etats sont "au contact" des Professionnels (et des Elus) : ils sont donc naturellement sensibles à leur état d'esprit. Ils ont aussi la charge (première) des conséquences sociales et régionales, aussi bien en termes financiers qu'en termes humains, sociaux et politiques.

La PCP doit être comprise, et autant que possible, admise en attendant d'être, pourquoi pas, soutenue et portée par le secteur. Pour se rapprocher de cet objectif, la PCP doit répondre à plusieurs conditions, classées ici par ordre croissant de difficulté :

- elle doit être progressive et non brutale : un bon exemple a été la solution au problème des mesures techniques en octobre 1991,
- aussi claire et simple que possible : besoin d'explications face à la complexité inhérente à la pêche,
- incitative chaque fois que possible,
- dégagée de considérations étrangères à la pêche,
- cohérente dans ses aspects ressources/structures/marchés,
- adaptable aux diversités,
- tout en étant juste et équitable, ce qui est un dilemme permanent.

La PCP est très loin de satisfaire ces conditions. Il faut donc beaucoup travailler...

# The Relationship between Fleet Capacity and Fishing Effort

**Gregory Valatin**

Sea Fish Industry Authority, 10 Young Street Edinburgh EH2 4JQ United Kingdom

ABSTRACT

*An integral part of the fisheries management policies currently being pursued within the European Community are the structural regulations and targets aimed at controlling fleet capacity. Constraining fleet capacity is usually viewed as essential in order to limit fishing effort and thus fishing mortality. Analyses of variability in fishing effort of vessels in the U.K. fishing fleet are presented, together with evidence from other sources such as a survey of skippers of U.K. fishing vessels. The implications of these results for relating fishing effort to fleet capacity are then outlined.*

## 1. INTRODUCTION

With many important fish stocks in a state of decline, it has become commonplace to hear the view that there are "too many boats and too few fish". Certainly judging by the current state of fish stocks it is evident that at current levels of utilization, a serious mismatch exists between fleet capacity and available fishing opportunities. Therefore in order to halt further decline, this mismatch is a matter which needs to be urgently addressed.

The "obvious" solution is to reduce fishing effort and fleet capacity by restructuring the fleet, using measures such as paying decommissioning grants for boats to leave the industry. In order for such structural policies to be successful in improving the state of a fishery, it is likely that a permanent reduction in fishing effort will be required. This implies that it is likely to be necessary to control both capacity and its utilization, in order to ensure that capacity reductions are not offset by remaining vessels expanding their effort, such that the effort of the fleet as a whole is unchanged.

On closer inspection however, it appears by no means a simple task to quantify how fleet capacity is translated into effort and catches of the particular stocks of interest.

It must be stressed that the following discussion represents a synthesis of ideas at an early stage of evolution. Views expressed are the author's own, and do not necessarily reflect those of any of his colleagues in the Fishery Economics Research Unit.

## 2. FISHING EFFORT AND FLEET CAPACITY

According to the European Commission's recent report (EC-D6XIV, 1991) to the Council and European Parliament on the Common Fisheries Policy (CFP), fish stocks in Community waters are generally "in danger" as a result of over-fishing. As a consequence, the report argues that "substantial" reductions in fishing effort and capacity are now required, with a major obstacle to the rational evolution ofthe CFP being fleet overcapacity. Thus the establishment of "a fleet adapted to available resources" has become a major emphasis in creating the CFP's stated aim of "sustainable fishing".

Before examining the links between effort and capacity, it is helpful to clarify what is to be understood by these terms. When the primary interest is to consider the effects of fishing on particular fish stocks, the most relevant concept is effective (or "output") fishing effort, which measures fishing mortality on particular stocks. Effective effort is usually defined in terms of the proportion of a fish population taken by fishing, or conversely, which survive fishing. Thus effective effort may be thought of in terms of the definition often used for fishing mortality (Cunningham *et al.*, 1985) of :

Effective effort (F) = -natural log (proportion of fish surviving fishing)

In exploring the links between fleet structure and catch, nominal (or "input") fishing effort, provides an important intermediate concept, which is generally more directly related to fleet capacity than is effective effort. It is usually defined in terms of the time and fishing power exerted by the fleet, although it may also be thought of in terms of the area of sea screened in the course of fishing.

Nominal effort is often taken to include only that time that vessels actually spend fishing (e.g. hours fishing), this being most directly related to effective effort. However, ancillary activities such as the time needed to steam between grounds and port, and in searching for fish, are also of considerable importance in determining the effectiveness of a fleet to catch fish, by limiting the time available for fishing. Thus for example, for any period of time and stock level, the further away from fishing ports that fish are located, the more steaming time necessary, and therefore the less time available for fishing and the less fish the fleet could expect to catch (ceteris paribus). While time spent on ancillary activities is important in influencing a fleet's catch, as well as affecting costs and therefore the returns from fishing, it is obviously less easy to relate nominal effort based on such measures as days at sea to effective effort, than it is with those based on measures such as hours fishing.

Where fish are uniformly distributed, nominal effort (in terms of time actually spent fishing) and effective effort are usually closely related for any given size of stock. The relationship between these two concepts being typically characterized by the multiplication by a catchability coefficient (Cunningham *et al.*, 1985), such that :

Effective effort (F) = catchability coefficient (q) x nominal effort (f)

In addition to the problems mentioned above due to ancillary activities aspect of nominal effort, even in the narrow sense of time spent fishing, aggregate nominal effort often cannot be easily translated into overall fishing mortality. Aggregation problems arise as a consequence of differing stock concentrations between grounds, such that different catches are taken in different grounds using the same nominal effort. Of course differences in catch rates between grounds would be of no consequence if they were due solely to purely random factors. However, the existence of such differences can also result from differences in the costs and risks associated with fishing different grounds. Therefore, the distinction between the effective and nominal effort is of importance.

One further effort concept, which by definition is most directly related to fleet capacity, is that of "capacity utilization", which refers to the extent to which fleet capacity is used. For simplicity, this definition of effort will be used in the remaining sections of this paper. The question of how capacity is used will be returned to after first considering how capacity is itself defined and measured.

Fleet capacity is generally defined as a fleet's capability to catch fish. For administrative purposes, capacity is usually defined in terms of an aggregate of those physical attributes of the vessels in the fleet, which are considered important determinants the fleet's ability to catch fish. For example, the European Community's Multi-Annual Guidance

Programme uses aggregate tonnage and aggregate engine power as measures of fleet capacity. In the U.K. a system of "capacity units" is used, which comprises an aggregate of vessel length, breadth and engine power (Tucker, 1988), such that :

$$\text{vessel capacity units} = \text{length [M]} \times \text{breadth [M]} + 0.45 \times \text{power [KW]}.$$

There can be little doubt that such measures of capacity do indeed help to determine an upper bound to a fleets' ability to catch fish. However, there are several important considerations. These fall into 4 categories :

i) Fleet & fishery heterogeneity

ii) Measurement & aggregation of vessel capacity

iii) Investment dynamics & "Capital Stuffing"

iv) Effective control of capacity & associated costs

Obviously, in order to decide what a fleet's capability to catch is, it is necessary to decide which species and stocks are to be included in assessing this capability. On one hand for simplicity, it is far easier to use aggregate measures of fleet capacity across many fisheries. Such measures also have the advantage that they recognize that one of the critical features of many fishing enterprises is adaptability and their ability to switch fisheries. However on the other, the narrower the range of species and stocks included in defining catch capability, the easier it is likely to prove to effectively manage particular fish stocks. For example, it seems unlikely that managing cod stocks on the basis of capacity measures which include vessels potting for lobsters, or catching sharks, would prove to be very effective.

Following on from the definitional specifics of fleet and species/stocks, the question arises as to which are the characteristics of the fleet that are significant in determining its catching capability. For simplicity, it is easiest to consider initially the capability of an individual vessel, before considering that of the fleet as a whole.

Most obviously the capability of a fishing vessel to catch fish will depend upon its size, engine power, and the type and technical efficiency of gear and other equipment (such as fishfinders) employed. The skill with which the vessel is operated by its skipper and crew, and crew size may also be of importance.

Of course, a vessel's ability to catch fish also depends upon the availability of fish to be caught. For most species this will depend largely on the stock size, although for pelagic stocks, the ability of a vessel to catch fish may be far less dependent on the size of the stock (subject of course to the stock being above a minimum threshold level), and depend more upon seasonal migration patterns.

In any year, the capability of a vessel to catch fish will also depend upon the amount of time that is available for actually fishing. Spatial factors, such as the distance from port of fishing grounds, environmental factors, such as the extent to which tides and heavy seas prevent fishing, and operational factors, such as the amount of time needed for vessel repairs and provisioning, may all be of importance.

Even crewing arrangements and the scope of harbour and onshore facilities servicing the fleet's operations could be expected to be of importance in determining the amount of time available for fishing by affecting the turn-around time needed between trips. For example, the capability to catch fish of vessels based at deep water harbours with sea access unrestricted by tidal, or other sea conditions, could be expected to be greater than otherwise identical vessels based at harbours where boats are frequently unable to get out of the harbour (ceteris paribus). Thus, even harbour improvement schemes may result in an increase in fishing capacity.

However, supposing that the capacity of each vessel in the fleet is adequately assessed, consideration of the Fallacy of Composition suggests caution in assuming that even in the short-run, the capability of the fleet as a whole to catch fish is necessarily equal to the sum of individual vessel capacities. For example, this would be very unlikely to be true if crowding externalities were significant, or conversely, if there was significant information transfer between skippers regarding current stock locations and differences in catch rates between grounds.

Indeed the frequently used definition of effective effort (see above), by implicitly assuming diminishing returns to nominal effort, appears to imply that fleet capacity is less than the sum of individual vessel capacities. Or conversely, that the capability of an individual vessel to catch fish is inversely proportional to the total effort of the fleet and therefore (ceteris paribus) to the size of the fleet.

In addition to the measurement and aggregation problems alluded to, in order to effectively control capacity, it is useful not just to consider how to assess fleet capacity in a static sense, but also to examine the dynamic forces which normally work to influence investment and therefore change capacity. Although comprehensive analysis of this complex area is outwith the scope of this paper, at a very simple level, economic theory suggests that there is a tendency for fishing operations (and thus capacity) to expand until the returns from fishing are equal to opportunity costs. This is due in large part to "The Prisoners' dilemma" aspect of competitive use of a common resource, whereby individual fishermen attempt to increase their own returns even though this implies lower returns for other fishermen. Where catches are controlled, such expansion is often termed "capital stuffing" and frequently results in the dissipation of economic rent despite attempts to regulate fisheries and maintain profitability. "Overcapacity" in terms of fleet capacity being greater than catching opportunities, therefore is usually in large part due to economic forces, although other factors such as investment lags and stock depletion may also be of importance.

Of course the causes of overcapacity may be of mere academic interest to fisheries managers so long as it is possible to adequately control capacity. Certainly in terms of administrative practicality, it is a simple enough exercise to control the number of vessels in the fleet through a licensing scheme, and controlling the size of vessels may pose relatively few problems either. (Although even here problems may arise, such as that encountered in the UK where vessel size was controlled on the basis of registered length, and circumvented by increases in overall length).

However, controlling other important aspects, such as the technical efficiency of operation, or the skill with which a vessel is operated, are likely to prove far more problematic. Controlling the use of increasingly effective electronic gadgetry, such as fish-finders for example, does not appear such an easy administrative task. Increasing technical efficiency is especially difficult to measure and control as it is largely driven by a continuous process of innovation, as fishermen seek new ways of increasing their own catches and returns from fishing. As such, it also represents the element which is likely to expand most rapidly if controls are placed on other aspects of capacity.

Supposing that administrative problems associated with controlling capacity are solved, what then of the costs entailed ? Obviously there are administration and enforcement costs entailed in any management regime, and the more difficult an aspect of capacity to control, the higher the associated administrative costs could be expected to be.

Perhaps less obviously, to the extent that regulations reduce the flexibility of fishing operations, there is an associated cost imposed on the existing fleet. Also, to the extent that a new regulation erects a barrier to new entrants wishing to operate fishing vessels, there would be an associated increase the costs affecting both existing vessel owners wishing to upgrade their vessels, as well as to those wishing to join the fleet subsequently.

For example, controlling capacity might be expected to result in an inflationary impact on prices paid for vessels in the fleet and their associated licences, due to the right to fish acquiring a value in itself and being capitalized in higher vessel prices. While such a price increase would represent a windfall gain to existing vessel owners, it would necessarily make becoming a fishing vessel operator more costly for subsequent entrants. Of course, there might also be expected to be some more immediate gains for the remaining fishermen too, as any reductions in fleet capacity would be expected to increase the profitability of the vessels remaining in the fleet.

New regulations may have other important distributional impacts too. Although all fishermen are covered by a particular regulation, some fishermen may well be more adversely affected than others, thereby introducing distortions into the manner in which the fishing industry operates due to the differences in the costs imposed.

Fishermen often adapt their fishing operations to new regulations. Thus for example, it is quite possible that the cost implications for the fleet of controlling capacity may also have considerable bearing on capacity utilization.

What then determines capacity utilization ? It would certainly be incorrect to assume that vessels of a certain size, engine power and gear engaged in a particular fishery may quite easily be mapped onto taking a particular level of catch, thereby assuming that other factors, or even the skipper, and crew are of no consequence.

Despite the obvious generalization that fishermen go fishing to catch fish, there appears to be very little evidence that volume of catch is the main concern. On the contrary, there is evidence that this is not the case (Valatin, 1991a), and therefore it would be very surprising if capacity utilization was purely a function of capacity.

In a recent survey carried out by the Fishery Economics Research Unit (Valatin, 1991a), only one of the skippers of 227 UK fishing vessels interviewed said that his primary objective in going fishing is to catch as many fish as possible. Just over two-fifths (41 %) said that they aim for maximum, or adequate profits, while over one quarter (28 %) said that their

main objective is grossings (i.e. total revenue). Such findings underlie the assertion that fishing is indeed an economic activity and therefore that the determinants of capacity utilization, as well as of capacity itself, need to be sought in terms of economic factors, rather than purely in terms of the physical characteristics of fishing vessels.

To some extent the measure of capacity used in the UK does recognize this, as the capacity unit formulation was based mainly upon comparing revenue earned, rather than vessel catches (Tucker, 1988), However, once the importance of economic factors is recognized, it obviously becomes far more complex to identify what "a fleet adapted to available resources" would comprise of, than would be the case were the catches of the stocks of interest directly proportional to vessel capacity for any given stock level. For example, crewing arrangements may be of critical importance in determining capacity utilization.

The apparent diversity of skippers is also of interest as it implies not only that capacity may change as a result of changes in the skill with which a vessel is operated, but also capacity utilization may change as a result of a change in objectives, or attitudes of the skipper. Such changes may be most common with a change of skipper, but also as the results of the skippers survey showed, it is not uncommon for a particular skipper's objectives and attitudes to fishing to alter over time too. For example, a decision which obviously affects capacity utilization, is whether to work a vessel full-time, or part-time.

However, fleets seldom operate at full capacity. Indeed, it may be most efficient for a fleet to concentrate operations during seasons when fish are easiest to catch and profitability is high, thereby maintaining some degree of "over-capacity" at other times.

The results of a recent study of the activity levels of fishing vessels carried out by Seafish (Valatin, 1991b) also suggests that trying to identify a stable relationship between capacity and its utilization may be problematic. Although due to data availability and confidentiality constraints, the definition of capacity used was more limited than it might otherwise have been, the results did nonetheless suggest that substantial variation in capacity utilization exists between similar vessels.

In that study, days at sea data was analysed for all vessels in the English and Welsh fleet making landings declarations during 1987, with vessels being classified by length (16 groups), fishing method (9 groups), year built (10 groups) and base port/region (14 groups). The mean number of days at sea during 1987 was found to be 106, with a standard deviation of 78 days. (Vessels built during 1986-87, many of which would not have been fully operational for a full year in 1987, were excluded from the analysis).

The variability in the activity of vessels resulting from these differences was estimated using multiple classification analysis. The results showed the length, age, method and base port/region classifications all to be significant in explaining the variance in days at sea, although significant interaction effects were found to exist.

In order to examine the activity levels of similar vessels, data relating to the 403 vessels in the categories of at least five vessels was retained for further analysis. The distribution of days at sea of these vessels had the same mean and standard deviation (of 106 and 78 days respectively) to that of the fleet as a whole, suggesting that it formed a representative sample. A summary of the variability in days at sea for those vessel categories containing at least 10 vessels is shown in Table 1.

Analysis using a composite length, age, method and base port/region classification suggested about two thirds of the variability in effort was associated with such differences. Thus the results implied that on average, 36 days at sea out of the mean of 106 days were unassociated with differences in length, method, age and base port/region.

As fleets do not generally operate at full capacity and effort cannot be easily related to capacity, in order to prevent an expansion of effort, it is likely to be necessary to control both capacity and capacity utilization. While the existence of a stable relationship between capacity and its utilization may be argued to be of no consequence for fisheries management where it is also proposed to directly regulate capacity utilization, further questions then arise concerning both how capacity utilization may be effectively regulated and also at what cost.

One of the more obvious methods of regulating capacity utilization is to restrict fishing activities on the basis of each individual vessel's level of capacity utilization in the recent past (e.g. based on the number of days a vessel fished during a specified reference period). However, in a similar manner to using catch records as the basis for future quota allocations, such regulatory methods can have the perverse effect of increasing capacity utilization and nominal effort by discouraging vessels from reducing their activity. Thus, maintaining, or increasing the vessel's activity record may

become an objective in itself, as fishermen try to maximize their future opportunities and the associated resale value of their boat, or fishing licence. In fact just such reasoning appears to have been influential on some of the one sixth (15 %) of the skippers interviewed in the FERU survey who said that their primary objective is to take their quota.

Certainly, as with any regulation, regulation of capacity utilization would imply further administrative costs, as well as increased fishing costs due to loss of flexibility. In addition to the more tangible costs, to the extent that a new regulation reduces a fishermen's flexibility of operations, they may also result in significant costs in terms of reducing any non-pecuniary benefits associated with participation in fishing. For example, the vast majority (89 %) of skippers interviewed in the FERU survey said that they enjoyed fishing, with "freedom" and "independence" being amongst the factors most frequently mentioned as particularly enjoyable.

## 3. CONCLUSIONS

Current scientific evidence points to the serious condition of many of the fish stocks in European Community waters and this is a cause of urgent concern. The parlous state of fish stocks is attributed to a mismatch between fleet capacity and fishing opportunities such that there are "too many boats and too few fish".

The current trend in fisheries management is to solve this problem by using structural policies to reduce fleet capacity and effort. Some of the important considerations entailed in such an approach have been highlighted. It is hoped that the exploration presented may contribute to a fuller understanding of the implications of current trends in fisheries management.

However, it ought to be stressed that the considerations highlighted should not by themselves be regarded as implying that the current approach to fisheries management is either especially appropriate, or inappropriate. Such judgements are generally based upon a comparison of alternatives. Such a comparison is outwith the scope of this paper.

## REFERENCES

**EC DGXIV** (1991). Report 1991 from the Commission to the Council and the European Parliament on the Common Fisheries Policy.

**Cunningham S., M. R. Dunn, and D. Whirmarsh** (1985). *Fisheries Economics : An Introduction.* Mansell Publishing, London, p.30.

**Tucker C.T.** (1988). Study of the Proposed Amendments to the U.K. Fishing Vessel Licensing System. MAFF Commission, Technical Report No. 344, Sea Fish Industry Authority.

**Valatin G.B.** (1991a). Skippers Motivation Survey : The Determinants of Supply. Occasional paper No.1, FERU, Sea Fish Industry Authority.

**Valatin G.B.** (1991b). The Impact of a Decommissioning Scheme on Aggregate Fishing Effort : The Variability in Effort of Similar Boats. Unpublished paper, FERU, Sea Fish Industry Authority.

TABLE 1 :
ACTIVITY OF ENGLISH AND WELSH VESSELS IN 1987 BY METHOD-LENGTH-AGE-REGION CATEGORY (WHERE AT LEAST 10 VESSELS).

| FISHING METHOD | LENGTH GROUP (ft) | YEAR BUILT | BASE REGION | DAYS AT SEA MEAN | MIN | MAX | S.D. |
|---|---|---|---|---|---|---|---|
| OTTER TRAWL | 35-39 | 1976-80 | SW small ports | 67 | 2 | 170 | 59 |
| OTTER TRAWL | 45-49 | 1951-60 | NE small ports | 125 | 72 | 200 | 40 |
| OTTER TRAWL | 50-54 | 1961-65 | NE small ports | 136 | 22 | 198 | 51 |
| SEINE NET | 60-64 | 1971-75 | Grimsby | 198 | 162 | 222 | 19 |
| OTHER NETS | <30 | unknown | NE small ports | 35 | 3 | 101 | 32 |
| OTHER NETS | <30 | unknown | SE (all ports) | 55 | 4 | 113 | 36 |
| OTHER NETS | 30-34 | 1976-80 | NE small ports | 52 | 5 | 133 | 45 |
| POTS & CREELS | <30 | unknown | NE small ports | 78 | 10 | 188 | 58 |

Source: SFIA (1991).

# The European Community Decision Making Process : Fisheries with Reference to the Role of the European Parliament

**David I.A. Steel** *

European Parliament Rue Belliard, 97-113 B-1047 Bruxelles, Belgique

ABSTRACT

*Fisheries, although a relatively small industry at the European level is nevertheless a major Community policy. This in itself affects the way in which fisheries decisions are reached at the Community level. The paper focuses on the decision-making process within the E.C. at a time when the Community is undertaking a review of the basic conservation policy, when it is shaping up for the Single Market and when the relationships between the institutions as a whole are under consideration. Given the importance of 1992 to fisheries, the paper first describes the decision - making process with particular reference to the fisheries sector. The paper then goes on to examine the role of the European Parliament in the decision - making process. It will consider both the influences brought to bear on the Parliament and the influence which the Parliament can exert on other Community institutions. The paper also considers how Parliament's influence may be changing over time.*

*The paper draws on a number of case studies which are of interest both from the political standpoint and from the broader socioeconomic view such as changes to conservation legislation, the review of the CFP and the market for salmon. Wherever relevant, the examples are used to show how fisheries policy decisions are taken within a broader strategic framework.*

## 1. INTRODUCTION

1992 is a watershed year for the European Community. It marks the completion of the Single Market. Progress is also under way to extend the scope of the Single Market to the Member States of the European Free Trade Association. EC

* The views are those of the author alone

Member States are now progressing with the ratification of the Maastricht Treaty aimed at achieving economic, monetary and political union. The European Commission has published financial proposals aimed at providing a financial framework for the next five years. Negotiations are to begin shortly on further enlargement of the Community.

After agriculture, fisheries is the industry most subject to Community policy. Together the Community is one of the world's major fisheries powers. It is the world's largest trader in fish. Recent developments in important commodities such as tuna, salmon and herring have important implications for fish trade and policy. The Community has fisheries agreements with over twenty countries. 1992 is the year, too, in which the Common Fisheries Policy is up for a ten-year review provided for in the January 1983 policy agreement[1]. While the immediate policy requirements of this review are limited, the European Commission has taken the opportunity afforded by the review of undertaking a thorough going analysis of the Common Fisheries Policy and has put on the table significant ideas for future policy development.

The purpose of the introduction is twofold. On the one hand, it is to suggest that the major themes which are outlined above - notably the European Economic Space, Enlargement of the Community - not only portend a major increase of Community influence but in certain respects are crucially dependent on fisheries questions and secondly that as other themes such as the current review of Community finances and the review of the Common Fisheries Policy are of major importance to the future of the fishing industry, it is an opportune time to examine the decision making process in the European Community, using the Community's fisheries policy as an example.

The paper will focus on the area of the author's own experience, namely the European Parliament, examine a limited number of subject areas of relevance to Members of IIFET and consider the role of the Parliament in the development of policy on the issues covered.

## 2. THE DECISION MAKING PROCESS : THE COMMUNITY FRAMEWORK

Essentially, it is the European Commission, the administration, which makes legislative proposals. The voice of the industry is heard through a fisheries consultative committee and scientific advice is provided through a scientific and technical committee of national experts. The European Parliament (directly elected since 1979) and the Economic and Social Committee (which represents the two sides of industry) give their opinion and the National Governments, operating as the Council of Ministers takes the final legislative decisions. Council fear of protracted annual haggling over fish quotas initially led to the exclusion of the Parliament from consultation over the implementing legislation flowing from the principal conservation legislation of 1983. However, as the European Parliament has grown in influence so it has fought for greater rights, not just of consultation and being able to bring fisheries matters to public attention but also to increase its Parliamentary powers in other directions such as over the Community budget or in relations with third countries.

The increasing status of Members of the European Parliament (MEPs) has also increased their ability to intervene directly with European Commissioners and to use their contacts to bring national Ministers and Commissioners together. These networks have further developed in recent years with at least two MEPs becoming fisheries Ministers in their own countries (Kent Kirk, Denmark and David Curry, UK). Former Ministers have also become involved with fisheries in the European Parliament (Niels Kofoed, Denmark).

While the principal role of the Parliament is to provide a formal opinion on Commission proposals, Parliament can also produce reports under its own initiative and also has various means of bringing matters to the fore through oral and written questioning of the Commission and Council of Ministers and through the debating of urgent resolutions. While it is always difficult to prove direct cause and effect, it can be shown how ideas developed in the Parliament find there way into Commission documents and often directly into Community legislation.

1. Council Regulation 170/83 of 25/1/83 *establishing a community system for the conservation and management of fishery resources. OJ L24 - 27/1/83.*

## 3. THE MAIN ELEMENTS OF THE COMMON FISHERIES POLICY

The Common Fisheries Policy covers the following areas :

i) *policy for the conservation and management of fishery resources*

fixing total allowable catches (TACs) (not in Mediterranean) ; technical conservation measures ;

ii) *market policy*

marketing standards, management through producer organisations, a withdrawal system, external trade policy ;

iii) *surveillance policy*

inspection and monitoring, Community inspectorate and financial help for national monitoring and inspection costs ;

iv) *policy on fishery agreements with third countries*

competence for international affairs since 1976 ;

v) *structural policy*

monitoring of multi-annual guidance programmes and co-financing measures to adjust capacity, modernise the fleet, develop new fisheries and aquaculture, improve shore based facilities ;

vi) *research policy*

since 1987, Community research programmes in the fisheries and aquaculture sector supported by a budget of 30 m ECU in the period 1988-1992.

## 4. FISHERIES IN THE EUROPEAN PARLIAMENT

Over the decade from the enlargement of the Community to the settlement of January 1983 fisheries policy was a focus of Community disharmony centred on the failure of the Council of Ministers to agree a conservation policy. Naturally, in this period fisheries representatives focused their attention and limited financial means on the Council of Ministers. The appointed European Parliament, which had given its opinion on the Commission proposals in 1977, was of little relevance.

In 1979, however, a new democratically elected Parliament was set up. In November a fisheries working group was established with Robert Battersby, MEP for Humberside in England elected Chairman. Over the Parliament's first five years, the 22 Members of the working group established the Parliament as a forum for public debate on fisheries at the European level and established its credibility as an interlocutor with the Commission with a series of reports on the development of a common policy, control and surveillance, the Mediterranean, social aspects of fisheries policy and the development of aquaculture. The Parliament was successful in achieving a separation between agriculture and fisheries in the Community budget, thus allowing a separate fishing policy to develop. During this period, Parliament can take the credit for establishing a Community fisheries inspectorate - a major step forward in Community competence, in drawing attention to the problems of quota hopping, for ensuring a public debate and understanding of the questions related to the further enlargement of the Community, and for focusing attention on the plight of the Atlantic Salmon - leading to the formation of the international body NASCO. The Parliament also established itself as a voice for the peripheral areas dependent on fishing.

In particular, the Parliament was able to stand back from the day to day management of the policy and point the way forward in several policy areas. Slowly, the Parliament began to show itself as the bridge between the fishing industry at the local level and the Community institutions.

During the second legislature from 1984 to 1989, fisheries became a full sub-committee of the European Parliament's agriculture committee.

The main reports of the Committee covered : the fisheries sector and enlargement, structural policy, research, fisheries agreements with third countries, the estimation and management of fish stocks, the common organisation of the market and the fish processing industry. At the end of the period, the committee produced a report in the name of Parliament's Vice President, Nicole Pery, entitled "Achievements and prospects of Europe's fisheries policy".[2]

The accession of Spain and Portugal in 1986 which doubled the number of Community fishermen and increased the tonnage of the fleet by some 50 percent also increased the political interest in fisheries in the European Parliament with MEPs from the new Member States coming to play an active role on the Fisheries Committee. While the arrival of Spanish and Portuguese Members has created new internal tensions, particularly with regard to access to North East Atlantic waters, it has greatly increased interest in areas such as access to third country waters which is of particular importance to the Spanish distant water-fleet, structural policy and research. Spanish MEP Miguel Arias has played an important role in pursuing fisheries questions through the budgetary procedure.

During the 1984 to 1989 period, the Parliament was probably most influential in the field of structural policy. De Feo notes the extent to which the new legislation agreed at the end of 1986 took up proposals made by Parliament both in an own initiative report prior to the publication of the Commission proposal and in its report on the Commission's legislative proposals which were also largely accepted by the Commission in a revised text to its own proposal.[3] The 1986 legislation provided the Community with substantial funding of 800m ECU for the period 1987/1991, not only for vessel modernisation and new building but also significant sums for aquaculture, exploratory fishing and joint ventures, as well as limited aid for port facilities, market initiatives and other measures. [4]

De Feo also reminds us of the Parliament's budgetary powers in this respect by inscribing a sum of 127m ECU of expenditure in the 1987 budget, allowing the new measures to be financed.

The Pery report of December 1988 was also significant in that it was the first major Community report to sum up the achievements of the CFP and point the way forward to 1992. While confirming the basic principles of relative stability and limitation of access to coastal waters, it is interesting to see how ideas on conservation and management have been taken forward into the Commission's current review exercise as a basis for longer term policy - notably the development of ideas on multispecies, multiannual TACs and the Commission's preparedness to study the possibility of applying a system of individual quotas, with reference to the post-2002 situation.

The current Parliament so far has focused in particular on important technical measures and on the ongoing review of the Common Fisheries Policy. There has also been progress on the budget with the creation in 1990 of separate fisheries guarantee and guidance funds. A significant feature of the current period has been the number of meetings between the fisheries sub-committee and fisheries representative organisations as well as a series of seminars with committee members and senior Commission officials. Recent meetings have ranged from representatives from the Shetland Isles to French and Spanish tuna processors.

There has, too, been a substantial increase in briefing material provided to MEPs on all the Commission proposals and EP reports. All these activities demonstrate not simply the growing influence of the Parliament in policy formulation but of the movement away from Council lobbying towards concentrating on the initial stages of legislation to ensure that relevant interests are taken care of *before* the publication of legislative proposals and throughout the legislative process. Let us look at a few examples.

## 5. FISHERIES AGREEMENTS

Formally, the consultation of Parliament in connection with the conclusion of fishery agreements with non-member countries is based on Article 43 of the Treaty which provides that Parliament is to be consulted before the Council ratifies an agreement. In practice, this means that Parliament merely provides a rubber stamp after agreement has been reached.

2. Nicole Pery *Report on the achievements and prospects of Europe's fisheries policy ("Blue Europe") - DOC A2-0319/88 - EP 1988*
3. Alfredo De Feo *Les progrès de l'Europe bleue et la participation du Parlement européen* - Revue du Marché Commun numéro 309 - 1987
4. Council Regulation 4028/86 of 18/12/86 on *Community measures to improve and adapt structures in the fisheries and aquaculture sector* . OJ L376 - 31/12/86

However, on the one hand Parliament has pressed the Commission consistently on this matter so that there is now much more discussion with Parliament's fisheries sub-committee during the progress of negotiations. Also fisheries agreements are often with countries in particularly sensitive regions and thus the conduct of negotiations or potential negotiations have been influenced not only by the views of Member State Governments which provide the initial mandate to negotiate but also by the public debate engendered by the European Parliament. Namibia is a current example.

Much more significantly, however, has been the use of powers won by the European Parliament under the so-called Single Act which requires Parliament to give its assent to overall agreements with third countries. In the case of Morocco, refusal of the European Parliament in January 1992 to give its assent to a protocol with that country threw negotiations with this major fisheries partner into disarray. Thus, while the formal powers may be weak, the scope for influence is greatly enhanced.

## 6. TECHNICAL MEASURES

In the case of so-called technical measures, the European Parliament would not normally be consulted on those measures required for the implementation of the Conservation Regulation 170/83. However, as Community fish stocks have declined so "technical measures" have assumed a greater political importance and we can see how Parliament has pressed successfully to have its say and how Parliament's opinion has helped to shape Community policy.

In July 1990. for instance, the Commission published proposals to increase substantially the standard mesh size from 90mm to 120mm. [5] As the change was based on regulation 170/83 the European Parliament would not be consulted.

However, at the first meeting of the fisheries sub-committee after the submission of the proposal MEP Paul Howell drew Parliament's attention to the far-reaching effects of the Commission proposal and called for Parliament to be consulted. This was followed by a letter from British MEPs of all parties to President Delors and by a debate in the European Parliament calling again for consultation. Significantly at this debate Commissioner Marin backed Parliaments' call for consultation. [6] The Council of Ministers having failed to reach agreement on the proposals belatedly agreed to consult the Parliament. In October 1991 Parliament adopted its opinion calling inter alia for an increase in mesh size to 100 mm with further increases on a step by step basis.[7] When the Council of Ministers met at the end of the month agreement was reached very much along the lines of the solution proposed by the European Parliament.

## 7. LARGE SCALE DRIFT NETTING FOR TUNA

Back in August 1989 MEP Madron Seligman tabled a parliamentary resolution calling for Community legislation to ban high seas drift netting in its waters and to support international efforts to regulate purse-seine fishing and drift netting.[8] This motion was followed up with reports on both drift netting and purse-seine fishing for tuna.

In a resolution of November 1991 the Parliament called on the Commission to introduce legislation to prohibit imports into the EC of all tuna products harvested by purse-seining on dolphins, together with a ban on tuna imports from other cetacean-endangering fishing methods such as high seas drift nets.[9]

When the European Commission published its proposal to limit drift netting for tuna in Community waters to nets of less than 2.5 km there was little enthusiasm because as well as the French fleet, UK and Irish vessels were conducting experimental voyages. While UK MEPs strongly opposed the fishery on animal welfare grounds and were lobbied by organizations such as Greenpeace and the Worldwide Fund for Nature, it was noticeable that the French authorities drew

5. COM(90)371 of 31/7/90
6. Debates of European Parliament 12/12/90
7. Debates of European Parliament 10/10/91
8. Motion for a resolution by Mr Seligman on the danger to marine animals and other non-target species from purse-seine and drift netting (Doc. B3-0012/89)
9. Minutes of EP 22/11/91

on the "greens" and environmental groups such as Robin des Bois to support French drift net fishing. Nevertheless, Parliament's endorsement of the Commission proposal again helped to smooth the way for agreement in the Council of Ministers - an agreement which would allow traditional fishing to continue after 1993 if it can be proved that other species are not endangered.[10] Parliament also played a part in calling for Community action to protect the Community market against low cost imports caused by trade restrictions elsewhere.

## 8. SALMON

The development of salmon farming in the Community has been of great interest to MEPs as it is a central feature of the aquaculture structural programmes for the UK and Ireland and takes place in some of the most peripheral regions of the Community. It is significant, however, that as the industry developed with Community support the Commission warned of future commercial problems. An October 1987 Commission paper said of the UK programme : "Despite the major potential of aquaculture in the UK and the satisfactory completion of the previous programme, the objective nevertheless appears very ambitious and could come up against, in particular, commercial difficulties which could have negative effects on the profitability of the investments contemplated."

These difficulties became apparent by 1989 when the Scottish and Irish salmon farming industries asked the EC to investigate allegations of dumping by Norwegian salmon exporters. In March 1991 the Commission terminated its anti-dumping proceedings. The Commission had recommended the imposition of an 11 percent tariff against Norwegian salmon but there had been no support from Member States other than the UK and Ireland. The Commission would merely "continue to follow closely the market trend for farmed salmon and the export of salmon to the Community". If further discussions with Norway were unsuccessful the Commission would consider whether to initiate new anti-dumping proceedings. On 8 November 1991, however, the Commission agreed a regulation making imports of Atlantic salmon subject to observance of minimum prices. What role did the European Parliament play in achieving Community action ?

At a seminar with Commission officials at La Toja in Spain, MEPs were told that no other Member States supported the UK and Ireland and even they did not give the matter their full support. This stimulated action by MEPs, in particular, Sir Jack Stewart-Clark who arranged for the salmon growers to meet with Commissioner Andriessen's private office (cabinet), with fisheries officials and with the Parliament's fisheries committee.

The growers expressed their concern to the Parliamentary committee that "political considerations in the EC/EFTA discussions are working against salmon farmers. There is wrangling between Community members and the Norwegians over the Common Fisheries Policy and access to fishing grounds. The impression which we have had is that these talks are seen as more important than our problems, and that no one, and DGI (directorate for external relations) in particular wants that particular boat to be rocked. Our fear is that our problems are being ignored in pursuit of another deal."[11] However action was continuing. According to *Eurofish Report* "External Relations Commissioner Frans Andriessen agreed to the industry-Commission meeting as a result of pressure exerted by the industry, taken up by MEP Sir Jack Stewart-Clark".[12] The MEP was also able to arrange a meeting between the Secretary of State for Scotland and Commissioners during his visit to Strasbourg and to press the British fisheries Minister. He also urged the fisheries Commissioner to raise the matter at the next meeting of fisheries Ministers.

The industry was of the view that it was this concerted effort which galvanised that UK's Ministry of Agriculture into action. On 27 August the Ministry produced a press release entitled "John Gummer takes up salmon farmers' case with EC". In this release the Minister referred to the earlier contacts between himself and the Scottish Secretary and the Commission and stated that he had now written to Commissioner Andriessen "to bring to his attention the evidence submitted by the Scottish industry".[13]

10. Debates of European Parliament 10/10/91
11. Scottish and Irish Salmon Growers Associations' Presentation to EP Fisheries Sub-Committee 27/6/91
12. Eurofish Report 20/6/91
13. MAFF News Release 284/91 27/8/91

During the autumn pressure was kept up on the Commission and the fisheries committee made use of a report prepared on the possibilities of salmon ranching to focus on the market situation for farmed salmon. Thus when the subject was debated in the European Parliament on 22 November MEPs were able to welcome the Commissioner's decision to introduce a minimum price system but also to call for this to continue after February 1992.[14]

## 9. FISHERIES AND FUTURE FINANCING OF THE COMMUNITY

An interesting link between the development of fisheries policy and the development of the Community as a whole is to be found in the current discussions over the future financing of the Community.

The limited structural funding made available in 1983 as a concomitant to the Conservation policy agreed that year provided Community funding for modernisation and new vessel building.

The substantial increase in fisheries structural funding in 1986 led to the exclusion of fisheries from the doubling of structural funds as a whole which was agreed by the European Community in 1988. However, the agreement on regional, social and agricultural spending did provide a precedent for fisheries in that Community structural policy now became five objectives which focused on particular problems in particular types of region ranging from backward industrial regions, so-called objective 1 to problem rural areas known as 5b regions. There had been talk of creating fisheries regions but no objective criteria existed. However, the 1983 conservation regulation pointed a way ahead. Article 8 states "Before 31 December 1991 the Commission shall submit to the Council a report on the fisheries situation in the Community, the economic and social development of the coastal areas and the state of the stocks and their likely evolution."

There was a further development in 1989 when Commissioner Marin took over responsibility for fisheries and third world development because he brought with him his previous experience as Commissioner responsible for social policy.

Social policy as such has been a problem area for fisheries. On the one hand, there is a Community context in safety standards for fishing vessels - an important matter given fishing's poor record - and there has been pressure from within the Parliament for progress on social policy, but on the other there is deep suspicion in certain Member States and in certain fleet sectors of Community attempts to interfere in working practices particularly in an industry which is for the most part family owned in many Community countries and where the scope for enforcing land based measures would be limited. Thus, despite the Commitment to develop social policy under Articles 117 and 118 of the Treaty of Rome, the progress of traditional social policy has been slight.

However, as the degree of overcapacity in the Community fleet has become more acute so the Community has seen a solution in the social policy field. The Pery Report of 1988 stressed the need for policy to take account of the socio-economic dimension of the fisheries sector of the regions concerned.

In November 1990, a group of academics led by the late John Gulland presented a report to the Commission highlighting the degree of over capacity in the Community fleet.

The group believed "the reduction in fleet capacity required for the Community's fisheries as a whole is not less than 40 % on average".[15] Clearly a reduction of anything like this volume of capacity would cause considerable economic and social dislocation.

In its outline paper on the factors to be taken into account in its review of the Common Fisheries Policy due by the end of 1991, the Commission recalled the Gulland figure and indicated that a significant volume of compensation would be required to soften the blow of any major restructuring and to provide alternative employment. The report stated "It would be desirable for accompanying measures to be conceived as an integral part of the reform of the structural funds in order to improve the economic and social cohesion of the Community".[16]

14. Debates of European Parliament 22/11/91
15. *Report of an independent group of experts on guidelines for the preparation of multi-annual guidance programmes in relation to the fishing fleet for the period 1992-1996.* European Commission 19/11/90
16. *The Common Fisheries Policy.* SEC(90)2244 - European Commission - 6/12/90

The subject was also fully discussed at a two-day seminar with Commission officials and MEPs at Arcachon in September 1990. The Commission's ten-year review of the CFP presented in 1991 further highlights the need for the designation of fishing regions.[17] The review also provides an opportunity to take the matter further because of the requirement for reports on the socio-economic condition of the regions - reports which were being completed in the spring of 1992 and will form the basis for the designation of fisheries dependent regions to benefit from the designation of a so-called objective six which has now been set out in the various documents produced by Commission President Jacques Delors in the aftermath of the Maastricht Summit of December 1991.

The Commission paper "From the Single Act to Maastricht and Beyond" states : "Because of the specific features of areas and regions directly dependent on the fishing industry there might be a case for adding an Objective 6 covering structural programmes for all regions involved in fishing."[18] This has been followed up by the paper *"The Community's Finances between now and 1997* which states that there will be a 58 percent increase in the allocation for the structural funds and that, inter alia this will go towards "structural measures in the fishing industry. This mainly involves :

- improving and adapting fisheries and aquaculture structures ;
- improving processing and marketing conditions for fisheries and aquaculture products ;
- formulating socio-economic flanking measures for the conversion of areas dependent on fishing."

While there will be a battle both in the Community and at Member State level over the volume of resources to be committed to the overall Community budget and while there may also be intense discussion over the definition of socioeconomic dependence on fishing and particularly over any more generalised moves towards a regionally based policy, the concept of support for fishing regions as an accompaniment to fleet restructuring has, with Parliamentary support, become an established part of Community thinking even without any formal legislative proposals.

## 10. CONCLUSION

The purpose of this paper has been to show how the influence of the European Parliament has grown in recent years. The paper has focused on a number of specific examples with which the author is familiar. The paper also shows how fisheries is an element in major Community decisions such as the financing of the Community in the light of the Maastricht agreement. Here too we can see the influence of the Parliament in developing Community policy.

17. *Report 1991 from the Commission to the Council and the European Parliament.* SEC(91)2288 fin 18/12/91
18. *From the Single Act to Maastricht and Beyond* . COM(92)2000 11/2/92

# The Common Fisheries Policy and the Role of Producer Organisations in South West England : Economic Considerations

**John Slaymaker, Aaron Hatcher and Stephen Cunningham**

Centre for Marine Resource Economics, University of Portsmouth,
Locksway Road Portsmouth PO4 8JF United Kingdom

ABSTRACT

*Within the Common Fisheries Policy (CFP), the statutory functions of Producer Organisations (PO's) are relatively limited relating primarily to the common organisation in the market for fishery products. The possibility of a wider role for PO's was referred to in European legislation but not in detail.*

*In the UK, PO's have been given wider responsibilities via the use of the sectoral quota management system. This paper discusses fisheries management in South West England paying particular attention to the emerging role played by PO's and issues arising from such developments.*

*The paper concludes with a brief discussion of possible developments of the CFP on the basis of a more regionalised structure and a more formalised role for PO's.*

## 1. INTRODUCTION

The role of Fish Producers' Organizations (POs) in the United Kingdom has developed substantially since the 1970s. They were originally established as marketing organizations which acquired statutory EC functions relating to the common organisation in the market for fish and fishery products. No statutory function in fisheries management was envisaged for them, although the possibility of a wider role was mentioned in legislation. Since 1984 most UK POs have become centrally involved in fisheries management, assuming responsibility for the management of separate quotas allocated to them by the UK Government under the so-called 'sectoral quota' management arrangements. In addition, a

recent consultation paper by the UK government (MAFF, 1992) clearly envisages a wider role for POs in terms of effort control and decommissioning. The growing importance of POs as a tool of fisheries policy in the UK clearly raises issues for the future of fisheries management, not just in the UK, but throughout the European Community.

This paper, based on exploratory research undertaken at the Centre of Marine Resource Economics at the University of Portsmouth (eg Hatcher, 1991), discusses the developing management role of POs based in the South West of England, in particular the South Western Fish Producers Organisation (SWFPO). The aim is to identify the issues arising and to evaluate their significance. In addition, the paper briefly addresses the possible future role of POs within the broader European context in the light of the recently published review of the Common Fisheries Policy (Commission of the European Communities, 1991).

## 2. THE UK SECTORAL QUOTA MANAGEMENT SYSTEM

The Shetland FPO was the first UK PO to be given a 'sectoral allocation' (for Area IV & VI haddock) in 1984. The system was subsequently extended to other POs and other stocks (including pelagics) in Areas IV & VI and soon became central to UK quota management in these areas. Sectoral management of Area VII stocks began in 1990 when the Irish Sea POs (the Anglo-North Irish, Northern Ireland and Fleetwood FPOs) took sectoral quotas for VIIa cod, whiting, plaice and sole in order to protect their fishing from Scottish vessels. Government Fisheries Departments (GFD) extended sectoral quota management to the rest of Area VII during 1991. 1992 is the first full year of sectoral quota management for the south west of England POs.

The operation of the UK sectoral quota management system may be explained by reference to the figure 1.

*Under 10m vessels* have a separate allocation, regardless of whether they are members of POs or not, and this is managed directly by GFD. In the case of such vessels, fishing is simply either unrestricted or prohibited.

The *over 10m fleet* is divided into the 'sector' and the 'non-sector' for the purposes of quota management.

The *sector* is defined as vessels in membership of a PO for which a sectoral allocation has been made for a particular stock. For example, the SWFPO has taken a sectoral quota for Area VII megrim in 1992 - SWFPO members are therefore defined as being "in the sector" for Area VII megrim.

The *non-sector* comprises vessels not in membership of a PO or those in membership of a PO for which no sectoral allocation has been made for a particular stock. For example, the SWFPO has not taken a sectoral quota for Area VII saithe in 1992 - SWFPO members are therefore in the non-sector for Area VII saithe.

It is therefore apparent that the same vessel can be in the sector for some stocks and in the non-sector for others.

*Non-sector allocations* are managed directly by GFD through 'licence variations'. These list restrictions for appropriate stocks and are issued as required, according to the pattern of quota uptake. For example : 'no restriction', 'x tonnes per vessel per calendar month' (either flat rate or according to length or horsepower band or whether vessel is a beam trawler or non-beam trawler), 'suspension' (when it is considered necessary to reserve allocation for later in the year) or 'closure' (when the non-sector allocation is exhausted). The basic aim of management is to 'share out' quota between vessels and throughout the year, while neither under-utilising nor overshooting the total quota.

*Sectoral allocations* are managed by the POs themselves through the imposition of restrictions similar to those used GFD, but clearly they may be operated in a manner better suited to the particular local requirements of the PO membership (in terms of fishing methods, sizes of vessel, seasonality of fisheries and market demand, weather etc). Sectoral allocations are offered and granted by GFD in response to requests from POs. Allocations are calculated as a percentage of the total UK quota on the basis of the landings track record of the PO's licensed membership (ie vessels over 10m) over the preceding 3 years (2 years for pelagic stocks). The track record itself is calculated as a percentage of the total UK quota *uptake* in those preceding years for the stock in question. Allocations are usually made at the beginning of the year but POs can and do make requests at other times.

The decision to apply for and to accept a sectoral allocation by a PO depends on a number of factors. Essentially, it is worth while the PO taking a sectoral allocation if as a result its members are likely to be better off in terms of fishing opportunities for the particular stock than they would be in the non-sector. This point is discussed further in section 4.

*Withdrawal from the sector* is allowed by GFD provided that the PO's management during the year in question has not been less restrictive than that applied to the non-sector. For example, in April 1992 the SWFPO moved into the non-sector for Area VII hake after provisional sectoral allocations for this stock (together with Area VII anglers and megrim) were revised downwards by GFD to increase the non-sector's allocation because of the re-registration and licensing of formerly excluded 'Anglo-Spanish' ('quota-hopping') vessels.

The sectoral quota may change during the year for a number of reasons, which may also have a knock-on effect on subsequent years' allocation. For instance, *swaps* are allowed between POs provided they are ratified by GFD. At present all swaps must balance. Where different species are involved, transactions are calculated on the basis of cod equivalents. Since allocations are always made on the previous three years' track record, any net change in landings at the end of the year as a result of swaps will affect subsequent years' allocations accordingly. *Increases in allocation* can otherwise only be achieved by a PO through new membership at present.

*Reallocations of quota* by GFD are often necessary in the autumn. GFD reserve the right to reallocate part of a PO's quota to the non-sector if the PO looks likely to underutilise its allocation. The underlying principle is "if you don't use it, you lose it."

*Closure of a fishery* may also be imposed by GFD even if some POs have allocation left on paper for the year. If uptake by the non-sector or the =10m fleet (or indeed by other POs) were to overshoot their allocation so that the total UK quota were exhausted before the end of the year, then GFD would have no option but to close the fishery to all vessels. Compensation adjustments may, however, be agreed to by GFD in allocating quotas for the subsequent year.

If a PO is left with *unused quota* at the end of the year it inevitably loses a part of its quota for the following year since allocations are always based on the immediately preceding three years' track record. Once again, the "if you don't use, it you lose it" principle applies.

If a PO *overshoots its quota*, it will only be penalised in the following year if another PO or the non-sector has been prejudiced as a result (ie. has lost fishing opportunities that would otherwise have been available). Excesses are always discounted from the PO's track record.

## 3. POS IN THE UNITED KINGDOM

There are currently 14 officially recognised POs in the UK. These are classified by the EC as representing predominantly 'high-seas', 'offshore' or 'local inshore' fishing vessels :

High-sea fishing :

The Fish Producers' Organisation (Grimsby)

Grimsby FPO

Offshore fishing :

Aberdeen FPO

Anglo-Scottish FPO (Berwick)

Fleetwood FPO

NE of Scotland Fishermen's Organisation (Peterhead)

Scottish Fishermen's Organisation (Edinburgh)

Local inshore fishing :

Anglo-North Irish FPO (Kilkeel, Co Down)

Cornish FPO (Newlyn)

Fife FPO Northern Ireland FPO (Portavogie, Co Down)

Shetland FPO (Lerwick)

South Western FPO (Plymouth)

Yorkshire and Anglia FPO (Bridlington)

## 4. PRODUCER ORGANISATIONS IN SOUTH-WEST ENGLAND

The two POs in the South West of England are the Cornish Fish Producers' Organisation (CFPO) and the South Western Fish Producers' Organisation (SWFPO). In terms of gross earnings, roughly 70 % of the Cornish fleet belongs to the CFPO and 80 % of the Devon fleet to the SWFPO. The main areas of operation for member vessels are primarily in ICES Area VII where a wide range of species are caught, but the emphasis is on high unit value species such as sole, monkfish, hake, lemon sole and plaice. Many of these species are subject to "pressure stock management"[1]. A high proportion of landings are exported to other EC countries, notably France, Spain and the Netherlands.

Historically, both POs operated market support for a narrow range of species, primarily mackerel and pilchard. However, in recent years the POs have successfully encouraged members not to target pelagic species in the absence of viable markets so that the withdrawal system now operates only rarely. Significantly, market support arrangements have never operated for prime demersal species. South West fisheries witnessed a major development in 1991 when both POs took sectoral quotas for the first time.

The South Western FPO Ltd was established in 1974 and was the first PO in UK to be recognised by the EC. The SWFPO currently has 161 members, based mainly in Brixham and Looe, but including vessels from elsewhere in the south and southeast (eg Shoreham) and the Channel Islands. The common link for membership is increasingly the areas and species fished rather than the base port. During 1991 the SWFPO took sectoral quotas for 4 stocks in Area VII (anglers, megrim, hake and VIId sole). In 1992, its first full year of sectoral management, the SWFPO took sectoral allocations of 18 stocks, but this was later reduced to 17 when it moved back into the non-sector for Western hake. These 17 stocks are : Sole VIIa, VIId, VIIe, VIIfg, VIIhjk ; Plaice VIIa, VIId, VIIe, VIIfg, VIIhjk ; Whiting VIIa, VIIb-k, IV, VI ; Anglers VII, Megrim VII, Pollack VII, and Western mackerel.

## 5. ISSUES ARISING FROM SECTORAL QUOTA MANAGEMENT IN SOUTH WEST ENGLAND

Preliminary research concentrating on the emerging management role of the SWFPO in particular led to the identification of a number of issues relating to decision making by PO managers and to the sectoral quota management system as a whole.

A fundamental issue for POs is the decision whether or not to take a sectoral allocation. Two possible kinds of benefit may flow from an allocation, and these might be termed 'catch increase' and 'catch insurance'.

**Catch increase** will occur if, as a result of a sectoral allocation, PO vessels are able to land more of a given stock than they would be able to if they remained in the non-sector. This would arise if the average catches of PO members over the track-record period were higher than the average for the non-sector (although in practice this is difficult to know with certainty). The PO needs to have a good track record of catches over the three years prior to taking an allocation. Because sectoral quotas are allocated as a *percentage* of the total UK quota uptake, it is more important that the PO's track record is good relative to total landings than as an absolute amount. In 1991 the SWFPO, for example, decided to wait before applying for an allocation for Area VII whiting as catches were still increasing from the new pair trawling fleet in Looe.

**Catch insurance** may arise in the sense that, even if fishing opportunities are expected to be no better than in the non-sector, it might be wise to take a sectoral allocation if it is considered likely that a reallocation or early closure might

1. Pressure stocks are those (effectively all quota stocks) for which unrestricted fishing is considered by UK government to be inappropriate. Vessels wishing to exploit such stocks must be licensed and must observe periodic restrictions attached to such licences.

result in fishing opportunities in the non-sector being 'unexpectedly' prejudiced. This would not only harm members in the short term but there would be the prospect of a bad year in the track record. It may be wise for a PO to opt for a sectoral allocation lower than it might ideally have sought if the need for 'insurance' is perceived. This was the reasoning behind the SWFPO's request for VIId sole in July 1991 and its late decision (contradicting its own position of just a month previously) to opt for anglerfish, megrim and hake as well in September of that year. Interestingly, for opposite reasons, the SWFPO moved out of the sector for hake in April 1992, as discussed above.

There is always the possibility that something may reduce the expected take up by the non-sector, so that later in the year more is available to those vessels than to PO boats. This happened to the Scottish Fishermens' Organisation (SFO) in 1990, when in December non-sector boats were on unrestricted fishing for North Sea cod and haddock, while SFO vessels had no cod left and only 2t pcm of haddock.

Nevertheless, the general arguments in favour of the sectoral quota system are reasonably well rehearsed, for example in the paper by Goodlad (1992). The major advantage of the system is that day to day decisions on quota management can be taken at a more appropriate level, that is at the level of the PO membership, and that there will inevitably be more flexibility and responsiveness to changing requirements. It is argued that local fishermen are better placed than GFD to decide how to allocate the quota between boats and over the fishing year, according to the many relevant factors, including market demand. In this way, POs are able in theory to 'maximise potential profitability' of their members. It is also reported that fishermen are likely to pay far greater respect to management measures imposed by their own PO than to those imposed from higher up. This has important implications for the success of quota management and enforcement.

The manner in which a PO manages its sectoral allocation will depend on the particular characteristics of its membership in terms of target species, sizes of vessel etc. The SWFPO, for example, has so far only used flat rate monthly restrictions (ie. the same for all member vessels). The Shetland FPO allocates quota on a bi-monthly basis according to vessel size (measured in terms of both length and horsepower) while the Anglo-Scottish PO imposes monthly restrictions according to crew size. Some POs with pelagic quotas (eg. Shetland) make annual allocations to individual vessels.

The immediate advantages of a sectoral allocation to PO members are often stark. For example, in May 1992 the following restrictions were applied by GFD to non-sector vessels fishing in Area VII :

| | |
|---|---|
| Plaice VIIa | 5 tonnes/vessel/month |
| Whiting VIIb-k | 5 tonnes/vessel/month |
| Anglers | 8 tonnes/vessel/month |

Whereas SWFPO members at the same time were on the following restrictions imposed by their own PO :

| | |
|---|---|
| Plaice VIIa | Unrestricted |
| Whiting VIIb-k | 10 tonnes/vessel/month |
| Anglers | Unrestricted |

The existence of two separate groups (sector and non-sector) is understandably potentially divisive, and there are already signs of conflict between the two groups, as the following examples illustrate.

In 1990 there was controversy over misreporting of whitefish catches in Area VII. A number of Scottish vessels were accused of taking North Sea fish (particularly cod and haddock), for which as PO members they had sectoral quotas, and reporting these catches as coming from the Irish Sea where they were part of the non-sector, so dishonestly saving their own sectoral allocations for later in the year. Because the catches were counted against the non-sector for Area VII, this led to severe early restrictions on fishermen in South West England, including a closure of the non-sector cod fishery in VIIa. Although the argument was never completely resolved, for 1991 and 1992 GFD automatically issued allocations (based on track records) for all three areas VI, VI and VII when POs took allocations of cod, haddock, whiting or saithe in any one or more of these areas. The 1990 figures for cod, haddock and saithe in Area VII have been ignored in calculating the appropriate track records. Consequently, in 1991 and 1992 some northern POs holding sectoral quotas in Areas IV and VI were given unrequested Area VII allocations for the same species of a few tonnes or in some cases zero (ie. no fishing allowed at all).

Another area of controversy has been the recent reallocation of quota from the sector to the non-sector in Area VII by GFD to compensate for the re-instatement of the so-called 'quota hoppers' to the UK Register, as mentioned previously. At the same time, a number of former 'quota hoppers' are now in the process of setting up their own 'Anglo-Spanish PO' to be based in Milford Haven, a move which is not welcomed by other fishermen in the south west.

In the south west, to some extent sectoral quotas have been seen as a refuge from pressure on the non-sector from the Anglo-Spanish 'flagships' and a possible repeat of the sort of problems arising from the 1990 VIIa misreporting scandal.

A fundamental issue relating to the sectoral quota management system as a whole, and one which may well become problematic before too long, is the relative size and constitution of the sector and the non-sector.

POs have a legal duty not to discriminate against applicants (for example, on grounds of race or sex), but nevertheless retain the right to refuse applicants membership. This is significant, for there is no advantage to a PO with sectoral quotas in accepting a new member whose track record for the relevant stocks is less than the corresponding average for the existing membership. The increase in the SWFPO's membership from 1991 to 1992, for example, comprised boats with good track records of sole and plaice.

If POs are striving for a quality of membership based upon track records and they are permitted to do so, then it is possible that one might witness the emergence of elite clubs only open to the most successful fishermen, where any benefits accrue. While efficiency gains and rent generation might be facilitated as a result, there will also be distributional consequences and equity issues.

The benefits of PO membership therefore arguably depend on a proportion of the fleet remaining outside the sector. It also follows logically that if all vessels were in POs with sectoral allocations, then the problems of management with a fleet that is significantly over capacity would simply be transferred from GFD to the POs. This has led to sectoral management being viewed by some fishermen in the south west as a case of GFD trying to 'pass the buck'.

Expanding the size of existing POs or forming new ones may therefore not be desirable for improved resource management. There is no evidence that problems between POs or between POs and the non-sector will disappear, and until fleet capacity moves into line with the available catches, conflict about equitable treatment will always remain. The UK government's proposals (MAFF, 1992) on the increased role for POs in fleet capacity reduction appear to be an acknowledgement of the problems, and could be interpreted as a recognition that purely relying on sectoral quota management as the single role for POs is inadequate.

The consultation paper issued by GFD on effort control and decommissioning in April 1992 contains the following suggested changes to the role of POs in fisheries management :

> i) *Free trading* of quota between POs : Swaps need no longer balance and quota could be sold by one PO to another. Quota could in theory be swapped with non-sector, but not bought or sold.
>
> ii) POs could *buy* the track record of a member vessel wishing to exit from the fleet (but only as an alternative to decommissioning funded by Government). Sectoral allocation would then be calculated as if the vessel had stayed in the PO but had not fished : its track record would be absorbed by the remaining members so that at the end of three years its track record would have expired but those of the other vessels in the PO would be enhanced accordingly.
>
> iii) While licensing is to be extended to under 10m vessels from 1993, these licences will be simple permits and there are no plans at present to change the way in which the under 10m allocations are managed by GFD.

## 6. CONCLUSION

In the mid-term review of the Common Fisheries Policy (Commission of the European Communities, 1991), the European Commission hints that POs might play a more significant role in fisheries management throughout the EC. One of the objectives proposed for the revised policy is as follows :

> "distribution of responsibility at all levels, in accordance with the subsidiarity principle, conferring responsibility on the parties concerned, in particular the fishermen's organisations which could be given the task of implementing the management measures at the appropriate level." (page v)

It is also stated that :

> "The principle of subsidiarity requires appropriate sharing of responsibility among the Community, the Member States, the regions and the fishery professionals.
>
> The hierarchy of rules (clarified and simplified rules, national implementing measures, administrative provisions and Community intervention) must allow much of the work of implementation to be delegated to the various parties concerned (national, regional and professional authorities), giving them sufficient scope to choose the means and the methods used. Here the rule must be to optimize the degree of flexibility allowed to the various partners" (page 66)

We actually know relatively little about the way in which fisheries management by POs might develop, and as economists we need to use our conceptual frameworks and techniques to further understanding of POs in order to help identify their most appropriate role in the future of fisheries policy in Europe.

## REFERENCES

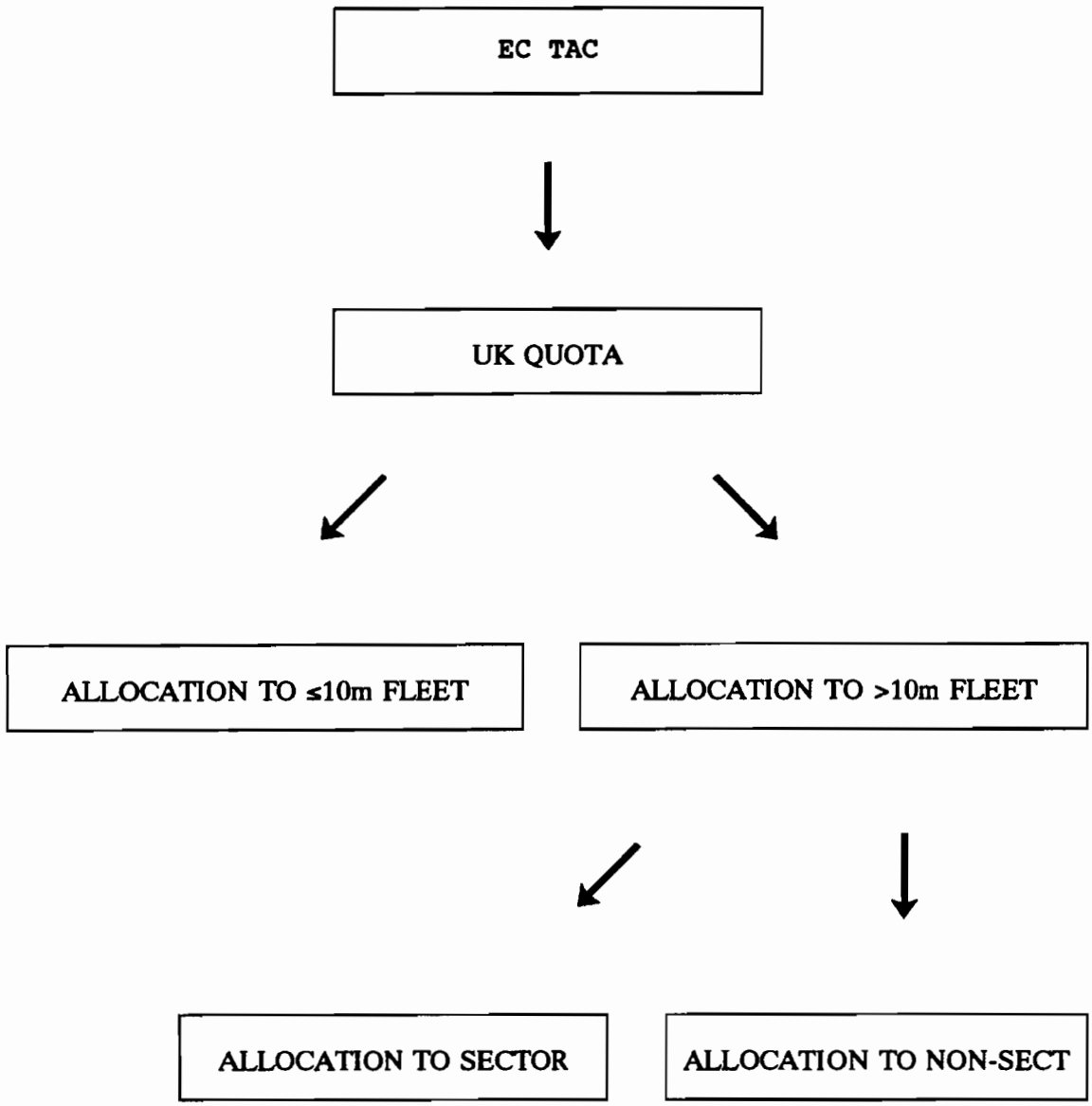
**MAFF (Ministry for Agriculture, Fisheries and Food)** (1992) ."Effort Control and Decommissioning" Consultation Paper for Fishing Industry Organisations.

**Hatcher A.** (1991). *Area VII Quota Management and the Role of Producers' Organisations in Devon and Cornwall.* CEMARE (Centre for Marine Resource Economics), University of Portsmouth, Report R15, 115p.

**Commission of the European Communities** (1991). *Report 1991 from the Commission to the Council and the European Parliament on the Common Fisheries Policy.* SEC(91) 2288 final.

**Goodlad J.** (1992). "Fisheries Management by Sectoral Quotas - An Assessment of the UK System" Paper presented at the annual conference of the European Association of Fisheries Economists. Salerno, Italy.

**FIGURE 1 :**
**THE UK SECTORAL QUOTA SYSTEM**



# Evaluating Socio-Economic Impact of EEC Fishery Policy Using a Social Accounting Matrices Approach

**G. Cella, V. Placenti and M. Spagnolo ***

I.R.E.P.A. Istituto Ricerche Economiche per la Pesca E l'Acquacoltura, via B. Croce, 35, 84100 Salerno, Italy

ABSTRACT

*Aim of the paper is to suggest and apply a methodological scheme for the evaluation of socio-economic impacts of EC fishery policy at sub-regional level within a general planning framework, when variations in the scheme of fishing are also introduced. The proposed evaluation approach considers the direct effects of the activity and the effects variations will have on the rest of the economic system through the interdependencies of sectors - the indirect effects. The impact of the overall effects of a reduction in fisheries and related sectors considers the role of production, intermediate and final consumption and investment. Effects are estimated using the Social Accounting Matrix (SAM) which approach make use of existing interdependencies in the economic system. The analysis has been applied to five administrative italian regions. Results are reported and expressed in terms of four indicators : the value of gross output, value added, incomes earned by employees and employment.*

## 1. THE IDENTIFICATION AND CHARACTERISTICS OF ZONES HIGHLY DEPENDENT ON FISHERIES AND ANCILLARY SECTORS

### *1.1 Identification of the zones through the measurement of relative dependence : a traditional approach*

#### 1.1.1 Introduction

The investigated area is comprised of five administrative regions containing 26 administrative provinces (of which 18 are on the coast) (fig. 1). It has four administratively distinct coastlines, which in turn are subdivided up into 16 maritime

* This research is part of a larger work commissioned by EC, Directorate for Fisheries, Direction of Structures, within a series of socio-economic studies in the Community.

districts each with autonomous maritime control and powers of jurisdiction. Each of these districts has its own particular geographical and social characteristics. The existence of around 300 landing-points with the consequent dispersion of the fleet and employment along the 2,000 km of coast is the dominant characteristic of fishing activities.

In the area under study there are no "real" centres of fisheries. In fact, to the distribution of resources and the consequent dispersion of the fleet along the entire coast, should be added the structural characteristics of fishing methods and supporting activities. The entire area is, therefore, characterised by dissagregated and disaggregating fishing activities whether in physical, economic or social terms.

To summarise, fishing activities in the area under consideration are the sum of a series of highly localised situations which, determined by the widely varying characteristics of the local sea's ecosystem, have given rise to a multiplicity of locally specific methods of production. **Thus, one cannot assert that there exist "geographical zones highly dependent upon fisheries" which go beyond the confines of the local administrative unit (comune) in which fishing is carried out.**

Looking at the situation from the overall point of view, the degree of concentration of the fleet and the landing places and, therefore, employment is so low that fishing activities in the area in question appear as a continuum along the length of the coast.

**Thus, it is important to stress that the relative importance attributed to fishing will be highly sensitive to choice of the level of geographical dissagregation to which the suggested socioeconomic indicators relate. The evaluation of socioeconomic indicators changes radically when one passes from the regional to the provincial level. Furthermore, it is only at the level of the local administrative unit (comune) that the role and relative importance of fishing in the local economy (principally as regards employment) can be identified with clarity and precision.**

With regard to the question of employment, it should be pointed out that, in the context of the territorial subdivision for the purposes of economic analysis, and, in particular, labour economics, the "local labour systems" and the "functional labour regions" in Italy are territorially correlated entities, both of which are designed to identify local labour markets and are therefore a point of reference in the design and management of active labour market policy.

The model of the territorial repartition of Italy represents a development of the "Standard Metropolitan Areas (SMSA)" (USA- 1960), the "Functional Economic Areas (FEA)" (USA-1970), the "Standard Metropolitan Labour Areas (SMLA)" (GB-1978), the "Travel to Work Areas (TTWA)" (GB-1974), the "Daily Urban Systems (DUS)" (GB-1979), as well as the "Regionale Arbeitsmarkte" (RDF) and the "Zones d'Etude de l'Emploi (ZEE)" (FR-1985).

The territorial dimensions of "local labour markets" in Italy do not go much beyond communal boundaries, and, more or less, coincide with the said comunes. Furthermore, according the ISERS model [1]of the functional repartition of the territory (IT-1990), Italian comunes have, on average, a degree of occupational autonomy (self contained employment) of over 90 %, or, in other words, almost all employment opportunities are contained in the comune of residence of the workers. This is all the more true in areas in which the local economy is heavily dependent on fisheries and ancillary activities. In other words, this implies the penalisation of geographical labour mobility with the consequent rigidity in employment in productive areas (administrative comunes or provinces).

To this rigidity, is added the intersectoral rigidity, whether at a regional, comunal or local level, which characterises productive activity in the area in question. If one adds the specialised character and the emargination of fisheries, one can only emphasise the meaninglessness of the identification of specific geographical zones which are highly dependent on fisheries and ancillary activities. **It is not unreasonable to suggest that, in the area under study, there are as many zones which are highly dependent on fisheries as there are landing-places.**

Unfortunately, this suggestion cannot be verified by a quantitative analysis. In fact, in Italy, the absense of a data on the relevant variables at a communal (local administrative unit) level and the implicit difficulties of estimation impede the precise identification, or rather ordering, of the degree of relative dependence of comunes on fisheries.

We report, however, results obtained at the level of the administrative region and at that of the province (tables 1 and 2). The latter provide the basis for the identification of the "zones highly dependent on fisheries" (even if the concept is not really applicable in the present case). The relative dependence being assessed in primarly and secondly terms on employment and in economic terms (tables 3 and figure 1).

1. A. Erba *et al.*, *Partizioni funzionali del territorio: il modello*, Franco Angeli, 1990.

The statistics relating to employment in, and the value added of, fishing employed for the classification of administrative regions are the official ISTAT figures, whilst for related activities the statistics are the result of our estimates produced on the basis of the classification of the individual economic activities related to fishing (of which there are more than 250) drawn from the sectoral interrelationships between branches and sectors of economic activity at the national level, grouped into the 17 branches of economic activity (SEC classification) at the regional level which were constructed for each individual administrative region under consideration.

### 1.1.2 Relative dependence at the level of administrative regions and provinces

The population present in the investigated area represents 32 % of the national total and comes to 18,200 million people, of whom 40 % are in the labour force. The high rate of unemployment (roughly 17 % compared to the national average of 12 %) in the area, however, brings total employment down to around 6,200 or 29 % of national employment. A consequence of this is the lower per capita gross output of the area equal to 11,100 ECU compared to the national average of 12,200 ECU.

Employment in fisheries represents just 0.27 % of total employment in the area and produces just 0.10 % of total wealth. If one considers also activities related to fisheries the degree of relative dependence increases to 0.44 % in terms of employment and 0.24 % in terms of economic value.

There are substantial regional disparities in the area under consideration and it is rather difficult to classify one in particular as the administrative region which is highly dependent on fishing, even though Liguria has the highest values of the relevant statistics. Such a classification would ignore 80 % of employment in, and 70 % of valued added produced by, fisheries and ancillary activites in the area.

Rather, there is a balance between the relative degree of dependence in economic and occupational terms both for fishing and for all the activities connected to it. This is the consequence of the specific productive structures and the relative weight that local economies have within the individual administrative regions and/or the geographical area under study.

One may thus identify the existence of "zones highly dependent on fisheries" distributed in patches across the entire area. This distribution is even more clearly identified when one considers the individual provinces (see table 2).

This demonstrates the difficulty of application and the limited usefulness of economic measures applied to individual regions or provinces in the area.

Nevertheless, four "zones highly dependent on fisheries and ancillary activities" have been identified in area. On the basis of the relative importance of fisheries, in economic and occupational terms, the zones are : the provinces of Livorno and Grosseto in Tuscany ; the province of Latina in Latium ; and, the Imperia province in Liguria (see table 3). It is important to stress that the identification is highly dependent on the specific criteria adopted. Indeed, the results for the above provinces are not so far away from those for other provinces in the area. It may be noted that the adoption of the above criteria immediately leads one to the consideration of just three of the five administrative regions in the area, excluding precisely the regions in which employment opportunities outside fishing are much more limited with respect to the other three.

For the regions with weaker economies, being penalised in this way, would only aggravate the already existing problems in terms of the productivity of labour and capital.

These considerations lead one to suggest the use of alternative criteria for identifying zones highly dependent on fisheries, leaving aside measures which only take account of the direct effects of fisheries on employment and production.

## 2. IDENTIFICATION OF THE ZONES USING THE SOCIAL ACCOUNTING MATRIX (SAM) APPROACH

### *2.1 Criteria employed for the identification of geographical areas which are highly dependent on fisheries*

A consideration of the economic and social importance of variations in the scale of fishing should take account, not just of the direct effects of the activity under consideration, but also the effects variations will have on the rest of the economic system through the interdependencies of sectors - the indirect effects.

The analysis of direct and indirect effects through the economic analysis of productive interdependencies have helped to resolve similar problems to the one under consideration here. One thinks of the example of the report prepared by M.I.T. economists regarding the dispute between Canada and the United States concerning fishing rights in the George Bank area, which came before the Aja High Court of Justice [2].

The evaluation of the overall (direct and indirect) effects of a reduction in fisheries and ancillary activities takes into account the roles of production, intermediate and final consumption and investment.

As regards the roles of production and consumption, a reduction in the level of activity in any sector in a particular area will have immediate repercussions for the level of income generated and distributed in the area through that activity. In the absence of specific (e.g. legislative) constraints, almost immediately one witnesses a reduction in the demand for labour in the activity, probably affecting the weaker segment of the labour force disproportionately. These are the direct effects, to which are added a series of indirect effects on incomes and employment depending on the interdependencies in production and consumption.

With regard to interdependencies in consumption, the initial reduction in the fishing activity gives rise to a reduction in incomes and therefore a reduction in expenditure financed by those incomes. In as much as part of local incomes are spent on local products, there will be a further reduction in local production with its consequent effects on incomes and so on. At this point, it is clear that the true overall effects comprise not only those considered above, but also include a series of spillover or indirect effects resulting from interdependencies in the local economy. For reasons of brevity, in the literature on the subject all overall effects (including direct and indirect effects) are called multipliers of second type.

As regards the role of investment, a reduction in the activity of interest also gives rise, to a certain extent, to a variation in investment flows, apart from that necessary to cover the replacement of equipment. Also in this case, the reduction in demand will give rise to a series of secondary effects as described above.

### *2.2 Methodological issues : a quasi-SAM approach*

The quantification of the effects outlined above can be undertaken using Social Accounting Matrices (SAM) which delineate existing interrelationships in the economic system. These interrelationships are captured not just as concerns production but also with regard to the generation, distribution, redistribution and expenditure of incomes. With the purpose of taking into account of the most important interrelationships, tables were constructed which may be thought of as a "half-way house" between the traditional Input-Output model and a typical SAM with a complete structure. This "half-way house" is termed a quasi-SAM, which, on the one hand takes account of interdependencies in production, whilst on the other, although including the generation and distribution of incomes, does not take into account all the aspects of these flows (ignoring, for example, the redistribution of incomes, effects on different social groups and so on) which, although interesting, in our case, appear to be of secondary importance.

### *2.3 Results : overall effects*

Table 2.6 reports the overall results for the administrative regions in the area. The results are expressed in terms of four indicators of a socioeconomic character. These indicators are : the value of gross output ; value added ( in other words the sum of distributed incomes) ; incomes earned by employees (salaries and wages) and, employment.

The impact on each indicator is considered for each region of a given reduction (one billion lire, roughly equivalent to 650 thousand ECU) in the value of produce of the fishing sector of that region. On the basis of data on production and value added for each segment of the fleet, it is straightforward to derive the corresponding figures in terms of the reduction in tonnage and productive units (see tables 5 and 6).

**It should be stressed that having reported the effects of a specific reduction, one may immediately evaluate the effects of any given change in the scale of fishing in the region under consideration (see tables 6, 7 and the appendix).**

2. P.G. Jordan, K.R. Polenske, *Multiplier impacts of fishing activities in New England and Nova Scotia,* 1988.

For every reduction in fishing of one billion lire, the area under consideration will witness, on average, a reduction in gross output of two billion lire (around 1.3 million ECU) in each region, with small variations between administrative regions (see the first column of table 6). The gross income of the area considered would fall by 1.3 billion lire (equal to 850 thousand ECU) on average (see column 2) with the consequent average reduction in employees' incomes of 700 million lire (equal to 450 thousand ECU) in the area (see column 3).

**The most worrying results encountered in the study relate to employment.** In this regard, one finds that a reduction of one billion lire (650 thousand ECU) reduces unemployment by 70 thousand working units (see column 4). Finally, column 5 gives the reduction in annual employment in the region arising out of a unit reduction in employment in fishing which, on average, comes to around 1.38.

It should be remembered that the reductions in employment are expressed in terms of the full-time annual manhours. Thus, the concept of a working unit does not necessarily correspond to actual employees whose actual working hours will vary between types of work. In other words, the figures refer to the volume of work in productive activities.

**In practice, the results obtained concerning the effects of a unit reduction in gross output (see tables 6, 7 and appendix) allow the calculation of the overall variation in any of the relevant quantities.** Specifically, GRT, KW, number of boats, volume of produce, or prices both by geographical area or fishing method.

Once the structural parameters concerning fishing activities in specific regions have been derived (for example : GROSS OUTPUT/GRT, GROSS OUTPUT/KW, GROSS OUTPUT/HOURS, GROSS OUTPUT/WORKING UNITS, GROSS OUTPUT/EQUIPMENT etc.,), in order to analyse any conceivable scenario, it is sufficient to define the amount (in terms of value) by which the output of the region falls. Multiplying this by the relevant indicator(s) given for the specific region gives the overall impact of the reduction on the quantity of interest.

In the case of the administrative regions in the area, and more generally, the case of Italy, the structural parameters of fishing activities (by type of boats, fishing method and geographical area) have been derived by IREPA [3]on behalf of the Ministry for the Merchant Navy and European Commission. Tables 4 and 5 reproduce some of these parameters which underly the calculation of overall impact, in this case concerned with the reduction in tonnage.

In practice, once the proportionate reduction in tonnage of the regional fishing fleet has been established, the overall effect is calculated on the basis of the gross tonnage of boats in the area. Through the use of the parameter GROSS OUTPUT/GRT the equivalent reduction in gross output (in value terms) is then derived. This figure is reported in unitary terms and the ratio is applied to the regional socioeconomic indicators. Finally, given the ratio of annual full-time equivalent manhours to regional employment, the overall effect in terms of the actual number of people employed is determined.

As regards overall employment effects, the reduction of 650 thousand ECU results in the loss of around 50 jobs, 40 of which in fishing sector.

To summarise, for every reduction of one billion lire (equal to 650 thousand ECU) in fisheries, there are, more or less, 40 fewer seamen employed in fisheries and ten fewer employees in ancillary activities.

**This may be translated into a reduction in the loss of 300 jobs in area I.1, following the reduction of 2 % in gross tonnage required by the Commission's for the period 1991-1996.**

### 2.3.1 Impact of the direct and indirect effects

From the overall indicators, it is possible to derive some general indications.

On Gross Output

Gross output is the indicator which varies the least between regions.

The differences that do exist, with Tuscany first followed by Campania with the other three administrative regions in the area bringing up the rear, depend fundamentally on two type of interaction in production : the interaction between fishing and other activities ; and, interactions within the latter.

3. IREPA, *Sistema di rilevazione sistematica ed organica degli indicatori economici della pesca in Italia,* 1991; *Le interelazioni settoriali nella pesca italiana: un' analisi input-output,* Dec. C (85) 2223/7, 1986; *Standardizzazione dei parametri tecnici ed economici della pesca italiana,* Dec. C (85) 2223/6, 1986.

The indicator under consideration is predominantly affected by the interactions between fisheries and other related activities and is less influenced by factors which are internal to the sector, such as, for example, the productivity of labour and capital. This gives an idea of the level of interdependence which links the fishing sector with the rest of the regional economy. This level is moderately intense and is fairly uniform across different regions (although there are some important differences which distinguish Tuscany and Campania from the other regions probably due to the greater interdependence between the sector and the rest of the economy).

**These considerations underline the fact that, in the case of the regions under consideration, fishing is a "pervasive" activity.** Even if it is adequately integrated with other activities, fishing has not given rise in any of the regions to particular territorial concentrations of fishing itself, nor of related industries. Fishing is an activity with a long tradition, and has not given rise, apart from in some particular cases, to the range of activities that produce a vertically integrated industrial complex.

On investment

The relative uniformity of the low level of investment flows confirms, indirectly, the absense of vertical integration in the productive process, or rather, the non-existence of a geographical area in which there is sufficient vertical integration of production to assert the existence of multi-sector productive processes, and, in the last instance, of "zones highly dependent on fishing". The low level of flows does not only depend on the low rate of substitution of equipment in all of the regions considered, but also on the fact that there is no concentration of boat building or of the construction of other fishing equipment in the area.

On value added and incomes

The indicator on value added shows the same lack of interregional variability as gross output. However, there are significant regional differences in labour productivity in the sectors bearing the brunt of the secondary effects. This reflects differences in the relative weight of labour and capital between regions.

The same is true of the impact on incomes, which is both of significant proportions and uniform across regions, as are the effects on employees' incomes (salaries and wages).

On employment

The impact on employment varies greatly from region to region which is due to the substantial differences in labour productivity across sectors. **As regards employment in the fisheries sector and induced employment, one notes that the direct and indirect effects are roughly proportional. Where the direct impact on employment in fishing is relatively small, so too is the fall in employment in other activities and vice versa.**

**Of the greatest importance to the present study, there is a tendency for the sizes of the direct and indirect effects to vary in opposite directions across regions, thereby dampening regional differences.**

This tendency is particularly pronounced in the case of gross output and value added, slightly less so in the case of employees' incomes, but, as indicated above, is entirely absent in the case of employment. This demonstrates the degree of complementarity that exists between the fisheries sector and ancillary activities. In other words, this shows the relative importance of the indirect effects in determining the dependence of geographical areas on the fisheries sector. The results obtained, with the aid of the construction of regional quasi- SAM's (which for the the sake of simplicity are not all given here, see final report), demonstrate, in general, that where the direct effects are small, the indirect effects are large and vice versa.

This tendency of compensatory movements in the two types of effects modifies, or rather, overturns the results obtained by the analysis above of the direct effects by themselves (see point 1), giving an entirely different picture of the "relative dependence of geographical zones on fisheries", as well as providing further evidence of the pervasive nature of this activity. Furthermore, it allows one to assert definitively the similarity of the regions in the area in terms of their relative dependence on fisheries.

### 2.3.2 Some considerations on the direct and indirect effects

The analysis up to here has been based on the assumption that a reduction in the scale of fishing will induce a more or less proportional contraction in employment.

In reality, the decrease in employment may well be more than proportional if a reduction in output is accompanied by a rationalisation of productive processes aimed at sustaining profit levels in the face of lower output.

Above all, if supported by incentives, the tendency to sustain stable profit levels becomes a serious likelihood. If, on the one hand, this leads to an increase in the indirect effects felt by ancilliary industries, such as boat building (indirect effects which, however, need not necessarily be felt in the inland areas of the region), on the other, they will also have a more than proportionate direct effect on the number of people involved in fisheries.

Unlike the indirect effects on investment, which do not necessarily occur in the same region and will tend to affect skilled industrial manpower, the direct effects on fisheries will be felt by the weakest segment of the workforce, for whom the transfer to another occupation is extremely problematic. This is true because the affected segments are the weakest in the work force, but also because the habits and traditions of fishermen do not adapt well to the rhythym required in other productive processes.

Regional differences in the effects on employment, which in Campania is almost twice the size of the effect in Liguria and Tuscany (see table 7), may be explained by the greater intensity of employment with respect to output in these two regions compared with the other three. This is particularly true of service sectors, which are the sectors which feel the indirect effects to the greatest extent.

One last consideration regards the significance of the indirect effects arising from the failure to substitute equipment in the fishing sector. This is an important aspect, given the insufficiency of available funds for the modernisation of boats. Indeed, it is well known that the large number of boats of an advanced age require a substantial financial undertaking, in the absense of which boat owners tend to postpone their decision to modernise from their own funds. In the absence of a substantial transfer intervention through capital loans as opposed to capital grants, it is extremely likely that things will remain the way they are.

The effects of the lack of investment are of a purely indirect character, whilst the overall effects have both direct and indirect consequences. In order to gain a clearer picture of the importance of the former, one needs to compare them, not with the overall impact, but with the indirect effects. The results of this comparison, which for simplicity of exposition are laid out just in the final report, confirm the limited role of these effects, which are however, substantial. It is worth noting that, at least in Liguria, Tuscany, Latium and Campania, these effects represent about 10 % of the indirect effects.

If accompanied by a policy providing incentives, concentrated on contributions on capital loans, a demand for investment aimed at replacing existing capital equipment in order to improve efficiency could be created. In this case, the effects under consideration would be positive and substantial and would counteract the negative trends in the economic and social indicators considered.

### *2.4 Results : sectorial and regional analysis*

A sectorial and regional analysis allows the evaluation and comparison of the impact on the socioeconomic indicators considered at the level of the 17 sectors for each region. With the aid of these results, it is possible to consider in detail the effects of different ways of reducing fishing in each of the regions under study.

The fundamental results emerging from these dissagregated data (which are given in appendix) is that, apart from those already noted, there are no substantial regionally specific effects. On the contrary, **the most important finding is that the indirect effects reach significant levels, not through a concentration in regional sub-systems, but in their pervasive presence of a large impact throughout all the sectors,** albeit with different levels of incidence. The greatest sectoral concentration in indirect effects is no more than 15 % (reached in very few cases). Furthermore, these relatively high levels of concentration occur in the service sectors (trade, lodging and catering). This demonstrates that these more concentrated effects are due to changes in the distribution of income expenditure rather than to specific cases of productive integration between fishing and other sectors.

## 3. CONCLUDING COMMENTS AND PROPOSALS

The identification of geographical zones which are highly dependent on fisheries and ancillary activities on the basis of the analysis of relative dependence (considered in section 1), can only give an indication of the direct effects on the local

economy, thus indicating the zones at immediate risk. The analysis using the SAM approach has demonstrated, on the other hand, that direct and indirect effects compensate each other, thus equalising relative dependence across individual areas and regions.

In general terms, a reduction in fishing activities in the Tyrrhenian regions in Italy would produce substantial socioeconomic effects, both direct and indirect. The latter, even if some caution must be used in giving excessive weight to the precision of estimates, appear to almost double the consequences on the socioeconomic indicators. Whether one considers total income, employees' incomes or employment, the secondary effects are always substantial. Their presence and the way in which they are induced, provides useful information for the refinement of policies aimed at compensating the negative effects under consideration.

It is clear that these policies must be altered according to whether they are intended to counteract direct or indirect effects.

In the case of direct effects, policies should be concentrated territorially, and aimed at supply. Territorial concentration is necessary because the direct reduction in incomes and employment will occur in coastal areas. The concentration on supply is important because it is necessary to identify alternative productive activities able to provide adequate incomes. The principal problem is not so much incomes, as that of transfering workers who, as members of fishing boats' crew, have acquired very specific traditions and working habits, to other forms of work with very different working rhythms and organisation. This is an extremely difficult problem, as has been shown by a study carried out by the New England Institute for Employment Policy in 1982 regarding the possibility of transfering the fishermen of the area to other activities, and by the experience of the various attempts that have been made in Italy over the last ten years to bring about such transfers.

As regards the indirect effects, on the other hand, their pervasive nature and the varied routes which they follow suggest that the appropriate action would be a policy aimed at sustaining the level of regional demand. Obviously, such policies could be coordinated with those aimed directly at the fisheries sector, however, without the need for a particular territorial concentration since it has been shown that the secondary effects have the peculiarity to be widely diffused amongst all the regions' activities.

It is important to remember that, as is noted above, the demand for investment could play an important role in counteracting negative indirect effects. Thus, alongside a policy on supply aimed at aiding the re-absorbtion of the labour force leaving the fishing sector, a policy encouraging the substitution of capital equipment would be useful. Unfortunately, however, such a policy will only be beneficial in regions which are able to satisfy this investment demand in significant measure.

In the absense of this capability, the positive effects will be felt by different regions to those suffering the damage. Thus, in regions which do not produce a substantial quantity of capital goods, the only remaining alternative is a policy aimed at sustaining final demand.

## 4. APPENDIX : METHODOLOGICAL NOTES

1. The application of Input-Output analysis to the evaluation of the effects (at a regional level) of different possible scenarios regarding the evolution of fisheries in our country requires the availability of intersectoral tables with two basic characteristics. On the one hand, the sectoral breakdown must be sufficient to allow the identification of fisheries as a sector separate from other primary activities. On the other, a territorial breakdown is also necessary to allow the differentiation of the socio-economic effects at a regional level.

These two requirements are not satisfied by available sources of official statistics.

On the one hand, national tables are available in which the degree of sectoral breakdown is sufficient, but these neglect the territorial aspect (ISTAT, "Tavole settoriali dell'economia italiana a 92 branche produttive per l'anno 1985"). On the other, there are tables constructed at the regional level (Progetto FORMEZ-ISTAT, "Tavole delle interdipendenze settoriale delle regioni italiane al 1986). The latter, however, contain a lower degree of sectoral disaggregation, considering just 17 productive sectors in which fisheries appear as part of the "Agriculture, forestry and fishery products" category and not as a separate sector.

This implies that the first step in the analysis consisted in the breakdown of the regional tables to separate fisheries from the other activities with which it was aggregated. In order to undertake this disaggregation, a method was employed based on the indirect information of fisheries at the national level (contained in the Italian tables), and direct information on production, value added, net taxes on production and total intermediate costs of fisheries for each region in the analysis (see Table A1).

The national table was first aggregated from 92 to 18 sectors, which included, on the one hand, fisheries (sector 1) and on the other, the 17 sectors included in the regional tables. Thus, the "disaggregated" regional table (in which the fisheries sector is separated from other activities) for region j takes the form :

$TR_j =$

| | Fishery | Agriculture | Other activities |
|---|---|---|---|
| Fishery | $bgg\ C_n^j\ F^j$ | $bg_1 (x_1^j - F^j)$ | $bg.x_{.n-1}$ |
| Agricult. | $b_1g\ C_r^j\ F^j$ | $a_{11}\, x_1^j - (b_1g\ C_r^j\ F^j + bg_1\, x_1^j)$ | $(a_1 - b_1)\, x_{n-T1}$ |
| Other activities | $b.g\ C_r^j\ F^j$ | $a_{.1}x_1^j - b.g\ C_r^j\ F^j$ | $a_{n-1}\, x_{n-1}$ |
| Value added | $V_g^j$ | $V_1^j - V_g^j$ | $V_{n-1}$ |
| GRT at factor c. | $F^j$ | $x_1^j - F^j$ | $x_{.n-1}$ |

where scalars (with a double subscript), vectors (with a subscript and a superscript) and matrices (with a single superscript) indicated by the letters a, x and V, are derived from the following decomposition of the original regional matrix (with 17 sectors) of input coefficients, the vector of gross sectoral output (x) and the vector of sectoral value added (V) :

| | Agriculture and fishery | Other activities |
|---|---|---|
| Agr. and fishery | $a_{11}$ | $a_1$ |
| Other activities | $a_{.1}$ | $a_{n-1}$ |
| G.R.T. at f.c. | $X_1^J$ | $x_{n-1}$ |
| Value added at f.c | $V_1^j$ | $V_{.n-1}$ |

Subsequently, scalars and vectors indicated by the letter b are derived from the following decomposition of the national matrix with 18 sectors (fisheries plus the 17 sectors contained in the regional tables) :

| | Fishery | Agriculture | Other activities |
|---|---|---|---|
| Fishery | $bgg$ | $bg_1$ | $bg.$ |
| Agricult. | $b_1g$ | ..... | ..... |
| Other activities | $b.g$ | ..... | ..... |

The circumflex accent indicates vectors transformed into diagonal matrices, $F^j$ and $Vg^j$ indicate gross output and value added (both at factor cost) of fisheries in region j.

Finally, $Cr^j$ is a correction coefficient included to take account of differences between cost structures at the regional and national levels.

In the procedure outlined above, both at the regional and national levels, total intermediate transactions are considered, that is to say, including both internal production and imports. This was necessary because the regional tables provide information on total transactions. It goes without saying that this implies a further adjustment to derive the effects at a regional level. Appropriate coefficients are required which take account of spacial limits in the propagation of the effects. Following current practice, the following coefficient was employed :

$$t_i^r = \frac{X_i^r}{X_i^r + M_i^r}$$

where $Xi^r$ is gross regional output of good i and $Mi^r$ represents imports of good i in the same region. The coefficients thus derived allow the construction of the diagonal matrix t employed in the procedure outlined below.

2. Once eighteen sector regional tables had been constructed (with fisheries included separately as the first sector) multipliers were estimated according to the following procedure. For the sake of notational simplicity, given that the procedure is applied to each individual region, we omit the regional superscipt from hereon. Thus, we have :

a (18x18 matrix) = matrix of total regional input coefficients

$\hat{t}$ (18x18 matrix) = matrix of adjustment coefficients to derive the regional specific demand for inputs.

x (18x1 vector) = gross regional output of each sector

m (18x1 vector) = imports iof the eighteen types of good

f (18x1 vector) = final regional demand comprising consumption (public and private), investment (opublic and private), and (gross) exports

q (18x1 vector) = indicates the composition of goods required for the annual substitution of capital equipment in the fisheries sector (measured in terms of units of gross output of the sector)

From which we may write the following identity :

$$x = \hat{t}ax + f - m \tag{1}$$

rearranging terms, this may be expressed as :

$$\begin{pmatrix} 1 & -ts_1 a_1 \\ 0 & 1 - \hat{t}_{n-1} a_{n-1} \end{pmatrix} \begin{pmatrix} m_1 \\ x_{n-1} \end{pmatrix} = \begin{pmatrix} t_1 a_{11} - 1 \\ \hat{t}_{n-1} a_1 \end{pmatrix} x_1 + \delta - \begin{pmatrix} 0 \\ m_{gg-1} \end{pmatrix} \tag{2}$$

in which fisheries is separated from other activities. The level of production is also considered as exogenous, whilst imports of fish products are considered endogenous. The vectors $x_{n-1}$and $m_{n-1}$ represent the vectors x and m without their first element. The vectors a . 1 and $a_1$ . indicate respectively the input coefficients for fisheries and the intermediate demand for fish products by other sectors. $m_1$ and $x_1$ are imports and output of fish products and the $a_{n-1}$ is the matrix excluding the first row and column (corresponding to fisheries). From (2) :

$$\begin{pmatrix} m_1 \\ x_{n-1} \end{pmatrix} = \begin{pmatrix} 1 & -t_1 a_1 \\ 0 & 1 - \hat{t}_{n-1} a_{n-1} \end{pmatrix}^{-1} \left( \begin{pmatrix} t_1 a_{11} - 1 \\ \hat{t}_{n-1} a_1 \end{pmatrix} x_1 + \delta - \begin{pmatrix} 0 \\ m_{n-1} \end{pmatrix} \right) \tag{3}$$

Equation (3) allows the evaluation of the indirect regional effects arising from a reduction $\Delta x_1$ in the output of the fisheries sector in the region under consideration. If one makes the plausible assumption that the substitution of capital equipment is proportional to annual sales, then the reduction $\Delta x_1$ will lead to a corresponding reduction $\delta \Delta x_1$ in the regional demand for investment.

Thus :

$$\begin{pmatrix} \Delta m_1 \\ \Delta x_{n-1} \end{pmatrix} = \begin{pmatrix} 1 & -t_1 a_1 \\ 0 & 1 - t_{n-1} a_{n-1} \end{pmatrix}^{-1} \begin{pmatrix} t_1 a_{11} - 1 \\ t_{n-1} a_1 \end{pmatrix} \Delta x_1 + \begin{pmatrix} 1 & -t_1 a_1 \\ 0 & 1 - t_{n-1} a_{n-1} \end{pmatrix}^{-1} tq \, \delta \Delta x_1 \tag{4}$$

where the first part of the right hand side represents the indirect effects due to the reduction in fishing activities, whilst the second part indicates the indirect effects of the reduction in the substitution of capital equipment.

The sum of direct and indirect effects is given by :

$$ET = \Delta x_1 + \Delta x_{n-1} \tag{5}$$

where $\Delta x_{n-1}$ is derived from (4).

3. The multipliers calculated above are different from normal demand multipliers. However, from these the indirect consequences of different hypothetical reductions in output may be calculated. This formulation, however, only takes account of the effects employed for the calculation of the first type of multiplier, that is, effects transmitted exclusively through productive interdependencies. It is well known that this type of methodology is unsatisfactory because it does not take account of the effects of the distribution of expenditure of incomes. Thus, one needs to have recourse to the second type of multiplier which also takes account of these effects. In order to introduce these additional effects it is necessary to rewrite (4) as :

$$\begin{pmatrix} \Delta m_1 \\ \Delta x_{n-1} \\ \Delta v \end{pmatrix} = \begin{pmatrix} 1 & -t_1 a_{1.} & -\gamma_1 \\ 0 & 1 - \hat{t}_{n-1} a_{n-1} & -\gamma_{n-1} \\ 0 & -v_{1.} & 1 \end{pmatrix}^{-1} \left\{ \begin{pmatrix} ta_{11} - 1 \\ \hat{t}a_{.1} \\ v_1 \end{pmatrix} \Delta x_1 + \begin{pmatrix} t_1 q_1 \\ \hat{t}_n q_{n-1} \\ 0 \end{pmatrix} \delta \Delta x_1 \right\} \tag{6}$$

where v represents regional value added, $v_1$ is the (marginal) coefficient of value added of fisheries, $v_{1.}$ is the (marginal) coefficient of value added in other sectors. The $\gamma$ terms represent the marginal propensity to consume for individual goods. If one assumes that consumers have Cobb-Douglas utility functions (and therefore spend the same proportion of income on each good), $\gamma$ may be estimated by :

$$\gamma i = t_i' \alpha_i C (1 - \tau) \tag{7}$$

where C is the total marginal propensity to consume, $\tau$ is the marginal tax-rate and $\alpha_1$ is the exponent on $C_1$ in the utility function (Regarding the technical coefficients it is assumed, a la Leontief, that marginal and average coefficients are equal. The same consideration applies to the coefficients on value added).

As before, the indirect effects may be subdivided into those due to a reduction in fishing activity and those due to the reduction in the substitution of capital equipment.

4. In section 2. the direct and indirect effects were measured in terms of gross output. In section 3. they were measured in terms of gross output and aggregate value added. They may also be expressed in terms of sectoral value added and as well as in terms of incomes and employment. These latter indicators allow a consideration of the effects not just in economic terms but also in terms of the social impact. If v, w and e are the diagonal matrices of value added, income (per unit of output) and employment (per unit of output) coefficients respectively, it follows that the vectors :

$$\hat{v} \begin{pmatrix} \Delta \chi 1 \\ \Delta \chi_{n-1} \end{pmatrix}; \quad \hat{w} \begin{pmatrix} \Delta \chi 1 \\ \Delta \chi_{n-1} \end{pmatrix}; \quad \hat{e} \begin{pmatrix} \Delta \chi 1 \\ \Delta \chi_{n-1} \end{pmatrix}$$

measure the direct (the first element in each vector) and indirect (the remaining 17 elements) effects in terms of value added, employees' incomes and employment.

In the present study, notwithstanding the problems of estimation and the need to not overstress the precision of the estimates produced when interpreting the results, we believe, considering the literature in this area, that the more useful conclusions are to be drawn from the second type of multipliers.

## REFERENCES

**IREPA** (1986). Le interrelazioni settoriali nella pesca italiana : un'analisi input-output, CEE, DEC C(85) 2223/7.

**IREPA**(1986). Standardizzazione dei parametri tecnici ed economici della pesca italiana - DEC C(85) 2223/6.

**Jordan P.G. and K.R. Polenske** (1988). Multiplier impacts of fishing activities in New England and Nova Scotia.

**Erba A.** *et al.* (1990). Partizioni funzionali del territorio : il modello ISERS, Franco Angeli.

**IREPA** (1991). Sistema di rilevazione sistematica ed organica degli indicatori economici della pesca in Italia, M.M.M.

**IREPA** (1992). Studio socio-economico a diffusione regionale nel settore della pesca e dell'acquacoltura (area I.1 e I.3), CEE.

| TAB. 1 | SOCIO-ECONOMIC INDICATORS FOR FISHERIES AND AQUACULTURE BY REGION - AREA I.1 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ZONE | GENERAL FEATURES OF THE ZONE | | | | | NUMBER OF JOBS IN FISHERIES AND RELATED ACTIVITIES - units 1988 | | | ADDED VALUE OF FISHERIES AND RELATED ACTIVITIES - Mio ECU 1989 | | | RELATIVE DEPENDENCE | | | |
| | TOTAL POPULATION 000 '89 | WORKING FORCE 000 '89 | TOTAL NUMBER OF JOBS 000 '89 | G.D.P. TOTAL Mio ECU | G.D.P. PER CAPITA Mio ECU | FISHERMEN ONLY | OTHER JOBS | TOTAL | LANDINGS & FIRST HANDLING | OTHER ACTIVITIES (*) | TOTAL | IN TERMS OF JOBS %o | | IN ECONOMIC TERMS %o | |
| | a | | b | c | d=c/a | e | f | g=e +f | h | i | j= h +i | e/b | g/b | h/c | j/c |
| LIGURIA | 1706 | 705 | 634 | 24462 | 14,339 | 2448 | 3148 | 5596 | 47,005 | 95,997 | 143,002 | 4 | 9 1/2 | 2 | 6 |
| TOSCANA | 3526 | 1508 | 1369 | 47802 | 13,557 | 3088 | 2672 | 5760 | 26, 482 | 43,033 | 69,515 | 2 1/2 | 4 | 1/2 | 1 1/2 |
| LAZIO | 5100 | 2163 | 1889 | 70509 | 13,825 | 2227 | 2381 | 4608 | 78,121 | 131,030 | 209,151 | 1 | 2 1/2 | 1 | 3 |
| CAMPANIA | 5735 | 2230 | 1719 | 44542 | 7,767 | 5022 | 2928 | 7950 | 25,820 | 27,828 | 53,648 | 3 | 4 1/2 | 1/2 | 1 |
| CALABRIA (**) | 2111 | 834 | 610 | 14083 | 6,671 | 3839 | 535 | 4374 | 18,537 | 4,643 | 23,180 | 6 1/2 | 7 | 1 1/2 | 1 1/2 |
| AREA I.1 | 18178 | 7440 | 6221 | 201398 | 11,079 | 16624 | 11664 | 28288 | 195,965 | 302,531 | 498,496 | 3 | 4 1/2 | 1 | 2 1/2 |
| ITALIA | 56836 | 23870 | 21004 | 691462 | 12,166 | 54450 | 37321 | 91771 | 1063,245 | 1238,687 | 2301,932 | 2 1/2 | 4 1/2 | 1 1/2 | 3 1/2 |

(*) Figures on added value of related activities in the table are estimated underlying hypotheses were that jobs in related activities produce an amount of gross added value against factor costs per capita, by administrative region, equal to the corresponding multiplier of regional added value as obtained by our processing of regional input-output tables (see chapter 2.2)

(**) Included Crotone coastal department

Source: I.R.E.P.A., I.S.T.A.T., TAGLIACARNE INSTITUTE

| TAB. 2 | SOCIO-ECONOMIC INDICATORS FOR FISHERIES AND AQUACULTURE BY 18 PROVINCE ABOVE 26 - AREA I.1 (*) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ZONE | GENERAL FEATURES OF THE ZONE | | | | | NUMBER OF JOBS IN FISHERIES AND RELATED ACTIVITIES - units 1988 | | | ADDED VALUE OF FISHERIES AND RELATED ACTIVITIES - Mio ECU 1989 | | | RELATIVE DEPENDENCE | | | |
| | TOTAL POPULATION 000 '89 | WORKING FORCE 000 '89 | TOTAL NUMBER OF JOBS 000 '89 | G.D P. | | FISHERMEN ONLY | OTHER JOBS | TOTAL | LANDINGS & FIRST HANDLING | OTHER ACTIVITIES | TOTAL | IN TERMS OF JOBS %o | | IN ECONOMIC TERMS %o | |
| | | | | TOTAL Mio ECU | PER CAPITA Mio ECU | | | | | | | | | | |
| | a | | b | c | d=c/a | e | f | g=e +f | h | i | j= h +i | e/b | g/b | h/c | j/c |
| Imperia | 221 | 82 | 73 | 2837 | 12,8 | 430 | 553 | 983 | 8,257 | 16,864 | 25,121 | 6 | 13 1/2 | 2 | 9 |
| Savona | 291 | 108 | 97 | 4001 | 13,7 | 769 | 989 | 1758 | 14,766 | 30,159 | 44,925 | 8 | 18 | 3 1/2 | 11 |
| Genova | 996 | 370 | 333 | 14577 | 14,6 | 818 | 1052 | 1870 | 15,707 | 32,080 | 47,787 | 2 1/2 | 5 1/2 | 1 | 3 1/2 |
| La Spezia | 234 | 87 | 78 | 3046 | 13,0 | 431 | 554 | 985 | 8,276 | 16,894 | 25,170 | 5 1/2 | 12 1/2 | 2 1/2 | 8 1/2 |
| Massa C. | 204 | 79 | 72 | 2151 | 10,5 | 14 | 12 | 26 | 0,120 | 0,210 | 0,330 | 1/2 | 1/2 | 0 | 0 |
| Lucca | 382 | 148 | 134 | 5020 | 13,1 | 598 | 517 | 1115 | 5,128 | 8,326 | 13,454 | 4 1/2 | 8 1/2 | 1 | 2 1/2 |
| Pisa | 387 | 150 | 136 | 5431 | 14,0 | 12 | 10 | 22 | 0,103 | 0,161 | 0,264 | 1/2 | 1/2 | 0 | 0 |
| Livorno | 343 | 133 | 121 | 4486 | 13,1 | 1736 | 1502 | 3238 | 14,888 | 24,190 | 39,078 | 14 1/2 | 27 | 3 1/2 | 8 1/2 |
| Grosseto | 220 | 85 | 77 | 2485 | 11,3 | 728 | 630 | 1358 | 6,243 | 10,146 | 16,389 | 9 1/2 | 17 1/2 | 2 1/2 | 6 1/2 |
| Viterbo | 277 | 102 | 89 | 3334 | 12,0 | 12 | 13 | 25 | 0,421 | 0,715 | 1,136 | 1/2 | 1/2 | 0 | 0 |
| Roma | 3772 | 1397 | 1220 | 53692 | 14,2 | 1115 | 1192 | 2307 | 39,113 | 65,598 | 104,711 | 1 | 2 | 1/2 | 2 |
| Latina | 469 | 173 | 151 | 6202 | 13,2 | 1100 | 1176 | 2276 | 38,587 | 64,717 | 103,304 | 7 1/2 | 15 | 6 | 16 1/2 |
| Caserta | 815 | 244 | 188 | 6233 | 7,6 | 140 | 82 | 222 | 0,720 | 0,770 | 1,490 | 1 | 1 | 0 | 0 |
| Napoli | 3124 | 936 | 721 | 24361 | 7,8 | 3243 | 1891 | 5134 | 16,673 | 17,972 | 34,645 | 4 1/2 | 7 | 1/2 | 1 1/2 |
| Salerno | 1062 | 318 | 245 | 8523 | 8,0 | 1639 | 956 | 2595 | 8,427 | 9,086 | 17,513 | 6 1/2 | 10 1/2 | 1 | 2 |
| Cosenza | 781 | 225 | 174 | 5289 | 6,8 | 140 | 19 | 159 | 0,676 | 0,165 | 0,841 | 1 | 1 | 0 | 0 |
| Catanzaro | 775 | 224 | 172 | 5080 | 6,6 | 537 | 75 | 612 | 2,593 | 0,651 | 3,244 | 3 | 3 1/2 | 1/2 | 1/2 |
| Reggio Cal. | 592 | 171 | 131 | 3712 | 6,3 | 1598 | 222 | 1820 | 7,716 | 1,927 | 2,643 | 12 | 14 | 2 | 2 1/2 |
| Total of the 18 Provinces | 14945 | 5032 | 4212 | 160460 | 11,03 | 15060 | 11445 | 26505 | 188,414 | 300,631 | 489,045 | 3 1/2 | 6 1/2 | 1 | 3 |
| AREA I.1 26 Provinces | 18178 | 7440 | 6221 | 201398 | 11,079 | 16624 | 11664 | 28288 | 195,965 | 302,531 | 498,496 | 2 1/2 | 4 1/2 | 1 | 2 1/2 |
| ITALY | 56836 | 23870 | 21004 | 691462 | 12,166 | 54450 | 37321 | 91771 | 1063,245 | 1238,687 | 2301,932 | 2 1/2 | 4 1/2 | 1 1/2 | 3 1/2 |

(*) The reported values refer to 18 coastal provinces alone, not to all of 26 provinces of the corresponding administrative regions, therefore total amounts of area I.1 do not correspond to the sum of columns. Work-force and job totals by province may be inconsistent with the regional total or zone total, due to a systematic defect in the ISTAT work-force survey sampling pattern.

Source: I.R.E.P.A., I.S.T.A.T., TAGLIACARNE INSTITUTE

| TAB. 3 | ZONES DEPENDENT ON FISHERIES AND ANCILLARY ACTIVITIES - AREA I.1 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ZONE | GENERAL FEATURES OF THE ZONE | | | | | NUMBER OF JOBS IN FISHERIES AND RELATED ACTIVITIES - units 1988 | | | ADDED VALUE OF FISHERIES AND RELATED ACTIVITIES - Mio ECU 1989 | | | RELATIVE DEPENDENCE | | | |
| | TOTAL POPULATION 000 '89 | WORKING FORCE 000 '89 | TOTAL NUMBER OF JOBS 000 '89 | G.D.P. TOTAL Mio ECU | G.D.P. PER CAPITA Mio ECU | FISHERMEN ONLY | OTHER JOBS | TOTAL | LANDINGS & FIRST HANDLING | OTHER ACTIVITIES | TOTAL | IN TERMS OF JOBS %o | | IN ECONOMIC TERMS %o | |
| | a | | b | c | d=c/a | e | f | g=e +f | h | i | j= h +i | e/b | g/b | h/c | j/c |
| **Imperia** | 221 | 82 | 73 | 2837 | 12,8 | 430 | 553 | 983 | 8,257 | 16,864 | 25,121 | 6 | 13 1/2 | 2 | 9 |
| **Savona** | 291 | 108 | 97 | 4001 | 13,7 | 769 | 989 | 1758 | 14,766 | 30,159 | 44,925 | 8 | 18 | 3 1/2 | 11 |
| **La Spezia** | 234 | 87 | 78 | 3046 | 13,0 | 431 | 554 | 985 | 8,276 | 16,894 | 25,170 | 5 1/2 | 12 1/2 | 2 1/2 | 8 1/2 |
| **Livorno** | 343 | 133 | 121 | 4486 | 13,1 | 1736 | 1502 | 3238 | 14,888 | 24,190 | 39,078 | 14 1/2 | 27 | 3 1/2 | 8 1/2 |
| **Grosseto** | 220 | 85 | 77 | 2485 | 11,3 | 728 | 630 | 1358 | 6,243 | 10,146 | 16,389 | 9 1/2 | 17 1/2 | 2 1/2 | 6 1/2 |
| **Latina** | 469 | 173 | 151 | 6202 | 13,2 | 1100 | 1176 | 2276 | 38,587 | 64,717 | 103,304 | 7 1/2 | 15 | 6 | 16 1/2 |
| Source: I.R.E.P.A., I.S.T.A.T., TAGLIACARNE INSTITUTE | | | | | | | | | | | | | | | |

| TAB. 4 | BASIC PARAMETERS FOR THE CALCULATION OF THE OVERALL EFFECTS OF A UNIT REDUCTION IN FISHING ACTIVITIES - 1991 | | |
|---|---|---|---|
| ZONE | G.O. / G.R.T. '000 ECU | G.R.T. | HOURS |
| LIGURIA | 4.458 | 7354 | 1153 |
| TOSCANA | 3.673 | 14201 | 1299 |
| LAZIO | 8.740 | 14631 | 1556 |
| CAMPANIA | 4.781 | 15654 | 2318 |
| CALABRIA | 4.781 | 5470 | 2318 |
| Source: I.R.E.P.A. | | | |

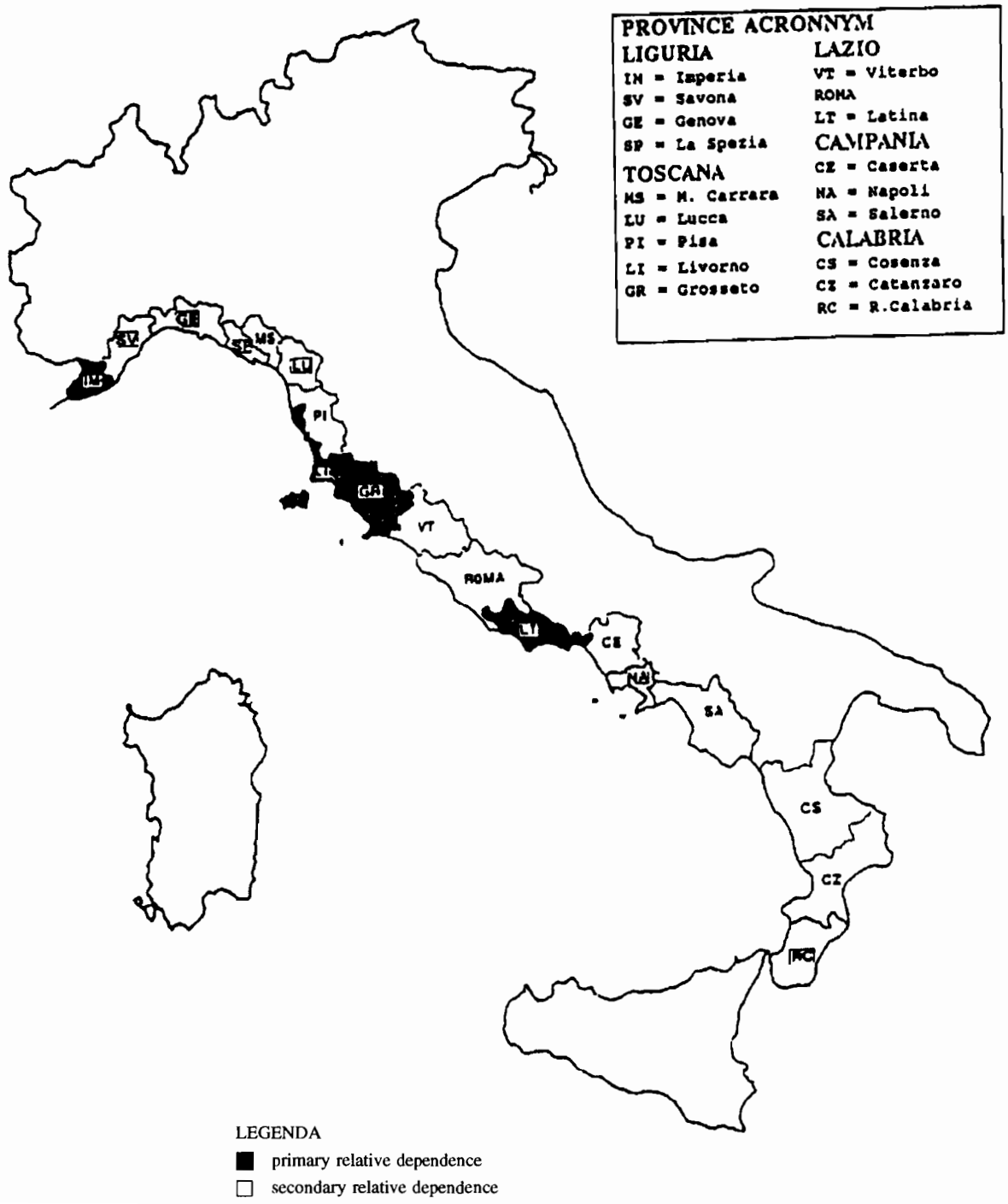
| TAB. 5 | REGIONAL ECONOMIC ACCOUNTS AND THE REDUCTION IN EMPLOYMENT IN FISHERIES AND OTHER SECTORS | | | | | |
|---|---|---|---|---|---|---|
| ZONE | G.O. | G.V.A. | GROSS INCOME | ANNUAL WORKING UNITS (000's) | Δ EMPLOYMENT IN FISHERIES | Δ TOTAL EMPLOYMENT |
| | [1] | [2] | [3] | [4] | [5] | [6] |
| LIGURIA | 1.865 | 1.310 | 0.685 | 39.020 | 34 | 38 |
| TOSCANA | 3.373 | 1.953 | 1.115 | 128.242 | 99 | 120 |
| LAZIO | 7.032 | 4.907 | 2.345 | 108.461 | 70 | 117 |
| CAMPANIA | 4.597 | 2.933 | 1.571 | 256.847 | 111 | 139 |
| CALABRIA | 1.523 | 1.070 | 0.496 | 61.521 | 27 | 36 |
| AREA I.1 | 18.390 | 12.373 | 6.212 | 594.091 | 341 | 450 |
| Source: I.R.E.P.A. | | | | | | |

| TAB. 6 | SUMMARY OF THE OVERALL EFFECTS OF A UNIT REDUCTION IN GROSS OUTPUT IN FISHERIES (= 1 billion lit.) ON FOUR SOCIO-ECONOMIC INDICATORS BY REGION | | | | |
|---|---|---|---|---|---|
| ZONE | Δ G.O. | Δ G.V.A. | Δ WAGES AND SALARIES | Δ ANNUAL WORKING UNITS (000's) | |
| | | | | Unit reduction in G.O. | Working units in fisheries |
| | [1] | [2] | [3] | [4] | [5] |
| LIGURIA | 1.884 | 1.323 | 0.692 | 39 | 1.42 |
| TOSCANA | 2.135 | 1.236 | 0.706 | 81 | 1.21 |
| LAZIO | 1.817 | 1.268 | 0.606 | 28 | 1.67 |
| CAMPANIA | 2.034 | 1.298 | 0.695 | 114 | 1.25 |
| CALABRIA | 1.928 | 1.354 | 0.628 | 78 | 1.34 |
| | | | | | |
| AREA I.1 | 1.960 | 1.296 | 0.660 | 68 | 1.38 |
| Source: I.R.E.P.A. | | | | | |

| TAB. 7 | REDUCTION IN WORKING UNITS EMPLOYED IN FISHING AND IN ALL ACTIVITIES RESULTING FROM A UNIT REDUCTION IN GROSS OUTPUT IN FISHERIES (= 1 billion lit.) | | | |
|---|---|---|---|---|
| ZONE | REDUCTION IN WORKING UNITS IN FISHERIES | | REDUCTION IN WORKING UNITS IN REGION | |
| | Working units | Index | Working units | Index |
| LIGURIA | 27.83 | 53 | 39.41 | 58 |
| TOSCANA | 66.92 | 128 | 81.17 | 120 |
| LAZIO | 16.82 | 32 | 28.03 | 41 |
| CAMPANIA | 91.06 | 175 | 113.05 | 166 |
| CALABRIA | 58.10 | 111 | 77.88 | 115 |
| | | | | |
| AREA I.1 | 52.15 | 100 | 67.91 | 100 |
| Source: I.R.E.P.A. | | | | |

| TAB. A1 | Value added, intermediate costs and net taxes in fisheries (million lire) | | | | | |
|---|---|---|---|---|---|---|
| ZONE | Intermediate costs | | Value added at factor costs | | Net indirect taxes | |
| | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 |
| LIGURIA | 23.383 | 25.204 | 75.612 | 84.293 | -4.808 | -8.039 |
| TOSCANA | 18.161 | 19.122 | 41.983 | 29.663 | -2.921 | -3.582 |
| LAZIO | 42.151 | 39.059 | 126.509 | 117.602 | -8.192 | -11.501 |
| CAMPANIA | 23.991 | 23.072 | 42.631 | 41.468 | -3.236 | -4.738 |
| CALABRIA | 11.965 | 12.915 | 29.827 | 36.183 | -2.029 | -3.605 |
| Source: I.R.E.P.A. | | | | | | |

**FIGURE 1 :**
**AREA I.1: ZONES HIGHLY DEPENDENT ON FISHERIES AND ANCILLARY ACTIVITIES**



# Aquaculture, sectoral dynamics by M. Antona and D. Bailly

L'aquaculture a deux visages : d'une part, il s'agit d'activités traditionnelles qui ont géré depuis plusieurs siècles leur propre développement avec une intervention publique très limitée ; d'autre part, ce sont des productions résultant du volontarisme public, produit direct des laboratoires de recherche. Toutes les communications présentées dans cette session font référence à ce second type d'aquaculture, dans lequel on trouve deux types de filières :

- celles dont le succès est de courte durée et les réalisations en deçà de l'investissement public et privé consenti,
- celles qui connaissent un développement majeur et posent tous les problèmes de la recherche d'autonomie envers l'aide publique.

Dans ce contexte, émanent plusieurs questions économiques dont l'intensité et l'actualité dépendent souvent du stade de développement des filières aquacoles. Les recherches économiques réalisées sont encore loin d'être à la mesure de l'investissement public technique et technologique en aquaculture. L'économie de l'aquaculture semble rester, à tort, une discipline marginale de l'économie des pêches. Les communications de cette session présentent donc l'intérêt d'être représentatives des contraintes et des enjeux de ce développement aquacole. Elles illustrent autant la diversité des questions de recherche que la difficulté pour les économistes à les traiter dans le cas de l'aquaculture.

Si l'on analyse l'aquaculture sous l'angle de la dynamique des filières, la réponse reste à construire pour une interrogation majeure. Existe-t-il aujourd'hui possibilité *d'émergence* d'une filière aquacole sans soutien public massif en terme d'investissement comme de recherche ou transfert ? Cette nécessité du soutien est constatée par tous mais peu explicitée. La communication de

There are two aspects to aquaculture : on the one hand there are traditional activities which have developed over several centuries with very limited public intervention, and on the other productive activities which are a direct result of public will, a direct product of research. All the papers presented in this session refer to the second type of aquaculture where two different kinds can be distinguished :

- those with only short-lasting success and where the public and private investments made exceed the results obtained
- those achieving a major development which then pose all the usual problems of the search for autonomy from government support.

In this context, many economic questions which arise depend for their intensity and their relevance on the stage of development of the aquaculture system. Economic research is far from matching technical and technological public investment in aquaculture. Wrongly, aquaculture seems to remain a marginal discipline in fisheries economics. The papers in this session are interesting because they demonstrate the stakes and constraints in aquaculture development. They show that research topics are both varied and difficult for economists in the case of aquaculture.

If the dynamics of the whole chain of aquaculture activities are considered, it is clear that the following major question remains to be answered: is it possible today to have an aquaculture sector without massive public support in terms of investment, research or transfer? This need for support is noted by all but seldom explained. The paper of J. Ungson is concerned with the role of research in innovation transfer in the initial phase of an aquaculture activity. Does this mean that aquaculture can be compared to a high technology sector in

J. Ungson aborde à ce propos le rôle de la recherche pour le transfert de l'innovation au stade du démarrage d'une activité d'aquaculture. Cela signifie-t-il que l'aquaculture peut être assimilée à un secteur à haute technologie, pour lequel on constate le même recours à l'investissement public en recherche-développement ? Au contraire, est-ce le caractère familial et la production de nature artisanale qui rend impossible toute mise au point de nouvelle filière de manière endogène, comme en agriculture ? La question du calcul économique du coût public est aussi abordée dans la communication de J. Ungson qui montre, au moyen d'une analyse coûts-bénéfices que le sea-ranching de la daurade japonaise au Japon ne peut être envisagé sans un soutien à l'activité et surtout des bonifications de taux d'intérêts qui influent sur le coût d'opportunité du capital.

Une fois prise l'initiative de démarrage d'une activité d'aquaculture, les options retenues par la recherche définissent les premiers pas de la *" période infantile "* des filières de production, selon les termes employés par S. Shaw et M. Gabbott.

Même si la viabilité des filières reste encore fortement liée à l'intervention publique pour la protection du secteur, les questions à aborder concernent plus le relais du soutien public par un secteur privé ou encore l'identification des facteurs-clés du développement. Dans la protection du secteur, interviennent alors les aides à la production ou à la commercialisation. En référence au cas de l'industrie de la mytiliculture en Ecosse et en Irlande, S. Shaw et M. Gabbott relèvent comme facteur-clé de développement l'existence d'une demande nationale, relayée éventuellement dans un second temps par une demande à l'exportation. De ce fait, la coopération entre entreprises du secteur permet d'atteindre la taille critique pour fournir des marchés d'aquaculture en croissance et pour lesquels la différenciation des produits joue encore très peu.

Le stade de *croissance* est marqué par les questions qui concernent la viabilité des types d'entreprises (artisanal versus industriel, intensif versus extensif, a forte composante main-d'œuvre versus capital-intensif) ou encore l'enjeu des gains de productivité. Rainer Cedrins aborde ainsi le choix de la taille « optimale » et celui du système technique dans le cas de l'aquaculture du saumon en Scandinavie. L'innovation comme facteur de réduction de l'incertitude et de gain de productivité est traitée par K. Hansen. L'auteur présente une analyse fine des paramètres qui jouent sur la diffusion de l'innovation informatique dans les fermes d'aquaculture. Le rôle de l'innovation sur la dynamique économique d'une filière constitue une voie de recherche prometteuse en aquaculture pour laquelle le même appel à l'investissement public en recherche-développement est fait ? Ou au contraire, est-ce le caractère familial et la production de nature artisanale qui rend impossible toute mise au point de nouvelle filière de manière endogène, comme en agriculture ? La question du calcul économique du coût public est aussi abordée dans la communication de J. Ungson qui montre, au moyen d'une analyse coûts-bénéfices que le sea-ranching de la daurade japonaise au Japon ne peut être envisagé sans un soutien à l'activité et surtout des bonifications de taux d'intérêts qui influent sur le coût d'opportunité du capital.

Once the decision has been taken to start an aquaculture activity, the options developed through research define the first steps of the infant period of the production line according to the terms used by S. Shaw and M. Gabott.

Even if the viability of activities remains strongly linked to public intervention providing protection for the sector, the questions to be considered are more concerned with replacing public support by the private sector or else with identifying the key factors in development. Subsidies to production and to marketing also intervene in the protection of the sector. When referring to the case of mussel culture in Scotland and in Ireland, S. Shaw and M. Gabott note that a key factor in development is the existence of national demand supported at a later stage by export demand. Thus, cooperation between businesses in the sector allows for a critical size to be reached in growing aquaculture markets in which product differentiation has still only a small part to play.

The stage of growth is marked by questions concerned with the viability of certain types of businesses (artisanal vs industrial; intensive vs extensive; labour vs capital-intensive) or with the importance of productivity gains. Rainer Cedrins deals with the choice of an "optimal" size and that of the technical system in the case of salmon aquaculture in Scandinavia. Innovation as a factor of uncertainty reduction and productivity gain is dealt with by K. Hansen. The author presents a precise analysis of the parameters which have an impact on the diffusion of computing innovation in aquaculture farms. The role that innovation plays in the economic dynamics of a sector is a promising research area in aquaculture where innovations are developing especially in biotechnology, genetics and quality definition.

At the stage of maturity the market becomes the major question and the object of most research. In the papers presented, the case of salmon markets is discussed from the viewpoints of price formation and market development. The Norwegian syndrome shows very well how difficult it is to foresee market evolution in aquaculture products. It also shows how difficult it is to evaluate interactions between markets of different fisheries products and aquaculture.

ture où les innovations se développent notamment en matière de biotechnologie et génétique, ou encore de définition de la qualité.

Le marché devient l'interrogation majeure et l'objet de la quasi-totalité des recherches au stade de la *maturité des filières*. Dans les communications présentées, le seul cas du marché du saumon est discuté sous l'angle de la formation des prix et de l'évolution des marchés. Le syndrome norvégien est révélateur de l'incapacité de prévoir l'évolution des marchés des produits d'aquaculture. Il illustre également les difficultés que pose l'évaluation des interactions entre marchés des différents produits de pêche et d'aquaculture.

Plusieurs constats en guise de conclusion...

(i) Les communications présentées font souvent référence à l'économie des productions industrielles, avec des analyses en terme de pôle de croissance, de stratégie d'innovation privée, qui parfois, semblent éloignées de la réalité des secteurs. A l'opposé, il est peu fait mention des travaux en économie de l'agriculture qui abordent l'entreprise en terme de flexibilité, de gestion de la variabilité annuelle, de savoir-faire ou de transmission de patrimoine.

(ii) Il est à noter que la filière de la crevette est peu étudiée, alors qu'elle fournit matière à des questionnaires intéressants en terme de dynamique sectorielle, en terme de marchés ou en terme d'impact sur l'environnement comme nouveau facteur-clé de développement.

(iii) L'approche économique de l'aquaculture révèle un bon niveau d'expertise sur les secteurs mais aussi plus de constats *a posteriori* que de capacité d'anticipation. L'on rejoint ici le problème souvent abordé du manque de données fiables, durables et de l'absence de méthodes adaptées à une approche construite de l'économie de ce secteur.

Several statements to conclude:

(i) The papers presented are often concerned with the economics of industrial production with analyses in terms of economic growth, of private innovation strategies sometimes distant from the reality of the sectors. On the other hand, work in agricultural economics dealing with businesses in terms of flexibility, management of natural variability, know-how or inheritance transfer is little mentioned.

(ii) We note that the prawn sector is little studied even though it provides interesting questions in terms of sectoral dynamics, markets or in the impact on the environment as a new key factor in development.

(iii) The economic approach to aquaculture shows a good level of expertise concerning the sectors although more statements *a posteriori* than in anticipation. Here again we meet with the problem of reliable, lasting data and the lack of methods adapted to a constructed approach of this sector's economics.

# A Comparative Study of the Development of Mussel Farming in Scotland and Ireland with Emphasis on the Development of Marketing

**Mark Gabbott[a], Susan A Shaw and Juliette Gibbs[b]**

[a]University of Stirling, Department of Marketing Stirling FK9 4LA

[b]University of Strathclyde, Department of Marketing, Stenhouse Building, 173 Cathedral Street, Glasgow G4 0RQ, Scotland

ABSTRACT

*This paper reports a study of the comparative development of mussel farming in Scotland and Ireland. It suggests that key factors in development are the incentives to adopt suitable marketing structures and in particular the incentive for industry members to co-operate to achieve a critical mass. When government support is of a sufficient volume and in harmony with the objectives of individual growers this also acts as a stimulus to development.*

## 1. INTRODUCTION

The ability of an industry to successfully take advantage of the opportunities which are available will depend, among other factors, on the way in which it is organised, the activity of industry members and the activity of support agencies. This paper examines two industries which display significant differences as well as similarities in the manner in which growth has been pursued. It is hoped that this analysis will make some contribution toward the identification and understanding of critical success factors for aquaculture development.

The industries used in this analysis are the mussel farming industries of Scotland and Ireland. Both industries are comprised mainly of small businesses with similar problems in terms of finance, marketing and industry organisation. The paper starts with a review of the key factors identified in existing literature which encourage industry development. It then describes the pertinent features of the two chosen industries before presenting some general conclusions applicable for policy makers.

The words growth and development are often used interchangeably and in most circumstances the distinction is not important. However, in considering a particular industrial sector there is a need to distinguish simple unidimensional growth (such as growth in output) from the more permanent and pervasive development which implies both growth and changes to the technical and institutional arrangement in an industry. It is with both development and growth that this paper is concerned and with the factors which need to be considered when understanding development in aquaculture.

## 2. FACTORS ENCOURAGING DEVELOPMENT

### *2.1 Scale*

A number of different disciplines have contributed towards the identification of key criteria associated with industry development. While the evidence is equivocal some broad themes can be identified which will aid the comparative analysis. The first of these is scale.

The scale or size of an industry is important in determining the extent to which the industry or company has access to economies of scale in production or in marketing. Some authors have pointed to the role of size in predicting profitability of industrial companies and upon the observation that larger companies appear to be more profitable (Buzzell et al 1975). This would suggest a linear relationship between size and profitability. With this model the imperative from a development perspective would be to ensure sufficient scale among individual industry members. Other writers have pointed to the existence of a U shaped profitability curve with both large and small firms being profitable. The larger firms are profitable due to differentiation and/or cost advantage, the smaller due to niche marketing. This is consistent with the view of development writers such as Meier (1989) who writes that there is a critical number or size of business necessary to develop a market and secure profitable growth. The issue of numbers is different from size and is discussed further in Section 2.4 below but the role of size is also consistent with the 'big push' model presented by Rosenstein-Rodan (1943). Others such as Peters (1987) and Howard (1990) challenge the merits of size for its own sake and point toward the role of organisation and structural parameters in determining success including the extent to which businesses are driven by customer needs and are efficient implementers of appropriate strategies rather than simply questions of scale.

### *2.2 Method of Organisation*

While the foregoing suggests that many factors influence competitive success, often this literature is orientated towards situations where there is potential for the differentiation of products and services. This is not always the case as in agricultural markets and the agricultural marketing literature tends to take a different focus. While accepting the existence of niche markets for primary and value added products in aquaculture (see Shaw 1990 and Barker 1981) most products are largely undifferentiated and have to be sold in major markets where small scale operations are at a disadvantage. The small high cost producer with options to sell locally directly to final consumers, retailers or the food service sector can do so due to easy access to markets via short distribution channels offering opportunities for higher margins. By contrast the larger producer can take advantage of larger orders and access to a wider variety of customers and markets. The knowledge and skills necessary to service the larger market successfully are likely to be much greater than those in supplying local markets. Where the size discrepancy is greatest ie in a situation where there are a large number of small producers but a smaller number of purchasers or where the scope for sale in local markets is limited, there are benefits in co-operation (Barker 1981). This co-operation can take many forms but has a number of advantages such as cost savings, competitiveness and the delivery of consistent customer benefits (Shaw 1990).

### *2.3 Orientation of Development*

A third factor identified by Little (1970), Bhagwati (1978) and Kreuger (1978) is the debate concerning the orientation of development. This relates to whether the industry is orientated toward serving internal markets and pursuing an import substitution or internal market development role or whether there is an export orientation, serving international markets.

The World Bank (1991) suggests that import substitution polices as a development engine have been notably unsuccessful while polices which use an export or outward orientation have produced sustained growth and productivity by virtue of wider competitive experience and a larger market. The presence of a domestic market for the product will undoubtedly dominate the first stages of industry development. The extent to which domestic orientation can support continued growth will depend upon the size of the market and upon the activities of competitors and government.

### *2.4 The Role of Externalities*

Samuelson (1976) points to the existence of external economies or diseconomies which accrue to members of an industry. External economies consist of favourable effects upon the firm which emanate from the activity of other firms or people. Externalities can have a considerable impact upon the development path of a particular industry. Social capital such as roads, communications and general infrastructure have effects upon access to resources and access to markets. Wherever there are externalities a strong case can be made for limiting or reducing individual freedom to act in favour of a collective or collaborative approach.

One of the externalities associated with development is the role of government both in setting macro economic conditions conducive to growth and specific policies aimed at the development of particular industries. In terms of ensuring even development but development based upon sustainable growth, governments have used a development strategy based upon the protection of 'infant industries'. It is argued that a young industry faced with foreign competition will be unable to cope with the early stages of experimentation and financial pressure. As a result comparative advantage cannot be capitalised upon. However industries could be given some protection in the early phase of development and thereby achieve sufficient scale to break out of protection and compete effectively both nationally and internationally. Protection is only one form of intervention in respect of infant industry. Others may include subsidy of production, technology or marketing as well as help with investment in people or capital.

A common model used to explain the patterns of development on this basis and to identify potential industries or projects is to identify 'growth points', 'growth poles' or 'poles de croissance' (see Perroux 1950, Boudeville 1957 and Zarka 1958, see also a critique by Gravier 1958 in favour of 'forces motrices'). These growth poles or growth points have a high potential for development because their effects are felt in a wide area both geographic and economically. These growth points are associated with labour skills (or human capital), high income elasticity of demand or more importantly consist of industries with complex interrelations of intermediate goods, buying supplies from many suppliers and selling products onward to many markets. These growth points within an industry could be identified as processing capacity, marketing arrangements or co-operatives which offer primary markets to a small fragmented producer group but of sufficient combined scale to undertake specialised marketing and take advantage of available economies. This links to both the "big-push" model and to the agricultural marketing tradition described above.

## 3. RESEARCH METHODOLOGY

The themes which emerge from the literature therefore suggest that the issues of market orientation, size of individual operations, size of collective organisation and the role of government agencies are relevant to the success of industry development. In the second part of this paper we consider these factors in relation to the Scottish and Irish mussel industries. This is based upon a comparative analysis of the findings of two studies of these industries in 1991 (Shaw et al 1991 and Gabbott et al 1991). Both industries can be regarded as relatively new industries which wish to grow and both operate in broadly similar climatic conditions. The studies consisted of a series of interviews and meetings with influential parties in each industry as well as use of secondary data sources. Normal qualitative research techniques such as data triangulation were used to check the consistency of findings. Following Van Maanen (1983) we sought to come to terms with the meaning, not the frequency of phenomena. The issues involved were complex since they involved not only an analysis of events but also an understanding of the reasons why actors behaved in particular ways. This paper presents a synthesis of these results and, due to the nature of the material, conclusions are tentative at this stage.

## 4. DEVELOPMENT OF THE SCOTTISH AND IRISH MUSSEL INDUSTRIES

In Scotland production of cultivated mussels has grown from 200 tonnes in 1985 to 457 tonnes in 1990 to 1,024 tonnes in 1991. There is also a single large producer using wild stocks who produced approximately 1,100 tonnes in 1991. The development of the Scottish industry has been slow with forecast increases in output often not materialising. Production has reached a plateau with little sign of continuing growth until 1991. The majority of producers harvest less than 10 tonnes per year. These small producers are mainly part-time and enter and leave production based upon market prices.

The Irish industry by contrast has shown consistent underlying growth in production of both cultured and dredged mussels over the last five years. Output of cultured mussels has improved from 1,636 tonnes in 1985 to 3,700 tonnes in 1990 to an estimated 4,000 tonnes in 1991. There is also a strong industry based upon dredged mussels from wild or managed beds which has grown from 10,358 tonnes in 1985 to an estimated 15,000 tonnes in 1991. There are also a large number of small cultivated producers often part-time.

## 5. ANALYSIS

### *5.1 Common Development Issues*

There are a number of similarities between the two selected industries in Scotland and Ireland which provide a common set of development criteria :

i) a wide range of managerial skills and capabilities within each industry with varying degrees of understanding of marketing.

ii) a wide range of objectives between companies based upon location and size.

iii) a reluctance of major producers to become involved in cooperative ventures thereby supporting others.

iv) supportive development agencies providing advice and technical and scientific support as well as capital grants.

v) encouragement to co-operate by state agencies.

The wide variety of managerial skills and capabilities is a function of the secondary nature of mussel production for some farmers, providing additional income on a part-time basis, with little interest in encouraging growth in order to support full-time activity. Individual business growth may not be feasible in some cases due to resource constraints but discussions with industry experts in both countries suggested that this was not generally a major issue. At the same time in each industry there are larger businesses which, while still relatively small require full-time incomes and normal profit criteria. These businesses are often owned and run by individuals, not necessarily local to the area and often with considerable previous business experience. The problems of integrating a part-time approach with the objectives of the larger producers needs to be recognised. The second main theme of this section is the role of the support agencies. Both industries have government and trade support agencies. In the case of government agencies these are a channel for European Community finance as well as technical and marketing advice. The trade agencies are similar in function although there are different links to producers and to government and other agencies. The final theme of the similarities between the two industries is a recognition of the benefits of co-operation but difficulties in implementing co-operative schemes due to location factors, differing objectives of producers and the type of capital investment necessary.

### *5.2 Differences in approach*

In addition to a number of similarities between the industries there are also a number of differences :

(i) Markets and Marketing Channels

A key difference between the two industries is in access to markets and access to different types of distribution channel. This factor emerged from the research as being probably the most critical issue in the differential rates of progress in the two countries. Scotland has a domestic orientation based upon accessible intermediaries and large domestic markets. This has two features. First, there are local markets for output to local retail outlets and restaurants. Secondly, there is a widespread network of wholesalers and traders within Scotland and in the wider British market who are able to take product from growers. In turn the mussels are destined either for the British retail or catering sector or for export markets, particularly in France. Many of these wholesalers trade in a variety of fish products, often landed in adjacent areas of Scotland and are willing to deal with discontinuous quantities of variable quality. In addition in most cases, particularly on the mainland, transport is readily available to customers. Thus there is not a problem in securing outlets, nor is great skill required to supply them.

The problem faced is one of low prices as a result of variable, discontinuous quantities and limited bargaining power. This has hindered the development of a premium image for the product. The output was also not sold or promoted through the major growth outlets in multiple retailing because of image and lack of consistency of quality. This has ensured continuing low profitability in the industry which in itself acted as a disincentive to expansion. However, because these options were available, even if they were not optimal for the development of the industry, this muted the incentive to forego independence through co-operative types of organisation.

By contrast, Ireland has virtually no domestic market for its produce and does not have the same infrastructure of local wholesale intermediaries as is the case in Scotland. The industry has been dependent upon international export markets for significant development. The production areas of Bantry and Kenmare were dependent originally upon the presence of a local processor who provided a market for local produce. In the early stages the processing capacity was sufficient to encourage investment by some producers, as the processor provided a local or regional growth point allowing local development to occur. The situation changed dramatically after the failure of the processor in Bantry and corresponding fall in local prices. This left formerly dependent producers of relatively large scale in need of markets for their produce. The solution was to re-direct production to the wholesale markets of France. Initially a short term solution, favourable market conditions at the time led producers to co-operate informally in the provision of capital equipment, transport arrangements and market information to enable the placing of large volumes of Irish rope grown mussels. Subsequently a more formal co-operative structure emerged based upon shared local interests which overcame initial reluctance to co-operate. This organisation provides some central administrative support as well as marketing expertise but members are not obliged to participate. In many ways the arrangement can still be classified as informal.

This experience highlights the importance of localised growth points in providing a development path from small scale fragmented production to larger scale production formats. While the adjustment from local to international orientation disrupted Irish production in the short term, the necessary scale of production was present to allow an orderly re-orientation and provide the basis for long term growth.

In order to secure a place in the international market the Irish producers have recognised the need to develop marketing skills aimed primarily at providing consistent quality, volume and prompt delivery. French wholesalers were used to the Irish dredged mussel which was of poor quality and irregular delivery. As a result the growing cultured sector had to change perceptions in order to achieve market share. Thus the imperative for structural change to secure development was much greater in the Irish than in the Scottish case. New marketing structures, formal and informal became a prerequisite for development.

(ii) Location

A further issue is the locational factor. The Scottish industry is widely dispersed geographically, with producers in particular regions not necessarily seeing a communality of interest with their more distant counterparts elsewhere in Scotland. This was probably exacerbated by differences in grant structures in different areas with island areas typically being treated more favourably than the mainland. This has reduced the incentive for processors to locate in any one of these areas because of supply limitations. The lack of processors willing to take product and work with producers has in turn dulled the incentive for individual producers to expand. This has probably tended to reinforce the link with wholesalers rather than other growers. By contrast, Irish mussel producers are geographically clustered in the two main areas of Bantry and Kenmare. The proximity of a large number of producers operating under similar constraints has engendered a significant local identity. Individual producers have recognised shared interests especially in the provision of infrastructure and capital equipment that contrasts markedly with the Scottish experience. This 'local effect' has provided the necessary impetus to overcome traditional reluctance to co-operate and has been recognised as a major strength of the Irish industry.

(iii) Structure

The problems of size in determining the development of an industry have already been discussed. Both the Scottish and Irish industry have a range of producer sizes. In Scotland there are a smaller number of large producers with output of over 50 tonnes per year than is the case in Ireland, with the majority of Scottish farms producing less than 10 tonnes per year (Table 2). The objectives of these producers vary according to the markets which they serve and the competitive position that they hold. Nevertheless, in Scotland larger producers have been reluctant to join with their smaller counterparts in co-operative groups. Discussions with individual companies suggest that this is primarily associated with a view that the gains in such a relationship are disproportionately linked to the smaller rather than the larger member. Larger companies have developed markets, often international ones. They see future development as being less risky when under their own control. In particular they are concerned about variable quality standards among smaller producers and lack of reliability of delivery. Larger companies have developed and expanded their businesses at the same time that smaller producers have failed and left the industry. This fear of co-operation has been exacerbated by the reluctance of smaller producers themselves to join such groups. Some discussions to form regional co-operatives are still underway but currently are making little progress.

A judgement of the current situation is that the future development of the Scottish industry is most likely to come through larger companies and their satellites. A recent trend is for larger growers to develop contractual arrangements with their smaller counterparts so that the smaller producer grows and harvests to the dictates of the larger business. This is attractive to the larger growers because they have the necessary marketing expertise. They also urgently need increased production volume if they are to be able to sell to the major multiple retailers. The smaller producers are more responsive than before because of the saturation of local markets. Recent more favourable prices, coupled with grants have encouraged the entry of new producers into the industry, often people seeking full-time as opposed to part-time earnings from the sector. This has had the effect of depressing local prices and thus the small grower can no longer rely on the traditional easy marketing option. The responsiveness of smaller producers may also have increased due to the campaigns, conducted both by the trade association and the state agency, to persuade them that they are too small for successful marketing. However, the incentive for co-operation in the traditional sense has been dulled because of the rise of the larger businesses. Contract sales offer an easier marketing solution for them.

However in Ireland there have been significant steps forwards in encouraging co-operation which are of much earlier origin than those in Scotland. Much of the impetus toward co-operation has been borne of geographic proximity and the facing of similar production and marketing problems. This has produced an environment characterised by the sharing of capital equipment, in some cases the parcelling of production to ensure transportation economies and common marketing activity. This co-operation has been used to lobby government for specific funding, investment in infrastructure and to generally promote local interests. However, as in Scotland there is still reluctance to join the main trade association, the Irish Shellfish Association. Set up initially with help from BIM under the auspices of the Irish Salmon Growers Association there has been some lack of interest especially among the larger growers who would be under-represented in terms of voting power and whose local interests are already being served through the activities of the co-operatives in Bantry and Kenmare. Future development is likely to come from the activities of the larger producers in Ireland who have been able through internal organisation and marketing expertise to successfully manage the re-orientation of their industry from serving local wholesale markets to serving international markets directly.

(iv) Externalities

The similarities between the countries in relation to the activity of government have already been identified. Both governments operate through two channels, the administrative department of the civil service and a specialised agency concerned with fisheries. Both countries pursue policies to improve technical efficiency in production, provide training for staff and undertake the funding of feasibility and marketing reports. Both countries have been agents in the administration of the grants awarded to the industries by the European Commission. However, there have been differences in the extent of support, its apparent success, and in approach to the two industries.

In Ireland EC support is considered to have been crucial to the development of individual projects and for the industry as a whole (Shaw et al 1990). The two Irish development agencies, BIM and UNG worked very closely with the industry in the submission of grant applications and most applications were for a reasonably substantial scale of operations. This is linked to support for marketing and the co-operation described above. By contrast, in Scotland while many small growers also received very substantial support, particularly on the outer isles, many did not survive. Badly located and lacking the support of the organisation in marketing, they never achieved the critical volumes necessary for sustainable development.

The Irish agency has a specific aquaculture development plan of which the shellfish industry forms a part. It provides a strategic role in identifying the direction of development. The power to pursue these strategic objectives is vested in the Irish agency by virtue of its responsibility for development grants and loans which it can use to encourage or discourage development. This is either geographically through the selective aiding of facilities, sectorally through grant aiding of certain projects or on the basis of scale via the distinction in funding between pilot and commercial scale developments. BIM provides funding under an aquaculture grants scheme directed at two main production phases, pilot development and commercial development. Pilot development funding is the first stage of financial assistance. If successful the applicant can then access the comercial development scheme which in turn gives access to European Commission funds. Over the last ten years BIM has invested IR£6.7m as part of a total private investment in aquaculture valued at IR£45m. In 1989 BIM paid a total of £287,901 in grants to mussel projects alone.

The Scottish Regional Development Agency, Highlands and Islands Enterprise (formerly the Highlands and Islands Development Board) is also involved in the development of its industry. Marketing funds have been made available for the development of the industry trade association and the industry has been strongly encouraged by the agency to re-structure itself. In 1989 HIE invested a total of £410,000 in the Scottish shellfish industry ; £370,000 in the form of capital grants and £40,000 for generic promotion. However, a number of difficulties can be cited.

First, marketing funding has been primarily associated with the trade association in their attempts to develop generic promotion and higher quality standards. However, this activity has been built on an industry structure which has discouraged co-operation. The trade association has faced the problem that it could not develop a quality scheme because of a lack of consensus among farmers, due to fragmentation. The fragmentation and low levels of output further made financing the scheme very difficult. In any case, the fragmented structure of the industry and the generally poor standards of marketing limit the effectiveness of the trade association. Higher quality standards are more likely to come in a piecemeal fashion through the larger growers and their business with multiple retailers.

## 6. CONCLUSIONS

This paper has been a study of two emerging industries in the early stages of development. Conclusions can only be tentative, given that the development process is still underway. Findings are also tentative because of the difficulty in identifying the impact of different causal variables. However, from the evidence it appears that to understand the development process the roles of existing and new marketing channels must be understood with a recognition that existing institutional arrangements can inhibit as well as enable development. Co-operation to achieve development is likely when there is convergence among industry members, in their objectives, in their characteristics and in their location. Finally, state agencies can play an enabling role in development when sufficient resources are available, when their objectives are in harmony with those of the industry and where their activities are part of a strategic approach to growth and development.

## REFERENCES

**Barker J.W.** (1981). *Agricultural Marketing,* Oxford University Press

**Bhagwati J.** (1978). *Foreign Trade Regimes and Economic Development : Anatomy and Consequences of Exchange Control,* Ballinger, Mass

**Boudeville J.R.** (1957) Contribution à l'Etude des Pôles de Croissance Brésilien, *Cahiers,* Sevre F No **10**

**Buzzell R.D., B.T. Gale, R.G.M. Sultan** (1975). Market Share - A Key to Profitability, *Harvard Business Review,* November-December

**Darwent D.F.** (1969). Growth Poles and Growth Centres in Regional Planning, *Environment and Planning,* **I** p5-32

**Gabbott M.J., S.A. Shaw, J. Gibbs** (1991). A Study of the Economics and Marketing of Mussels and Oysters in Ireland, FAR Programme of the European Community

**Gravier J.F.** (1958). *Paris et le Desert Francais,* Flammarion, Paris pp148-169

**Highlands and Islands Development Board (now HIE)** (1990). Memorandum to the House of Commons Agricultural Committees Enquiry into Fish Farming in the United Kingdom

**Howard R.** (1990). Can Small Business Help Countries Compete ? *Harvard Business Review,* November-December

**Kreuger A.** (1978). *Liberalisation Attempts and Consequences*, Ballinger, Cambridge Mass., referenced in World Bank Report 1991, ibid

**Little T.M.D., T. Scitovsky, M. Scott** (1970). *Industry and Trade in Some Developing Countries : a Comparitive Study,* Oxford University Press, London

**Padden C.** (1990). Evaluation of the Effectiveness of European Commission Support Policies for Aquaculture, EAFE/EC 1990

**Meier Gerald M.,** (1989). *Leading Issues in Economic Development,* Oxford Univerity Press, London

**Perroux F.** (1950). Economic Space : Theory and Application, *Quarterly Journal of Economics,* **64,** pp80-104

**Peters T.** (1987). *Thriving on Chaos,* Pan-MacMillan, London

**Rosenstein-Rodan P.N.** (1961). Notes on the Theory of Big Push, in Elli H S and Wallich H C (eds), *Economic Development of Latin America,* St. Martin, New York

**Samuelson** (1976). *Economics,* 10th Edition, Magraw Hill

**Shaw S.A.** (1990). *Marketing : A Practical Guide for Fish Farmers,* Fishing News Books, Oxford

**Shaw S.A., M.J. Gabbott, J. Gibbs** (1991). A Study of the Economics and Marketing of Mussels and Oysters in the UK, FAR Programme of the European Community

**Shaw S.A., A. Nieland, D. Whitmars, M. Gabbott, S. Horn , D. Scott** (1990). Evaluation of the Effectiveness of the Aquaculture Support Policies of the Commission with Special Reference to Regulation EEC 4028/86, Country Report No 11, United Kingdom

**Van Maanen J.** (1983). *Qualitative Methodology,* Sage, London

**World Bank Report** (1991). *The Challenge of Development* , Oxford University Press, London

**Zarka C.** (1958). Un Example de Pole de Croissance : l'Industrie Textile du Nord de la France 1830-1870, *Revue Economique,* January p100

**TABLE 1.**
**SCOTTISH AND IRISH PRODUCTION OF MUSSELS, FARMED AND TOTAL PRODUCTION 1987-1991 (TONNES)**

| | Scotland | | Ireland | |
|---|---|---|---|---|
| | Farmed | Total | Farmed | Total |
| 1987 | 371 | 755 | 1500 | 16393 |
| 1988 | 463 | 1687 | 1800 | 14474 |
| 1989 | 440 | 1503 | 2200 | 11700 |
| 1990 | 457 | 1468 | 3700 | 16200 |
| 1991 | 1024 | 2124 | 4000* | 19000* |

* estimates

Sources: Scottish Office
MAFF
BIM, Dept. of Marine
ISG

**TABLE 2.**
**NUMBER OF MUSSEL FARMS BY SCALE OF PRODUCTION 1991**

| | | Scotland | Ireland |
|---|---|---|---|
| 0-10 | tonnes | 21 | 0 |
| 11-50 | tonnes | 13 | 82 |
| 51-100 | tonnes | 2 | 2 |
| 100+ | tonnes | 2 | 10 |
| Total | | 38 | 94 |

Sources: Scottish Office
BIM, Dept. of Marine

# Economic Evaluation of the Red Sea Bream Ranching in Kagoshima, Japan

**Julita R. Ungson[a], Hachiro Hirata[b] and Yoshiaki Matsuda[b]**

[a]Mariano Marcos State University, Batac, Ilocos Norte, Phillippines

[b]Kagoshima University, 4-50-20 Shimoarata, Kagoshima City, Japan

ABSTRACT

*The purpose of this paper is to demonstrate the usefulness of simple economic data in assessing the economic status of sea ranching activity in preparation to any decission facing fishery policy makers, to analyze the productivity, cost structure and profitability of the major activities of sea ranching.*

*This paper considers different approaches in dealing with the cost components of sea ranching (fingerling production, fingerling release and the whole sea ranching). A total of 150 cases were examined with annual cost treated with and without depreciation, opportunity cost ranging from 0-8 % basing from the present value of investment and subsidy rates of 0 %, 25 %, 50 %, 75 % and 100 % with its effects on profit, breakeven price and production.*

## 1. INTRODUCTION

Red sea bream is considered as a prime fish in Japan because of its high demand and market value. The high price of red sea bream and wide distribution in the coastal waters of Japan will cause problems on resource depletion, if not controlled. Thus, the government has encouraged coastal enhancement or sea ranching of primary species like red sea bream.

Sea ranching activities in Japan have been initiated by the government by establishing sea ranching centers and other facilities. At present, red sea bream ranching in Japan is already in an experimental stage where the government is in the process of gradually transferring the responsibility to the private sector such as sea ranching associations and fisheries cooperatives.

Red sea bream ranching in Japan started at the Kanagawa Prefecture and followed by other prefectures. In Kagoshima Prefecture, red sea bream ranching begun in 1974. There had been numerous studies conducted regarding the sea ranching activity but focussed mainly on the technical and biological aspects. Until now very few studies, if any, had been conducted to investigate the economics of the activity.

In order to understand the present economic status of the red sea bream ranching in Kagoshima and its potential to operate in a long range term including privatization, the goal of this study is to collect and analyze economic information from different agencies involved in sea ranching.

The objective of this paper is to determine the amount of capital investment needed in sea ranching and its present value and to analyze the productivity, cost structure and profitability of the sea ranching activity.

## 2. METHODOLOGY

Data collection was conducted through surveys and interviews with different agencies directly involved in sea ranching such as fisheries cooperatives, Kagoshima Prefecture Fisheries Experiment Station, Kagoshima Prefecture Mariculture Center and the Kagoshima Prefecture Marine Ranching Association. Ideally, a long time-series costs and earnings are needed to calculate the economic performance of the activity and its changes over time. Unluckily, the available data do not allow the construction of the necessary time-series for establishing a reliable trends. Thus, the analysis focussed mainly on the 1990 financial data. The data were analyzed by conventional cost-return and break-even analyses, using profit as an economic indicator. Comparisons were made among 150 different combinations of depreciation (with and without), five opportunity costs (0, 3, 6, 7 and 8 % of investment capital) and five subsidy rates (0, 25, 50, 75 and 100 % of operating cost). Subsidy was assumed to be given equal percentage to fixed and variable costs. Throughout the analyses, economic concepts and depreciation, present value, opportunity cost and subsidy were included.

The red sea bream ranching activity is composed of two major activities of fingerling production and fingerling release, the analysis treated them seperately and as a whole. The 1990 financial data of the red sea bream ranching program was provided by the Kagoshima Prefecture Marine Ranching Association. These data were utilized in making the balance sheet of the two activities of sea ranching and also the two activities were combined together in order to see the economic performance of the whole activity.

## 3. COST-RETURN ANALYSIS

The Kagoshima Prefecture Marine Ranching Association is designated by the government as in-charge in the whole implementation of the sea ranching activity. The association considered only the out of pocket expense incurred during the conduct of the said activity as its cost components. Economic factors like the present value of the capital invested, opportunity cost, depreciation, subsidy and harvesting cost were not considered. In this analysis, these economic factors were thourougly considered at different levels except for harvesting costs and its corresponding effects on the economic performance of the activity.

## 4. FINGERLING PRODUCTION

Table 1 presents the summary of the economic performance of the red sea bream fingerling production. It shows the different approaches in dealing with the cost components specifically on depreciation (with and without), opportunity cost (0 %, 3 %, 6 %,7 %, 8 % investment) and subsidy rates (0 %, 25 %, 50 %, 75 %, 100 %). It could be noted that all possible alternatives (50 cases) in dealing with cost was dealt with from the highest case (with depreciation, with interest rate (8 %) and without subsidy) representing a typical private investment at perfect free market to the lowest case (without depreciation, without interest and with 100 % subsidy). Results showed that out of the 25 cases only six cases will generate profit and the 19 cases show a big loss where the cost component includes depreciation of the facilities used in the production of red sea bream fingerlings. Annual cost with depreciation, without opportunity cost, with subsidy rates of 25 %, 50 %, 75 % and 100 % exhibited a positive return (profit) on the investment of Y3,978,000, Y26,274,000, Y48,569,000 and Y70,864,000 respectively. Moreover, 2 cases where the annual cost includes depreciation with 3 % opportunity cost at 75 % and 100 % subsidy rates also give profits of Y7,794,000 and Y30,089,000.

Twenty five cases were also considered where the annual cost did not include depreciation cost. Results showed that only 8 cases will generate profit despite the fact that depreciatiom was not included in the annual cost. Profits are observed where the out of pocket expense, without depreciation, without opportunity cost and with subsidy rates of 0 %, 25 %, 50 %, 75 %, and 100 %.

The findings show that even depreciation is fully counted, the fingerling production becomes profitable with over 25 % subsidy rates if opportunity cost is negligible or over 75 % subsidy rate if less than 3 % opportunity cost is adopted. If depreciation is not counted, fingerling production becomes profitable without subsidy if opportunity cost is negligible or with over 50 % subsidy rates with minimal opportunity cost of 3 %. Fingerling production is highly capital intensive and it needs a lot of subsidy from the government. This implies that a great amount of money should be pumped into the activity for it to survive. Otherwise, the amount of fingerling production or the price of fingerling should be increased. However, an increase in fingerling production would entail additional expenses in terms of additional capital investment like an expansion of hatchery facilities and additional variable cost like labor cost. On the othe hand, increasing the price per fingerling should be checked by demand and supply conditions for the fingerlings. At present, mariculturists in Japan is no longer interested in fingerlings raised at mariculture centers, the major interest of which is sea ranching. This is because fingerlings from mariculture centers are inferior to fingerlings produced from private hatcheries dealing with improved varieties for mariculture. Thus, this approach is not also optimistic.

## 5. FINGERLING RELEASE

The second phase is the fingerling release activity. The same approach in the analysis of cost for fingerling production was done. A total of 50 cases, 25 cases for the annual cost with depreciation and 25 cases without depreciation as shown in Table 2. Opportunity costs also ranges from 0 to 8 % and subsidy rates from 0 to 100 %. All cases shows profits even in the highest case (with depreciation, with 8 % opportunity cost and without subsidy which exhibited a profit of Y75,719,000). It should be noted that the revenue from fingerling release was just an estimation based on the available data on the number of fingerling released which was provided by the Kagoshima Prefecture Marine Ranching Association and the recapture rate of 14 %, average weight of a 2 year old red sea bream which is 0.34 kg provided by the Kagoshima Prefecture Fisheries Experiment Station and the price per kilogram of red sea bream less than 1 kilogram at Y2,000 - Y4,000/kilogram (Ichikawa, 1990). However, a conservative estimate of Y2,000/kg was used in the computation. Further, any harvesting cost was not included in the analysis.

## 6. WHOLE SEA RANCHING

Another approach in the economic analysis was to combine the costs incurred in fingerling production and fingerling release activities as shown in Table 3. The results show that the whole activity is fairly profitable.

The 25 cases where the annual cost includes depreciation, 14 cases show positive returns (profits) while 11 cases will incur losses. The whole red sea bream ranching activity becomes profitable in the case where the annual cost includes depreciation, if opportunity cost does not exceed 3 % regardless of the amount of subsidy given and also the case where the opportunity cost is 6 % with subsidy rates of 50 % and above, likewise at 7 % opportunity cost with 100 % subsidy rates are adopted.

The other 25 cases where the annual cost without depreciation were considered, 16 cases will generate profits while 9 cases will experience losses. If depreciation is not accounted, the whole red sea bream ranching is profitable with opportunity cost not to exceed 3 % even without subsidy. Further, profitable cases of 6 % opportunity cost with subsidy rates of 25 % and above or 7 % opportunity cost with subsidy rates of 75 % and above.

## 7. BREAKEVEN ANALYSIS

The breakeven price and production of fingerling production activity are shown in Table 4. The breakeven prices of fingerlings where the annual cost includes depreciation ranged from Y0 to Y74/pc while in cases where the annual cost without depreciation, the breakeven price per fingerling ranged from Y0 to Y63.

The present situation of Y18/pc on the average is a case where the annual cost includes depreciation at 0 % opportunity cost and 25 % subsidy rate or a case where the annual cost does not include depreciation at 3 % opportunity cost and 50 % subsidy rate.

The breakeven production was also computed at Y12/pc and Y32/pc. Breakeven production at Y12/pc ranged from 0 to 23,813,583 pieces where the annual cost includes depreciation. However, if depreciation is not included on the annual

cost the breakeven production ranged from 0 to 20,357,583 pieces. Nevertheless, if the price per fingerling is Y32/pc breakeven production ranged from 0 to 8,930,094 pieces if the annual cost includes depreciation but if it did not include depreciation, it ranged from 0 to 7,634,094 pieces.

Table 5 shows the breakeven analyis of the red sea bream fingerling release activity in Kagoshima, 1990. The analysis was also done using the same approach in fingerling production. The case where the annual cost with depreciation the breakeven price ranged from Y0 to Y674 per kilogram. The breakeven production with depreciation at Y2,000 per kilogram ranged from 0 to 19,261 kilograms. However, in the case without depreciation it ranged from 0 to 18,806 kilograms.

Table 6 presents the breakeven analysis of the combined activity of the red sea bream ranching. With depreciation, the breakeven prices ranged from Y0 to Y5,677 per kilogram while the breakeven prices without depreciation ranged from Y0 to Y4,935 per kilogram. These ranges are plausible at current market condition.

The breakeven production with depreciation at Y2,000 per kilogram ranged from 0 to 162,142 kg. While 0 to 140,952 kg for the production without depreciation. The upper sides of the production are 2.4 to 2.8 times higher than the present total production of 57,120 kilograms. However, this is impossible unless a great improvement occurs in the recovery rates.

Even assuming 20 % increase in recovery rates, the upper limit of target production is 68,544 kg. This implies that the sea ranching operations are economically viable at 3 % opportunity cost and 25 % subsidy rate, at 0 % opportunity cost and subsidy rate or at 6 % opportunity cost and 100 % subsidy rate with depreciation whereas viable at 3 % opportunity cost and 0 % subsidy or at 6 % opportunity cost and 100 % subsidy when depreciation is excluded.

Depreciation is the cost for continuity of the operation and opportunity cost can be regarded as the interest on capital investment whereas subsidy is a transfer payment from government to public activities in terms of price support etc. thus reducing costs or increasing the revenue associated with economic activities. The fingerling production was more capital intensive than fingerling release activity while the former's economic alternatives were less than the latter's that is excluding harvesting costs. The result is more desirable when both fingerling production and release activities were combined.

Although the harvesting cost was excluded due to the fact that it varied widely among commercial and recreational fishermen, the result implies that many economically viable alternatives for red sea bream ranching in Kagoshima exist. This means that the current sea ranching activity in Kagoshima is sound as a non-profit economic activity. The current performance represents that the operation is vital at 100 % subsidy on operating cost even if 6 % interest on investment capital were charged, opportunity cost with depreciation at over 25 % subsidy on operating cost without borrowed capital investment or without depreciation at over 25 % subsidy on operating cost with less than 3 % interest on capital investment.

In summary, the breakeven analysis is simple and vital to consider public or quasi-governmental or non-profit organization on economic activity such as sea ranching as well as profit maximizing private enterprise's activities. Any economic activity involves costs and revenue. If the revenue exceeds total costs, any economic activity could be justified in particular for the non-profit and economic activity. Conditions for justification, however, changes widely according to political as well as economic environment. These environmental differences are treated as plausible variations in depreciation, opportunity cost and subsidy in the analysis.

## 8. CONCLUSION

In order to realize the idea of privatization of the sea ranching activity, it is imperative to reduce the cost of fingerling production. This could be materialized by increasing the survival rate of fingerlings. Thus, researches on sea ranching should now focus on this aspect like genetic improvement of brooders that will yield high survival rate of fingerlings. Also, a research on how to improve the recapture rate by exploring on the optimum release size of fingerlings that would minimize rearing cost during the intermediate culture, high survival rate after release and high recapture rate.

## REFERENCES

**Anonymous** (1991). Kagoshima Prefecture Marine Ranching Association Article. Unpublished (In Japanese)

**Ichikawa I.** (1990). Personal communication.

**Shiihara H.** (1986). Results and problems of red sea bream ranching in Kagoshima Bay. *Fishery Series* No. **59**: Kagoshima Prefecture Fisheries Experiment Station, 122p. (In Japanese)

Table 1 Cost-return analysis of the red sea bream fingerling production activity in Kagoshima, 1990

(Unit: 1,000 yen unless specified)

| Investment cost (a) | Cases | Annual cost with depreciation (b) | Opportunity cost at varying interest rate (c)* | | | | | Subsidy on annual cost at varying subsidy rates (d)** | | | | Adjusted annual cost (e)=b+c-d | Profit (h) = g-e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0% | 3% | 6% | 7% | 8% | 0% | 25% | 50% | 75% | 100% | | |
| 944 854 | | | | | | | | | | | | | | |
| | 1 | 89 181 | 0 | | | | | 0 | | | | | 89 181 | -18 317 |
| Present value of | 2 | 89 181 | 0 | | | | | | 22 295 | | | | 66 886 | 3 978 |
| capital investment | 3 | 89 181 | 0 | | | | | | | 44 591 | | | 44 590 | 26 274 |
| | 4 | 89 181 | 0 | | | | | | | | 66 886 | | 22 295 | 48 569 |
| 3%= 1,359, 174 | 5 | 89 181 | 0 | | | | | | | | | 89 181 | 0 | 70 864 |
| | 6 | 89 181 | | 40 775 | | | | 0 | | | | | 129 956 | -59 092 |
| 6%= 1,944,044 | 7 | 89 181 | | 40 775 | | | | | 22 295 | | | | 107 681 | -36 797 |
| | 8 | 89 181 | | 40 775 | | | | | | 44 591 | | | 85 365 | -14 501 |
| 7%= 2,185,980 | 9 | 89 181 | | 40 775 | | | | | | | 66 886 | | 63 070 | 7 794 |
| | 10 | 89 181 | | 40 775 | | | | | | | | 89 181 | 40 775 | 30 089 |
| 8%= 2,457,277 | 11 | 89 181 | | | 116 643 | | | 0 | | | | | 205 824 | -134 960 |
| | 12 | 89 181 | | | 116 643 | | | | 22 295 | | | | 183 529 | -112 665 |
| Total production (f) | 13 | 89 181 | | | 116 643 | | | | | 44 591 | | | 161 233 | -90 369 |
| | 14 | 89 181 | | | 116 643 | | | | | | 66 886 | | 138 938 | -68 074 |
| 3,857,000 pieces | 15 | 89 181 | | | 116 643 | | | | | | | 89 181 | 116 643 | -45 779 |
| | 16 | 89 181 | | | | 153 019 | | 0 | | | | | 242 200 | -171 336 |
| Gross revenue (g) | 17 | 89 181 | | | | 153 019 | | | 22 295 | | | | 219 905 | -149 041 |
| | 18 | 89 181 | | | | 153 019 | | | | 44 591 | | | 197 609 | -126 745 |
| 70,864,000 yen | 19 | 89 181 | | | | 153 019 | | | | | 66 886 | | 175 314 | -104 450 |
| | 20 | 89 181 | | | | 153 019 | | | | | | 89 181 | 153 019 | -82 155 |
| | 21 | 89 181 | | | | | 196 582 | 0 | | | | | 285 763 | -214 899 |
| | 22 | 89 181 | | | | | 196 582 | | 22 295 | | | | 263 468 | -192 604 |
| | 23 | 89 181 | | | | | 196 582 | | | 44 591 | | | 241 172 | -170 308 |
| | 24 | 89 181 | | | | | 196 582 | | | | 66 886 | | 218 877 | -148 013 |
| | 25 | 89 181 | | | | | 196 582 | | | | | 89 181 | 196 582 | -125 718 |
| | | | | | | | | | | | | | | |
| | | Annual cost | | | | | | | | | | | | |
| | | without depreciation | | | | | | | | | | | | |
| | 26 | 47 709 | 0 | | | | | 0 | | | | | 47 709 | 23 155 |
| | 27 | 47 709 | 0 | | | | | | 11 927 | | | | 35 782 | 35 082 |
| | 28 | 47 709 | 0 | | | | | | | 23 854 | | | 23 855 | 47 009 |
| | 29 | 47 709 | 0 | | | | | | | | 35 782 | | 11 927 | 58 937 |
| | 30 | 47 709 | 0 | | | | | | | | | 47 709 | 0 | 70 864 |
| | 31 | 47 709 | | 40 775 | | | | 0 | | | | | 88 484 | -17 620 |
| | 32 | 47 709 | | 40 775 | | | | | 11 927 | | | | 76 557 | -5 693 |
| | 33 | 47 709 | | 40 775 | | | | | | 23 854 | | | 64 630 | 8 234 |
| | 34 | 47 709 | | 40 775 | | | | | | | 35 782 | | 52 702 | 18 162 |
| | 35 | 47 709 | | 40 775 | | | | | | | | 47 709 | 40 775 | 30 089 |
| | 36 | 47 709 | | | 116 643 | | | 0 | | | | | 164 352 | -93 488 |
| | 37 | 47 709 | | | 116 643 | | | | 11 927 | | | | 152 425 | -81 561 |
| | 38 | 47 709 | | | 116 643 | | | | | 23 854 | | | 140 498 | -69 634 |
| | 39 | 47 709 | | | 116 643 | | | | | | 35 782 | | 128 570 | -57 706 |
| | 40 | 47 709 | | | 116 643 | | | | | | | 47 709 | 116 643 | -45 779 |
| | 41 | 47 709 | | | | 153 019 | | 0 | | | | | 200 728 | -129 864 |
| | 42 | 47 709 | | | | 153 019 | | | 11 927 | | | | 188 801 | -117 937 |
| | 43 | 47 709 | | | | 153 019 | | | | 23 854 | | | 176 874 | -106 010 |
| | 44 | 47 709 | | | | 153 019 | | | | | 35 782 | | 164 946 | -94 082 |
| | 45 | 47 709 | | | | 153 019 | | | | | | 47 709 | 153 019 | -82 155 |
| | 46 | 47 709 | | | | | 196 582 | 0 | | | | | 244 291 | -173 427 |
| | 47 | 47 709 | | | | | 196 582 | | 11 927 | | | | 232 364 | -161 500 |
| | 48 | 47 709 | | | | | 196 582 | | | 23 854 | | | 220 437 | -149 573 |
| | 49 | 47 709 | | | | | 196 582 | | | | 35 782 | | 208 509 | -137 645 |
| | 50 | 47 709 | | | | | 196 582 | | | | | 47 709 | 196 582 | -125 718 |

Table 2. Cost-return analysis of the red sea bream fingerling release activity in Kagoshima, 1990

(Unit: 1,000 yen unless specified)

| Investment cost (a) | Cases | Annual cost with depreciation (b) | Opportunity cost at varying interest rate (c)* | | | | | Subsidy on annual cost at varying subsidy rate (d)** | | | | | Adjusted annual cost (e)=b+c-d | Profit (h)=g-e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0% | 3% | 6% | 7% | 8% | 0% | 25% | 50% | 75% | 100% | | |
| 13 208 | | | | | | | | | | | | | | |
| | 1 | 37 380 | 0 | | | | | 0 | | | | | 37 380 | 76 860 |
| Present value | 2 | 37 380 | 0 | | | | | | 9 345 | | | | 28 035 | 86 205 |
| of capital investment | 3 | 37 380 | 0 | | | | | | | 18 690 | | | 18 690 | 95 550 |
| | 4 | 37 380 | 0 | | | | | | | | 28 035 | | 9 345 | 104 895 |
| 3% = 13,604 | 5 | 37 380 | 0 | | | | | | | | | 37 380 | 0 | 114 240 |
| | 6 | 37 380 | | 408 | | | | 0 | | | | | 37 788 | 76 452 |
| 6% = 14,000 | 7 | 37 380 | | 408 | | | | | 9 345 | | | | 28 443 | 85 797 |
| | 8 | 37 380 | | 408 | | | | | | 18 690 | | | 19 098 | 95 142 |
| 7% = 14,132 | 9 | 37 380 | | 408 | | | | | | | 28 035 | | 9 753 | 104 487 |
| | 10 | 37 380 | | 408 | | | | | | | | 37 380 | 408 | 113 832 |
| 8% = 14,265 | 11 | 37 380 | | | 840 | | | 0 | | | | | 38 220 | 76 020 |
| | 12 | 37 380 | | | 840 | | | | 9 345 | | | | 28 875 | 85 365 |
| Total production | 13 | 37 380 | | | 840 | | | | | 18 690 | | | 19 530 | 94 710 |
| (f) | 14 | 37 380 | | | 840 | | | | | | 28 035 | | 10 185 | 104 055 |
| | 15 | 37 380 | | | 840 | | | | | | | 37 380 | 840 | 113 400 |
| 57120 kgs. | 16 | 37 380 | | | | 989 | | 0 | | | | | 38 369 | 75 871 |
| | 17 | 37 380 | | | | 989 | | | 9 345 | | | | 29 024 | 85 216 |
| Gross revenue*** | 18 | 37 380 | | | | 989 | | | | 18 690 | | | 19 679 | 94 561 |
| (g) | 19 | 37 380 | | | | 989 | | | | | 28 035 | | 10 334 | 103 906 |
| | 20 | 37 380 | | | | 989 | | | | | | 37 380 | 989 | 113 251 |
| 114,240,000 yen | 21 | 37 380 | | | | | 1 141 | 0 | | | | | 38 521 | 75 719 |
| | 22 | 37 380 | | | | | 1 141 | | 9 345 | | | | 29 176 | 85 064 |
| | 23 | 37 380 | | | | | 1 141 | | | 18 690 | | | 19 831 | 94 409 |
| | 24 | 37 380 | | | | | 1 141 | | | | 28 035 | | 10 486 | 103 754 |
| | 25 | 37 380 | | | | | 1 141 | | | | | 37 380 | 1 141 | 113 099 |
| | | | | | | | | | | | | | | |
| | | Annual cost | | | | | | | | | | | | |
| | | without depreciation | | | | | | | | | | | | |
| | 26 | 36 471 | 0 | | | | | 0 | | | | | 36 471 | 77 769 |
| | 27 | 36 471 | 0 | | | | | | 9 118 | | | | 27 353 | 86 887 |
| | 28 | 36 471 | 0 | | | | | | | 18 236 | | | 18 235 | 96 005 |
| | 29 | 36 471 | 0 | | | | | | | | 27 353 | | 9 118 | 105 122 |
| | 30 | 36 471 | 0 | | | | | | | | | 36 471 | 0 | 114 240 |
| | 31 | 36 471 | | 408 | | | | 0 | | | | | 36 879 | 77 361 |
| | 32 | 36 471 | | 408 | | | | | 9 118 | | | | 27 761 | 86 479 |
| | 33 | 36 471 | | 408 | | | | | | 18 236 | | | 18 643 | 95 597 |
| | 34 | 36 471 | | 408 | | | | | | | 27 353 | | 9 526 | 104 714 |
| | 35 | 36 471 | | 408 | | | | | | | | 36 471 | 408 | 113 832 |
| | 36 | 36 471 | | | 840 | | | 0 | | | | | 37 311 | 76 929 |
| | 37 | 36 471 | | | 840 | | | | 9 118 | | | | 28 193 | 86 047 |
| | 38 | 36 471 | | | 840 | | | | | 18 236 | | | 19 075 | 95 165 |
| | 39 | 36 471 | | | 840 | | | | | | 27 353 | | 9 958 | 104 282 |
| | 40 | 36 471 | | | 840 | | | | | | | 36 471 | 840 | 113 400 |
| | 41 | 36 471 | | | | 989 | | 0 | | | | | 37 460 | 76 780 |
| | 42 | 36 471 | | | | 989 | | | 9 118 | | | | 28 342 | 85 898 |
| | 43 | 36 471 | | | | 989 | | | | 18 236 | | | 19 224 | 95 016 |
| | 44 | 36 471 | | | | 989 | | | | | 27 353 | | 10 107 | 104 133 |
| | 45 | 36 471 | | | | 989 | | | | | | 36 471 | 989 | 113 251 |
| | 46 | 36 471 | | | | | 1 141 | 0 | | | | | 37 612 | 76 628 |
| | 47 | 36 471 | | | | | 1 141 | | 9 118 | | | | 28 494 | 85 746 |
| | 48 | 36 471 | | | | | 1 141 | | | 18 236 | | | 19 376 | 94 864 |
| | 49 | 36 471 | | | | | 1 141 | | | | 27 353 | | 10 259 | 103 981 |
| | 50 | 36 471 | | | | | 1 141 | | | | | 36 471 | 1 141 | 113 099 |

Table 3. Cost-return analysis of the whole sea ranching in Kagoshima, 1990

(Unit: 1,000 yen unless specified)

| Investment cost(a) | Cases | Annual cost with depreciation (b) | Opportunity cost at varying interest rate (c)* | | | | | Subsidy on annual cost at varying subsidy rate (d)** | | | | Adjusted annual cost (e)=b+c-d | Profit (h)=g-e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 3% | 6% | 7% | 8% | 0% | 25% | 50% | 75% | 100% | | |
| 958 062 | 1 | 126 561 | 0 | | | | | 0 | | | | | 126 561 | 58 481 |
| | 2 | 126 561 | 0 | | | | | | 31 640 | | | | 94 921 | 90 121 |
| Present value | 3 | 126 561 | 0 | | | | | | | 63 281 | | | 63 280 | 121 762 |
| | 4 | 126 561 | 0 | | | | | | | | 94 921 | | 31 640 | 153 402 |
| 3% = 1,372,778 | 5 | 126 561 | 0 | | | | | | | | | 126 561 | 0 | 185 042 |
| | 6 | 126 561 | | 41 183 | | | | 0 | | | | | 167 744 | 17 298 |
| 6% = 1,958,044 | 7 | 126 561 | | 41 183 | | | | | 31 640 | | | | 136 104 | 48 938 |
| | 8 | 126 561 | | 41 183 | | | | | | 63 281 | | | 104 463 | 80 579 |
| 7% = 2,200,112 | 9 | 126 561 | | 41 183 | | | | | | | 94 921 | | 72 823 | 112 219 |
| | 10 | 126 561 | | 41 183 | | | | | | | | 126 561 | 41 183 | 143 859 |
| 8% = 2,471,542 | 11 | 126 561 | | | 117 483 | | | 0 | | | | | 244 044 | -59 002 |
| | 12 | 126 561 | | | 117 483 | | | | 31 640 | | | | 212 404 | -27 362 |
| Total production | 13 | 126 561 | | | 117 483 | | | | | 63 281 | | | 180 763 | 4 279 |
| (t) | 14 | 126 561 | | | 117 483 | | | | | | 94 921 | | 149 123 | 35 919 |
| | 15 | 126 561 | | | 117 483 | | | | | | | 126 561 | 117 483 | 67 559 |
| 57,120 kgs | 16 | 126 561 | | | | 154 008 | | 0 | | | | | 280 569 | -95 527 |
| | 17 | 126 561 | | | | 154 008 | | | 31 640 | | | | 248 929 | -63 887 |
| Gross revenue | 18 | 126 561 | | | | 154 008 | | | | 63 281 | | | 217 288 | -32 246 |
| (g)*** | 19 | 126 561 | | | | 154 008 | | | | | 94 921 | | 185 646 | -606 |
| | 20 | 126 561 | | | | 154 008 | | | | | | 126 561 | 154 008 | 31 034 |
| 185 042 | 21 | 128 561 | | | | | 197 723 | 0 | | | | | 324 284 | -139 242 |
| | 22 | 126 561 | | | | | 197 723 | | 31 640 | | | | 292 644 | -107 602 |
| | 23 | 126 561 | | | | | 197 723 | | | 63 281 | | | 261 003 | -75 961 |
| | 24 | 126 561 | | | | | 197 723 | | | | 94 921 | | 229 363 | -44 321 |
| | 25 | 126 561 | | | | | 197 723 | | | | | 126 561 | 197 723 | -12 681 |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | Annual cost | | | | | | | | | | | | |
| | | without depreciation | | | | | | | | | | | | |
| | 26 | 84 180 | 0 | | | | | 0 | | | | | 84 180 | 100 862 |
| | 27 | 84 180 | 0 | | | | | | 21 045 | | | | 63 135 | 121 907 |
| | 28 | 84 180 | 0 | | | | | | | 42 090 | | | 42 090 | 142 952 |
| | 29 | 84 180 | 0 | | | | | | | | 63 135 | | 21 045 | 163 997 |
| | 30 | 84 180 | 0 | | | | | | | | | 84 180 | 0 | 185 042 |
| | 31 | 84 180 | | 41 183 | | | | 0 | | | | | 125 363 | 59 679 |
| | 32 | 84 180 | | 41 183 | | | | | 21 045 | | | | 104 318 | 80 724 |
| | 33 | 84 180 | | 41 183 | | | | | | 42 090 | | | 83 273 | 101 769 |
| | 34 | 84 180 | | 41 183 | | | | | | | 63 135 | | 62 228 | 122 814 |
| | 35 | 84 180 | | 41 183 | | | | | | | | 84 180 | 41 183 | 143 859 |
| | 36 | 84 180 | | | 117 483 | | | 0 | | | | | 201 663 | -16 621 |
| | 37 | 84 180 | | | 117 483 | | | | 21 045 | | | | 180 618 | 4 424 |
| | 38 | 84 180 | | | 117 483 | | | | | 42 090 | | | 159 090 | 25 952 |
| | 39 | 84 180 | | | 117 483 | | | | | | 63 135 | | 138 528 | 46 514 |
| | 40 | 84 180 | | | 117 463 | | | | | | | 84 180 | 117 483 | 67 559 |
| | 41 | 84 180 | | | | 154 008 | | 0 | | | | | 238 188 | -53 146 |
| | 42 | 84 180 | | | | 154 008 | | | 21 045 | | | | 217 143 | -32 101 |
| | 43 | 84 180 | | | | 154 008 | | | | 42 090 | | | 196 098 | -11 056 |
| | 44 | 84 180 | | | | 154 008 | | | | | 63 135 | | 175 053 | 9 989 |
| | 45 | 84 180 | | | | 154 008 | | | | | | 84 180 | 154 008 | 31 034 |
| | 46 | 84 180 | | | | | 197 723 | 0 | | | | | 281 903 | -96 861 |
| | 47 | 84 180 | | | | | 197 723 | | 21 045 | | | | 260 858 | -75 816 |
| | 48 | 84 180 | | | | | 197 723 | | | 42 090 | | | 239 813 | -54 771 |
| | 49 | 84 180 | | | | | 197 723 | | | | 63 135 | | 218 768 | -33 726 |
| | 50 | 84 180 | | | | | 197 723 | | | | | 84 180 | 197 723 | -12 681 |

Table 4. Break-even analysis of the red sea bream fingerling production in Kagoshima, 1990

(Unit: 1,000 yen unless specified)

| Investment cost (a) | Cases | Annual cost with depreciation (b) | Opportunity cost at interest rates of (c)* | | | | | Subsidy rates on annual cost (d)** | | | | | Adjusted annual cost (e)=b+c-d | Price yen/piece(i) | Breakeven point Production (j) pieces (at Y12/pc) | pieces (at Y32/pc) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0% | 3% | 6% | 7% | 8% | 0% | 25% | 50% | 75% | 100% | | | | |
| 944 851 | 1 | 89 181 | 0 | | | | | 0 | | | | | 89 181 | 23 | 7 431 750 | 2 786 906 |
| | 2 | 89 181 | 0 | | | | | | 22 295 | | | | 66 886 | 17 | 5 573 833 | 2 090 188 |
| Present value | 3 | 89 181 | 0 | | | | | | | 44 591 | | | 44 590 | 12 | 3 715 833 | 1 393 438 |
| | 4 | 89 181 | 0 | | | | | | | | 66 886 | | 22 295 | 6 | 1 857 917 | 696 719 |
| | 5 | 89 181 | 0 | | | | | | | | | 89 181 | 0 | 0 | 0 | 0 |
| 3%= 1,359,174 | 6 | 89 181 | | 40 775 | | | | 0 | | | | | 129 956 | 34 | 10 829 667 | 4 061 125 |
| | 7 | 89 181 | | 40 775 | | | | | 22 295 | | | | 107 661 | 28 | 8 971 750 | 3 364 406 |
| 6%= 1,944,044 | 8 | 89 181 | | 40 775 | | | | | | 44 591 | | | 85 365 | 22 | 7 113 750 | 2 667 656 |
| | 9 | 89 181 | | 40 775 | | | | | | | 66 886 | | 63 070 | 16 | 5 255 833 | 1 970 938 |
| 7%= 2,185,980 | 10 | 89 181 | | 40 775 | | | | | | | | 89 181 | 40 775 | 11 | 3 397 917 | 1 274 219 |
| | 11 | 89 181 | | | 116 643 | | | 0 | | | | | 205 624 | 53 | 17 152 000 | 6 432 000 |
| 8%= 2,457,277 | 12 | 89 181 | | | 118 843 | | | | 22 295 | | | | 183 529 | 48 | 15 294 083 | 5 735 281 |
| | 13 | 89 181 | | | 116 643 | | | | | 44 591 | | | 161 233 | 42 | 13 436 083 | 5 038 531 |
| Total production (t) | 14 | 89 181 | | | 116 643 | | | | | | 66 886 | | 138 938 | 36 | 11 578 167 | 4 341 813 |
| | 15 | 89 181 | | | 116 643 | | | | | | | 89 181 | 116 643 | 30 | 9 720 250 | 3 645 094 |
| 3,857,000 pieces | 16 | 89 181 | | | | 153 019 | | 0 | | | | | 242 200 | 63 | 20 183 333 | 7 568 750 |
| | 17 | 89 181 | | | | 153 019 | | | 22 295 | | | | 219 905 | 57 | 18 325 417 | 6 872 031 |
| Gross revenue (g) | 18 | 89 181 | | | | 153 019 | | | | 44 591 | | | 197 609 | 51 | 16 467 417 | 6 175 281 |
| | 19 | 89 181 | | | | 153 019 | | | | | 66 886 | | 175 314 | 45 | 14 609 500 | 5 478 563 |
| 70 864 | 20 | 89 181 | | | | 153 019 | | | | | | 89 181 | 153 019 | 40 | 12 751 583 | 4 781 844 |
| | 21 | 89 181 | | | | | 196 582 | 0 | | | | | 285 763 | 74 | 23 813 583 | 8 930 094 |
| | 22 | 89 181 | | | | | 196 582 | | 22 295 | | | | 263 468 | 68 | 21 955 667 | 8 233 375 |
| | 23 | 89 181 | | | | | 196 582 | | | 44 591 | | | 241 172 | 63 | 20 097 667 | 7 536 625 |
| | 24 | 89 181 | | | | | 196 582 | | | | 66 886 | | 218 877 | 57 | 18 239 750 | 5 839 906 |
| | 25 | 89 181 | | | | | 196 582 | | | | | 89 181 | 196 582 | 51 | 16 381 833 | 6 143 188 |
| | | Annual cost without depreciation | | | | | | | | | | | | | | |
| | 26 | 47 709 | 0 | | | | | 0 | | | | | 47 709 | 12 | 3 975 750 | 1 490 906 |
| | 27 | 47 709 | 0 | | | | | | 11 927 | | | | 35 782 | 9 | 2 981 833 | 1 118 188 |
| | 28 | 47 709 | 0 | | | | | | | 23 854 | | | 23 855 | 6 | 1 987 917 | 745 469 |
| | 29 | 47 709 | 0 | | | | | | | | 35 782 | | 11 927 | 3 | 993 917 | 372 719 |
| | 30 | 47 709 | 0 | | | | | | | | | 47 709 | 0 | 0 | 0 | 0 |
| | 31 | 47 709 | | 40 775 | | | | 0 | | | | | 88 484 | 23 | 7 373 667 | 2 765 125 |
| | 32 | 47 709 | | 40 775 | | | | | 11 927 | | | | 76 557 | 20 | 6 379 750 | 2 392 406 |
| | 33 | 47 709 | | 40 775 | | | | | | 23 854 | | | 64 630 | 17 | 5 385 833 | 2 019 688 |
| | 34 | 47 709 | | 40 775 | | | | | | | 35 782 | | 52 702 | 14 | 4 391 833 | 1 646 938 |
| | 35 | 47 709 | | 40 775 | | | | | | | | 47 709 | 40 775 | 11 | 3 397 917 | 1 274 219 |
| | 36 | 47 709 | | | 116 643 | | | 0 | | | | | 164 352 | 43 | 13 696 000 | 5 136 000 |
| | 37 | 47 709 | | | 116 643 | | | | 11 927 | | | | 152 425 | 40 | 12 702 083 | 4 763 281 |
| | 38 | 47 709 | | | 116 643 | | | | | 23 854 | | | 140 498 | 36 | 11 708 167 | 4 390 563 |
| | 39 | 47 709 | | | 116 643 | | | | | | 35 782 | | 128 570 | 33 | 10 714 167 | 4 017 813 |
| | 40 | 47 709 | | | 116 643 | | | | | | | 47 709 | 118 643 | 30 | 9 720 250 | 3 645 094 |
| | 41 | 47 709 | | | | 153 019 | | 0 | | | | | 200 728 | 52 | 16 727 333 | 8 272 750 |
| | 42 | 47 709 | | | | 153 019 | | | 11 927 | | | | 188 801 | 49 | 15 733 417 | 5 900 031 |
| | 43 | 47 709 | | | | 153 019 | | | | 23 854 | | | 176 874 | 46 | 14 739 500 | 5 527 313 |
| | 44 | 47 709 | | | | 153 019 | | | | | 35 782 | | 164 946 | 43 | 13 745 500 | 5 154 563 |
| | 45 | 47 709 | | | | 153 019 | | | | | | 47 709 | 153 019 | 40 | 12 751 583 | 4 781 844 |
| | 46 | 47 709 | | | | | 196 582 | 0 | | | | | 244 291 | 63 | 20 357 583 | 7 634 094 |
| | 47 | 47 709 | | | | | 196 582 | | 11 927 | | | | 232 364 | 60 | 19 363 667 | 7 261 375 |
| | 48 | 47 709 | | | | | 196 582 | | | 23 854 | | | 220 437 | 57 | 18 369 750 | 6 888 656 |
| | 49 | 47 709 | | | | | 196 582 | | | | 35 782 | | 208 509 | 54 | 17 375 750 | 6 515 906 |
| | 50 | 47 709 | | | | | 196 582 | | | | | 47 709 | 196 582 | 51 | 16 381 833 | 6 143 188 |

# Adoption of Innovations in the Norwegian Aquaculture Industry - Perceived Attributes

**Kåre Hansen**

Norwegian Institute of Fisheries and Aquaculture, P.O. Box 2511, N-9002 Tromsoe, Norway

ABSTRACT

*The paper discusses which attributes of innovations are perceived by aquaculture farms as important in the adoption process. When one peruses the adoption research literature, one may be surprised at how little effort has been devoted to analyzing "innovation" differences (that is, in investigating how the properties of an innovation affect its rate of adoption). This type of research can be of great value to change agents seeking to predict the reactions of their clients to an innovation, and perhaps to modify certain of these reactions by the way they name and position an innovation and relate the new idea to existing beliefs.*

*The paper discusses empirical findings from a study of Norwegian salmon farms who have adopted a unique external marketing information system. The Norwegian aquaculture industry consists of about 700 small farms located along the Norwegian coast. To provide the farmers with market information, a farmer-owned company has developed a computerized market information system.*

*We have carried out a study on the early adopters of the system to explore which attributes of the innovation are perceived by the farms as important in the adoption process.*

*The data is gathered from a questionnaire sent to early adopters of the system. We have used the factor analysis approach which is a common approach to the interpretation of scaling type instruments. This technique explicitly addresses the question of what distinct factors are being recorded for the sample unit.*

## 1. INTRODUCTION

This paper discusses the attributes of innovations that are perceived by Norwegian aquaculture farmers as important in the adoption process. When one peruses the adoption research literature, one may be surprised with how little effort has been devoted to analyzing "innovation" differences (that is, in investigating how the properties of an innovation affect

its rate of adoption). This type of research can be of great value to change agents seeking to predict the reactions of their clients to an innovation, and to modify certain of these reactions by the way they name and position an innovation and relate the new idea to existing beliefs.

In organizational innovativeness studies, a highly quantitative approach to data set is used. The dependent variable of adoption behaviour is typically measured as a composite score, composed of the adoption of from ten to twenty innovations. The innovation process for each such innovation is thus submerged through aggregation into an overall innovativeness score for each organization. As a result, differences among the innovations are lost (Rogers, 1983).

Our approach, as suggested by Downs & Mohr (1976), is a single-innovation study. The innovation we have studied is an information technology innovation ; "Marinet".

This innovation consists of two parts. The first part is an external marketing information system which provide the farmers with different kinds of marketing information. Via a telephone connection, they can log on to the system from their personal computer in search for marketing information from a database updated by an organization owned by the farmers.

The second part is a management information system. This system makes it possible to the users to improve their control of the production process and provides the farmers with information for management decisions.

This innovation was chosen as an example of information technology (IT). In our context IT is interesting because it has an affect on both the external contacts and relationships of the organizations and on different levels within the organizations (Rousseau, 1985).

The innovative Norwegian aquaculture industry are adopting a lot of new technologies as a mean to sustain their competitive advantages. Knowledge about factors which inhibit or facilitate innovations are therefore crucial in that process.

## 2. THEORY

While a great deal of research has been concerned with the determination of differences between adopter categories, there has been relatively little research conducted in relation to the differences between innovations. The characteristics or attributes of innovations can have a pronounced effect on their rate of adoption, and consequently this is an important area of research. We will stress that it is the potential adopters perception of the attributes of an innovation which is the most important dimension in relation to the rate of adoption. It is not the perception of attributes by experts in the particular field or by the innovating organization itself that is important.

It can be assumed that perception of the attributes of an innovation will vary between different groups or organizations as their situations change. It is therefore generally accepted that perception is, partially, situationally determined. An additional reason for interest in perceived attributes of innovations is as a basis for a standard classification scheme for types of innovations on which they could be compared, and which would provide a stronger basis from which to generalize on the results of particular studies.

Wilkening (1954) in the United States, and Emery, Oeser and Tully (1958) in Australia made some of the earliest attempt to determine which attributes of innovations affect the rate of adoption. These studies examined the diffusion of various agricultural innovations within particular communities. By mapping the differential rates and patterns of acceptance the authors determined which attributes affected diffusion most. Mort and Cornell (1941) undertook the first study on educational innovations where this approach was adopted.

It was mainly attributes that where economic in nature that where focused on in these three studies, for example expected profitability, expenditure required and risk associated with adoption.

Barnett (1953) extended the research and suggested that material innovation would have a higher rate of adoption than non-material innovation because they are more easily communicated and their utility is more demonstrable. Menzl (1960) ranked medical innovations on the basis of his estimates of their communicability, risk and persuasiveness.

Studies from research traditions like sociology, medical and rural sociology, anthropology, education, geography and marketing have, to date, examined a large number of attributes of innovations. These have ranged from those which are

highly specific to those that have highly generalised attributes (Lancaster & Taylor, 1986). Clearly as the rationale for the study of attributes of innovation lies in the desire to develop a standard of classification scheme for innovations, the more generalised and more universally applicable attributes are of greatest interest.

Rogers (1983) has, to this end, proposed five innovation attributes which, he believed, were as comprehensive, mutually exclusive and universally relevant as possible. The selection of these five characteristics was based on past writings and research. The attributes are :

- *Relative advantage*
- *Compatibility*
- *Complexibility*
- *Trialability*
- *Observability*

Each attribute is discussed in detail in the following section.

### *2.1 Relative advantage*

Relative advantage is the degree to which an innovation is perceived as being better than the idea it supersedes. The nature of the innovation largely determines what specific type of relative advantage (often expressed in economic or social terms) is important to the adopters, although the characteristics of the potential adopters also effect which dimensions of relative advantage are most important.

The adoption and diffusion of an innovation is an uncertainty-reduction process. When organizations pass through the innovation-decision process, they are motivated to seek information in order to decrease uncertainty about the relative advantage of an innovation. They want to know the degree to which a new idea is better than an existing practice. In the search for innovation-evaluation information, relative advantage is therefore often the most important element.

### *2.2 Compatibility*

Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. An innovation that is more compatible is less uncertain to the potential adopters.

An innovation that is incompatible with the organizations values and beliefs will often blocks its adoption. Many change agents face difficult assignments in promoting innovations that run counter to strongly held values.

An innovation may be compatible also with previously adopted ideas. Previous ideas or practice is a familiar standard against which the innovation can be interpreted, thus decreasing uncertainty. The rate of adoption of an innovation is effected by the old idea that is supersedes. However, if the innovation was completely congruent with existing practice, there would not be an innovation for the adopting organization. Such a very highly compatible innovation is still useful if it is seen as the first step in a series of innovations that are to be introduced sequentially.

The compatibility of an innovation is also indicated by the perceived needs that it meets by the clients. Change agents need to determine the needs of their clients, and then recommend innovations that fulfil these needs. The difficulty then lies in how to reveal these needs. Clients may not recognize that they have needs for an innovation until they are aware of the new idea or of its consequences.

### *2.3 Complexibility*

Complexibility is the degree of difficulty involved in undertaking and using a particular innovation. Potential adopters will perceive an innovation at some point on a complexity-simplicity continuum. The complexity associated with an greater innovation the lower, it is hypothesized, will be the rate of adoption of the innovation.

### *2.4 Trialability*

Trialability is the degree of which an innovation can be used on a trial basis before adoption needs to be confirmed. An innovation that is trialable is less uncertain for the adopter. The early adopters can not rely on others evaluation and experience in their adoption-process. The trialability is therefore perceived as more important for relatively early adopters.

### *2.5 Observability*

Observability is the degree to which the benefits (relative advantage) and other attributes of an innovation are apparent to non-adopters. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to describe to others. It is suggested that observability will be positively related to rate of adoption.

Technological innovations consists of two components. The hardware aspect is the technology as materials or physical objects. The software aspect is the information base for the tool which enable the adopter to use the innovation as a problem solver. There is, in other words, an interaction between the tool and the way it is used.

Usually the software component of a technological innovation is not so apparent to observation, so innovations in which the software aspect is dominant possess less observability, and usually have relatively slower rates of adoption. A higher degree of trialability can compensate for less degree of observability. New technology as information technology will have a dominant software aspect. Knowledge about the relationship described above is therefore essential to change agents.

## 3. METHOD

The selling firm of "Marinet" provided us with a list of addresses of aquaculture farms that had adopted the system until march 1991. At this stage of the diffusion process, 68 farms has adopted the system. A questionnaire and introductory letter was sent to the adopters and it was given one week deadline for answering. As a respondent "teaser", a lottery ticket and pre-paid envelope was enclosed the questionnaire. This resulted in 59 % respondent rate without any reminder, which we consider as an outstanding rate given normal rate in postal questionnaires to be 20 to 30 % (Wärneryd *et.al.*, 1990). To our repeated reminders the respondent rate increased to 74 %. Table 1 explains the population and return rate of the questionnaire.

Through contact with the adopters who was not willing to answer the questionnaire, it was our impression that they do not differ significantly from the respondents in any aspects of rate of adoption, adoption behaviour or perception of innovation attributes. On that ground we have no reason to suspect systematic errors in the data.

### *3.1 Dependent variables*

The rate of adoption or adoption behaviour is generally measured as the number of organizations or individuals who adopt a new idea in a specified period. We have developed two measures on adoption behaviour which we have used in the questionnaire :

- *time when the innovation was adopted (year and month).*
- *to which degree new technology is perceived as an opportunity for improved efficiency in the production process.*

### *3.2 Independent variables*

Perceptions or concepts typically cannot be measured directly, but may be approached via a set of tests, scales, and other measures (Kleinbaum *et.al.*, 1987). This set of measures will be interrelated and contribute in varying proportions to the perception or concept itself. Based on the five innovation attributes ; relative advantage,

compatibility, complexibility, trialability and observability, we developed a set of 12 statements in an attempt to measure these characteristics. The statements are reproduced in table 2.

The respondent was asked to indicate the extent of their agreement or disagreement by writing the number that best described their reaction to the statements [strongly agree (1), agree (2), neither agree nor disagree (3), disagree (4), strongly disagree (5)].

The most common approach to the interpretation of this Likert summated scaling instrument is that of factor analysis (Green *et.al.*, 1988 ; Baron, 1990). This technique explicitly addresses the question of what distinct characteristics (factors) are being recorded for each sample unit. It specifically avoids the danger of presuming the relationship between scales and factors, and even avoids presumptions about the number of factors perceived by respondents. Factor analysis seeks sequentially, linear combinations of the original variables which explain as much variation in the original data set as possible, and yet are constrained to be independent of each other factor.

After the factor analysis, it is necessary to examine the contributions of each of the factors to the rate of adoption and adoption behaviour. This relationship is explored by using multiple regression.

## 4. RESULTS

We have indicated that one important type of variable in explaining the rate of adoption of an innovation is its perceived attributes. In Rogers (1983) there is a summary of investigations of perceived attributes of innovations and their rate of adoption. Almost every one of these studies reports a positive relationship between attributes (relative attributes, compatibility, complexibility, trialability, and observability) and rate of adoption.

In addition to these perceived attributes of an innovation, other variables such as (1) the extent of change agents promotion efforts in diffusing the innovation, (2) the nature of the social system, (3) the nature of communication channels diffusing the innovation at various stages in the innovation-decision process, and (4) the type of innovation-decision process, effect an innovation's rate of adoption. In this paper we are concerned about the perceived attributes of the innovation. These attributes are derived from a factor analysis of a set of statements (table 2).

Mathematically there are as many factors as original variables or statements. The selection procedure is, however, based on the criteria of maximizing variation explained. Thus, if there are only few real dimensions in the variable set, the first few factors will explain most of the variability. At the other extreme, if each original variable was independent, then all factors would be required to explain their variability.

The resultant factors are each linear combinations of all variables. To assist in interpretation of the meaning of each factor a further mathematical procedure is added to the analysis. This is known as "rotation", and involves a mathematical transformation so that each factor lies as close as possible to a distinct set of original variables. In the two-dimensional case this is equivalent to rotating the conventional vertical and horizontal axes about the origin ; hence the name.

It seemed appropriate to examine the data set with this kind of technique to establish how many real dimensions of perception exists in the respondents minds, and select rationally the appropriate variables and their relative contribution to each revealed factor. The specific method used was a principal components extraction with orthogonal (Varimax) rotation.

The number of factors extracted is chosen on the basis of the Kaiser criterion and by means of the Scree test (Hair et.al., 1990 ; Norusis, 1990 ; Stewart, 1981). The Kaiser criterion argues that any factor which explains more than 1 % of total variation should be retained since it performs better than an original (standardized) variable. In this data set, the Kaiser criterion suggested 5 factors. The number of factors excluded the use of Scree test which would have been an appropriate statistic if the Kaiser criterion had suggested an excessive numbers of factors.

The next stage of the analysis was to rotate the original factor solution to a configuration in which each factors loads heavily on as few variables as possible. The Varimax rotation achieved this while preserving orthogonality of the factors and is reproduced in Table 2.

In this table each factor is identified by enclosure of significant loadings in a box, terminated by a horizontal line which is drawn across the table to delimit the scales contributing to that factor (loadings scores 0,3 are supressed in the table). Each block of scales appears in a numerical sequence from Factor 1 through to Factor 5.

Naming or identification of the five factors remains subjective and is based on the scales contributing to the factor in question.

It is apparent that a "cost-benefit orientation" factor is substantially reproduced in Factor 1. This is confirmed when an inspection is made of scale descriptions in the matrix of rotated factor scores shown in table 2. The factor makes the largest contribution (25 %) to explaining the total variation in the data set.

It appears that "Complexibility" is reproduced in Factor 2. The factor correlates to which degree the innovation was perceived as difficult to use in the beginning, to which degree an introductory course was necessary or not, and valuation of uncertainty how the innovation was anticipated to effect on the working procedures. The factor explains 10 % of total variation in the data set.

By examining the contributory scales, Factor 3 might be labelled "Knowledge of consequences" since the scales are mainly about valuation of economic consequences and felt scepticism to the innovation in the early adoption phase. The factor contribute in explaining 12 % of total variation in the data set.

Factor 4 contains scales of to which extent information technology (IT) is used to other functions in the firm and to which degree the users have positive experience in using IT previous to the adoption of "Marinet". Factor 4 might, therefore, be named "Previous experiences" and explains 15 % of the total variation.

By inspecting the scale descriptions on the fifth factor, it might be labelled "Trialability" since the scale mainly correlates to the degree the innovation was seen in use within other firms previous to adoption and how decisive the opportunity to test the system in advance effected the adoption decision. The factor explains 9 % of the total variation in the data set.

The five factors above explain a total of 71 % of the variation in the data set.

### *4.1 Juxtaposition with Rogers framework*

In table 3 we have compared the factors derived from the data set with the attributes outlined by Rogers (1983). The juxtaposition shows that the perceived attributes of the innovation "Marinet" to a great extend are dimensions of Rogers universally attributes.

The "Cost-benefit orientation" factor is a subdimension of relative advantage. It is hypothesized in the research literature that the higher the perceived relative advantage of an innovation is, the higher is the rate of adoption of that innovation (Grønhaug, 1991).

The factor "Previous experiences" is sorting under the attribute of compatibility. The degree of compatibility of an innovation can both inhibit and facilitate adoption. If the new idea is completely compatible with previous practice we are no longer facing an innovation. Such a very highly compatible innovation is still useful if it is seen as the first step in a series of innovations that are to be introduced sequentially.

"Knowledge of consequences" is a dimension of the attribute observability. Some innovations are easily communicated to others, whereas others are difficult to describe and communicate to non-adopters. It is, however, suggested in the literature that the innovation's trialability is able to compensate for some of the negative relation which is inherent in less observable innovations. The factors "Trialability" and "Complexibility" are labelled the same as Rogers attributes. Therefore they are not further discussed.

### *4.2 The influence of attributes on adoption behaviour*

We will now examine the contribution of each of the five factors to the adoption behaviour. Because there are five explanatory factors, a single graphical exposition is not possible. We are using multiple regression to explore the relationship.

Table 4 presents the regression results with explanatory variables listed in order of entry to the regression. The factor "Knowledge of consequences" is the only factor that explains time of adoption. The explanatory power is 19 %. No other factors are significant and contribute nothing to explanatory power. The regression shows, in other words, that the perceived observability of an innovation leads to less uncertainty and facilitate adoption of the innovation in question.

An another measure on adoption behaviour is to which extent new technology is perceived as an opportunity for improved efficiency in the production process. Table 5 shows that in this case the factor "Previous experiences" contribute to the explanatory power ($R^2 = 0,18$). We can therefore conclude that if the perception of new technology as an opportunity leads to actual innovative behaviour, compatibility with previous experiences plays a crucial role in that process.

## 5. CONCLUSIONS

In this study we have revealed those perceived attributes of a information technology innovation which facilitate its rate of adoption. The study of perceived attributes are important because it is the receivers'perceptions of the attributes of innovations, not the attributes as classified by experts or change agents, that affect their rate of adoption. Like beauty, innovations exists only in the eye of the adopter. And it is the adopter's perceptions that influence the adopter's behaviour.

The analysis extracted 5 factors in our data set. The five perceived factors are :

- "Cost-benefit orientation"
- "Complexibility"
- "Knowledge of consequences"
- "Previous experiences"
- "Trialability"

A juxtaposition with Rogers framework suggested that these factors to a great extend are dimensions of his universally attributes.

In the subsequent analysis we have examined the contribution of each of the factors to rate of adoption and adoption behaviour. This analysis revealed that "Knowledge of consequences" was the only factor that explained time of adoption. The factor "Previous experiences" contributes to the explanatory power of adoption behaviour.

In most of the reported studies in Rogers (1983), perceived relative advantage was the single most important attribute that facilitate adoption. Surprisingly, perception of this factor is not significant and contribute nothing to explanatory power of innovative behaviour in our data set. On the other hand, dimensions of relative advantages are inherent in the factor "Knowledge of consequences".

When organizations pass through the innovation-decision process, they seek information in order to decrease uncertainty. This research shows that perceived attributes affect an innovation's rate of adoption. New technology as the information technology innovation studied here, tends to have a dominant software aspect. Perceived compatibility with past experiences and needs and perceived observability tends to be important for the organizations adopting information technology innovations.

This knowledge is essential to the change agents promotion efforts in diffusing innovations.

## REFERENCES

**Barnett H.** (1953). *Innovation : The Basis of Cultural Change*, New York, McGraw-Hill.

**Baron** (1990). Factors Influencing Innovation, *Technovation*, vol. **10**, no. 6.

**Downs and Mohr** (1976). Conceptual Issues in the Study of Innovation, *Administrative Science Quarterly*, vol. **21**, december

**Emery, Oeser and Tully** (1958). Information Decision and Action : A Study of the Psychological Determinants of Change in Farming Techniques, *Melbourne University Press*, Carleton.

**Green, Tull and Albaum** (1988). *Research for Marketing Decisions*, (Fifth Ed.), Prentice-Hall Inc., Englewood Cliffs, NJ.

**Grønhaug** (1991). Innovasjon, markedsføring og konkurranseevne, *Praktisk økonomi og ledelse*, nr. **3**.

**Hair, Anderson and Tatham** (1990). *Multivariate Data Analysis* , New York, Macmillan Publishing Company.

**Kleinbaum, Kupper and Muller** (1987). *Applied Regression Analysis and Other Multivariable Methods* , (2.ed.), PWS-KENT, Boston.

**Lancaster and Taylor** (1986). The Diffusion of Innovations and Their Attributes : A Critical Review, *The Quarterly Review of Marketing*, summer.

**Menzel** (1960). Innovation, Integration and Marginality, *American Sociological Review* , vol. **25**, Oct.

**Mort and Cornell** (1941). *American Schools in Transition* , Teacher's College, Columbia University, New York.

**Norusis** (1990). *The SPSS Guide to Data Analysis for Release 4*, SPSS Inc., Chicago, IL.

**Rogers (1983).** *Diffusions of Innovations* , (third Edition), The Free Press, New York.

**Rousseau** (1985). Issues of Level in Organizational Research : Multi-level and Cross-level Perspectives, i *Research in Organizational Behaviour*, 7, JAI Press, Inc. Greenwich, CT.

**Stewart** (1981). The Application and Misapplication of Factor Analysis in Marketing, *Journal of Marketing Research*, vol. 18.

**Wilkening** (1952). Acceptance of Improved Farm Practice in Three Coastal Plain Communities, *North Carolina Agricultural Experimental Station Bulletin*, **98**.

**Wärneryd** *et.* al. (1990). *Att fråga - Om frågekonstruktion vid intervjuundersökningar och post enkäter*, Statistiska Centralbyrån, Stockholm.

**TABLE 1.**
**POPULATION AND RETURN RATE OF QUESTIONNAIRES**

| | N: |
|---|---|
| Mailed questionnaires: | 68 |
| "Marinet" not currently in use: | 10 |
| Sample: | 58 |
| Contact not obtained: | 5 |
| Not applicable questionnaires: | 10 |
| Applicable questionnaires returned: | 43 (74,1%) |

**TABLE 2.**
**PERCEIVED FACTORS OF "MARINET"**

| | F1: | F2: | F3: | F4: | F5: |
|---|---|---|---|---|---|
| We strongly recommend other farmers to adopt Marinet. | 0,92 | | | | |
| The initial cost of adopting Marinet is insignificant related to cost savings using Marinet. | 0,87 | | | | |
| Marinet helps us to provide daily the information needed in the production process. | 0,86 | | | | |
| In the beginning Marinet was perceived as complicate to use. | -0,30 | -0,78 | | | |
| The introductory course was essential to learn using the system. | | 0,74 | | | |
| There was a great deal of uncertainty how Marinet would effect on our working procedures. | | -0,71 | | -0,33 | |
| In the beginning we were sceptical about Marinet. | | | 0,77 | | |
| We was fully aware of the administrative consequences when we decided to adopt Marinet. | | | -0,76 | | |
| We are using information technology tools in solving other tasks in the firm. | | | | 0,84 | |
| We have positive experiences in previous use of information technology. | | | | 0,63 | |
| We saw the system in use with other firms before the adoption of the system. | | | | | 0,79 |
| The opportunity to test the system in advance was decisive in our decision to adopt Marinet. | | | | | 0,72 |

TABLE 3.
JUXTAPOSITION WITH ROGERS FRAMEWORK

| *Rogers framework:* | *Perceived attributes:* | *explained variation:* |
|---|---|---|
| Relative advantage | "Cost-benefit orientation" | 25 % |
| Compatibility | "Previous experiences" | 15 % |
| Observability | "Knowledge of consequences" | 12 % |
| Complexibility | "Complexibility" | 10 % |
| Trialability | "Trialability" | 9 % |
| Total variation explained: | | 71 % |

TABLE 4.
REGRESSION OF TIME OF ADOPTION ON ATTRIBUTES

| *Explanatory variable:* | *Coefficient:* | *t-statistics:* | *Contribution to explanatory power:* |
|---|---|---|---|
| *Significant variables* | | | |
| "Knowledge of consequences" | 4,027 | $2,675^{***}$ | $R^2 = 0,19$<br>$F = 7,16^{***}$ |
| *Insignificant variables* | | | |
| "Cost-benefit orientation" | | $-0,885^{NS}$ | |
| "Complexibility" | | $-0,023^{NS}$ | |
| "Previous experiences" | | $0,448^{NS}$ | |
| "Trialability" | | $-1,708^{NS}$ | |

TABLE 5.
REGRESSION OF NEW TECHNOLOGY AS AN OPPORTUNITY ON ATTRIBUTES

| *Explanatory variable:* | *Coefficient:* | *t-statistics:* | *Contribution to explanatory power:* |
|---|---|---|---|
| *Significant variables* | | | |
| "Previous experiences" | 0,310 | $2,566^{***}$ | $R^2 = 0,18$<br>$F = 6,59^{***}$ |
| *Insignificant variables* | | | |
| "Cost-benefit orientation" | | $0,082^{NS}$ | |
| "Complexibility" | | $0,284^{NS}$ | |
| "Knowledge of consequences" | | $-0,321^{NS}$ | |
| "Trialability" | | $-0,742^{NS}$ | |

# Scandinavian Aquaculture in a Global Perspective. A Study Concerning Structural and Marketing aspects

**Rainis Cedrins**

Swedish University of Agricultural Sciences. Department of Economics. Box 7013. S-750 07 Uppsala. Sweden

ABSTRACT

*Researchers at the Swedish University of Agricultural Sciences have been engaged since 1977 in research concerning economy and marketing in aquaculture. Consequently a lot of empirical materials have been presented and an immense network of personal contacts has been built up. This is the base for a three-year research project that will start in 1992. The purpose of the project is to analyse the behaviour of aquaculture firms in Nordic countries outside the different models in economic theory.*

*A special stress will be put on Porters and Ohmaes models concerning competition analysis, Mc Carthys and Kotlers marketing management models and different models concerning entrepreneurship, creativity, the innovation process and theories about personal networks.*

*The study will result in a normative model on how Scandinavian actors in aquaculture should act in the future market that is characterized by turbulence and change.*

## 1. BACKGROUND

A research project is established at the Swedish University of Agricultural Sciences, Department of Economics, concerning Scandinavian aquaculture in a global perspective. The stress is put on structural and marketing aspects.

The aim with the project is to explain how the different aquacultural firms in the nordic countries have acted or presented lack of activity concerning economic models in business development, marketing and competition strategies. Important concepts in the study are innovation, entrepreneurship and creativity. The main question will be what these concepts have mattered for the aquaculture in the different nordic countries.

It must be noticed that the study is not finished. However some interesting aspects that have been observed in the first stage will be discussed in this paper.

## 2. AQUACULTURE IN SCANDINAVIA

The Scandinavian countries are the first in the world regarding farmed production of salmonid fish weighing more than one kilogram. The produced quantity can be regarded in table 1.

Of Norways total produced amount 135 000 tons were exported 1991. As a comparison can be mentioned that the total catch of salmon in the Baltic sea is annually about 4 000 metric tons. The Norwegian aquaculture is dominating in Scandinavia and the other Nordic countries are to a high degree affected of the development in Norway. The production development in Norway is very remarkable as can be seen in table 2.

The primary production turnover was 5 milliard norwegian kronor 1991. The development has been affected of natural advantages as the golfstream and a long coast with sheltered fiords. Also an existing infrastructure is an important factor.

The primary production is nearly totally based on the family firm. About 1 000 such firms today account for most of the production. The technique is rather simple and the investmentcosts are low. The Norwegian regional policy is so formulated that only the local inhabitants have been able to receive permission to establish net cage cultivation at the coast.

However table 2 shows a significant break1991. Until 1991 the Norwegian aquaculture developed new markets and found selling possibilities for all the increasing production. Mainly it was due to the marketing efforts. These efforts were financed by producers and exporters who together put 3 percent of their total turnover in a market fund. About 90 percent of the farmed fish is exported to about 20 countries.

However the world supply of salmonide fish increased rapidly in 1989 and 1990. The catch of pacific salmon was very big and several countries increased their production of farmed fish. The profitable export market for Norwegian salmon in USA was closed due to new american import fees and duties. Consequently the Norwegian Fish Farmers' Sales Organization (FOS) had to freeze a large amount of the farmed fish. However this "frozen salmon mountain" increased drastically. It was 37 000 metric tons in autumn 1991 and cost a lot of money. In November 1991 FOS was facing bankruptcy. Today the Norwegian farmers situation is rather chaotic and they have to build up a new market organization.

## 3. CAGE CULTIVATION AND LANDBASED CULTIVATION

Although the situation in Norway today the fact is that Scandinavian fish farming has been very successful during the last ten years. In Denmark about 460 farms cultivate 35 000 metric tons of portionsized rainbowtrout (0,2-0,3 kg) in ponds. Most of the salmon and big rainbowtrout is however produced in net cages by family farms. However it is astonishing that a great amount of the resources concerning research development and education is concentrated on the so called landbased forms of cultivation today. The landbased forms of cultivation are largescale and dominated by big firms. In a theoretical sense the landbased forms have advantages compared with net cage technique. However the former have not commercially been successful in Scandinavia.

In Sweden big plants have faced bankruptcy and at last been sold symbolically for one Swedish krona. All the four Swedish nuclear power plants have ran fish farms or have had fargoing plans to do that, in order to get use of the hot waste water. But today all this kind of production is liquidated.

In Iceland a lot of big land based plants were established during 1985-1990. Today all these have gone in bankruptcy and nearly one milliard american dollars is lost. These plants were judged to death already from beginning because the financial and running costs were to high in relation to production.

In Norway some people today speak about the third generation of landbased plants and that these will be successful contrary to the earlier generations that have not shown any success. Part of the explanation why the landbased plants have not shown any success is due to the fact that the technique has failed when the production has been performed on a commercial scale.

However there are also reasons to assume that the failure is depending on imperfections concerning entrepreneurship, marketing analysis and competition strategies. These aspects will here be discussed.

## 4. THE ENTREPRENEURIAL CONCEPTION

Entrepreneurship still is a concept that lacks a general definition. The differences in opinion mainly have reference to the abilities and functions concerning the entrepreneurial concept. If entrepreneurship is a production factor or if it is at all a need for such a concept. The Austrian school does not regard the entrepreneur as a production factor but a "positive function". The market economy could not work without that function (Shand 1988).

Kirzner (1978) emphasize that the entrepreneur is not only a product of a market economy, but only the market economy with its profit mechanisms can create entrepreneurs. He means that the entrepreneurship is a kind of arbitrage. Profit opportunities arise when the prices at the product market are not adapted to the prices at the resource market. Something is sold to different prices at different markets due to lacking information between these markets. The entrepreneur takes advantage of this situation and redistributes the resources towards new balance. Kirzner means that the chance to get profit results in the entrepreneur's activity.

Also Schumpeter (1961) consider that it is the profit that stimulates entrepreneurship. Profit is, however, the result of an innovation. New technology and new products create imbalance on the market. Kirzner on the other hand stress the balance in action of the entrepreneur.

Gilder (1984) considers that the entrepreneur is both an discoverer of opportunities and a creator of opportunities. The entrepreneur not only use capital but is also a capital creator. Gilder means that the real entrepreneur does not begin with the objections but concentrates on activity. However, the activity must be performed in the right time. "Timing" is a very important concept for Gilder.

Bjerke (1989) has a definition that entrepreneurship is to force an idea or an investigation towards a new business project. It does not matter how splendid a business idea is, if nobody is able to conduct this idea through difficulties and traditions towards realization.

Johannisson (1984) stresses that creativity is a vital component in the concept of entrepreneurship. He means that entrepreneurship just like artistic activities is a question of breaking established patterns. It is to understand a new or revised pattern.

Hammarkvist, Håkansson and Mattsson (1982) stress the cooperation. They consider that "Entrepreneurs" act to get interplay between market and society, break standards and build up new things. This is often performed through creating and developing personal networks. Relations and network positions are often very important for a firm.

Hubendick, Johannisson and Josefsson (1982) discern three stages in the development of a firm. An innovative stage, a growth stage and an administrative stage. The innovative stage is characterized of creating ideas. It is in this stage that the creative investigations are found. The actors are more interested in technological aspects than marketing aspects.

In the growth stage the product idea is transformed to the business idea. The interest will change towards marketing aspects and the aim is to develop the firm. It is in this stage that the entrepreneur will be most useful.

In the administrative stage the firm has reached stability. Effectiveness, coordination and regulations are the main conceptions in this stage.

Hubendick, Johannisson and Josefsson mean that the entrepreneur is no friend of regulations. He must not necessarily be a good administrator, planner and delegator. Regarding those aspects Drucker (1985) has another opinion. Drucker speaks about "entrepreneurial management" as a most important conception. Without a management the new firm will not survive. Then it does not matter how successful the products are or how easy the firm acquires capital.

To manage a new established firm the following aspects are required in Druckers opinion :

i) Concentration on market.

ii) Liquidity and capital planning.

iii) A based management before the real business has started.

iv) That the entrepreneur makes decisions concerning his branch, his own role and his relations.

Drucker means that an entrepreneur who establish a firm shall not primarily concentrate upon profit. Cashflow, capital and control are more important conceptions. The new firm need liquidity analysis and liquidity prognosis. The circumstances that the new established firms in USA have got better on during the last years than before can be explained by the fact that they put more stress upon the above described aspects. A significant exception is the high technological firms.

Drucker means to sum up that the organizational aspects must be involved in the entrepreneurial concept.

Casson (1982) takes a further step and defines the entrepreneur as a person who is a specialist in making decisions concerning scarce resources during uncertain conditions. Casson means that the entrepreneur is a clever negotiator and activ planner. The organizational aspect in the entrepreneurship is of the same importance as the technical or marketing aspect.

The ability to combine is a quality that many authors emphasize concerning entrepreneurship.

Siropolis (1982) means that entrepreneurship is the available capacity for innovations, investments and expansion on new markets, new products and new forms of technology.

Hubendick, Johannisson and Josefsson consider that the entrepreneur often works with technology as well as economy and marketing unlike the investigator who put the main importance on the technological qualities of the product and often make a wrong estimation concerning the marketing aspects.

Concerning the risk, most authors consider that the entrepreneur is a risktaker but not a gambler or a speculator.

Bjerke means that the entrepreneur works with calculated risks. He is aware of what he has to lose but at the same time he takes the responsibility for a mission that seems impossible for others.

Nyström (1990) has formulated the situation in the following way :

"Our research indicates that entrepreneurship is a balancing act between strong risk creation and strong risk elimination. It is in the timing and balancing of risk that the successful innovative entrepreneur excels".

## 5. ENTREPRENEURSHIP AND AQUACULTURE. SOME INDICATIONS.

Cultivation of salmon in net cages in Norway is an example of successful entrepreneurship. A totally new activity is built up based on biological and infrastructural advantages. The technique did not exist before 1970. In terms of theory of innovation and entrepreneurship this form of aquaculture has become a profitable business.

To some extent it has been a question of "shooting for the moon" in Gilders terminology. This can be exemplified by the Norwegian establishment on the American salmon market 12 years ago. Probably it is a question of the "impossible" because USA is the leading nation in the world concerning pacific salmon fisheries. Pacific salmon is a competitor to the farmed atlantic salmon and big rainbow trout in Scandinavia. 1990 the global catch of atlantic salmon was about 800 000 metric tons. The american part was more than half of this amount.

Now the salmon fishing in America is performed mainly during the period April - November. During the other months there is no supply of fresh salmon. The Norwegian and partly Swedish fish farmers have taken advantage of this situation. The farmed fish can be slaughtered and transported fresh by air to USA during the whole year. The Norwegian farmers' marketing organizations have succeeded to profile the product. "Norwegian Salmon" today is a concept that the American consumer associate to "high mountains and deep fiords". Another effect is that many American restaurants have been forced to take up Norwegian salmon on the meny also during the period April - November when there is a supply of fresh pacific salmon because of consumers desire. These kind of export efforts have however been performed with a tendency of risk elimination to cite Nyström.

The risk elimination means that the Norwegian fish farmers try to develop markets in several countries. This fact is very important today when the American lobby of Pacific salmon interests have managed to restrict the Norwegian export. The Norwegian fish farmers were accused with dumping and the US auhorities determined in February 1991 to charge the Norwegian fishfarmers with a 24 percent dumping fee and a 2,27 percent subsidizing custom. The last word is not said in this affair. The Norwegian government has made a protest in GATT. GATT is now performing an investigation. Today only a few 100 kg of Norwegain salmon is exported to USA. Before 1991 the annual export was about 10 000 metric tons. Today France, Germany and Denmark are the largest importers of Norwegian salmon. All the successful Norwegian export have been realized through cooperation between small producers, the marketing organizations and the society. All this is entrepreneurial concepts to cite Hammarqvist and Johannisson. New markets with new requirements have been developed but all the "critical factors" that Drucker mentions have been solved.

The last two years however the production increase of farmed salmon has been so enormous that the farmers have been forced to "check". The smolt production and foddering have been limited. Part of the ready production has been freezed. These actions have however not been enough and in November 1991 the Norwegian Fish Farmers Sales Organization (FOS) went in bankruptcy due to a bad liquidity. Perhaps it has also been a tendency that the administration concerning regulations and restrictions has grown too much at the expense of marketing and product development in Norwegian fish farming. That is a tendency that Drucker warns against. Today however a new organization is built up with less regulations.

The fact that the land based plants have not succeeded in spite of big investments can partly be explained by the fact that the actors' have remained in the "innovative stage" in Hubendick's - Johannisson's - Josefsson's model. The actors became fascinated by the new technique and neglected to perform analysis concerning the marketing process. One of the landbased Norwegian fish farms now try to introduce the product on the American market described as "organic salmon". This product is guaranteed to be without artificial additions, disease and remains of medicine. But the traditional net cage farmers in Norway hardly will leave a product on market that is characterized of disease or remains of medicine. The farmers have a sophisticated quality control. Cage farmers and salmon fishermen could in their turn emphasize the high fish density in land based farms. High fish density is a precondition for profit in the land based farms but is hardly a selling argument because the food consumer today is target for an intensive debate concerning ethics in animal management.

In Iceland it is very difficult to manage net cage cultivation because it is hard to find sheltered locations. The established land based fish farms have demanded big capital investments that to a great extent have been financed by foreign capital. Due to the large global catch of pacific salmon 1989 - 1990 and the big Norwegian supply of farmed salmon the salmon prices drastically decreased.

This fact together with increased rate of interests, exceeding of calculated investments and problems concerning the technical operations caused a serious liquidity situation for the farmers in Iceland. In Druckers terminology it has been a question of bad "entrepreneurial management". An important fact is however that the costs for administration increased very rapidly. To a great extent this was due to the compensation for the external consultants. Their efforts could not save the companies. Deficient entrepreneurship cannot be replaced by consultancy. Drucker means that in USA the most hightechnological companies are most deficient concerning "entrepreneurial management". Perhaps this can also be significant for the Scandinavian aquaculture.

## 6. MODELS FOR COMPETITIVE ANALYSIS

Competitive analysis is a basic concept in business planning. One of the models that perhaps has received most attention is developed by Michael Porter. Porter (1980) emphasizes five competitive forces in a sector :

i) rivalry among present competitors

ii) the consumers' force of negotiation

iii) the suppliers' force of negotiation

iv) threats concerning new establishments

v) threats concerning substitutes

To control these forces there are three strategies

i) cost superiority

ii) differentiation

iii) focusing (market segmentation)

"Cost superiority" means that the company tries to look after all possibilities to get cost advantages. "Differentiation" means that the company tries to develop the products in a way that seems to be unique for the consumer in some sense. "Focusing" means that the company concentrates its resources toward a special market or target group and tries to satisfy its demands more successfully than the competitors do.

Porter emphasizes that the company only has ability to manage one of the strategies at the same time. But is is a question concerning how to choose the right strategy.

Kenichi Ohmae (1985) has developed a model where he points out four different ways how a firm can strenghten its position in relation to the competitors :

i) Key factors for success. If the firm change its resources to the keyfactors for success, it can reach competitive advantages even if the competitors have the same resources.

ii) Relative superiority. A firm is able to utilize its differences in relation to the competitors or take advantage of the competitors weak abilities. It can deal about technique, marketing organizations or something else that is less developed by the competitors.

iii) Offensive initiatives. Concentration on unconventional efforts to disturb the competitors positions. For instance to disturb the keyfactors for success for the competitors.

iv) Strategic freedom. The firm has the possibility to develop new markets by innovations. Innovations often include market segmentations in order to examine new demands and consuming patterns.

## 7. COMPETITION ANALYSIS AND AQUACULTURE

The net cage farmers in Norway have mainly taken advantage of "focusing" to control the competitors in Porters terminology. Competitors are mainly the global supply of pacific salmon, recently established cage farms in especially Chile and Canada and finally the landbased plants. In USA the target group is the first class restaurants in the big cities at the east coast. In the EC-countries the main customers of norwegian salmon are the big fish smoking companies.

The net cage farmers in Sweden and Finland have due to biological conditions mainly concentrated on big rainbow trout instead of salmon. The Finnish farmers have a superiority on their home market in relation to the competitors because the latter are confrontated with far reaching import quotas.

Also Swedish farmers use "focusing" as strategy and the target segment is the Japanese market. Japan representate the highest consumtion in world of fish and fish products in relation to its number of inhabitants.

The Japanese consumers demand a salmonide fish that is very red in the flesh. It is more easy to get red colour through additives in the fodder for rainbow trout compared with atlantic salmon. This fact the Swedish farmers have taken advantage to in the product development (strategic freedom in Ohmaes terminology). Especially bad in this connection is the caught salmon in the Baltic Sea that has a very pale flesh.

The fish farmers in Denmark mainly concentrate on portion sized (0,2-0,3 kg) rainbowtrout that is cultivated in ponds. In this sector the Danes possess a relative superiority in relation to ohter countries due to long time experience, technique and marketorganisation. 90 percent of the final product is exported to Germany.

To some extent also the Norwegian fish farmers have concentrated on "differentiation" and "strategic freedom" during the last years.

Among other things by introducing farmed cod. Today there is a shortage of cod during certain periods of the year. Then the market pay more for cod than salmon. 1990 about 2000 metric tons of cod were produced in net cages in Norway. Big research resources is also applied to halibut farming.

The land based farms have concentrated on cost superiority and partly of differentiation as competitive strategies. There is however a risk that the technique can be imitated of fish farmers in other countries. Landbased fish farming can be established at all coast areas if the deep of the water is more than 30 meters. Consequently it would be possible to establish such plants in the EC countries where the demand for salmon is very high. The traditional cage farming in Norway however has advantages that cannot be imitated in other countries. Firstly effects of the golfstream and big coast area with sheltered localities. An important fact is also that people are living along the total coast and that service and communications are available.

Porter mentions a lot of risk moments with cost superiority as competitive strategy. This strategy cause a constant pressure to the firm to keep its position. Consequently the firm is forced to constant investments in modern equipment and openness for technical improvements. All this demands large capital resources and stable marketprices. Stable marketprices are not existing in such a turbulent sector as aquaculture. Another risk with concentration on cost superiority is that necessary product developments and marketing efforts will not be recogniced in time due to the attention on the production costs.

The landbased Norwegian farms also try to use "differentiation" in their strategy. Because deep water is pumped up to the cultivation system, a water without algae and less diseasebringing bacteria is guaranteed. This will decrease the production costs. Representatives for the landbased farms will however use this fact as an argument that their fish is better than the net cage cultivated. This is an example of "offensive initiatives" in Ohmaes terminology. The representatives for landbased systems tries to disturb the traditional fish farmers key factor, the quality profiling.

## 8. COMPETITIVENESS ON NATIONAL LEVEL

In a later work from 1990 "The Competitive Advantage of Nations", Porter tries to explain, "Why does a nation achieve international success in a particular industry ?"

Porter uses four attributes in his so called "diamond model" :

i) Factor conditions. Human, physical, knowledge and capital resources. Infrastructure.

ii) Demand conditions. The nature of home demand for the industries product or service.

iii) Related and supporting industries. The presence of supplier industries and related industries.

iv) Firm strategy, structure and rivalry. The conditions concerning how companies are created, organized and managed. The nature of domestic rivalry.

Regarding the Norwegian aquaculture the success of the sector is mainly due to the "factor conditions" that have been discussed earlier, but also "related and supporting industries". Norway is one of the leading nations in the world fisheries. This "Know how" concerning all parts of fish, fisheries and fish processing has been very useful in the development of aquaculture.

The obstacle for Norwegian aquaculture out from Porters terminology is "demand conditions". Norway has only four million inhabitants and the home market is too small for the salmon supply. Consequently the dependence of a foreign market is total. The farmers organisations have solved the market problems rather well. However they have not been strong enough regarding negotiations in foreign countries. Therefore lobby interests managed to spoil the American market one year ago.

## REFERENCES

**Bjerke B.** (1989). *Att skapa nya affärer.* Lund.

**Casson M.** (1982). *The Entrepreneur. An Economic Theory.* Oxford.

**Cedrins R.** (1989). Vattenbrukets ekonomi och finansiering. 4 :e utgåvan. Sveriges Föreningsbankers Förbund. Stockholm.

**Cedrins R.** (1991). Landbaserade anläggningar - en konkurrensanalys saknas. *Nordisk Aquakultur. Nr 2.*

**Drucker P.** *Innovation and Entrepreneurship.* London.

**Gilder G.** (1984). *The Spirit of Enterprise.* New York.

**Hammarkvist K., H. Olov, M. Håkan and G. Lars** (1982). *Marknadsföring för konkurrenskraft.* Malmö.

**Hubendick U., B. Johannesson and B. Josefsson** (1982). *Entrepreneurskap - dynamiken i affärerna och företaget.* Lund.

**Johannisson B.** (1984). *Entreprenören - både meningsbyggare och företagsbyggare.* Göteborg.

**Kirzner I.** (1978). *Competition and Entrepreneurship.* Chicago.

**Nyström H.** (1990). *Technological and Market Innovation.* Chichester.

**Ohmae K.** (1985). *Strategiskt tänkande.* Värnamo.

**Porter M.** (1980). *Competitive Strategy.* Worcester.

**Porter M.** (1990). *The Competitive advantage of Nations.* Worcester.

**Schumpeter J.** (1961). *The Theory of Economic Development.* Cambridge.

**Shand A.** (1988). *The Capitalist Alternative.* London.

**Siropolis N. C.** (1982). *Small Business Management. A Guide to Entrepreneurship.* Boston.

TABLE 1.
PRODUCTION OF FARMED BIG SALMONID FISH IN THE SCANDINAVIAN COUNTRIES 1991. METRIC TONS.

| Country | Atlantic salmon | Rainbow trout (weighing more than one kilogram) |
|---|---|---|
| Norway | 145 000 | 5 600 |
| Faroe Island | 18 000 | 2 000 |
| Sweden | - | 4 300 |
| Finland | - | 16 000 |
| Denmark | - | 6 000 |

TABLE 2.
PRODUCTION OF ATLANTIC SALMON AND RAINBOW TROUT IN NORWAY 1971-1993. METRIC TONS

| Year | Atlantic salmon | Rainbow trout |
|---|---|---|
| 1971 | 100 | 450 |
| 1975 | 900 | 1 700 |
| 1980 | 5 000 | 3 500 |
| 1985 | 28 000 | 5 000 |
| 1988 | 80 000 | 9 000 |
| 1989 | 115 000 | 4 000 |
| 1990 | 160 000 | 3 500 |
| 1991 | 145 000 | 5 600 |
| 1992(prognosis) | 120 000 | 6 000 |
| 1993(prognosis) | 100 000 | 6 000 |

# What is the "Right" Price of Norwegian Salmon?

**Rögnvaldur Hannesson** *

Centre for Fisheries Economics, the Norwegian School of Economics and Business Administration, Helleveien 30, N-5035 Bergen-Sandviken, Norway

ABSTRACT

*A Stackelberg model for farmed salmon, with Norway as a price leader and the rest of the world as a competitive fringe, is discussed. The optimal price of salmon is shown to be between 30-40 NOK per kg., depending on the elasticity of demand and the fringe suppliers' elasticity of supply. Changes in the level of the competitors' marginal cost has relatively little effect on the price and affects mainly the quantity sold by the price leader versus the fringe suppliers.*

## 1. INTRODUCTION

The market for farmed salmon has changed radically over the last decade. In 1980 the average price of exported Norwegian salmon was about 57 "kroner", or 122 "kroner" at 1991 prices, and the quantity exported was 4,300 tonnes. By 1991 the price had fallen to 37 "kroner", while the quantity exported had increased to 134,700 tonnes.

The story is familiar. New products fetch a high price immediately after they are put on the market, while they are still in limited supply. High profits attract new suppliers, and after some time competition has pressed the price to a level that only allows the most efficient suppliers to survive. The fact that fish farmers have been going broke by the dozen indicates that this level has now been attained or possibly surpassed.

This development has taken place despite the fact that Norway has had a high market share. A high market share is not, however, sufficient to wield some control over the market price, in addition the industry must be so organized as to permit effective control over the quantity produced. The Norwegian salmon farming industry is quite fragmented, both on the production and the export side, and it is perhaps doubtful whether it would be at all possible to control the production

* I am grateful to Kjell Salvanes, Norwegian School of Economics and Business Administration, for valuable comments and assistance.

unless the ownership of farms becomes much more concentrated. That notwithstanding, the question what the optimal level of Norwegian salmon exports might be is interesting in its own right. Here an attempt will be made to answer that question with respect to the export of salmon to the European Community.

The Norwegian market share of farmed salmon in the European Community is about 60 per cent. There is some reason to believe that this share will remain high, despite the rapid development of salmon farming in other countries. The cost of salmon production in other European countries appears to be higher, and the scope of expanding production further at suitable sites in these countries is somewhat limited. The competition from overseas growers like Chile and Canada is likely to be limited by high freight costs of fresh salmon. These costs increase substantially once the freight exceeds volumes that can be accommodated by the freight capacity of passenger airplanes. A high and sustained market share will not suffice, however, to confer any market power unless there are no perfect substitutes for farmed salmon or these substitutes are themselves in limited supply. The latter appears a reasonable assumption; even if wild salmon is a near-perfect substitute to farmed salmon its supply is not likely to increase in the long term, while it is known to fluctuate substantially over time and hence to shift the demand curve for farmed salmon back and forth. An increase in the supply of near-perfect substitutes for salmon is most likely to be due to increased production of other farmed high quality fish, such as turbot and sea bass.

The way the problem is dealt with here is as follows. A a downward sloping demand curve is assumed for farmed salmon, characterized by a constant price elasticity. Changes over time are ignored. Norway is regarded as a market leader facing competition from competitive producers who adjust their production so that their marginal cost is equal to the market price. Norway as a market leader is supposed to maximize its salmon rent (difference between export income and production costs), taking into account how the competitive fringe adjusts to price changes. This leads to a traditional, static Stackelberg model of price leadership.

## 2. THE MODEL

Let the demand function be specified as

$$Q = AP^{-b}, \tag{1}$$

where Q is quantity demanded, P is the market price, and A and b are parameters, with b expressing the (constant) price elasticity of demand.

The marginal cost function is specified as

$$X = B \exp(gS), \tag{2}$$

where X denotes marginal cost, S is the quantity supplied, and B and g are parameters. These will not be the same for Norway and her competitors. The subscripts n and c will be used to distinguish between these two.

The parameter g is related to the elasticity of supply. It can be shown that the elasticity of supply is $(gS)^{-1}$

Following the traditional price leadership model, Norway is assumed to maximize her salmon rent (profits from exporting salmon), taking into account how the competitors will react to a change in the market price. Denoting the salmon rent by R, this entails

$$\max R = P(S_n + S_c) S_n - C(S_n), \tag{3}$$

where market clearance implies $Q = S_n + S_c$ and

$$C = \int_0^{S_n} X dS = B_n[\exp(g_n S_n) - 1]/g_n, \tag{4}$$

assuming there are no fixed costs.
The first order condition of maximizing (3) is

$$dR/dS_n = P - P[1 + dS_c/dS_n]S_n/b(S_n + S_c) - X_n = 0. \quad (5)$$

To evaluate the term $dS_c/dS_n$, differentiate (1) and (2) for the competitors:

$$dP = -P(dS_n + dS_c)/b(S_n + S_c),$$

$$dX_c = g_c B_c \exp(g_g S_c) dS_c$$

By assumption, $dP = dX_c$, from this we get

$$dS_c/dS_n = -P[b(S_n + S_c)g_c B_c \exp(g_c S_c) + P]^{-1}, \quad (6)$$

which, inserted in (5), makes it possible to solve for the optimal value of, given the value of the parameters, using Equations (1) and (2) to determine P and $S_c$.

## 3. NORWAY AS A MONOPOLIST

We will solve the above model under varying assumptions of its parameters which appear consistent with reality. On the demand side (Equation 1) we must specify the parameters A and b. Salvanes et al. (1991) reports various investigations of the markets for farmed salmon in Europe. The estimates of the price elasticity of demand in these investigations range from 1 to 2.9. Here we shall use four alternative values, 1.5, 2, 2.5 and 3. The parameter A will be calibrated so that the price is 37 for a demand of 170,000 tonnes, as this is close to the price and volume of farmed salmon in the EC market in 1991. Lacking an exact figure on this, we have estimated the volume on the basis of Norwegian exports and the production of farmed salmon in other European countries. The exports from Norway were 103,000 tonnes, and the production by the main competitors (Scotland, Ireland and the Faroe Islands) was 69,000, which corresponds to 63,000 tonnes of gutted fish head on. The price refers to the average Norwegian fob export price.

As a reference point, let us consider what the optimum price and quantity of farmed salmon in the EC market would be for Norway as a monopolist. Recent investigations into the profitability of Norwegian salmon farms report a production cost of 24.08 "kroner" per kg. live weight (figures from 1989) [1]. Allowing for a 10 per cent weight reduction for gutted fish gives a cost of 26.48 "kroner" per kg. Actual production cost for the 15 most efficient farms in 1987-1989 was 20 "kroner" per kg. live weight, according to investigations carried out by the Directorate of Fisheries. Adjusting for gutting and adding 3 "kroner" for freight and packing brings this up to 25 "kroner". Assuming a rising marginal cost curve from 25 "kroner", reaching 30 "kroner" at the 1991 supplies to the EC market (100,000 tonnes) appears reasonable and not likely to err on the low side. Maximizing the monopoly rent of Norway under this assumption gives the following result:

| Price elasticity of demand | Market price "kroner" | Norwegian supply 1000 tonnes |
|---|---|---|
| 1.5 | 60.65 | 81 |
| 2.0 | 51.43 | 88 |
| 2.5 | 46.50 | 96 |
| 3.0 | 43.59 | 104 |

According to these results, the world could be a lot happier place for Norwegian fish farmers if they were sole suppliers of farmed fish to the EC and took full advantage of this through monopolizing exports. The optimum market price and

1. Figure provided by "Kontali A/S" and based on production costs in 41 Norwegian fish farms which the EC inspected due to dumping accusations.

quantity are sensitive, however, to the price elasticity of demand. In particular it may be noted that with an elasticity of 3 the market price is not very much above the recent "cut-throat" [2] price of 37 "kroner" per kg., and the quantity supplied is identical to the actual supply in 1990 and 1991.

Given a high but not unreasonable price elasticity of demand (3 or more) it is thus not at all clear that the present prices and volumes are much different from what they would be under a perfect Norwegian monopoly in the supply of farmed salmon. What, then, are the implications of the presence of price-taking competitors in this market?

## 4. NORWAY AS A PRICE LEADER

If a large Norwegian market share for farmed salmon in the EC is at all sustainable, the long term marginal cost of Norwegian farms must be below that of her competitors, except perhaps for relatively low production volumes of the competitors. There is some evidence that this is the case. Recent investigations into the production costs of Scottish farms report a production cost per kg. live weight of 37.48 "kroner" for 1989 [3]. This translates into 41.23 "kroner" per kg. gutted fish, which is well above the figure reported for Norwegian farms (26.48, cf. above).

Below we shall report some results from maximizing the Norwegian salmon rent, for alternative values of the parameters of Equation (2) which all imply a cost advantage for Norway. These results and the assumptions are summarized in an Appendix.

Suppose, first, that the marginal cost curves of Norway and the competitors both start at 25 "kroner" per kg., which is close to the actual cost in the 15 most efficient Norwegian farms in 1987-89, as reported above. Assume that the marginal cost rises to 30 "kroner" for Norway at 100,000 tonnes and to 40 "kroner" at 60,000 tonnes for the competitors, both of which are close to the actual volumes supplied in 1991 and broadly consistent with the figures quoted above. Figure 1 shows the marginal cost curves. The results obtained show optimum Norwegian supplies ranging from 93,000 to 113,000 tonnes, competitors' supplies ranging from 59,000 to 51,000 tonnes, and price ranging from 39.87 to 37.45, when varying the price elasticity of demand from 1.5 to 3. Thus the optimum price is not much higher than the actual price in 1991 and is not very sensitive to the elasticity of demand. Even if the competitors are high cost producers they set an effective limit to how high the market price can be. The optimum Norwegian supply is more sensitive to the assumed price elasticity of demand, but nevertheless not very different from the actual Norwegian supply in 1991. Figures 2 and 3 show the optimum supply, price and the value of the Norwegian exports and salmon rent, for different assumptions of the price elasticity of demand.

The fact that the competitors supply less than they did in 1991, even if the market price is slightly higher, indicates that we may have set their marginal cost too high. Changing the parameter g in Equation (2) so that the marginal cost of the competitors is 35 "kroner" for a production of 60,000 tonnes produces the following results. The optimum supply ranges from 93.000 to 113.000 for Norway and 73.000 to 67.000 tonnes for the competitors, as the price elasticity of demand increases from 1.5 to 3. The optimum market price is also very similar to the price prevailing in 1991; it falls from 37.60 to 36.30 "kroner" as the price elasticity of demand increases from 1.5 to 3.

Lowering the marginal cost of the competitors further still, so that it becomes 30 "kroner" at a production volume of 60,000 tonnes, results in an optimum Norwegian supply in the range of 88,000 to 109,000 tonnes, with a supply from the competitors of 104,000 to 105,000 tonnes, and a price of 34.12 to 34.27 "kroner" per kg., for the said variations in the price elasticity of demand. This would reduce the Norwegian market share appreciably, or to about 50 per cent at a price elasticity of demand of 2.5.

The marginal cost curves so far assumed give Norway very little cost advantage for low volumes of production. What if the Norwegian farmers have a cost advantage at all levels of production? In this case Norwegian price leadership could have a quite dramatic effect on the competitors' supply. Figure 4 shows marginal cost curves with the same supply

2. This corresponds approximately to the average fob unit value of Norwegian exports of farmed salmon in 1990 and 1991, and covers various quality grades, sizes, etc.
3. This figure is reported by "Kontali A/S", and is based on "Costs and returns from farm salmon production in Scotland", published by the Agricultural and Rural Economics Department, The North of Scotland College of Agriculture.

elasticity for Norway and the competitors, where the competitors' curve is everywhere above the Norwegian curve. The parameters are adjusted so that the marginal cost is 30 "kroner" for Norway at a production volume of 100,000, and 35 "kroner" for the competitors at a production volume of 60,000 tonnes. Figure 5 shows the optimum supply, which ranges from 115,000 to 127,000 tonnes for Norway, and is practically constant at 66,000 tonnes for the competitors, as the price elasticity of demand increases from 1.5 to 3. This is a slightly greater supply than provided by Norway in 1991 (104,000 tonnes), and about the same for the competitors. However, if the marginal cost of the competitors is raised, the effect on their supply and market share is dramatic. Increasing the competitors' marginal cost to 43.45 "kroner" per kg. at a production level of 60,000 tonnes would virtually eliminate the competitors from the market. In this case it would be optimal for Norway to supply a quantity resulting in a price of about 39 "kroner" per kg., which would be below the competitors' marginal cost at all production levels.

## 5. CONCLUSION

The main conclusion to be drawn from this analysis is that the market price of salmon which would result from Norway taking advantage of its position as a price leader in the EC market for farmed salmon would not be much different from the price we have observed in the last couple of years, by some considered to be catastrophically low. The prices we have come up with under various, in our view reasonable, assumptions about the price elasticity of demand, the competitors' marginal cost of production and their supply elasticity, are all in the range 33 to 40 "kroner" per kg. The sensitive variables are the total quantity supplied and its division between Norway and its competitors. Only a slightly unrealistic assumption about the competitors' marginal cost of production (45 "kroner" at 60,000 tonnes) and their supply elasticity (the marginal cost is as high as 39 "kroner" even at virtually zero production) is sufficient to eliminate the competitors from the market, as a consequence of Norwegian price leadership. The most important variables for a presumptive Norwegian export cartel to know in order to exercise a successful price leadership thus is the production cost of its competitors and their elasticity of supply. These are also the variables on which information is least likely to be forthcoming.

## REFERENCES

**Salvanes K.G.** *et al* (1991). Naeringsstruktur i oppdrettsnaeringa (Structure of the Fish Farming Industry), Institute of Fisheries Economics, Norwegian School of Economics and Business Administration, Report No. 4, November 1991 (in Norwegian).

## APPENDIX

### Numerical results

| Price elasticity | Total | Supply Norwegian | Competitors | Price |
|---|---|---|---|---|
| $B_c = 25, B_n = 25, X_c(S_c = 60) = 35, X_n(S_n = 100) = 30$ | | | | |
| 1.5 | 166 | 93 | 73 | 37.59 |
| 2.0 | 170 | 100 | 70 | 37.00 |
| 2.5 | 175 | 107 | 68 | 36.57 |
| 3.0 | 180 | 113 | 67 | 36.30 |
| $B_c = 25, B_n = 25, X_c(S_c = 60) = 40, X_n(S_n = 100) = 30$ | | | | |
| 1.5 | 152 | 93 | 59 | 39.87 |
| 2.0 | 155 | 99 | 56 | 38.75 |
| 2.5 | 160 | 107 | 53 | 37.91 |
| 3.0 | 164 | 113 | 51 | 37.45 |
| $B_c = 25, B_n = 25, X_c(S_c = 60) = 30, X_n(S_n = 100) = 30$ | | | | |
| 1.5 | 192 | 88 | 88 | 34.12 |
| 2.0 | 200 | 96 | 96 | 34.11 |
| 2.5 | 207 | 103 | 103 | 34.20 |
| 3.0 | 214 | 109 | 109 | 34.27 |
| $B_c = 20, B_n = 25, X_c(S_c = 60) = 34.94, X_n(S_n = 100) = 23.94$ | | | | |
| 1.5 | 158 | 87 | 71 | 38.85 |
| 2.0 | 163 | 95 | 68 | 37.79 |
| 2.5 | 168 | 101 | 67 | 37.18 |
| 3.0 | 174 | 109 | 65 | 36.71 |
| $B_c = 25, B_n = 25, X_c(S_c = 60) = 35, X_n(S_n = 100) = 35.12$ | | | | |
| 1.5 | 155 | 74 | 81 | 39.35 |
| 2.0 | 156 | 78 | 78 | 38.62 |
| 2.5 | 156 | 80 | 76 | 38.29 |
| 3.0 | 157 | 82 | 74 | 37.99 |
| $B_c = 27, B_n = 25, X_c(S_c = 60) = 30, X_n(S_n = 100) = 30$ | | | | |
| 1.5 | 202 | 111 | 91 | 32.98 |
| 2.0 | 212 | 114 | 98 | 33.13 |
| 2.5 | 221 | 117 | 104 | 33.31 |
| 3.0 | 230 | 119 | 111 | 33.45 |
| $B_c = 31.5, B_n = 25, X_c(S_c = 60) = 35, X_n(S_n = 100) = 30$ | | | | |
| 1.5 | 181 | 115 | 66 | 35.49 |
| 2.0 | 185 | 119 | 66 | 35.47 |
| 2.5 | 189 | 123 | 66 | 35.46 |
| 3.0 | 193 | 127 | 66 | 35.47 |

$B_c = 39$, $B_n = 25$, $X_c(S_c = 60) = 43.45$, $X_n(S_n = 100) = 30$

| | | | | |
|---|---|---|---|---|
| 1.5 | 153 | 143 | 10 | 39.87 |
| 2.0 | 151 | 147 | 4 | 38.75 |
| 2.5 | 149 | 149 | 0 | 37.91 |
| 3.0 | 154 | 154 | 0 | 37.45 |

**FIGURE 1.**
**MARGINAL COST SCHEDULES MC(S = 100) = 30 (NORWAY) MC(S=60) = 40 (COMPETITORS)**

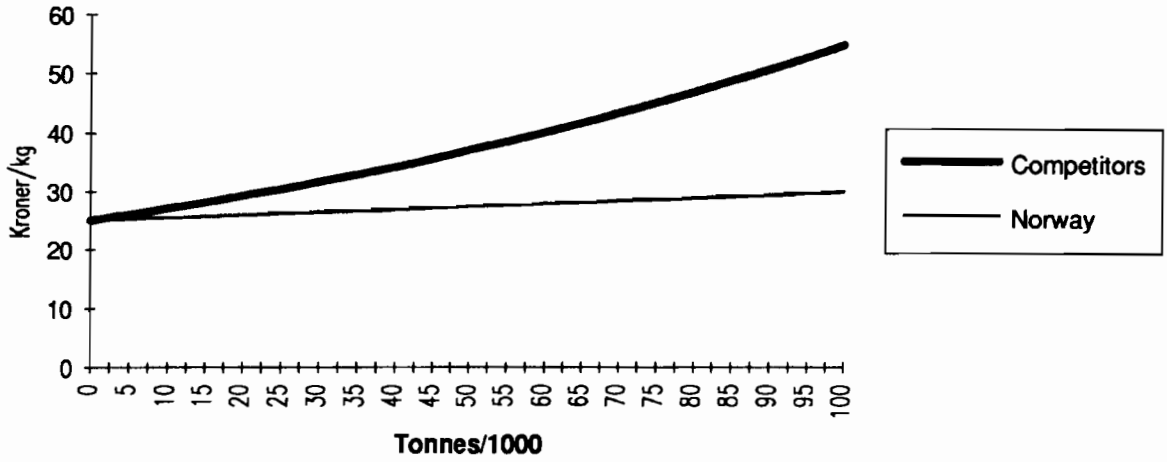



**FIGURE 2.**
**SUPPLY OF FARMED SALMON TO EC MC RISES FROM 25 TO 30 FOR S = 100 (NORWAY) AND TO 40 FOR S = 60 (COMPETITORS)**

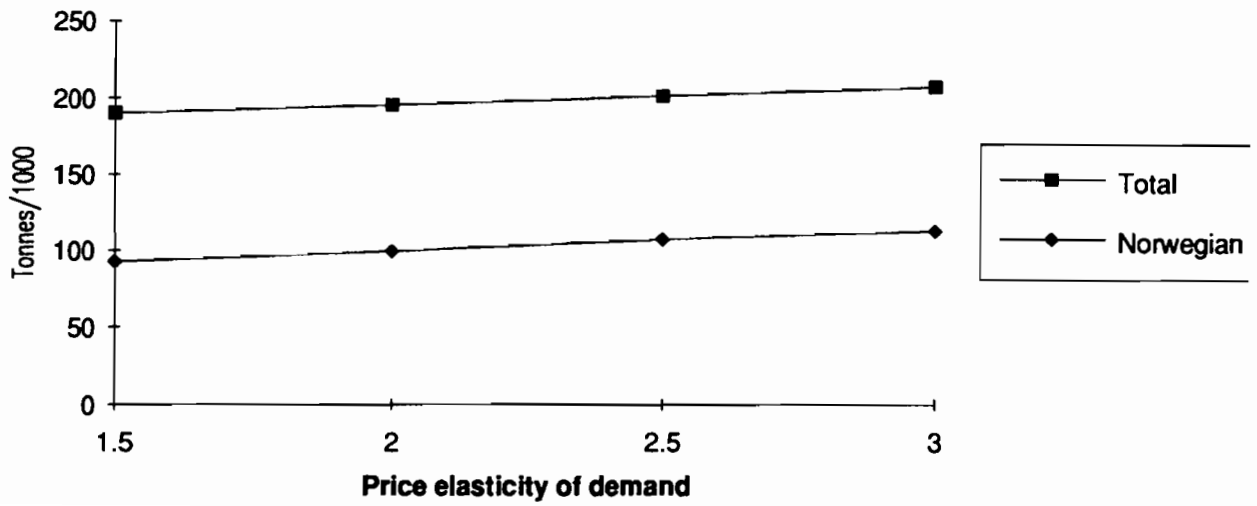


FIGURE 3.
PRICE (X 100), AND NORWEGIAN RENT AND VALUE (MILLION) OF SALMON EXPORT TO EC MC RISES FROM 25 TO 30 FOR S = 100 (NORWAY) AND TO 40 FOR S = 60 (COMPETITORS)

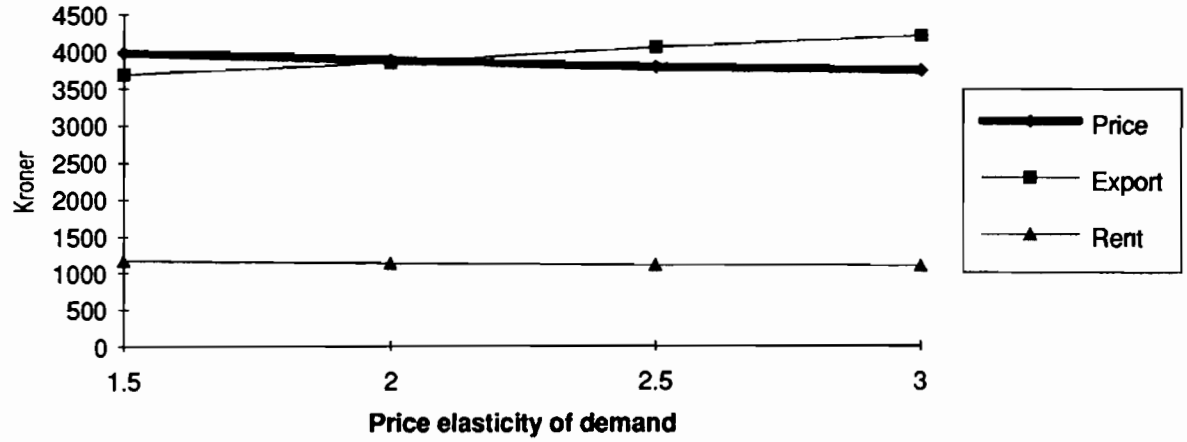



FIGURE 4
MARGINAL COST SCHEDULES MC RISES FROM 25 TO 30 FOR S = 100 (NORWAY) AND FROM 31.5 TO 35 FOR S = 60 (COMPETITORS)

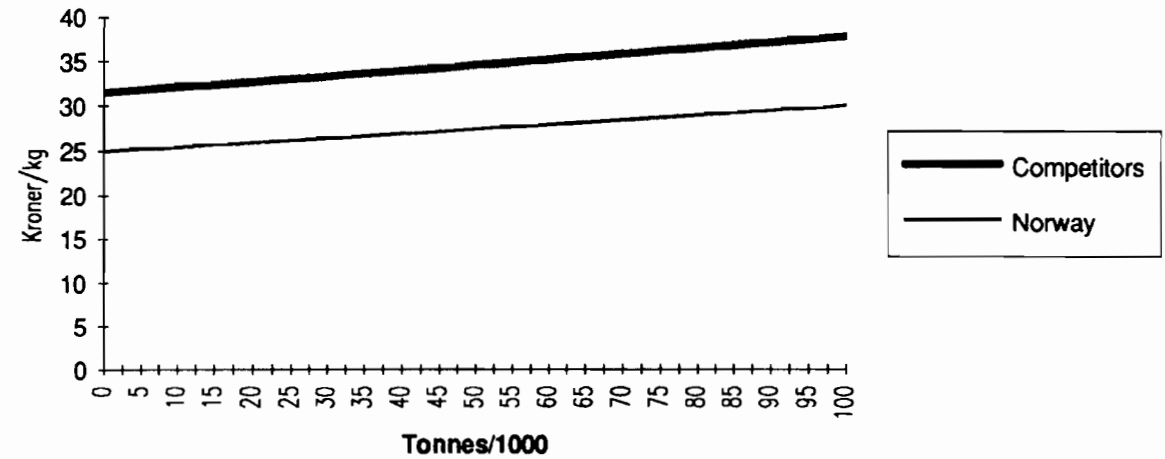


**FIGURE 5.**
**SUPPLY OF FARMED SALMON TO EC MC RISES FROM 25 TO 30 FOR S = 100 (NORWAY) AND FROM 31.5 TO 35 FOR S = 60 (COMPETITORS)**

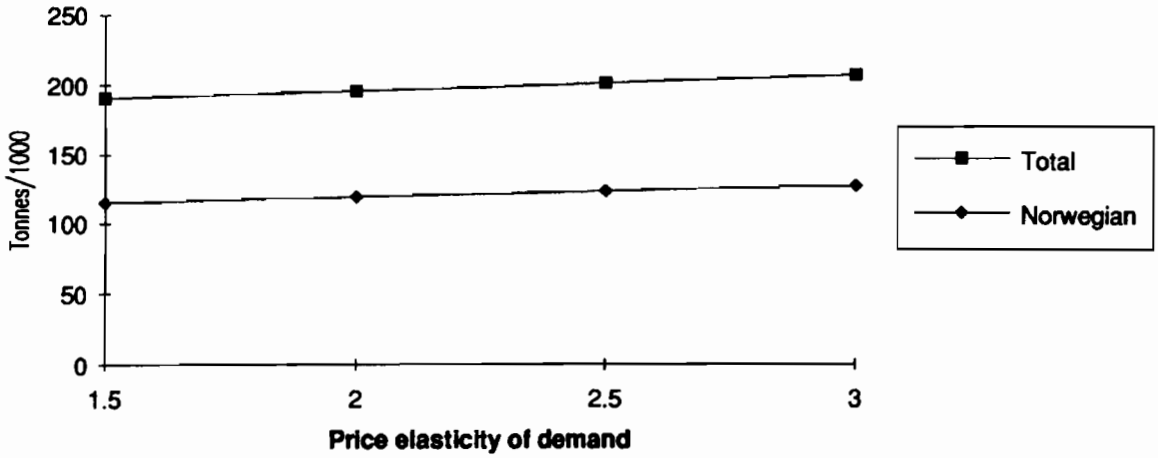
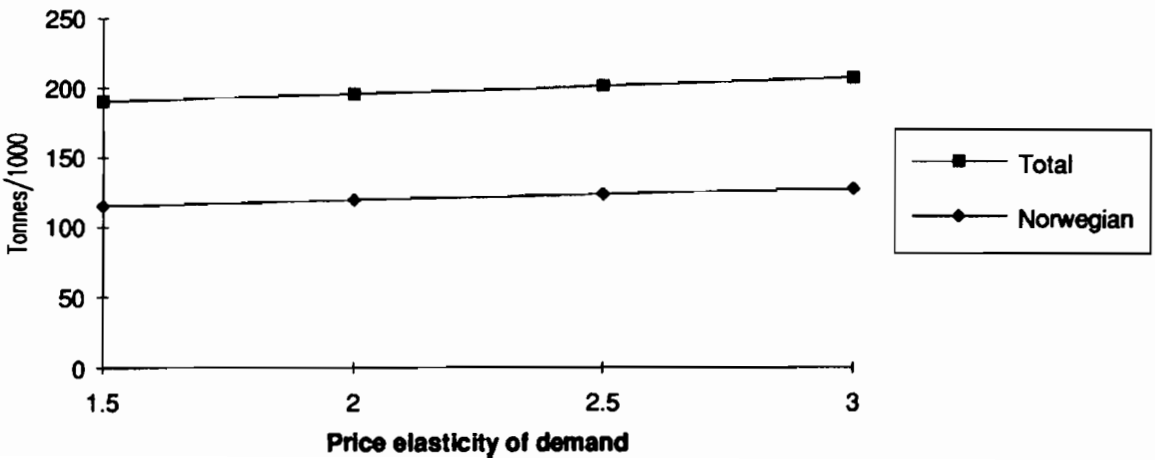



**FIGURE 6.**
**PRICE (X 100), AND NORWEGIAN RENT AND VALUE (MILLION) OF SALMON EXPORT TO EC MC RISES FROM 25 TO 30 FOR S = 100 (NORWAY) AND FROM 31.5 TO 35 FOR S = 60 (COMPETITORS)**



# Why 1991 Alaskan Salmon Prices Crashed

**Mark Herrmann[a] and Joshua A. Greenberg[b]**

[a]Department of Economics University of Alaska, Fairbanks, Alaska 99775

[b]School of Agriculture and Land Resource Management University of Alaska Fairbanks, Alaska 99775

ABSTRACT

*The 1991 Alaskan salmon season was a disaster. Fishermen's strikes and the dumping of salmon has brought a great deal of focus on what went wrong. This paper examines some possible factors that resulted in the lowest salmon prices in many years. The conclusion is that increased world supplies, coupled with tremendous Alaskan harvests, have brought pressures on Alaska that the salmon industry was ill prepared to handle.*

## 1. INTRODUCTION

The 1991 Alaskan salmon season was marked by tremendous turmoil. Two situations symbolized the stress that nearly everyone involved in the salmon industry felt. In Bristol Bay, the largest harvest area for sockeye salmon, the opening offer of $0.47 per pound was declined and a strike of 2,500 fishermen began. The end result was a settlement of $0.70 per pound, which was substantially lower than the 1990 price of $1.04, the 1989 price of $1.24, and the 1988 price of $2.25.

The situation was even worse for pink salmon. The price offered for humpies fell below the fishermen's breakeven point and millions of pounds of Prince William Sound pinks were harvested only to be dumped back into the ocean, given away to local citizens, or canned and given away in a much publicized airlift, funded by Exxon Oil, to the Soviet Union for humanitarian purposes. In addition, pink and chum salmon were given away in food lines and to local food charities. The price for pinks settled at $0.12 a pound, when processors were buying them at all, which meant that an average boat needed to catch a million pounds just to make boat payments (Fitzgerald, 1991). Frozen pink salmon retailed for as low as $0.99 per pound in the United States. (See figure 1 for all Alaskan exvessel prices).

* This publication has been prepared for **session 2** in the sixth annual meeting of ther IIFET in Paris, France July 1992. This publication is the result of research sponsored by Alaska Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, under grant no. NA90AA-D-SG066, project #M/81-01, and from the University of Alaska with funds appropriated by the state.

Since the 1991 season, there has been much speculation about what or who was to blame for the low prices. Suspicion has generally fallen into five areas (not necessarily in order of importance) : too much farmed salmon supply, unfair Japanese trading practices, poor quality of Alaskan fish, unfair U.S. wholesale pricing practices, and oversupply of wild stock.

A tremendous amount of effort has been devoted to solving the problem of low salmon prices. The governor of Alaska created a special Governor's Salmon Strategy Task Force to study the issue. The Alaska state legislature is reviewing the entire salmon enhancement program from a cost/benefit point of view. The Alaska Seafood Marketing Institute is spending more money on salmon advertising. Researchers are trying to find new markets for existing products and developing new products.

This paper will review some of these issues and offer the results of a model that attempts to explain the various factors that have been causing rapid salmon price decreases. The results discussed in this paper are tentative, as the core of the modelling research is presently under way.

## 2. IDENTIFICATION OF POSSIBLE CAUSES

Early blame for the depressed Alaskan salmon prices fell on the Japanese, and cases of Japanese bashing in Alaska were, unfortunately, all too common. Although this theory has since lost favor among most industry participants, the head of Alaska's antitrust office has recently claimed that there is evidence of Japanese market manipulation.

The quality of Alaskan salmon remains a concern. Not only is Alaskan salmon reputed to be of variable quality, but it is well documented that wild salmon is reputed to be of lesser quality than farmed salmon. In 1991, there were additional problems with the pink salmon harvest. First, there was a late run and the fish were turning sooner than expected. The Alaska Department of Fish and Game did not open pink salmon fishing in the straits where the fish are of excellent quality because of the danger of overharvesting the wild stock, which had not yet returned in sufficiently high numbers. In the hatchery bays, Prince William Sound Aquaculture Cooperative, a non-profit hatchery association, is allowed the first harvest of pink salmon, the sales of which support the hatchery. By the time Alaskan fishermen were able to harvest pinks, the overall quality of the fish was poor. In addition, the average weight of the run was a scant 2.7 pounds per fish.

It seems clear that, while there may be many factors contributing to the depressed salmon prices, the basic problem is that Alaska is, for the first time, facing a highly competitive industry. Problems such as those mentioned above are of less concern when one is the dominant supplier. Since 1980, the world supply of salmon has increased from 1.2 billion pounds to 2.3 billion pounds (Knapp), and Alaska's production share during this time period has declined from 44 to 31 percent (see figure 2). In addition, the U.S. share of Japanese salmon imports has slipped from 85 to 66 percent in the last four years.

## 3. THE MODEL

A 36-equation econometric model of the international supply and demand of salmon was constructed at Washington State University in 1989. The model was originally built to study the profitability of farmed Atlantic salmon in the Puget Sound of Washington State. But since it simultaneously models the supply and demand for farmed Atlantic salmon and wild Pacific salmon, the opportunity presented itself to use the model to examine why Alaskan salmon prices have been declining.

The model accounted for the flows of fresh and frozen salmon, shown in figure 3. Because of space considerations, the entire model will not be presented here (see Herrmann 1990 for the complete model). However, the variables that were estimated are listed below.

1. *Norwegian allocation of farm-raised Atlantic salmon*

   - Quantity allocated to the EEC

2. *EEC demand for salmon*

- Quantity demanded of Scottish and Norwegian farmed Atlantic salmon
- Quantity demanded of North American high valued Pacific salmon
- Quantity demanded of North American low-valued Pacific salmon

3. *Japanese demand for salmon*

- Quantity demanded of Norwegian farmed Atlantic salmon
- Quantity demanded of North American high-valued Pacific salmon
- Quantity demanded of North American low-valued Pacific salmon

4. *North American allocation of high-valued salmon*

- Quantity allocated to Japan
- Quantity allocated to the EEC

5. *North American allocation of low-valued salmon*

- Quantity allocated to Japan
- Quantity allocated to the EEC

6. *North American demand*

- Quantity demanded of Norwegian farmed Atlantic salmon

7. *North American inventory holdings*

- Quantity of high-valued salmon inventory
- Quantity of low-valued salmon inventory

8. *North American exvessel prices*

- Price of high-valued salmon
- Price of low-valued salmon

In the above model, North American high-valued Pacific salmon consists of sockeye, chinook, and coho, while the low-valued Pacific salmon consists of chum and pink salmon. These aggregations were made, on the basis of the value received by fishermen. In 1990, the average exvessel prices received in the United States for the high-valued Pacific species ranged from $1.04 to $1.83 per pound, while the average prices received for the low-valued species ranged from $0.31 to $0.49 per pound.

The model was built primarily for forecasting purposes and was constructed using quarterly data from 1982 to 1988. Thus, a forecast of future quantity levels and prices for this model starts in 1989. Since actual data is now available for 1989 and 1990, we can see how well the model predicted the 1990 salmon season. Prices for U.S. Pacific salmon in 1990 declined from the 1988 prices by 29 to 57 percent of their 1988 price, depending on species. The model predicted the decrease in price fairly well but still predicted 1990 prices too high by 15 to 25 percent. This indicates that there were structural changes in the late 1980s that the model was unable to pick up.

Even though the model overestimated 1990 prices, it is still possible to examine why prices decreased from 1988. The year 1990 was chosen because a complete data set for the actual values of the exogenous variables was not complete for 1991 ; however, inferences from the findings for 1990 can be made for 1991.

These figures were estimated by using the conditions that existed at the end of 1988 then systematically allowing the variables to take on their true 1990 levels and noting the effect on prices.

## 4. RESULTS

Figures 4 and 5 show the relative weight of some of the factors affecting the depression of 1990 prices from 1988 levels. The increased level of high-valued landings in 1990 over the 1988 level is estimated to have caused 76 percent of the decline in the high-valued exvessel price. Other market factors included an increase in farmed salmon supplies (10 percent factor), a strengthening of the U.S. dollar against the Japanese yen (8 percent), increased Japanese landings and inventory of salmon (4 percent), and increased landings of low-valued Pacific salmon (2 percent).

The exvessel price decline for low-valued Pacific salmon was estimated to have been a result of increased low-valued salmon production (68 percent), increased high-valued landings (13 percent), increased Japanese landings and inventory (13 percent), a strengthening of the U.S. dollar against the Japanese yen (8 percent), and increased farm supplies (1 percent).

It is important to note that increased farmed salmon supplies probably have had a much larger overall effect than indicated because the analysis started from the existing 1988 conditions, which already included a large amount of world farmed supplies. It is likely that if there had never been salmon farming, Alaskan salmon prices might well be higher today, despite the increased consumer demand for salmon in general that resulted from the availability of fresh salmon year-around. Also, the ability of the marketplace to absorb the increased Pacific landings of the last three years has probably decreased due to the overall high supplies of farmed salmon (this is reflected by the sensitivity of exvessel price to landings).

Although these simulations were for 1990, inferences can be made for 1991. For instance, total 1990 Alaskan salmon production was 31 percent higher than in 1988, and 1991 Alaskan production was even higher than 1990. World farmed salmon supplies in 1990 were 21 percent higher than in 1988, with 1991 levels close to the 1990 levels. These factors alone, with the accumulating inventory, were a major reason that Alaskan salmon prices continued to decline into 1991.

## 5. ALASKA ADJUSTS

It is obvious to all concerned with the Alaskan salmon industry that there is a lot of salmon on the market, which has increased competition and has made prices more sensitive to market conditions. However, some good has come from the 1991 disaster. For the first time in Alaska, there is more discussion about the marketing of salmon than about its production. Quality of salmon has become an increased concern both for the timing of harvests and for processing techniques. The Alaska Seafood Marketing Institute has received a modest increase in its advertising budget and is heightening the domestic marketing of salmon. Lower prices have also attracted some new domestic consumers.

Product development is also proceeding at a rapid pace, with pink salmon nuggets, microwaveable pink salmon fillets, and pink salmon surimi topping the list. Researchers in Alaska are developing a salmon market newsletter and an information base that will include data from the former Soviet Union.

Finally, the Alaska legislature has funded a complete review of the state's enhancement program. A cost/benefit analysis, which will incorporate a 96-equation demand model, a cost model, and a biological model, is being constructed to determine the future level of output and the mix of hatchery salmon that Alaska will produce.

## 6. FUTURE WORK IN THIS AREA

With the salmon industry changing so rapidly, structural changes are likely to take place. The model constructed at Washington State University is being expanded for the Alaska enhancement program review to include 1991 data, canned salmon, and exvessel price equations by regions and gear type. In addition, other experts' recent work, such as Cathy Wessel's work on Japanese inventories (1990), will be incorporated into the modelling effort.

## REFERENCES

**Fitzgerald R.** (1991). "Alaska's Problem : 'Too Many' Pinks." *Seafood Leader*, Vol. 11, No. 6, Nov/Dec.

**Knapp G.** (1992), Personal Communication 1992.

**Herrmann M.** (1990). "An Economic Analysis of World Salmon Markets : Effects of Salmon Farming". Ph.D. dissertation. Washington State University, August.

**Wessels C.** (1990). "Inventory Dissipation in the Japanese Whoilesale Market". Staff Series Paper. University of Rhode Island, December.

FIGURE 1.
ALASKAN EXVESSEL PRICES (1980-1991). (ADAPTED FROM : SOURCE : KNAPP (1992) NOTE : 1991 FIGURES ARE PRELIMINARY.)

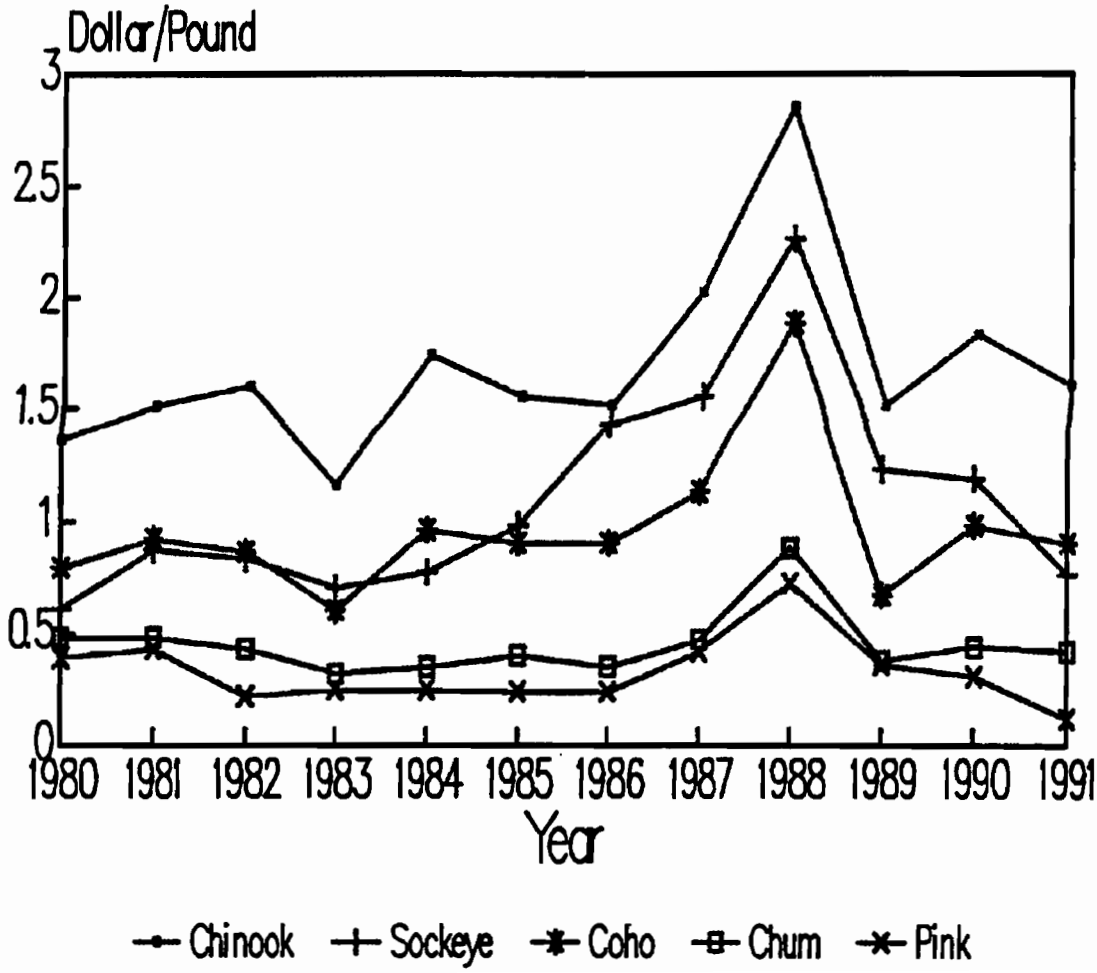


**FIGURE 2.**
**SALMON PRODUCTION BY SPECIES, 1980 TO 1991.**

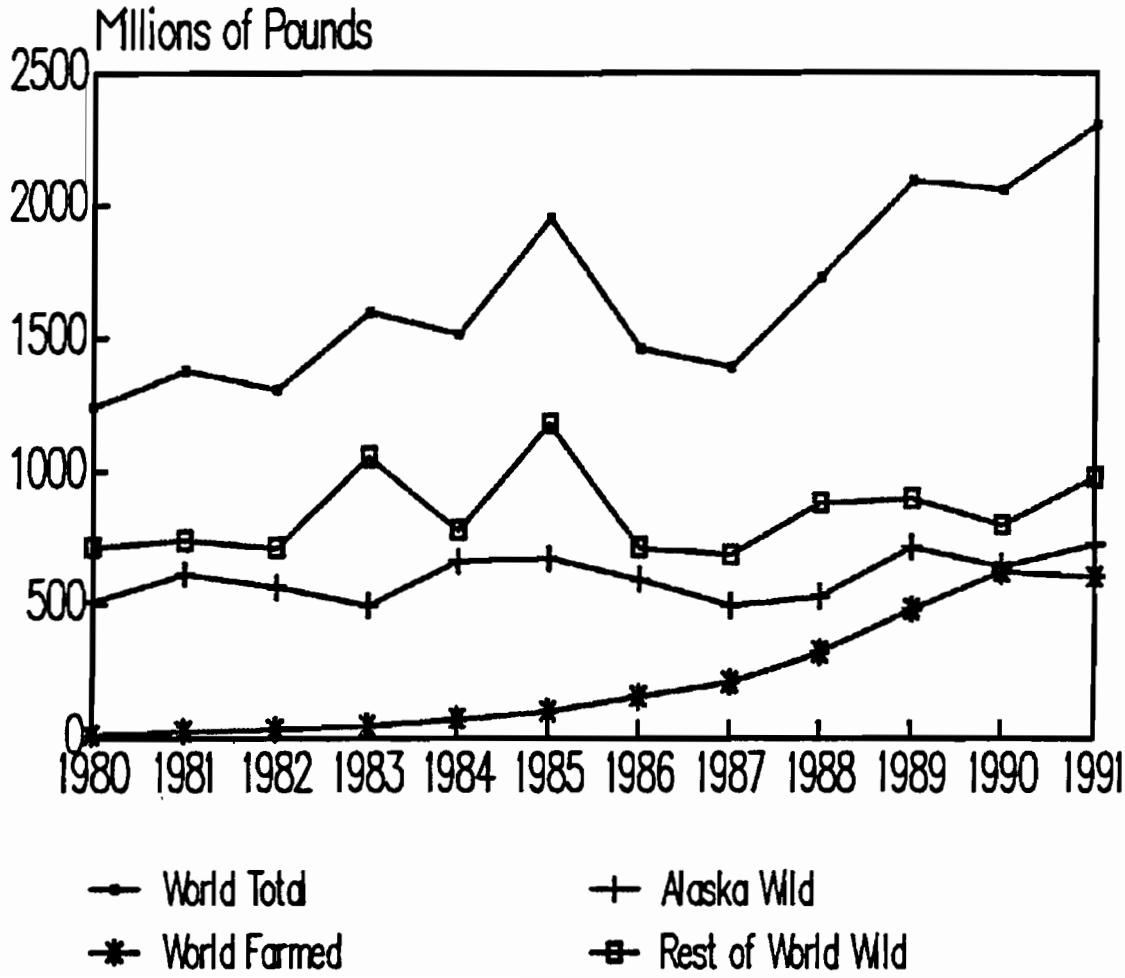


FIGURE 3.
INTERNATIONAL SALMON TRADE FLOWCHART.

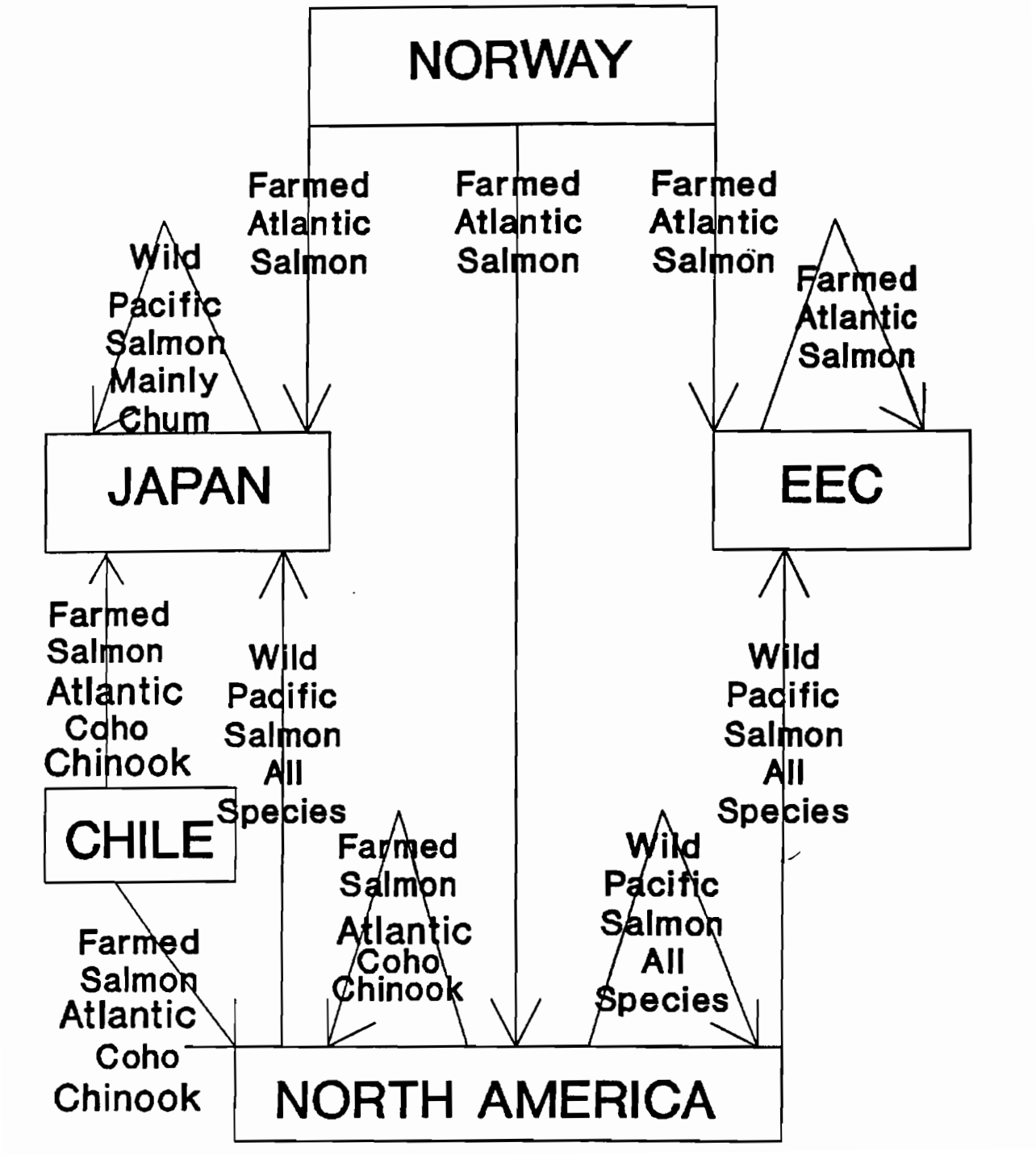


**FIGURE 4.**
**ESTIMATED INDIVIDUAL MARKET FACTORS AFFECTING THE DECREASE OF U.S. HIGH-VALUED PACIFIC SALMON PRICE FROM 1988 TO 1990.**

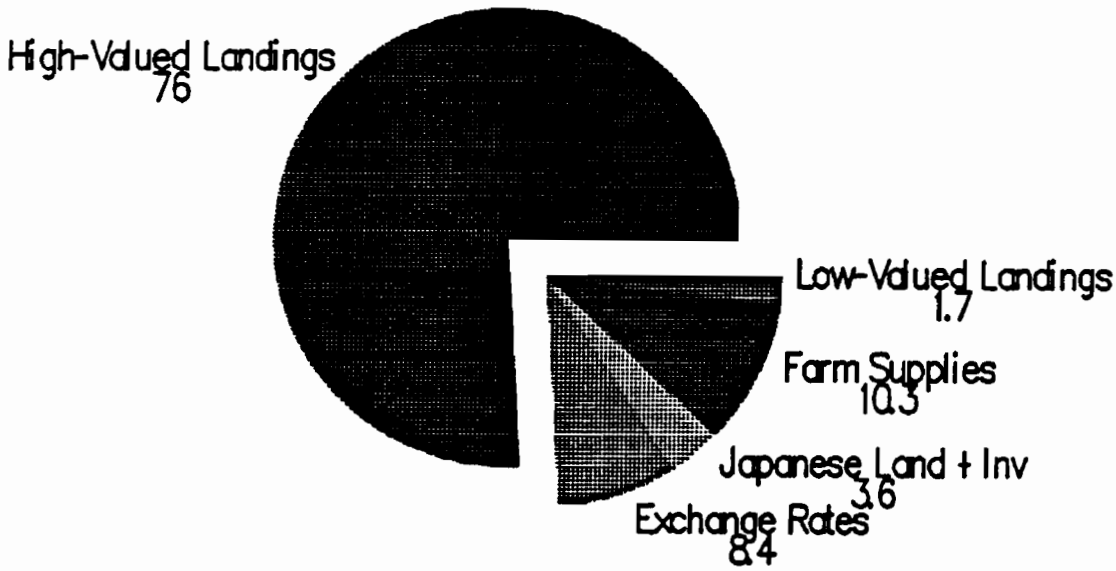
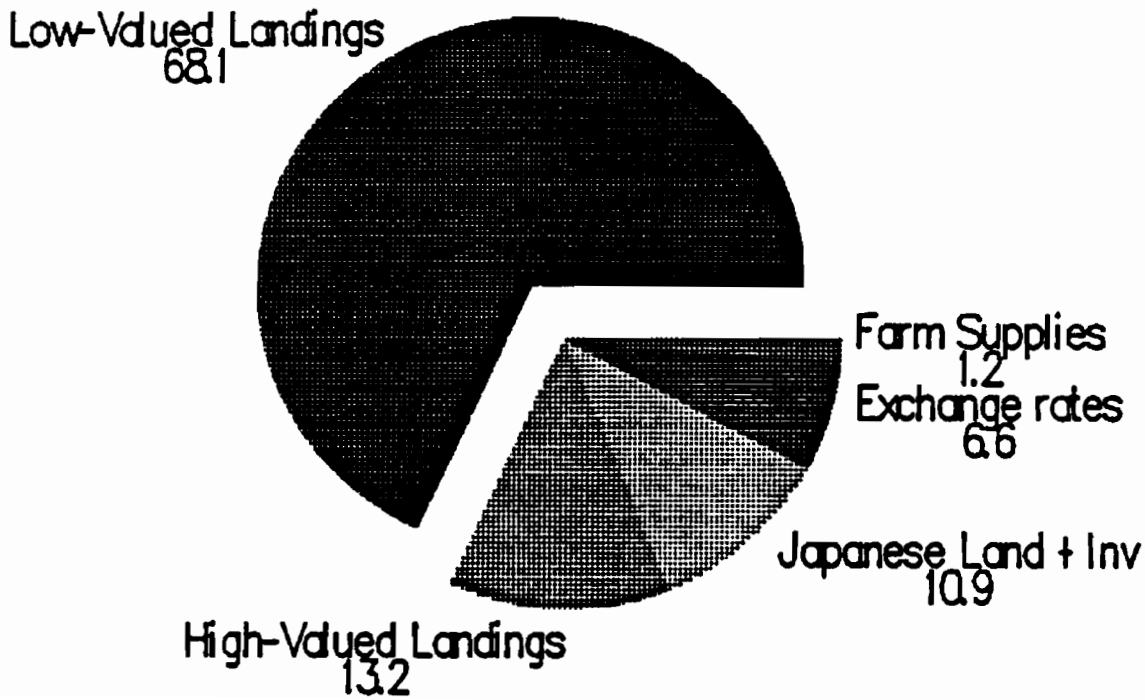



**FIGURE 5.**
**ESTIMATED INDIVIDUAL MARKET FACTORS AFFECTING THE DECREASE OF U.S. LOW-VALUED PACIFIC SALMON PRICE FROM 1988 TO 1990.**



# Fisheries Modelling by J.M. Gates

Les communications de cette session abordent à l'évidence un questionnement commun. Une partie des papiers concerne l'application des méthodes de programmation multi-objectifs (MOP). Dans ce groupe on retrouve ceux de Enriquez, Sylvia, Padilla et Copes, Seijo, Defeo et Alava. Un autre groupe d'auteurs s'intéresse davantage à l'économie des unités de pêche, avec par exemple une approche micro-économique des unités de production. Parmi eux on placera Arnarson et Jensson, Sampson, Anwar *et al.*

Enfin, un ensemble de textes reprennent le moule des modèles bioéconomiques classiques des pêcheries. On trouve les textes de Eide et Flaaten, Seijo et Defeo, Pascoe, Battaglene et Campbell, Danielsson, Rodgers, Sparre et Willman ainsi que Verdelhan. Alors que les textes relatifs aux méthodes MOP mettent en œuvre également des modélisations bioéconomiques, celles-ci utilisent une méthodologie harmonisante relativement nouvelle, ce qui justifie leur regroupement dans un ensemble séparé.

Le choix de ces regroupements est purement subjectif et des différences significatives demeurent au sein même de chacun des groupes. Néanmoins ces regroupements restent cohérents au moins pour notre propos introductif. Globalement l'ensemble des papiers de cette session illustrent l'utilité d'avoir des approches variées en matière de modélisation.

*Programmation multi-objectif (MOP)*

Le papier de Sylvia est consacré au rôle de ces approches MOP pour application à la pêche et à l'aquaculture. Le papier introduit une synthèse très utile de la théorie sur ces approches, la question des pêches ou de l'aquaculture restant plus suggérée qu'évidente. Le développement sur la dynamique de la « politique de frontières » est d'un

The papers in the fisheries modelling session have a discernible "clustering" of interests. One cluster is the application of multiple objective programming (MOP) methods. In this cluster are the papers by Enriquez, Sylvia, Padilla and Copes, and Seijo, Defeo and Alava.

Another cluster of papers examine in some detail "vessel economics", i.e. the microeconomic details of the technical production unit in fisheries harvest. In this group are the papers by Arnarson and Jensson, Sampson, and Anwar *et al.*

Last but not least is a cluster of papers which fit the traditional mold of bioeconomic models of fisheries. The papers in it are by Eide and Flaaten, Seijo and Defeo, Pascoe, Battaglene and Campbell, Danielsson, Rodgers, Sparre and Willman and Verdelhan. While the MOP papers involve bioeconomic modelling too, they have a relatively new, unifying methodology which justifies including them together as a separate group.

The choice of these clusters is purely subjective and there are significant differences between papers in each cluster. However, these clusters are convenient at least for discussion purposes. Collectively, the papers in session 3 demonstrate the utility of various approaches in modelling fisheries.

*Multiple Objective Programming (MOP)*

Sylvia's paper on MOPs is devoted to the role of MOP approaches in fisheries and mariculture. The paper is primarily a useful review of the theoretical literature on MOPs; the fisheries and mariculture content of the paper is more implied than evident. Of particular interest is the development of "dynamic policy frontiers". Because it is more theoretical than the joint paper with Enriquez, the two papers are complementary; I would recommend reading the Sylvia paper before reading the other MOP papers.

intérêt évident. Du fait de ces aspects théoriques privilégiés davantage dans ce papier que dans celui présenté avec Enriquez, il est préférable de consulter celui-ci avant tout autre sur la question des MOP.

Enriquez et Sylvia développent un modèle dynamique pour la pêcherie américaine de merlan du Pacifique. Les objectifs multiples, la valeur actualisée des revenus nets dans la transformation (PVNR), le volume de produits traités (YIELD) et la viabilité de la ressource renseignée par (la borne inférieure de) la biomasse des femelles matures (LSB). Ces trois thèmes reflètent les priorités exprimées par les aménageurs. Les instruments de régulation contiennent les quotas annuels, les allocations entre les différents groupes d'utilisateurs (spécialement les flottilles côtières et flottilles hauturières) et le nombre d'unités techniques (en transformation et capture) autorisées à entrer.

La fonction d'objectif actuelle est une combinaison convexe de PVNR et YIELD ; Le troisième objectif est rajouté en contrainte comme par exemple la valeur de la borne inférieure de la biomasse des femelles matures. Selon un processus stochastique, des solutions répétées sont générées pour les valeurs du recrutement et pour LSB et le poids convexe permet aux auteurs de tracer « frontière de politique » ou ensemble de points pour lesquels l'objectif fonctionnel est maximal, étant donnée la valeur des paramètres Les points extérieurs à cette frontière correspondent à des options politiques inefficientes en ce sens que des objectifs supplémentaires sont possibles sans diminution du premier.

Padilla et Copes développent et appliquent une méthode de programmation multi-objectifs à des pêcheries de petits pélagiques. Les objectifs considérés pour les différents engins, les différentes espèces capturées, incluent un maximum de profits du secteur productif, un maximum d'emplois, une optimisation des captures, et un accès équivalent pour les différents groupes de pêcheurs concurrents. Parmi ces objectifs, seulement ceux relatifs aux profits du secteur productif et à l'optimisation des captures sont pris en compte dans la fonction d'objectif ; les autres sont ajoutés en tant que contraintes pour des raisons de commodité. Padilla et Copes utilisent le modèle pour explorer la politique d'échange au travers de plusieurs des remèdes standards de l'aménagement des pêches incluant des mesures « non économiques » et des mesures économiques. La question du travail redondant, semble spécialement introduire des problèmes dans ce champ d'étude et les auteurs discutent rapidement la possibilité du travail plus intensif du fait des technologies et pratiques de capture. L'observation de leur figure 2 suggère que les frontières d'efficience entre profit et emploi sont pratiquement

Enriquez and Sylvia develop a dynamic MOP model for the Pacific whiting fishery of the United States of America. The multiple objectives are present value of net revenues in processing, processing product volume and resource viability as indicated by the (lower bound on) female spawning biomass. These three items reflect the expressed concerns of policy makers. Policy instruments include annual quotas, allocation between user groups (specifically, "inshore" versus "offshore" fleets) and the number of technical units (in processing and harvesting) allowed to enter.

The actual objective function is a convex combination of PVNR and YIELD; the third objective is added to the constraint set as a lower bound on spawning biomass. Repeated solutions of the model with stochastically generated recruitment and alternative values for LSB and the convex weights permit the authors to trace out the "policy frontiers" or locus of points for which the objective functional is maximal, given the assigned parameters. Points off this frontier are policy inefficient in the sense that more of one objective is possible without diminution of the other.

Padilla and Copes develop and apply a MOP to the small pelagics fishery. The objectives considered for this multiple gear, multiple species fishery, include maximum harvest sector profits, maximum fishing employment, catch optimization, and equal access for competing groups of fishers. Of these objectives, only the harvest sector profits and catch optimization are included in the objective function; the others are adjoined to the constraint set on the pragmatic grounds of convenience. Padilla and Copes use the model to explore the policy tradeoffs for several of the standard nostrums of fisheries management including "non economic" and economic management measures. The issue of redundant labor appears especially troublesome in the study area and the authors discuss briefly the possibility of more labor intensive harvesting technologies/practices. Examination of their Figure 2 suggests that the efficiency frontiers between profits and employment are almost parallel. If this perception is true, then an isocline for differing levels of fishing mortality would be an straight line with positive slope expressing the marginal rate of substitution between profits and employment.

Seijo, Defeo and Alava are concerned with a coastal bivalve fishery in Uruguay. This alone makes the paper noteworthy because the sedentary nature of the organism alters the usual fisheries model specification. A second paper by Seijo and Defeo develops the biology of the fishery in more detail. The objectives were biomass of species, cumulative catch and economic rent in each locality. The optimization procedures use a minimax

parallèles. Si cela est vérifié, alors une isocline pour différents niveaux de mortalité par pêche pourrait correspondre à une pente positive traduisant le taux marginal de substitution entre profit et emploi.

Seijo, Defeo et Alava étudient eux le cas des pêcheries de bivalves en Uruguay. La nature sédentaire de ces espèces, qui oblige à modifier des spécifications usuelles des modèles en pêche, rend le papier remarquable. Un autre texte de Seijo et Defeo développe en détail les aspects biologiques des pêches. Les objectifs sont la biomasse des espèces, les captures cumulés et la rente économique dans chaque localité. Les procédures d'optimisation utilisent les méthodes minimax pour les écarts par rapport aux objectifs et une procédure Box d'optimisation non linéaire. Ils concluent que ces approches permettent un calcul efficient des échanges entre objectifs.

*Comportement économique des unités de pêche*

Arnarson et Jensson s'intéressent davantage aux complexités liées à la gestion de flottilles modernes. Bien qu'il soit commode d'agréger de tels détails dans un modèle bioéconomique, l'approche qu'ils suivent est infiniment plus pratique pour les gestionnaires des flottilles et potentiellement plus simple également pour les scientifiques des sciences sociales cherchant à comprendre le comportement humain. Leur modèle est un simulateur faisant apparaître différents modules utilisant le langage PASCAL. La construction en module facilite les modifications pour s'adapter aux différentes pêcheries. Trois aspects particuliers sont à noter, un générateur de captures aléatoires, un concept de « valeur marginale du temps » et un module de production mixte. Le générateur de capture aléatoire est log-normal mais convient pour les autocorrélations observées sur les captures et les redistributions des flottilles en réponse à des chutes de production. La valeur marginale du temps est définie comme étant le coût d'opportunité attendu du temps « acheté » en référence au futur. Ce concept est utile pour les décisions impliquant les différentes périodes de temps - par exemple les trajets de différentes durées selon les alternatives de zone. Avec le simulateur, on trouve une routine de programmation linéaire pour optimiser les décisions de choix des combinaisons de productions mixtes pour des espèces actuellement embarquées. Leur modèle est capable d'éclairer sur les conséquences des changements de quotas sur les productions mixtes. A la réflexion ce modèle n'est pas surprenant si ce n'est qu'il aborde quelques points sur lesquels les modèles conventionnels restent muets.

Le papier de Sampson est à cheval entre ce thème et la modélisation bioéconomique. Il prend en compte un criterion on deviations from goals and a non linear optimization procedure by Box. They conclude that the approach permitted efficient calculation of tradeoffs between objectives.

*Vessel Economics Papers*

Arnarson and Jensson are concerned with and delve deeply into the complexities of managing a modern fishing fleet. Although it is convenient to subsume such detail in a bioeconomic model, the approach they follow is infinitely more useful to fleet managers and potentially a useful one for social scientists seeking to understand human behavior. Their model is a simulator written in modules using the PASCAL language. The modular construction facilitates modifications to fit different fisheries. Three features of interest are a random catch generator, a "marginal value of time" concept and a product mix module. The random catch generator is lognormal but allows for the observed autocorrelation of catches and the fleet relocation response to low catches. The marginal value of time is said to be the expected opportunity cost of time "bought" from the future. This concept is useful in decisions involving different time durations - for example trips of differing duration to alternative grounds. Within the simulator is a linear programming routine to optimize product mix decisions given the species mix currently being brought on board. Their model is able, for example, to give insight into the consequences of changes in quota level on product mixes. On reflection, this product mix effect is not surprising but it is something about which conventional models of fishing are silent.

The Sampson paper actually has a foot in both this and in the bioeconomic modelling clusters. It does invoke a simple population dynamics model but the invocation is unusual; it is used to infer the technology selection response of fishers and how these selections will be influenced by the characteristics of the resource as expressed in the population dynamics relationship. It is a good companion to more descriptive approaches of gear technology and has the merit of "linking" three of isolated worlds of technology, economics and biology.

The Anwar *et al.* paper is a detailed discussion of one component (gross revenue or "stock") of a "vessel simulator" being developed for the otter trawl fisheries of Northeastern United States. Since gross stock is the single most important determinant of economic performance, it deserves particular attention. The paper estimates a regression curve whose arguments include vessel characteristics, intensity of use and qualitative variables for port and month. The functional form is

simple modèle de dynamique de population mais avec une vocation inhabituelle ; il est utilisé pour déduire une réponse des pêcheurs en terme de choix de technologie en observant comment la décision va être influencée par les caractéristiques de la ressource exprimées au travers des interactions avec la dynamique des populations. C'est un bon outil pour des approches plus descriptives des technologies de pêche et il a le mérite de relier trois domaines souvent séparés, la technologie, l'économie et la biologie.

Le travail de Anwar *et al.* porte sur une discussion détaillée d'une composante (revenu brut ou « stock ») d'un simulateur de comportement d'unité de pêche appliqué aux pêcheries chalutières de loutres de mer du nord-est des Etats-Unis. Puisque le stock brut est le plus simple des déterminants majeurs de la performance économique, il mérite une attention particulière. Le papier produit une estimation par régression sur les caractéristiques du bateau, l'intensité d'utilisation ainsi que sur des variables qualitatives par port et par mois. La forme fonctionnelle est d'élasticité variable étant de forme linéaire quadratique diagonale en log. L'élasticité en tenant compte du nombre de jours de mer par mois est proche de l'unité mais décroissante. Consécutivement une analyse des résidus est employé pour créer des variables qualitatives mesurant « l'aptitude ». Ces variables se sont révélées robustes sur toute la période avec une tendance à une distribution stable des aptitudes. Ces différences ont des implications sur l'acceptabilité politique des choix de mesures de gestion, comme par exemple les quotas individuels transférables (QIT) et plus encore pour la crédibilité des estimations des unités techniques individuelles.

*Modèles bio-économiques*

Eide et Flaaten s'intéressent au cas de la pêcherie multispécifique de la mer de Barents qui reste l'une des principales pêcheries du monde. Leur modèle (ECONMULT) contient un module économique qui est un modèle de capture multiflottilles et un modèle biologique multiespèces. Leur papier porte essentiellement sur le module économique ; il s'agit d'un modèle d'optimisation par simulation, qui apparemment peut fonctionner sur une variété de structures. Un simple modèle cabillaud-capelan est la base des résultats numériques qu'ils rapportent ici. Le couple cabillaud-capelan représente une importante ressource conjointe partagée par la Norvège et la Russie. De façon intéressante, les meilleurs résultats, bien que seulement préliminaires, indiquent une solution interne dans laquelle les deux espèces sont capturées. Les auteurs attribuent exclusive

variable elasticity due to being a diagonal linear-quadratic form in logs. The elasticity with respect to days at sea in a given month is near unity but declining. A subsequent analysis of residuals is used to create qualitative variables measuring "skill". These variables were found to persist over time but with some tendency toward a stable distribution of skills. These differences have implications for the political acceptability of management measures, such as ITQs and most certainly for the credibility of forecasts for individual technical units.

*Bioeconomic Model Papers*

Eide and Flaaten are concerned with the Barents sea multiple species fishery which is one of the major fisheries of the world. Their model (ECONMULT) includes an economic component which is a multifleet harvest industry model and biological multiple species model. Their paper focuses on the economic component; it is a simulation and optimization model which apparently can be run in a variety of structures. A simple cod-capelin model is the basis of the numerical results they report. The cod-capelin complex is an important transboundary resource shared by Norway and Russia. Interestingly, the best results, admittedly preliminary, indicate an interior solution in which some of both species is harvested. The authors attribute this to 100% post spawning mortality of capelin and overgrazing of capelin if cod stocks are unharvested. It is clear from the paper that ECONMULT rests on a broad multidisciplinary research base which may be difficult to match in other areas.

The Seijo and Defeo paper describes the authors modelling work on the yellow clam fishery of Uraguay. This paper gives much more detail on the resource characteristics including the importance of spatial distribution of the resource for fisher behavior. The allocation of effort between areas is generated via a feedback between recruitment processes and an assumed rationality of fishers.

Pascoe, Battaglene and Campbell report their research on a multiple species shark fishery in southern Australia. Their particular focus is on uncertainty which has been a strong suit of agricultural economists from Australia for three decades. In a technical sense some of the approaches to decisionmaking under uncertainty are examples of MOPs. However models of economic decisionmaking under uncertainty (especially the static case) antedated MOPs. The context of their research is a divergence among biological scientists on the endogeneity of recruitment. The authors apply a minimax and a maximin criterion. The minimax criterion minimizes the

ment cela à la mortalité postnatale des capelans et à la suralimentation des capelans lorsque les stocks de cabillaud sont sous exploités. Il ressort clairement du papier que ECONMULT repose sur une base largement multidisciplinaire qu'il pourrait s'avérer difficile de reproduire à d'autres zones de pêche.

Seijo et Defeo présentent leur travail de modélisation appliqué aux pêcheries de palourde en Uruguay. Ce papier insiste sur les caractéristiques de la ressource intégrant l'importance des distributions spatiales face aux comportements des pêcheurs. L'allocation de l'effort par zone est généré par un feed-back entre processus de recrutement et une hypothèse de rationalité des pêcheurs.

Pascoe, Battaglene et Campbell rendent compte de leur recherche à propos des pêcheries de requin dans le sud de l'Australie. Leur attention se porte essentiellement sur l'incertitude qui a été pendant près de trois décennies l'objet d'interrogation des économistes ruraux en Australie. D'un point de vue technique certaines approches relatives aux processus de prise de décision sous incertitude sont des exemples de programmation multi-objectifs (MOP). Toutefois les modèles économiques de prise de décision sous incertitude (et particulièrement les cas statiques) sont antérieurs aux MOP. Le contexte de leur recherche est une divergence entre les biologistes sur le caractère endogène du recrutement. Les auteurs appliquent les critères minimax et maximin. Le critère minimax minimise les pertes ou le « regret » dans le cas d'un autre état de la nature. Le critère maximin maximise les résultats dans les pires scénarios imaginés. Le critère maximin est extrêmement pessimiste et suppose un adversaire malveillant (Mère Nature ?). Dans les cas où le potentiel de perte est élevé et irréversible ce degré de pessimisme peut avoir un sens. Quoiqu'il en soit, les auteurs affirment que ce n'est pas le cas pour la pêcherie considérée et prônent l'emploi du critère minimax. Leur approche est en filiation directe avec « le seuil minimal de sécurité » développé il y a quatre décennies par Ciriacy-Wantrup pour les politiques de conservation des ressources naturelles. Ils trouvent que le coût de maintien d'ouverture de la pêcherie cible, même si le recrutement exogène est incorrect, est moins important que les pertes dues à la fermeture si le caractère exogène est vérifié. Ils recommandent une politique intermédiaire de réduction des captures sur les espèces cibles avec dans le même temps une prévention ou au moins une réduction des captures des espèces de requin sévèrement menacés. Cela correspond essentiellement à augmenter le critère minimax avec une combinaison convexe des profits escomptés et la nature aléatoire des profits. Pour cela, les approches en terme de « valeur de variance espérée » (E-V), « minimum des écarts absolues » (MOTAD) ou « Focus-Loss » (F-L) sont les plus communément utilisées.

loss or "regret" should an alternative state of nature be found true. The maximin criterion maximizes the payoff under worst case scenarios. The maximin criterion is extremely pessimistic and presumes a malevolent opponent (Mother Nature?). In cases where loss potentials are high and irreversible this degree of pessimism may make sense. However, the authors argue that this is not the case for the fishery in question and advocate the minimax criterion. Their approach is a direct descendant of the "safe minimum standard" advocated four decades ago by Ciriacy-Wantrup for natural resource conservation policy. They find that the cost of keeping the target fishery open even if exogenous recruitment is incorrect is substantially less than the loss from closure if exogeneity is true. They recommend an intermediate policy of reducing target species catch while preventing or at least reducing catch of the severely depleted school shark. Essentially this corresponds to augmenting the minimax criterion with a convex combination of expected profits and riskiness of profits. Of these the most commonly used would probably be the "expected value-variance" (E-V), "minimum of the absolute deviations" (MOTAD) or "Focus-Loss" (F-L) approaches. In any case the expectation and risk measures would appear to be the subjective estimates of biological scientists.

Danielsson's paper reports on the Nordic Fisheries Management Model (NFMM) in general and the Icelandic version in particular. The bulk of his paper focuses on his own responsibility (economic data) in this coordinated multiple nation modelling effort. He also sketches his approach to modelling the processing sector.

Rodgers outlines a general bioeconomic simulation model for a multispecies fishery. The author notes that the same model may be used for (1) validation, (2) prediction and (3) control or optimization. For the author, the principal objectives of the model are to test the mathematical structure of the system so that a suitable optimization method can be developed and to generate answers to questions raised by proposed fishery management measures.

The Sparre and Willman paper describes a bioeconomic model (BEAM 4) for simulating space structured multiple species and Multiple fleet fisheries. This is the latest generation of the FAO issued simulator. It is written in TURBO PASCAL for MS-DOS machines and consists of submodels for biological/technical and economics. It appears to be a well documented model and worth consideration for a user who wishes to avoid the start up costs of model construction.

The De Verdelhan paper describes a bioeconomic simulator at Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER). The simulator is

lisées. Dans quelques cas les mesures d'espérance ou de risque pourraient apparaître comme des estimations subjectives des biologistes.

Danielsson rend compte quant à lui d'un modèle général de gestion des pêcheries nordiques (NFMM) avec une version particulière pour l'Islande. Le contenu de sa communication met l'accent sur ses propres responsabilités (données économiques) dans cet effort de modélisation coordonné pour différentes nations. Il applique également son approche à la modélisation du secteur de la transformation.

Rodgers construit un modèle de simulation bioéconomique pour des pêcheries multispécifiques. L'auteur note que le même modèle peut être utilisé pour (i) des validations, (ii) des prévisions, (iii) des contrôles ou des optimisations. Selon l'auteur, les principaux objectifs du modèle sont de tester la structure mathématique du système de telle sorte qu'une méthode d'optimisation convenable puisse être développée et générer des réponses aux questions introduites par les mesures de gestion des pêcheries.

Le papier de Sparre et Willman décrit le modèle bioéconomique BEAM4 qui simule la répartition spatiale des espèces et des flottilles en action sur les pêcheries. Il s'agit là de la dernière génération du modèle de simulation de la F.A.O. Il est rédigé en TURBO PASCAL dans une version pour MS-DOS et se présente sous forme de sous modules biologique, technique, économique. Il s'agit là d'un modèle bien documenté et valable pour un usager qui désire éviter l'investissement pour mettre en œuvre la construction d'un modèle.

De Verdelhan présente quant à lui un simulateur bioéconomique développé au sein de l'Ifremer dans la continuité des programmes initiaux rédigés en 1985 et mis à jour par Olivier le Pape en 1991. La version actuelle bénéficie d'écrans d'aide, de suppléments graphiques et d'options de calcul des effets de certaines mesures de gestion des pêcheries. Il est présenté par son auteur comme un outil pédagogique. Le modèle est écrit en TURBO PASCAL et contient des options qui prévoient un modèle de recrutement stochastique prenant en compte la structure d'âge de la population exploitée.

the current generation of a program developed originally by the author circa 1985 and modified by Olivier Le Pape in 1991. The current version benefits from the addition of help screens, supplemental graphics and an option to calculate the effects of certain fisheries management measures. It is regarded by its authors as a useful pedagogical. The model is written in TURBO PASCAL language and includes an option to allow stochastic (log normal) recruitment in an age class structured model. It is available on diskette from the author. An English language version exists.

# Multi-Objective Programming : an Application to the Pacific Whiting (Merluccius productus) Fishery

**Roberto R. Enríquez [a] and Gilbert Sylvia [b]**

[a]Facultad de Ciencas Marinas, Universidad Autonoma de Baja Claifornia, AP 453, Ensenada, B.C. Mexico

[b]Coastal Oregon Marine Experiment Station, Hatfield Marine Science Center, Newport, Oregon 97365 U.S.A

ABSTRACT

*This work focuses on multi-objective programming and its applications to fishery policy analysis and implementation. The main goals are to develop a dynamic multi-objective programming model of the Pacific whiting fishery in the United States and use this model to evaluate the applicability of multi-objective programming to fishery problems. A multi-objective function of three policy objectives - rents, utilization, and female spawning biomass - was constrained by an age-structured relationship representing the biological dynamics of the stock and by a set of linear relationships representing the harvest and processing dynamics of the fishery. Uncertainty was introduced by means of a stochastic recruitment relationship. Three policy instruments were considered : harvest quotas, harvest/processing capacity limits, and allocation between shore-based and offshore sectors of the fishery. Pareto optimal solutions for three policy objectives were generated by means of generating techniques.*

*Results are presented in the form of trade-off curves, or what may be termed for this problem, a "policy frontier." The results suggest that management of Pacific whiting in the United States is composed of non complementary objectives. Benefits from the fishery to a particular region or user group due to a particular set of regulations, may be offset by loses to other groups or regions. Large information requirements and computational burden are the major obstacles for the application of multi-objective programming to the Pacific whiting problem.*

*Despite these problems, the study concludes that multi-objective programming produces information consistant with the needs of the Pacific whiting fishery policy process.*

## 1. INTRODUCTION

Pacific whiting is commercially and ecologically one of the most important fishery resources along the West coast of the United States. The fishery is currently experiencing a period of rapid and profound transformation that could cause a substantial redistribution of benefits among domestic users. A major management issue is the problem of resource allocation between the domestic offshore and shore-based components of the fishery.

The main goals of this work are : (1) to develop a dynamic multi-objective programming (MOP) model of the Pacific whiting fishery in the United States ; and, (2) to use this model to evaluate the applicability of multi-objective programming to fishery policy problems. The main purpose of the model is to generate *Pareto-optimal* solutions for three policy objectives : rents, production, and (female) spawning biomass. The set of all *Pareto-optimal* solutions (the *noninferior set*) represents the *production possibility frontier* for the fishery in terms of the relevant objectives. Ballenger and McCalla (1983) refer to the noninferior set as the "policy feasible frontier." Rather than to produce precise numerical solutions, the emphasis at this point is on the usefulness of MOP for fishery policy implementation and analysis.

## 2. BASIC STRUCTURE OF THE PACIFIC WHITING MODEL

### *2.1 A Diagrammatic Representation of the Policy Problem*

Figure 1 shows a diagrammatic representation of the model. This representation of the policy problem consists of three components :

(i) *the regulatory process*, represented by a group of decision-makers, which have at their disposition a set of pre-established policy instruments ;

(ii) a set of biological, environmental, technological, and economic constraints that determine the *state of the system* ; and,

(iii) a set of identifiable and operational *objectives*.

In Figure 1 the rectangular shapes represent endogenous components of the model, the elliptical shapes represent exogenous components, and the arrows represent the important interactions among the different components. We acknowledge that the designation of exogenous components in the model is arbitrary. In reality, no component is completely exogenous. However, a degree of abstraction is necessary to keep the problem bounded.

### *2.2 Biological Dynamics*

The relationships describing the basic biological dynamics of Pacific whiting in the model closely follow the generalized age structured model (geographical version) developed by Dorn and Methot (1989 and 1991) and Dorn et al. (1990) to estimate long and short term yields for the Pacific whiting stock. This age structured model is the tool currently being used to set harvest regulations.

The model separates the stock at the beginning of the fishing season into four regions, according to the classification developed by Dorn, 1990 (see Figure 2) : (1) Eureka, Monterey, and Conception regions (EUR) ; (2) the southern part of the Columbia region (SCOL) ; (3) the northern part of the Columbia region and the U.S. portion of the Vancouver region (VNC) ; and, (4) the Canadian region (CA). Due to Pacific whiting's migratory behavior, catches from the different areas have different age, sex, sexual maturity and weight-at-age compositions, with the northernmost regions having, on average, larger and older fish, and a larger proportion of females.

### *2.3 Recruitment Variability and Biological "Risk"*

Pacific whiting presents extreme variations in recruitment (Hollowed and Bailey, 1989). To model recruitment variability we followed the iterative sampling statistical procedure proposed by Dorn and Methot (1989). This procedure consists of the sampling with replacement from the observed recruitment time series.

The extreme variability in the recruitment of Pacific whiting obscures the relationship between stock size and future recruitment (Hollowed et al. 1989). Without the knowledge of a stock-recruitment relationship, the effect of harvesting on the ability of Pacific whiting to produce successful recruitment cannot be assessed. Associated with harvests is a "risk"

of lowering the stock to a level where it has no longer the capacity of producing successful recruitment. Dorn and Methot (1989, 1991) and Dorn et al. (1990) assess this biological "risk" by focusing on the spawning biomass. The biological "risk" of a particular harvest strategy is determined by the proportion of years that the spawning biomass drops below a cautionary level of spawning biomass (457,000 mt). The current management strategy seeks to maximize yield while keeping biological "risk" at a fixed level (Dorn and Methot, 1989). The authors acknowledge that setting a cautionary level of spawning biomass as a reference to assess biological "risk" is arbitrary.

### *2.4 Harvest and Processing Dynamics*

The domestic Pacific whiting fishery consists of two components, a traditional "shore-based" fishery and a recently initiated "offshore" fishery. The shore-based fishery is primarily composed of the delivery of whiting by mid-water trawlers to shore-based processors, while the offshore fishery consists of factory trawlers and motherships processing at sea. It is assumed that offshore harvesters have incentives to fish for Pacific whiting at the southernmost region of the fishery early in the season so they can participate in the Alaskan pollock fishery later in the year (by June first). Accordingly, the model restricts offshore harvesting activities to the "EUR" region only. The model assumes also that the offshore fishery operates an average of six weeks per season. In contrast, the shore-based fleet depends on processors that are scattered along the coasts of California, Oregon, and Washington. The model assumes that the shore-based fishery season lasts an average of twenty five weeks a year. To keep the levels of harvest consistent with observed levels, fishing mortality across regions was restricted to be no larger in average than 0.5, and annual catches to be no less than fifty thousand mt per season. Even when the shore-based fishery has been expanding rapidly, it is unlikely that it will be able to harvest and process more than 150,000 mt of whiting per year. Accordingly, the shore-based fishery was restricted to no more than 150,000 mt of harvest per season, and the offshore fishery was restricted to no more than 300,000 mt Fishing mortality by the Canadian fishery was fixed at 0.15 annually.

Both fishery sectors consist of heterogeneous fleets and processing facilities producing a variety of product forms. We abstracted from this detail by arbitrarily aggregating the industry into "typical" or representative harvesting/processing units producing surimi. A "typical" shore-based unit consists of a plant with an output capacity of eighteen mt a day served by eight small mid-water trawlers with catch rates of fifteen mt a day. An offshore unit consists either of one factory trawler with an output capacity of sixty-two mt a day or a mothership with an output capacity of sixty-two mt a day served by ten large trawlers with a capacity of forty-eight mt a day. The aggregation was done based on capacity and cost information from the *Pacific Whiting Allocation Draft Analysis* (PFMC, 1992) and the *Oregon Economic Assessment Model* (Jensen and Radtke, 1990). Per unit costs of production, which include fishing and processing, were assumed to be independent of the level of output. Since Pacific whiting is but one of the species caught and processed by both fishing sectors, it is difficult to evaluate the proportion of annual fixed costs attributable to fishing and processing whiting. We adjusted the annual fixed cost figures to reflect the time that it is actually spent fishing for whiting. The model assumes that the capacity to utilize completely the Pacific whiting resource currently exists, and that construction of new vessels or processing facilities will not take place during the time horizon considered. The reader should be cautioned that the information currently available regarding costs of fishing and processing is based on preliminary estimates, and therefore, can only roughly estimate "true" opportunity costs. This is an area where further research is needed.

Catch rates were assumed to be independent of stock size. These may be reasonable assumptions for the range of harvest considered in this study given the schooling characteristics of Pacific whiting. Because Pacific whiting is only one component of the Pacific coast groundfish fishery, and because the volume of surimi produced from Pacific is small in relation to the total market supply, factor and product prices were considered to be independent of the fishery output. The prices of other products based on Pacific whiting such as fillets and headed and gutted may depend on some attributes such as fish size and temporal availability (Sylvia, 1991). However at this point the output of these product forms is small in relation to the production of surimi.

## 3. OBJECTIVES OF MANAGEMENT

Amendment 4 (Section 2.1) to the Pacific Coast Groundfish Plan defines three broad objectives for the groundfish fishery including Pacific whiting : conservation, economics, and utilization.

**Conservation :** Given that the stock recruitment relationship is unknown, it is not possible to use an equilibrium sustainable yield harvesting strategy for the Pacific whiting stock. In this analysis, we incorporated spawning biomass size as an objective of management. We assumed that spawning biomass is inversely related to biological "risk." For the purposes of this work biological "risk" is defined in an ordinal scale. That is, for any two levels of spawning biomass, say $SB_1$ and $SB_2$, if $SB_1$ is larger than $SB_2$ then the "risk" (probability of recruitment failure) associated with $SB_2$ is equal or larger then the biological "risk" associated with $SB_1$ . Additional justification for maintaining higher levels of spawning biomass as an objective of management comes from the ecological importance of Pacific whiting (Livingston and Bailey, 1985).

**Economics** : The economics objective in the model is measured by present value of net revenues (PVNR) at the processing level. This represents a departure from traditional analysis that consider net revenues at the harvesting level only.

**Utilization :** The objective of resource utilization in the current characterization of the Pacific whiting fishery is measured by the weight of product leaving the processing lines. The model considered only production from the United States fishery.

## 4. POLICY INSTRUMENTS

To analyze the effects of resource allocation on the levels of objectives, three policy instruments were considered : (1) an annual harvest quota ; (2) allocation between the offshore and shore-based fisheries ; and, (3) the number of fishing/processing "units" that are allowed to enter the fishery.

## 5. MATHEMATICAL REPRESENTATION OF THE MODEL

The following equations describe the model (see Table I for the glossary of symbols) :

Recruitment :

$$X_{t,r} = rec_t \tag{1}$$

Numbers-at-age, medial age classes,

$$X_{t,a} = \sum_k pr_{a,k} X_{t-1,a-1} e^{(-z_{t-1,a-1,k})} \tag{2}$$

Numbers-at-age, terminal age classes,

$$X_{t,A} = \sum_k pr_{A,k} X_{t-1,A-1} e^{(-z_{t-1,A-1,k})} + \sum_k pr_{A,k} X_{t-1,A} e^{(-z_{t-1,A,k})} \tag{3}$$

Total mortality

$$z_{t,a,k} = m_t + \sum_w F_{t,a,k,w} \tag{4}$$

Fishing Mortality

$$F_{t,a,k,w} = FM_{t,k,w} S_{a,k} \tag{5}$$

Catch in numbers

$$CN_{t,a,k,w} = \frac{F_{t,a,k,w}}{Z_{t,a,k}} pr_{a,k} X_{t,a} [1 - e^{(-Z_{t,a,k})}] \quad (6)$$

Catch biomass

$$CB_{t,w} = CN_{t,a,k,w} wg_{a,k} \quad (7)$$

Annual Catch by Fishery

$$CW_{t,w} = \sum_{a}\sum_{k} CB_{t,a,k,w} \quad (8)$$

Annual Production by Fishery

$$PROD_{t,w,f} = CW_{t,w} PF_{t,w,f} rr_{w,f} \quad (9)$$

Number of Fishing/Processing Units

$$NU_{t,w} = \frac{CB_{t,w}}{C_w} \quad (10)$$

Female Spawning Biomass

$$max. \quad SB = \sum_{t}\sum_{a} X_{t,a} ma_a pf_a wt_a \quad (11)$$

PVNR

$$Max.\ PVNR = \sum_{t}\sum_{w} \frac{1}{(1+i)^t} [(p - VC_w) CB_{t,w} rr_w - N_{t,w} fc_w] \quad (12)$$

Total Output

$$Max.\ OUTPUT = \sum_{t}\sum_{w}\sum_{f} PROD_{t,w,f}. \quad (13)$$

## 6. SOLUTION TECHNIQUE

The solution approach used in this analysis is consistent with the class of solutions known as "generating techniques" (see Cohon and Marks, 1975 for an excellent overview of MOP solution techniques). In particular we used a technique studied by Wendell and Lee (1977) and Corley (1980). This technique combines the characteristics of the *weighing* method (Zadeh, 1963) and the *constraint* method (Haimes *et al.* 1971). Consequently, Chankong and Haimes (1983) call this the *hybrid* method. According to the hybrid method *Pareto optimal* solutions for the Pacific whiting management problem can be characterized in terms of optimal solutions of the following problem :

$$max.\ w_p PVNR + w_y YIELD \quad (14)$$

s.t. $SB > L_{SB}$; *and, Equations* **1** *to* **10,**

Where $w_p$ and $w_y$ represent a set of arbitrary positive "weights" (at least one strictly positive), and $L_{SB}$ is a lower bound on the level of spawning biomass . Pareto optimal solutions can be generated by the parametric variation of $w_p$, $w_y$ , and $L_{sb}$ (see Chankong and Haimes, 1983 for a proof).

## 7. RESULTS AND DISCUSSION

Sixteen *Pareto optimal* solutions were generated over a fifteen year time horizon using the costs, capacities and price figures shown in Table II ; and the biological parameters estimated by Dorn and Method (1991) shown in Table III. Each solution represents the mean of five replicate runs with randomly generated recruitment time series. Net revenues were discounted to the initial period using a.90 discount factor. Four values wer chosen for $L_{SB}$ each representing a different level of spawning biomass (and therefore different levels of "risk") :

(i) $L_{SB} \geq 11.73$ million mt (equivalent to an annual average of 782 thousand mt) - this level corresponds to the optimal spawning biomass used in the variable and hybrid fishing mortality algorithms used by Dorn and Methot (1991) to estimate "sustainable" yields ;

(ii) $L_{SB} \geq 10.920$ million mt (annual average of 728 thousand mt), corresponding to the average spawning biomass of the moderate "risk" "sustainable" yield hybrid strategy ;

(iii) $L_{SB} \geq 10.365$ million mt (annual average of 691 thousand mt), corresponding to the average spawning biomass of the moderate risk "sustainable" yield variable mortality strategy ; and,

(iv) $L_{SB} \geq 9.555$ million mt (annual average of 637 thousand mt), corresponding to the average spawning biomass of the high risk "sustainable" yield variable mortality strategy.

The results are shown in table IV. and are represented in the form of isolines of "risk" in Figure 3. A caveat related to the numerical solutions must be noted. Although it is conceded that the probability of damaging the reproductive capacity of the stock increases as the level of spawning biomass is allowed to fall, the present analysis implicitly assumes that such damage will not be manifested during the time horizon of the analysis but will occur, if at all, at a later period. The validity of this assumption may decrease for lower levels of spawning biomass.

Figure 3 shows a two dimensional representation of a segment of the policy frontier in the form of isolines of "risk." With the additional assumption of monotonicity of preferences, only solutions on the policy frontier are relevant to the decision process. The policy frontier provides several important pieces of information.

(i) It represents the combinations of policy instruments representing (Pareto) efficient utilization of the resource in terms of the objectives considered. It also shows the maximum level of objectives (or combinations of objectives) attainable given the constraints of the problem.

(ii) The policy frontier explicitly reveals the trade-offs associated with policy alternatives. Inspection of the isolines of "risk" reveals that along these lines the trade-offs increase as one attempts to generate more of one objective. This result may have important implications for the validity of traditional cost-benefit analysis of fishery policy, which considers only the maximization of PVNR. Maximization of PVNR as the sole objective of management represents a corner solution (points 4, 8, 12, or 16) in the policy frontier. However, if both objectives are valued this may not be the preferred solution since a larger amount of yield can be obtained (at points 3, 7, 11 or 15) by a relatively small sacrifice in the level of net revenues. The same reasoning applies when maximum yield is the sole objective of management. Although not immediately obvious from the graphical representation, the trade-offs related to the level of "risk" can be evaluated by means of the marginal value (shadow price) associated with the constraint $L_{SB}$ (Chankong and Haimes, 1983). The marginals of $L_{SB}$ for the corner solutions (solutions where either $w_p$ or $w_y = 0$) are reported in Table IV. As shown in Table IV the marginals of the constraint $L_{SB}$ are negative and increase in absolute magnitude as the value of $L_{SB}$ increases. These numbers can be interpreted as the proportional amount of either *PVNR* or *YIELD*, that is lost (in the absence of recruitment failure) by not allowing a marginal decrease in the level of spawning biomass - that is, by not taking a marginal increase in "risk."

(iii) The policy frontier reveals the relationship between policy instruments and policy objectives. Inspection of Figure 3 suggests that along the isolines, increased allocation to the offshore fishery tends to produce more profits but less output. On the other hand allocation to the shore-based fishery provides for a better utilization of the resource (as defined in this work) given a fixed level of "risk." In addition, the results suggest that solutions with the same weights for PVNR and OUTPUT but with lower levels of risk (compare for instance solutions 4, 8, 12, and 16) tend to favor allocation to the shore-based fishery.

The principal factors behind these results are the geographical distribution of the resource and effort, the cost structure, and the harvesting/processing capacities of the industry sectors. The offshore fishery has a larger profit margin and generates more profits but since this fishery concentrates on the southernmost region of the fishery it harvests a larger proportion of younger and smaller fish. Therefore the offshore fishery imposes proportionally larger impacts on the stock for a given level of utilization. Solutions with larger amounts of *OUTPUT* favor allocation to the shore-based fishery, but only up to the assumed 150,000 mt total annual capacity of this fishery, any leftovers are assigned to the offshore fishery. The position and shape of the policy frontier is conditional on the assumptions regarding the geographical pattern of fishing effort and on the cost figures used. Changing any assumption, constraint or parameter can cause shifts and (or) changes in the general shape of the policy frontier. Therefore it is vital that the policy makers clearly understand the construction of a multiple-objective mathematical program before using the results as a guide for policy development. From the analyst standpoint, all the solutions on the policy frontier are equally desirable (i.e. all are *Pareto efficient*). It is up to the decision-makers to select the point on the frontier that better accommodates the needs of the Country.

## 8. CONCLUSION

In spite of the many uncertainties regarding the dynamics of the Pacific whiting fishery and the obvious oversimplifications of the model, we believe that this exercise shows the usefulness of MOP for fishery policy development and analysis. Information in the form of policy frontiers can help analysts and policy actors to systematically explore regulatory options and understand how benefits can be increased to one user group while minimizing losses to another group. MOP models, by focusing on the relationship between controls and benefits, can help decision-makers to better understand the impact of their decisions on user groups, regions, and the nation. This information also may help groups with different interests to more effectively bargain in the policy arena. The information in the policy frontier, however, is intended to complement decision-making, not to replace it, as solutions from many single objective approaches attempt to do. MOP makes explicit the normative elements and trade-offs implicit in single objective models. In short, the policy frontier may provide a basis for an operational definition of the concept of "optimum" yield.

Obviously, the use of MOP models involves a cost. These models are complex, usually requiring more information and data. MOP based models of the fishery require an interdisciplinary understanding of the system. These models are costly to solve, and solutions may be more difficult to understand and evaluate by the decision-makers. Making the benefits of multi-objective techniques outweigh its costs is the challenge ahead. In the case of Pacific whiting our future research using MOP will address a wider range of issues affecting the fishery including market dynamics, seasonal shifts in effort, international allocation, community impact, and economic risk assessment.

## REFERENCES

**Ballenger N.S. and A.F. McCalla** (1983). Domestic Policy and Trade Interactions : The Case Of Mexico. Paper presented to the International Trade Research Consortium. Tucson, Arizona.

**Chankong V. and Y.H. Haimes** (1983). *Multiobjective Decision Making : Theory and Methodology*. New-York : North-Holland.

**Cohon J.L. and D.H. Marks** (1975). A review and evaluation of multiobjective programming techniques. *Water Resources Research*, II(2), 208-217.

**Corley H.W.** (1980). A new scaler equivalence for Pareto optimization. IEEE *Transactions on Automatic Control*, AC(25), 829-830.

**Dorn M.W.** (1990). Spatial and temporal variability of the catch of Pacific hake in the United States Management Zone. Manuscript. National Marine Fishery Service, Alaska Fishery Science Center.

**Dorn M.W., R.H. Methot, E.P. Nunnallee and M.E. Wilkins** (1990). Status of the coastal Pacific whiting resource in 1990. In Pacific Fishery Management Council, Status of the Pacific Coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991 : stock assessment and fishery evaluation (document prepared for the Council and its advisory entities). Pacific Fishery Management Council, Metro Center, suite 420, 200 SW first Avenue, Portland, Oregon 97201.

**Dorn M.W. and R.D. Methot** (1991). Status of The Coastal Pacific Whiting Resource in 1991. IN : Pacific Fishery Management Council, Status of The Pacific Coast Groundfish Fishery Through 1991 and recommended Acceptable Biological Catches for 1992 : Stock assessment and fishery evaluation. (document prepared for the Council and its advisory entities). Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, Oregon 97201.

**Dorn M. and R.D. Methot** (1989). Status of the Pacific Whiting resource in 1989 and recommendations to management in 1990. In Pacific Fishery Management Council, Status of the Pacific Coast groundfish fishery through 1989 and recommended acceptable biological catches for 1990 : stock assessment and fishery evaluation (document prepared for the council and its advisory entities). Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Avenue, Portland, Oregon 97201.

**Haimes Y.Y., L. Lasdon and D. Wismer** (1971). On a bicriterion formulation of problems of integrated system identification and system optimization. IEEE *Transactions on Systems, Man and Cybernetics*, SMC-1, 296-297.

**Hollowed A.B. and K.M. Bailey** (1989). New perspectives on the relationship between recruitment of Pacific hake *Merluccius productus* and the ocean environment. *Can. Spec. Publ. Fish Aquat. Sci.*, **108 :** 207-220.

**Hollowed A.B., R. Method and M. Dorn** (1988). Status of the Pacific Whiting Resource in 1988 and Recommendations to Management in 1989. In : Pacific Fishery Management Council, Status of The Pacific Coast groundfish fishery through 1988 and recommended acceptable biological catches for 1989. Portland Oregon.

**Jensen W. and H. Radtke** (1990). *OCZMA Oregon Economic Assessment Model*. (Version 1.0). Oregon Coastal Zone Management Association : Newport, Oregon.

**Livingston P.A. and K.M. Bailey** (1985). Trophic Role of the Pacific whiting *Merluccius productus*. *Marine Fisheries Review*, **47** (2), 16-22.

**Pacific Fishery Management Council** (1992). Pacific Whiting Allocation Draft Analysis. A document presented for its review at the March 9-13, 1992 PFMC meeting. PFMC, Metro Center, Suite 420, 2000 SW First Avenue, Portland Oregon.

**Sylvia G.** (1991). Market Opportunities for Pacific Whiting. Report prepared for the Oregon Coastal Zone Management Association. Newport, Oregon.

**Wendell R.E. and D.N. Lee** (1977). Efficiency in multiple objective optimization problems. *Mathematical programming* **12,** 406-414.

**Zadeh L.A.** (1963). Optimallity and nonscalar-valued performance criteria. *IEEE Transactions on Automatic Control* AC-8, 59-60.

TABLE 1.
GLOSSARY OF SYMBOLS.

**Endogenous Variables:**

| | |
|---|---|
| *C* | per unit capacity. |
| *CB* | catch biomass. |
| *CW* | catch by fishery. |
| *CN* | catch in numbers. |
| *F* | fishing mortality. |
| *FM* | fishing mortality for ages with selectivity equal to one. |
| *NU* | number of fishing units |
| *PF* | proportion of catch used in the production of product form f |
| *PROD* | production by product form |
| *S* | selectivity |
| *SB* | spawning biomass, |
| *X* | numbers-at-age |
| *Z* | total mortality. |

**Exogenous variables and Constants:**

| | |
|---|---|
| *c* | per unit capacity. |
| *fc* | fixed costs per fishing unit. |
| *i* | interest rate. |
| *m* | natural mortality. |
| *ma* | proportion of mature females. |
| *p* | product price. |
| *pf* | proportion by weight of females in the population. |
| *pr* | proportion of the stock available (in numbers). |
| *rec* | recruitment. |
| *rr* | recovery rate. |
| *s* | selectivity. |
| *vc* | variable cost. |
| *wg* | individual weight by region. |
| *wt* | average individual weight of the population. |

**Indices:**

| | |
|---|---|
| *a* | *a = r, r+1,r+2...,A* age in years, |
| *A* | terminal age |
| *f* | product form. |
| *k* | *k = 1,2,...K* geographical region, |
| *r* | age-at-recruitment |
| *t* | *t = 1,2,...T* time in years. |
| *w* | fishery ("offshore" or "shore-based"). |

TABLE 2.
COSTS, CAPACITIES, AND OUTPUT PRICES FOR THE PACIFIC WHITING FISHERY "TYPICAL" OR REPRESENTATIVE FISHING/PROCESSING UNITS.

| | Shore-based* | Off-shore** |
|---|---|---|
| Harvest Capacity (mt/day) | 120 | 453.5827 |
| Output capacity (mt/day) | 18 | 62.369 |
| Average season length*** (days) | 180 | 42 |
| Capacity per season (mt) | 3240 | 2619 |
| Number fishing vessels in Unit | 8 | 1/10 |
| Variable costs ($/mt) | 1920 | 1671 |
| Annual fixed costs | 1817625 | 6532400 |
| Adjusted fixed costs**** | 1817625 | 1633100 |
| Output price ($/mt) | 2931.15 | 2931.15 |
| Recovery rates | 0.15 | 0.1375 |

Source: PFMC (1992) and Jensen and Radtke (1990).

*A shore-based unit consists of one plant with an output capacity of 18 mt a day served by eight trawlers with catch rates of 15 mt per day.
**An offshore unit consists of either a factory trawler with output capacity of 62 mt per day or a mothership with the same output capacity served by 10 trawlers with catch rates of 48 mt a day.
*** Assumed based on the geographical distribution of effort.
**** Adjusted on the basis of season length.

TABLE 3.
AGE-SPECIFIC CHARACTERISTICS OF PACIFIC WHITING.

| Age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natural Mortality | | | | | | | | | | | | | | |
| a | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 | 0.237 |
| Selectivity | | | | | | | | | | | | | | |
| EUR | 0.050 | 0.490 | 0.940 | 0.990 | 1.000 | 1.000 | 1.000 | 0.990 | 0.950 | 0.830 | 0.550 | 0.230 | 0.070 | 0.010 |
| SCOL | 0.110 | 0.250 | 0.480 | 0.720 | 0.880 | 0.960 | 1.000 | 1.000 | 1.000 | 0.920 | 0.510 | 0.100 | 0.010 | 0.000 |
| VNC | 0.010 | 0.510 | 0.200 | 0.510 | 0.820 | 0.960 | 1.000 | 1.000 | 0.980 | 0.880 | 0.590 | 0.220 | 0.050 | 0.010 |
| CA | 0.000 | 0.450 | 0.510 | 0.580 | 0.660 | 0.740 | 0.840 | 0.930 | 0.990 | 1.000 | 0.880 | 0.660 | 0.410 | 0.230 |
| Proportion of fish available | | | | | | | | | | | | | | |
| EUR | 0.816 | 0.618 | 0.716 | 0.481 | 0.318 | 0.327 | 0.361 | 0.298 | 0.217 | 0.202 | 0.291 | 0.223 | 0.194 | 0.344 |
| SCOL | 0.165 | 0.209 | 0.177 | 0.247 | 0.144 | 0.222 | 0.174 | 0.230 | 0.154 | 0.106 | 0.186 | 0.120 | 0.197 | 0.124 |
| VNC | 0.018 | 0.151 | 0.072 | 0.208 | 0.287 | 0.277 | 0.260 | 0.309 | 0.322 | 0.357 | 0.288 | 0.313 | 0.295 | 0.298 |
| CA | 0.000 | 0.022 | 0.035 | 0.064 | 0.252 | 0.175 | 0.205 | 0.163 | 0.307 | 0.335 | 0.235 | 0.344 | 0.314 | 0.234 |
| Weight of fish at age (KG) | | | | | | | | | | | | | | |
| EUR | 0.211 | 0.310 | 0.379 | 0.446 | 0.481 | 0.504 | 0.523 | 0.537 | 0.575 | 0.622 | 0.721 | 0.752 | 0.805 | 0.837 |
| SCOL | 0.261 | 0.360 | 0.429 | 0.496 | 0.531 | 0.554 | 0.573 | 0.587 | 0.625 | 0.672 | 0.771 | 0.802 | 0.855 | 0.887 |
| VNC | 0.311 | 0.410 | 0.479 | 0.546 | 0.581 | 0.604 | 0.623 | 0.637 | 0.675 | 0.722 | 0.821 | 0.852 | 0.905 | 0.937 |
| CA | 0.250 | 0.570 | 0.576 | 0.558 | 0.676 | 0.667 | 0.800 | 0.871 | 0.904 | 0.962 | 1.084 | 1.152 | 1.334 | 1.336 |
| Mean population weight at age (KG) | | | | | | | | | | | | | | |
| wt | 0.271 | 0.370 | 0.442 | 0.524 | 0.557 | 0.592 | 0.607 | 0.634 | 0.667 | 0.719 | 0.771 | 0.841 | 0.937 | 1.039 |
| Proportion of sexually mature females | | | | | | | | | | | | | | |
| ma | 0.000 | 0.500 | 0.750 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Proportion by weight of females in population | | | | | | | | | | | | | | |
| pf | 0.480 | 0.501 | 0.512 | 0.520 | 0.524 | 0.526 | 0.529 | 0.536 | 0.539 | 0.544 | 0.553 | 0.561 | 0.568 | 0.575 |
| Initial age composition* (billions) | | | | | | | | | | | | | | |
| | 0.678 | 0.528 | 0.352 | 0.780 | 0.085 | 0.000 | 0.702 | 0.012 | 0.003 | 0.006 | 0.182 | 0.005 | 0.004 | 0.069 |

Source: Dorn and Method, 1991.
*Corresponds to the year 1992.

TABLE 4.
WEIGHTS, POLICY INSTRUMENTS AND OBJECTIVES FOR THE SIXTEEN PARETO OPTIMAL SOLUTIONS. VALUES IN PARENTHESIS ARE STANDARD DEVIATIONS.

| | | | POLICY INSTRUMENTS | | | | | | OBJECTIVES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Allocation[2] | | Units[2] | | | | | |
| Solution Number | Weights Wp/Wo | | $L_{ss}$[1] 1000mt | Quota[2] 1000mt | SHO % | OFF % | SHO | OFF | PVNR[3] millions | OUTPUT[3] 1000mt | Spawning Biomass[3] 1000mt | $L_{ss}$ marginal |
| 1 | 0/1 | --- | 11730 | 200(137) | 67(29) | 33(29) | 5.9(1.5) | 3.8(6.3) --- | 88(37) | 437(134) | 782 | -0.054 |
| 2 | 1/400 | --- | 11730 | 197(134) | 64(28) | 36(28) | 5.5(1.6) | 4.1(5.9) --- | 94(39) | 433(128) | 782 | <0 |
| 3 | 1/80 | --- | 11730 | 183(152) | 47(38) | 53(38) | 3.9(2.2) | 5.2(6.9) --- | 101(39) | 394(131) | 782 | <0 |
| 4 | 1/0 | --- | 11730 | 170(159) | 31(41) | 69(23) | 2.3(2.3) | 6.3(6.5) --- | 102(39) | 359(121) | 782 | -0.018 |
| 5 | 0/1 | --- | 10920 | 220(140) | 65(30) | 35(30) | 6.3(1.2) | 4.3(6.7) --- | 101(36) | 479(124) | 728 | -0.050 |
| 6 | 1/400 | --- | 10920 | 217(139) | 62(31) | 38(61) | 5.8(1.4) | 4.8(6.5) --- | 108(38) | 470(120) | 728 | <0 |
| 7 | 1/80 | --- | 10920 | 205(139) | 46(36) | 54(36) | 4.2(2.2) | 6.0(6.6) --- | 115(37) | 440(129) | 728 | <0 |
| 8 | 1/0 | --- | 10920 | 188(153) | 29(40) | 71(40) | 2.4(2.3) | 7.2(2.3) --- | 116(37) | 397(120) | 728 | -0.017 |
| 9 | 0/1 | --- | 10365 | 232(139) | 65(31) | 35(31) | 6.6(1.0) | 4.7(6.7) --- | 109(35) | 505(119) | 691 | -0.043 |
| 10 | 1/400 | --- | 10365 | 228(148) | 58(31) | 42(31) | 5.7(1.5) | 5.5(6.8) --- | 118(38) | 494(115) | 691 | <0 |
| 11 | 1/80 | --- | 10365 | 218(148) | 41(38) | 59(38) | 4.0(2.3) | 6.9(6.9) --- | 124(36) | 466(127) | 691 | <0 |
| 12 | 1/0 | --- | 10365 | 202(148) | 24(39) | 76(39) | 2.2(2.3) | 8.0(6.4) --- | 125(36) | 425(121) | 691 | -0.016 |
| 13 | 0/1 | --- | 9555 | 247(135) | 61(30) | 39(30) | 6.7(1.7) | 5.4(6.8) --- | 122(35) | 537(126) | 637 | -0.036 |
| 14 | 1/400 | --- | 9555 | 244(141) | 52(31) | 48(31) | 5.6(1.9) | 6.5(6.4) --- | 131(36) | 526(109) | 637 | <0 |
| 15 | 1/80 | --- | 9555 | 236(137) | 38(36) | 62(36) | 4.0(2.4) | 7.9(6.8) --- | 137(35) | 502(115) | 637 | <0 |
| 16 | 1/0 | --- | 9555 | 223(125) | 23(36) | 77(36) | 2.3(2.1) | 9.1(6.2) --- | 138(35) | 466(118) | 637 | -0.015 |

1. $L_{ss}$ = constraint on spawning biomass.
2. Averages over the fifteen year time horizon.
3. As defined in the text.

FIG. 1.
A DIAGRAMMATIC REPRESENTATION OF THE PACIFIC WHITING MULTI-OBJECTIVE DECISION-MAKING PROBLEM.

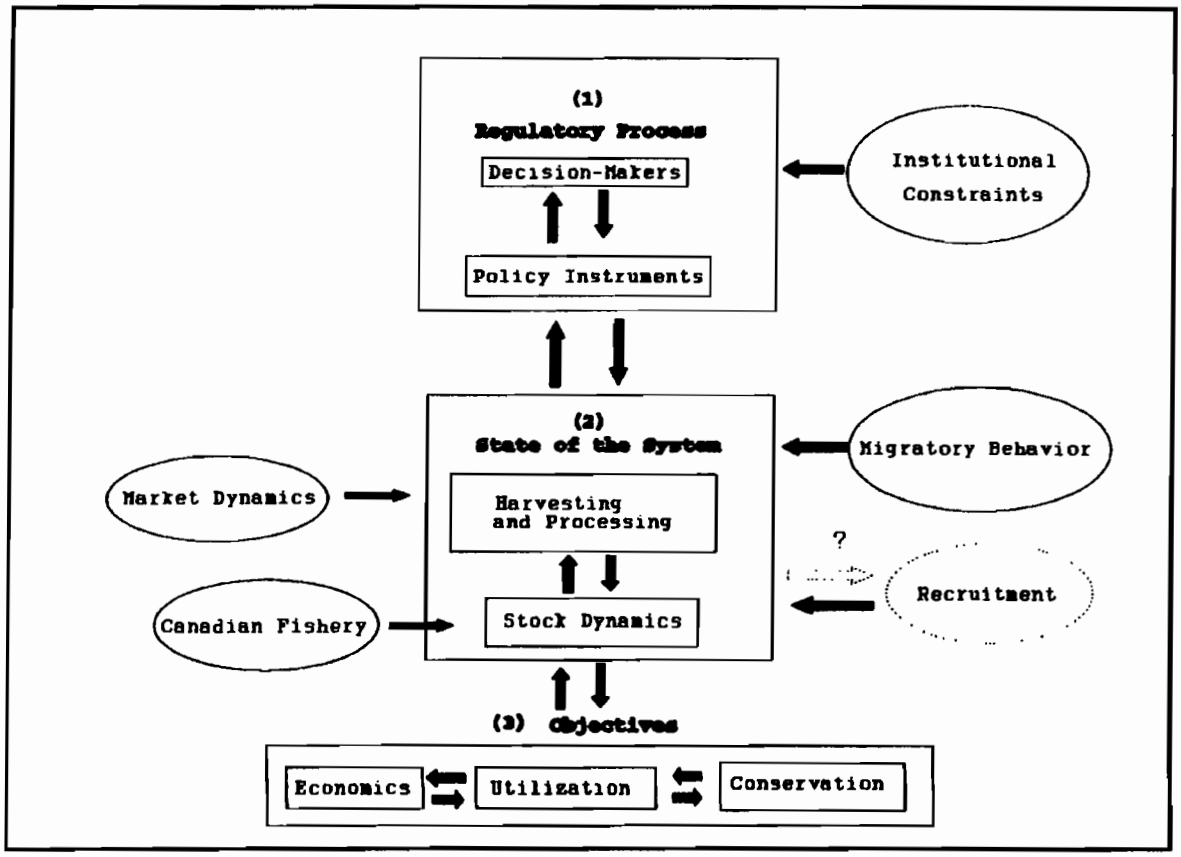


**FIG. 2.**
**GEOGRAPHICAL REGIONS USED TO SEPARATE THE PACIFIC WHITING FISHERY INTO FOUR SUB-FISHERIES.**

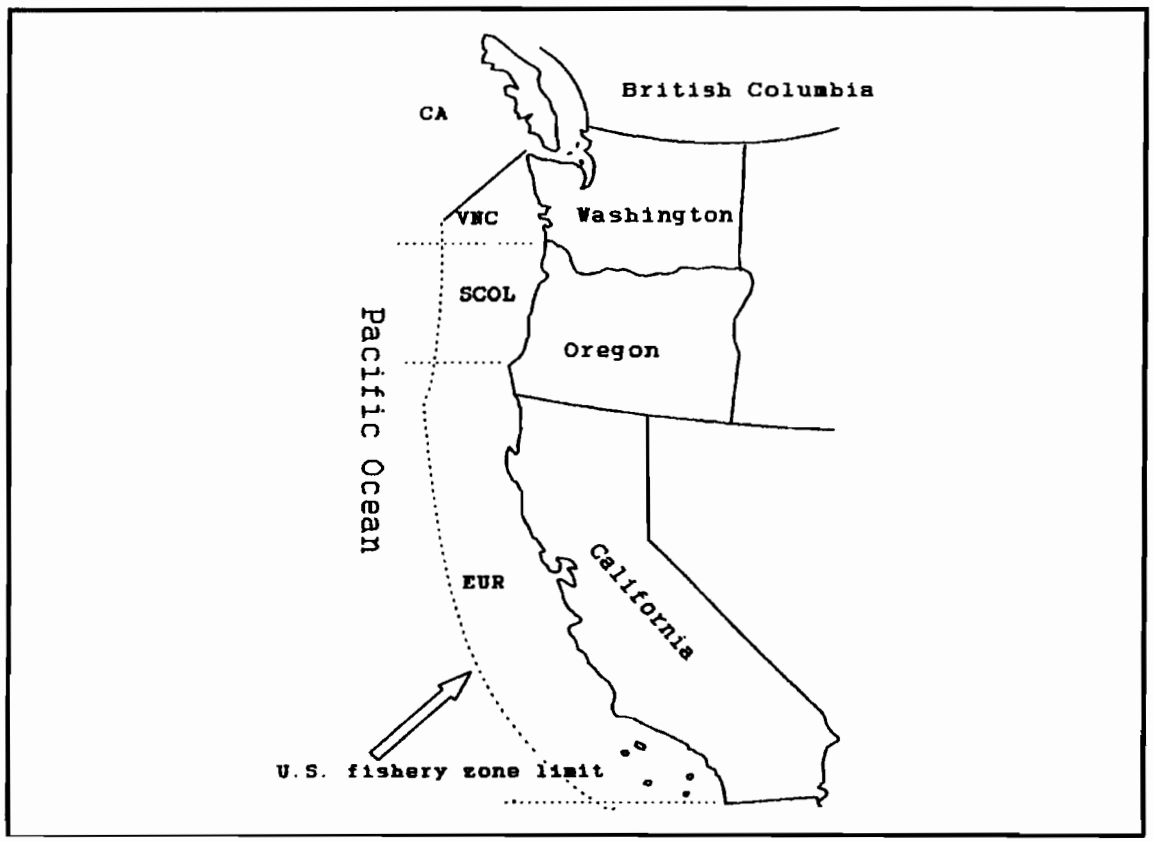
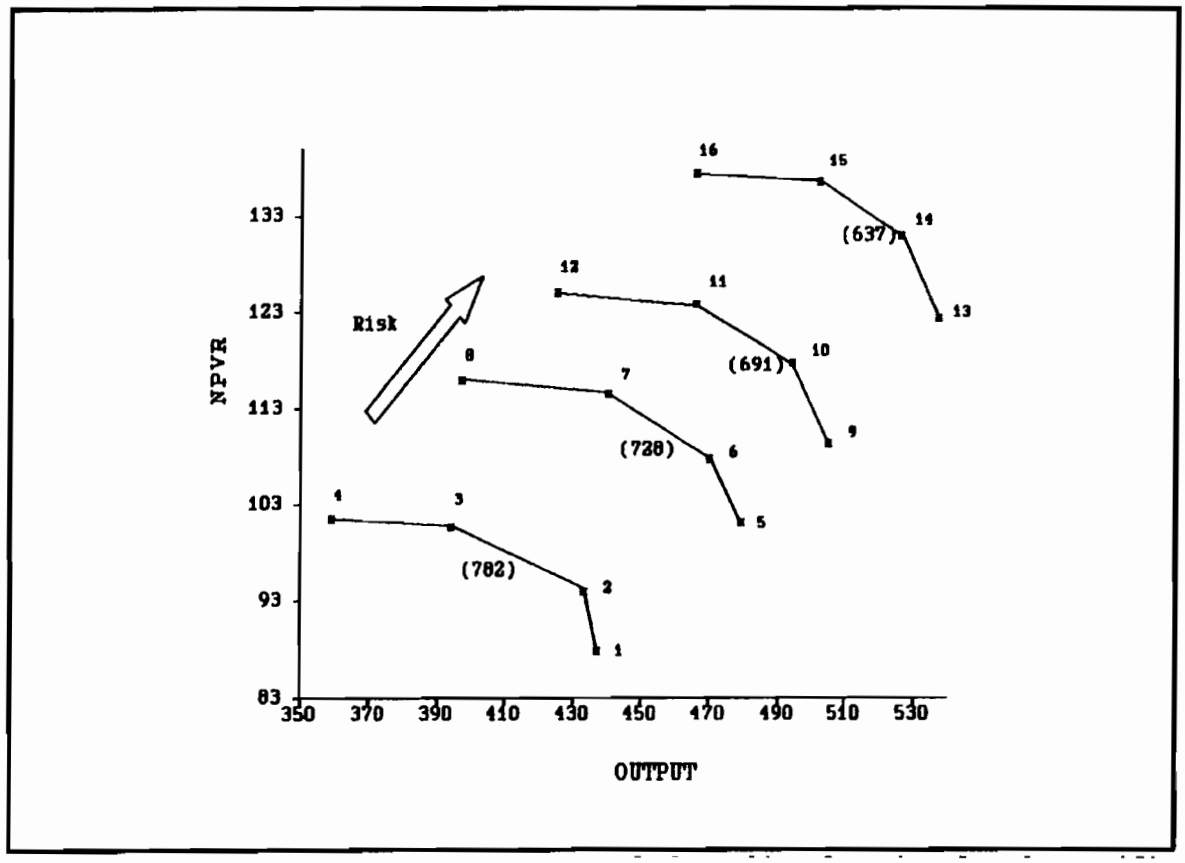


FIG. 3.
TWO DIMENSIONAL REPRESENTATION OF THE POLICY FRONTIER FOR THE PACIFIC WHITING POLICY PROBLEM. THE NUMBERS IN PARENTHESIS ARE AVERAGE ANNUAL SPAWNING BIOMASS CORRESPONDING TO THE LINES OF CONSTANT RISK.



# A Multiple-Criterion Optimization Approach for the Management of a Multispecies Fishery with Ecological and Technological Interdependencies

**Juan Carlos Seijo[a], Omar Defeo[a,b] and Anita de Alava[a] ***

[a]Centro de Investigación y de Estudios Avanzados del IPN. A.P. 73-CORDEMEX, 97310 Mérida, Yucatán, México.

[b]Instituto Nacional de Pesca, Constituyente 1497, Casilla de Correo 1612. 11200 Montevideo, Uruguay.

ABSTRACT

*Resource management decisions in multispecies fisheries with ecological and technological interdependencies, may involve additional conflicting criteria when accounting for the biomass effect of the non-targeted species. Currently, resource managers are increasingly concerned with the biodiversity effect of alternative management strategies.*

*This paper applies a multiple-criterion optimization approach as an aid to management of a multispecies sedentary mollusk fishery : the yellow clam (Mesodesma mactroides). In this fishery, there is incidental harvest of an unmarketed space competing species : the wedge clam (Donax hanleyanus). The approach includes coupling a bioeconomic simulation model with a multiple-criterion optimization algorithm. Fishery performance variables include the biomass effect on target species, fishery yield, net revenues received by fishermen, direct employment, and the biomass effect on the incidental species. Given the resource manager targets for the above mentioned performance variables, a min-max optimization strategy is used as an iterative procedure that finds the largest goal deviation and moves to minimize it. The method operates on all fishery management criteria until non-significant improvement can be made in the one with the largest target deviation vis-a-vis the fishery model response. Implicit in this condition is that at the end of the procedure, no further trade-offs are possible among goal deviations for additional reductions of the maximum goal deviation.*

*The result is an optimizing policy instrument vector. The min-max method, tends therefore to find multispecies Pareto optimal solutions. This can be a useful approach when conflicting multispecies fisheries management criteria are present, and target values in performance variables are made explicit by the decision maker.*

* We are grateful for the financial support granted by UNESCO (O. Defeo), through fellowships (Grants SC/RP 207038.0 and 267047.9) at CINVESTAV-IPN Unidad Mérida, Mexico. Financial support from the Governments of Mexico and Uruguay (O.D. and A.D.A.) is also acknowledged. Field research was supported by the Instituto Nacional de Pesca of Uruguay, Program 42/02/02/7450.

## 1. INTRODUCTION

Management of marine fisheries is significantly complicated by the fact that usually there are more than one criteria of relevance in evaluating the fishery performance. The problem is not just one of maximizing the economic rent generated by the fishery (given certain intertemporal preferences), but also of sustaining biomass of target and incidental (usually threaten) species above certain levels, and perhaps of maximizing food production, coastal employment, and export earnings. In this type of problem, decision makers must make trade-offs among conflicting criteria. Then, the goal of the optimization process must be to assist in ensuring that the best possible trade-offs are made in the given fishery management problem. This involves seeking the so-called "Pareto optimal solutions" to the multiple criterion optimization problem. A Pareto optimal solution in this context, has the property that one decision-making criterion cannot be improved by a decision without making the fishery performance worse off with respect to at least one other resource management criterion (Hannesson, 1978 ; Mendelssohn, 1979).

Optimal control theory has been applied to fisheries to identify the level of fishing effort that maximizes the net present value of economic rent in a variety of fishery contexts (Hilborn *et al.*, 1976 ; Hilborn, 1979 ; Clark, 1985 ; Cohen, 1987). Multi-criteria (Drynan and Sandiford, 1985) and/or non-linear optimization models (Agnew, 1979 ; Garrod and Shepherd, 1981 ; Kennedy and Watkins, 1986 ; Onal *et al.*, 1991) have seldom been used in fishery management. Díaz de León and Seijo (1992) developed a hybrid simulation-optimization model for the estimation of optimal management strategies of a tropical fishery that fulfill pre-existing resource manager preferences. The approach combined multi-criteria and non-linear optimization of a sequential (Willmann and García, 1985) fishery simulation model in a Pareto-optimal manner. The procedure allowed to work with multiple input-outputs, time delays, non linear functions and the natural trade-offs during the estimation process. It has been shown to be a useful decision-making aid, when explicit manager objectives are available.

The purpose of this study is to apply the above mentioned approach to a technologically and ecologically interdependent sedentary fishery, involving two intertidal mollusks of an exposed sandy beach of the coast of Uruguay : the yellow clam *Mesodesma mactroides* and its sympatric and unmarketed species : the wedge clam *Donax hanleyanus*.

## 2. RESEARCH METHODS

### *2.1 Study site and species involved*

The study was conducted on a 22 km sandy beach of the eastern coast of Uruguay comprised between Barra del Chuy (33°40'S, 53°29'W) and La Coronilla (33°50'S, 53°27'W). In this dissipative beach (*sensu* McLachlan, 1990), the yellow clam *M. mactroides* is dominant in biomass terms in the macrofauna community, being subjected to artisanal exploitation by means of simple implements such as shovels (Defeo, 1989). Another sympatric surf clam, *D. hanleyanus*, occurs in the intertidal zone of this exposed sandy beach, but in lower densities and biomass (Defeo *et al.*, 1992). Even though *D. hanleyanus* is not marketed in this area, it is also caught incidentally in this fishery and subjected to disturbance effects occasioned by fishing activities (i.e. sediment removal and resuspension). Furthermore, the observed alternance in abundance from recent long-term studies (de Alava, 1992) suggests that there are ecological interdependencies between both species.

Data was collected between March 1983 and March 1991 from 22 transects (one per km) perpendicular to the shoreline, covering ca. 200 sampling stations per season. Samples were obtained every 4 m across the beach (down to the limit of the clam bed) with a cylinder of 1/16 $m^2$ and continued in the downshore direction until at least two successive empty stations had been sampled.

The full range of sizes was covered for both species, i.e., from 1 to 76 mm for *M. mactroides* and from 1 to 30 mm for *D. hanleyanus*. In the former species, a recruit was defined as the organisms between 1 - 10 mm, and thus have been resident in the benthic population for same time. Adults were all organisms greater than 43 mm, the mean size of maturity according to Masello and Defeo (1986). In the case of *D. hanleyanus*, a recruit was defined as the organism that have attained a size comprised between 1 and 7 mm ; juveniles were considered as those included between 8 and 15 mm, the latter being the mean size at first maturity (Penchaszadeh and Olivier, 1975). Adults were all organisms greater than 15 mm.

The fishing ground was divided into four intertidal sections of similar size, with the boundaries set at right angles to the coastal line (Defeo, 1989 ; Defeo *et al.*, 1991). Population structure and abundance were examined discriminately by zones.

### *2.2 The fishery : management instruments and performance variables*

The yellow clam fishery of Uruguay has been regulated during the last few years by means of an overall catch quota, a minimum catch volume per fisherman and a minimum size regulation.

The explicit objectives of the resource management Institution have been identified as follows : (i) sustain the yield and corresponding net revenues of the fishery over time, (ii) provide employment opportunities for the artisanal fishermen of the localities of Barra del Chuy and La Coronilla, and (iii) avoid destructing resources which are incidentally caught when targeting at the yellow clam. Three management controls were selected : a) the number of authorized fishermen in each locality (Barra del Chuy and La Coronilla), b) an overall quota, and c) a minimum size restriction. The performance of the fishery system was evaluated using the following criteria : biomass of target and incidental species (ton), cumulative total catch (ton) of the yellow clam, and the economic rent obtained in each locality (US$). All variables were evaluated at the end of the season.

### *2.3 The modelling approach*

The analytic approach taken is the "min-max" optimization strategy discussed by Osycska (1984) and Manetsch (1985). The strategy involves minimizing with respect to a single criterion, namely, the maximum deviation of all fishery performance variables with respect to specific targets for each of them. The method works at the beginning with the criteria with the largest goal deviation until it no longer has the largest target deviation. Then, it proceeds to improve the next management criterion which at that point experience the worse goal deviation, and so on. The method stops when all the fishery performance criteria experience essentially the same goal deviations. M-OPTSIM (Manetsch, 1986), the optimization package used in this study, employs Box's "Complex" non-linear optimization algorithm (Box, 1965). It has proven to be an effective means of moving to the neighbourhood of the global optimum. As pointed out by Manetsch (1986), in highly complex optimization problems (such as management of ecologically and technologically interdependent sedentary fisheries), it is often difficult to locate global optimum solutions, and the method developed by Box (Kuester and Mize, 1973), is much more likely to do so than most non-linear programming methods.

A general conceptual model was built, which is composed of three blocks : the fishery model, (ii) the multi-criteria objective function, and (iii) the optimizing block that deals with the objective function, generating the optimal fishery policy vector.

### *2.4 Fishery Model*

The fishery model used is the one developed by Seijo (1986) ; Seijo *et al.* (1987) and Seijo and Defeo (this volume), expanded to consider ecological and technological interdependencies in a multispecies fishery. It is an age structured and spatial bioeconomic model designed using the systems simulation approach. The suggested ecological interaction between *M. mactroides* and *D. hanleyanus,* is that adults filter larvae out of the water column (de Alava, 1992), affecting recruitment success. The most abundant, *M. mactroides*, which have substantially larger siphons and a major filtration capacity, is assumed in this paper as the dominant competitor. Therefore, recruitment of *D. hanleyanus* is modelled through a multivariate density-dependent function which has as independent variables the density of spawning stock of *D. hanleyanus* and the density of juveniles and adults of *M. mactroides* at settlement time (de Alava, 1992).

### *2.5 The Multi-Criteria Objective Function*

Given the above mentioned model, **M**, a block diagram for the multi-criteria optimization problem which employs the Osyczka (1984) min-max strategy, is expressed in equation (1) as follows (Manetsch, 1985 ; Díaz de León and Seijo, 1992) :

$$\bar{f}_j(T) = M(\bar{\alpha}_j, T) \quad (1)$$

where :

$\bar{f}_j(T)$ = vector of values for the multi-criteria function corresponding to management option j, assessed in time horizon (0,T).

$\bar{\alpha}_j$ = decision parameter vector corresponding to the fishery management option j (j=1,2,...,J).

(0,T) = time horizon of interest for managing the multispecies fishery.

Model **M** is then operated in optimization mode as presented in Figure 1, where :

$Z_{ijk}$ = normalized deviation of the ith criterion value with respect to the management goal j and goal set k.

$\mathbf{Z_{jk}}$ can be expressed as follows :

$$Z_{jk} = MIN\,[MAX\,i\,(Z_{ijk})] \quad (2)$$

and, $\mathbf{Z_{ijk}}$ is estimated by equation (3) :

$$Z_{ijk} = \frac{(g_{ik} - f_{ij})}{|b_i|\, sgn(g_{ik} - b_i)} \quad (3)$$

where :

$g_{ik}$ = target for the ith criterion of the goal set k ($g_k$ is the target vector corresponding to the goal set k).

$b_i$ = "base" values for the ith criterion.

$\bar{\alpha}^*_j$ = parameter vector resulting from the min-max optimum $Z^*_{jk}$, $f^*_j$.

The sgn ( ) function changes the sign of $\mathbf{Z_{ijk}}$ for those goals which are less than the "base" values. This is how $\mathbf{Z_{ijk}}$ values related to different variables, different strategies and different goal sets can be compared.

The iterative procedure finds the largest deviation and minimizes it, operating on all criteria until no significant improvement can be made in the one with the largest goal deviation. The result is an optimal parameter vector. For this reason the "min-max" method tends to find Pareto-optimal solutions to the multi-criteria optimization problem.

The problem with this approach is the possibility of obtaining multiple solutions, some Pareto inferior to others. To cope with this, it was necessary to use a search procedure in an attempt to find a global optimal solution. This was achieved using the "Complex" method.

### *2.6 The Complex Optimization Method*

This method was developed by Box (1965) and applied in an enhanced manner to multi-criteria problems by Manetsch (1985, 1986). Its purpose is to find the maximum or minimum of a non-linear multivariate function subject to non-linear inequality constraints :

Objective funtion :

$$\text{Max } F\,(X_1, X_2, X_3, ..., X_n) \quad (4)$$

subject to :

$$G_i \le X_i \le H_i \text{ for } i = 1, 2, ... n..., k. \quad (5)$$

The implicit variables $X_{n+1}$, ... $X_k$ are dependent functions of the independent explicit variables $X_1$, $X_2$, ... , $X_n$, and the superior and inferior restrictions $H_i$ and $G_i$ could be either constants or independent variable functions. The method is a sequential search technique that attempts to find global optimal solutions (minima or maxima) since the initial set of

points are randomly scattered within the feasible region. Each of these sets of values corresponds to a vertex of a geometrical figure or "complex" generated in the n-dimension searching space. Associated with each vertex is a function value (calculated from the simulation model). The procedure converges towards the global optima, shrinking the search around that point (Manetsch, 1985). The problem was solved using the M-OPTSIM system (Manetsch, 1986) run on a personal computer. The solution was reached in the optimization module, calling the simulation model and the "min-max" strategy as subroutines.

## 3. RESULTS

The multiple criterion optimization approach used for this intertidal fishery was conducted for two sets of policy goals, which reflect the willingness of the decision maker to allow for tradeoffs among performance variables. These goal sets are presented in Table 1. In goal set 1, the decision maker is assumed to be willing to sacrifice biomass of the target species (*M. mactroides*) in order to increase biomass of the threatened species (*D. hanleyanus*) and economic rent perceived by fishermen of both localities. In goal set 2, the decision-maker explores the possibility of increasing the biomass of both species trying to achieve at the same time the previous level of economic rent. In order to proceed with the optimization procedure, constraints (upper and lower limits) for the policy instruments vector were specified (Table 2).

The optimized results obtained for the biologic and economic performance variables for each of the goal sets specified above, are presented in Table 3. With goal set 1, the willingness to achieve higher biomass levels in the threatened species (*D. hanleyanus*), and to increase economic rent in both localities, results in a small reduction of biomass (with respect to the base values) of the target species (*M. mactroides*). Biomass of the threatened species increases 31 %, while that of the target species decreases only 2.2 %. The economic rent obtained in each locality also increases by 17 %. The corresponding policy instrument vector involves increasing the number of fishermen, increasing the fish quota by 10 %, and a minimum size restriction of age 7 (quarters) instead of age 6. With goal set 2, the decision-maker is assumed to be willing to also increase biomass of the target species. In order to achieve the above, the optimizer selects a policy instrument vector that constraints substantially fishing effort and harvest, and further increases the minimum size restriction. This results in improvements in both levels of biomass with a substantial tradeoff in economic rent with respect to both base values and goal set 1. Optimized policy instrument vectors corresponding to each of the optimized goal sets, are presented in Table 4.

## 4. DISCUSSION

The multiple criterion optimization approach, employing min-max optimization has been found to be an effective means of generating a range of Pareto-optimal policy options which display feasible tradeoffs among economic and ecologic goals for a model of the multispecies fishery. The method allows decision making preferences and values to be incorporated explicitly by means of the goal sets specified.

The complexities of the ecological and technological interactions (Anderson, 1977) are observed in system performance when specifying goal set 1, which results in improvements in the final level of biomass of the threatened species at the cost of reducing the biomass of its dominant competitor, the target species. Here, the effect of the ecological interdependence of competitive coexistence is observed. To achieve the above, the optimizer increase the fishing pressure on the target species while increasing the minimum size restriction. It results in additional economic rent for both localities at the end of the run. The willingness to also increase the level of the target species biomass, goal set 2, results in two optimization effects. First, the level of fishing intensity is reduced (with respect to the previous goal set), which also reduces the pressure on the incidental species (technological interdependence). Second, a substantial reduction in economic rent for both localities becomes the **tradeoff**.

A number of goal sets can be explored generating a set of Pareto optimal solutions to this conflicting criteria optimization problem. To satisfy the preferences and values of those concerned with conservation of biodiversity, (and thus reducing to the maximum the threats to the incidental species), the decision-maker may have to select goal set 2, at the cost of

reducing the economic rent generated by the resource. On the other hand, the optimized solution of goal set 1, results in substantial increments in economic rent as well as in improvements in threatened species biomass, although at lower levels than with goal set 2. By selecting one or the other, the decision-maker will make also explicit its value judgements with respect to whose preferences count in the use of these renewable resources.

The approach presented here could be applied to other complex systems where conflicting criteria, and dynamic ecological and technological interdependencies are present (e.g. optimal management of transboundary resources).

## REFERENCES

**Agnew T.T.** (1979). Optimal exploitation of a fishery employing a non linear harvesting function. *Ecol. Model.* **6 :** 47-57.

**Anderson L.G.** (1977). *The economics of fisheries management.* The John Hopkins Press. Baltimore.

**Box J.M.** (1965). A new method of constrained optimization and a comparison with other methods. *Comp. J.* **8 :** 42-52.

**Clark W.C.** (1985). *Bioeconomic modelling of fisheries management.* J. Wiley & Sons, New York.

**Cohen Y.** (1987). A review of harvest theory and applications of optimal control theory in fisheries management. *Can. J. Fish. Aquat. Sci.* **44** (Suppl.2) : 75-83.

**de Alava A.** (1992). Interdependencias ecológicas entre dos bivalvos sympátricos en una playa arenosa de la costa atlántica urugaya. M. Sc. Thesis, Cinvestav México : xi + 75pp.

**Defeo O.** (1989). Development and management of an artisanal fishery for yellow clam *Mesodesma mactroides. Fishbyte* **7** (3) : 21-25.

**Defeo O., J.C. Seijo, J. Euan and M. Liceaga** (1991). Dinámica espacial del esfuerzo pesquero en una pesquería artesanal de la costa atlántica Uruguaya. *Inv. Pesq. (Chile)* **36 :** 17-25.

**Defeo O., E. Jaramillo and A. Lyonnet** (1992). Community structure and intertidal zonation of the macroinfauna in the Atlantic coast of Uruguay. *J. Coast. Res.* **8** : 830-839.

**Díaz de León A. and J.C. Seijo** (1992). A multi-criteria non-linear optimization model for the control and management of a tropical fishery. *Mar. Res. Econ.* **7** : 23-40.

**Drynan R.G. and F. Sandiford** (1985). Incorporating economic objetives in goal programs for fishery management. *Mar. Res. Econ.***2 :** 175-195.

**Eales J. and J.E. Wilen** (1986). An examination of fishing location choice. *Mar. Res. Econ.* **2 :** 331-351.

**Garrod D.J. and J.G. Shepherd** (1981). On the relationship between fishing capacity and resource allocations. In *Proceedings of a NATO Symposium on Applied Operations Research in Fishing*, ed. K.B. Haley, 321-336. Plenum Press, New York.

**Hannesson R.** (1978). *Economics of fisheries : an introduction.* Bergen-Oslo-Tromso. Universitetsforlaget.

**Hilborn R., J. Stander and W. Webb** (1976). Optimal exploitation of multiple stocks by a common fishery : a new methodology. *J. Fish. Res. Bd. Can.* **33 :** 1-5.

**Hilborn R.** (1979). Comparison of fisheries control systems that utilize catch and effort. *J. Fish. Res. Bd. Can.* **36 :** 1477-1489.

**Kennedy J.O.S. and J.W. Watkins** (1986). Time-dependent quotas for the southern bluefin tuna fishery. *Mar. Res. Econ.* **2 :** 293-313.

**Kuester J.L. and J.H. Mize** (1973). *Optimization techniques with Fortran.* McGraw Hill Book Company. New York.

**Manetsch T.J.** (1985). *Planning to meet economic and nutritional goals in developing countries. An application of multi-criteria optimization.* Unpublished manuscript, Michigan State University, East Lansing, Michigan. U.S.A.

**Manetsch T.J.** (1986). *M-OPTSIM. A microcomputer based program for system simulation and optimization.* Michigan State University, East Lansing, Michigan. U.S.A.

**Masello A. and O. Defeo** (1986). Determinación de la longitud de primera madurez sexual en *Mesodesma mactroides* (Deshayes, 1854). *Com. Soc. Malac. Uruguay* **6 :** 387-395.

**McLachlan A.** (1990). Dissipative beaches and macrofauna communities on exposed intertidal sands. *J. Coast. Res.* **6 :** 57-71.

**Mendelssohn R.** (1979). Determining the best trade-off between expected economic return and the risk of undesirable events when managing a randomly varying population. *J. Fish. Res. Bd. Can.* **36 :** 939-947.

**Onal H., B.A. McCarl, W.L. Griffin, G. Matlock and J. Clark** (1991). A bioeocnomic analysis of the Texas shrimp fishery and its optimal management. *Amer. J. Agr. Econ.* :1161-1170.

**Osyczka A.** (1984). *A multicriterion optimization in engineering.* Halsted Press, New York.

**Penchaszadeh P.E. and S.R. Olivier** (1975). Ecología de una población de "Berberecho" (*Donax hanleyanus*) en Villa Gessel, Argentina. *Malacología* **15 :** 133-146.

**Seijo J.C.** (1986). Comprehensive simulation model of a tropical demersal fishery : red grouper (*Epinephelus morio*) of the Yucatán continental shelf. Ph.D Dissertation. Michigan State University. *UMI, Dissertation Abstracts International* **47** (12).

**Seijo J.C., M. Solís-Ramírez and G. Morales** (1987). Simulación bioeconómica de la pesquería de pulpo (*Octopus maya*) de la plataforma continental de Yucatán. In *Sim. Invest. Biol. Ocean. Pesq.* ed. M. Ramírez-Rodríguez, 125-137. La Paz, B.C. México : CICIMAR.

**Willmann W.L. and S. García** (1985). A bio-economic model for the analysis of sequential artisanal and industrial fisheries for tropical shrimp (with case study of Suriname shrimp fisheries). *FAO Fish. Tech. Pap.*, N° 270, 49 p.

TABLE 1.
GOAL SETS SPECIFIED FOR THE MULTIPLE CRITERION VECTOR OF PERFORMANCE VARIABLES.

| PERFORMANCE VARIABLE | BASE | GOAL SETS 1 | 2 |
|---|---|---|---|
| Biomass of target species (ton) | 491 | 450 | 500 |
| Biomass of incidental species (ton) | 2.9 | 5 | 6 |
| Catch of target species (ton) | 50 | 75 | 50 |
| Economic rent loc 1 (US $ x $10^3$ ) | 110 | 150 | 150 |
| Economic rent loc 2 (US $ x $10^3$ ) | 110 | 150 | 150 |

TABLE 2.
CONSTRAINTS SPECIFIED FOR THE SELECTION OF THE OPTIMAL POLICY INSTRUMENT VECTOR.

| POLICY INSTRUMENT | LOWER LIMIT | UPPER LIMIT |
|---|---|---|
| Fishermen licences in loc 1 | 5 | 50 |
| Fishermen licences in loc 2 | 5 | 50 |
| Harvest quota | 25 | 100 |
| Minimum size restriction (age) | 4 | 8 |

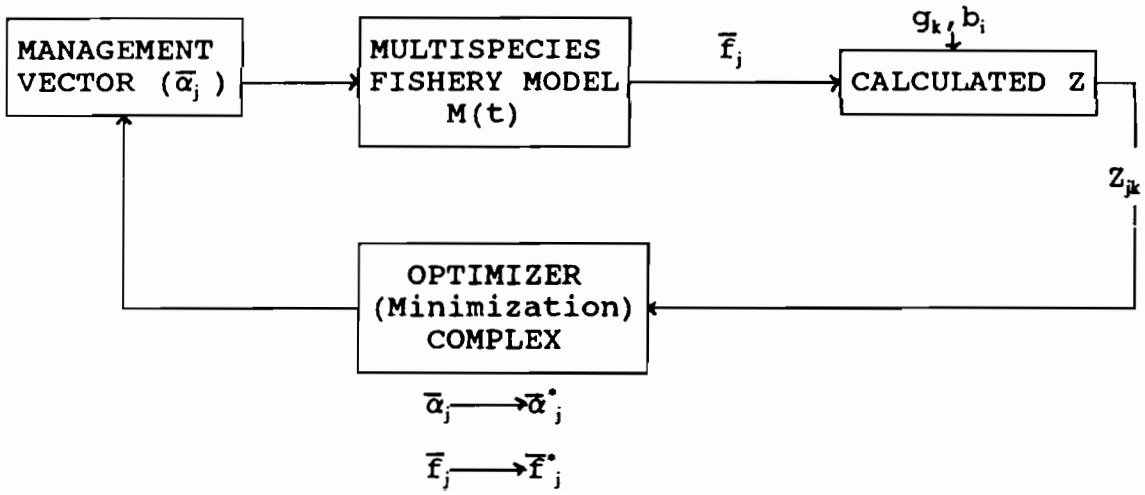
TABLE 3.
OPTIMAL LEVELS IN PERFORMANCE VARIABLES FOR DIFFERENT GOAL SETS.

| PERFORMANCE VARIABLES | BASE | GOAL SETS optimal solutions 1 | 2 |
|---|---|---|---|
| Biomass of target species (ton) | 491 | 480 | 510 |
| Biomass of incidental species (ton) | 2.9 | 3.8 | 4.1 |
| Catch of target species (ton) | 50 | 55 | 32 |
| Economic rent loc 1 (US $ x $10^3$ ) | 110 | 128.7 | 82 |
| Economic rent loc 2 (US $ x $10^3$ ) | 110 | 128.6 | 81 |

TABLE 4.
POLICY INSTRUMENT VALUES CORRESPONDING TO OPTIMAL SOLUTIONS PRESENTED IN TABLE 3.

| POLICY INSTRUMENT | BASE | GOAL SETS: optimal policy instrument 1 | 2 |
|---|---|---|---|
| Fishermen licences in loc 1 (#) | 13 | 29 | 12 |
| Fishermen licences in loc 2 (#) | 8 | 33 | 46 |
| Harvest quota (ton) | 50 | 55 | 32 |
| Minimum size restriction (age) | 6 | 7 | 8 |

**FIGURE 1.**
**BLOCK DIAGRAM FOR THE ITERATIVE OPERATION OF THE MULTISPECIES FISHERY OPTIMIZATION MODEL.**



# The Role of Multiobjective Policy Models in Fisheries and Aquaculture Development

**Gilbert Sylvia**

Coastal Oregon Marine Experiment Station, Department of Agriculture and Resource Economics,
Oregon State University, Newport, Oregon 97365

ABSTRACT

*The use of multiobjective policy models in fisheries and aquaculture are reviewed. Concepts form neo-classical economics and public choice theory are used to explore the potentials for these models under alternative theories of research management including pluralism, scientific management, and rights based approaches. Conceptual models in fisheries and aquaculture are developed to illustrate the discussion. Dynamic policy frontiers are then generated for purposes of comparative analysis. Results show that the class of multiobjective models known as multiattribute utility theory are consistent with a fisheries or aquaculture policy process characterized by principles of scientific management. Conversely, policy models based on more traditional multiobjective programming approaches are most appropriate when the policy process is driven by a pluralistic process. The paper concludes by emphasizing the role that multiobjective methods can play in moving the policy process from a scientific or pluralistic framework to one incorporating formal property rights.*

## 1. INTRODUCTION

Economists confront a wide range of issues when selecting approaches for analyzing natural resource problems. Economists must consider not only the issues which characterize the policy problem (e.g., policy objective(s), quality of the data, time horizons, budget constraints) but also their own analytical strengths and weaknesses. Often overlooked in the decision to develop the "best" approach, however, is consideration of the fundamental features which characterize both the policy process and the role which the economist plays within this process. Is the policy process orderly or chaotic ? Does it rely heavily on public participation or is it dominated by a few scientific managers ? Are economists important players in guiding and improving the process or are they merely perfunctory performers ?

These questions are particularly relevant to fisheries or aquacultural economists who work within a public policy process or "political marketplace". The "marketplace" may be bureaucratic if the management process is based on a closed system of scientific management, pluralistic if the decisions are reached through an open political process, or as is often the case, combine elements from both these approaches (Simmons and Mitchell 1984).

For most public policy problems analysts cannot use traditional market prices to capture and transmit information about the "highest valued" or "best" use(s) of the resource (the exception is where marketable property rights have been established). No well defined welfare function exists which can be "optimized" in order to determine the best set of public policies. In many cases decisions to manage and allocate are ultimately made using the "currencies" which characterize the political and bureaucratic arena - votes in the political arena, security and discretionary income within the corridors of bureaucratic management (Niskanen, 1975). The fundamental issue for policy economists is to determine the types of analytical approaches which will provide knowledge consistent with improving the performance of a "political marketplace".

The following paper discusses alternative approaches for developing economic policy information for fisheries and aquaculture. The first section of the paper reviews important features of the fisheries and aquaculture policy process. The next section reviews different classes of candidate modelling systems.

Concepts from neo-classical economics and public choice theory are used to explore the potential of these models under alternative theories of resource management including pluralism, scientific management, and rights based approaches. Conceptual applications are formulated to illustrate the discussion. Dynamic and capitalized policy frontiers are generated for purposes of comparative analysis. The paper concludes by emphasizing the role that multiobjective models can play in moving the policy process from a scientific or pluralistic framework to one incorporating formal property rights.

## 2. THE POLICY PROCESS

Economists have long recognized that natural resource problems including fisheries and aquaculture are characterized by more than one social objective (Crutchfield, 1972, Scott 1979). This feature is often reflected in the legislative mandates governing the use of these resources. For example, the U.S. Magnuson Fishery Conservation and Management Act (MFCMA) (United States Congress, 1976) stated as its primary goal to "provide for greatest overall benefits to the Nation" by realizing such objectives as "conserve the fisheries", "achieve optimum yield on a continuing basis", "promote sound conservation and management principles", "take into account the social and economic needs of the states", and "promote efficiency". Aquaculture policy includes similar objectives. For example, the Canadian government stated that their national goals for aquaculture development included "increasing economic returns", "improving the reliability of (seafood) supply", "creating new employment and enriching income possibilities," "being complementary to wild fisheries," and "encouraging sustainability" (Freshwater Fisheries Committee of Ministers, 1986).

However, while these objectives appear reasonable they may not be complementary. Increasing one objective such as regional benefits may decrease other goals such as national efficiency. The analyst, therefore, must determine the relative importance which society places on the alternative objectives. However, as articulated within the governing mandates and as interpreted by management agencies, objectives are seldom prioritized and often are too poorly defined to provide a consistent set of criteria for management purposes (Christy, 1977). Therefore, while mandates such as the MFCMA may stipulate comprehensive socio-economic analysis, they remain vague in describing how this information should be developed and measured (Jacobson et al., 1985).

Such a situation leads to socioeconomic analysis which is underfunded, ad-hoc, and crisis driven. Rather than socioeconomic information playing a significant role in guiding the fisheries policy process, the policy process itself significantly limits the extent of the socioeconomic analysis (Stokes 1983, Fricke 1985). Policymakers and other participants in the policy process are rarely provided the opportunity to carefully consider the implications of their decisions in terms of foregone social opportunities. One consequence is that policy decisions may become overtly "political" and represent only those interests which have successfully "captured" the policy process (Fricke 1985).

The marine aquacultural policy process shares many characteristics with fisheries. However, in a number of cases it may be even more complex because it occurs in an institutional setting known as "governance" (Dorcey, 1986, Hennessey and Robadue, 1986). Policy is not developed and implemented within a well ordered institutional process but evolves as multiple agencies attempt to formulate and implement policies based on vague legislative mandates. The process is characterized by extensive bargaining and the failure of the process to produce effective policies for aquaculture development is often due to the failure of the process to provide "functional" policy information, i.e., information which

demonstrates the relationships between socio- economic goals and institutional behavior (policy instruments) (Dorcey, 1986). Without this information bargaining agents cannot determine how their own goals can best be achieved "in light of agreements that appear possible and which provide benefits to all groups or result in the least costly trade-offs."

## 3. MODELING SCHEMES

Developing functional socioeconomic policy information requires sophisticated skills on the part of the policy analyst. These skills can be combined with powerful desktop computers and efficient solution algorithms. With the appropriate models, biological, economic, sociological, and regulatory information can be integrated and analyzed in a form consistent with the public policy process and guiding legislative mandates.

Sophisticated operational techniques exist to take advantage of this computational power. Although a detailed description of these techniques are beyond the scope of this paper, these techniques include multiple objective programming (Cohen and Marks, 1975), generating and goal programming (Willis and Perlack, 1980), adaptive learning (Rausser, 1978), and multilevel programming (Candler et al., 1981). While each approach (or combination of approaches) has distinct advantages, most analysts have considered multiple objective models to be superior to single objective approaches. Some analysts have also preferred multiple objective models which do not require a prior articulation of preferences, such as goal programming, since preferences are rarely known in most public policy problems. In addition, while some researchers believe that multiple objective models should simulate the bargaining process, other researchers believe that such an approach is too ideal in light of the complexity of most public policy issues (Cohon and Marks, 1975).

Some fisheries analysts, especially academic researchers, have attempted to develop formal policy models and operational programming techniques consistent with the policy process. Many of these approaches are summarized in Healey (1984) and Charles (1989). Although approaches have varied, including static and dynamic, single objective versus multiple objective, and passive versus active learning, multiobjective based techniques have received the most recent attention.While a multiple objective goal programming model has been used by Drynan and Sandiford (1985) for Scottish near-shore fishing fleets, and dynamic multiobjective programming by Charles (1989), the multiobjective approach receiving the most recent attention has been multiattribute utility analysis (MUA) (Keeney and Raiffa, 1976 ; Edwards and Newman, 1982).This technique has been applied to a number of fisheries including the New England herring fishery (Healey, 1984, 1985), the Skeena river salmon fishery (Keeney, 1977 ; Hilborn and Walters, 1977 ; Healey, 1984), the Oregon coho salmon fishery (Walker et al., 1983), and a Canadian invertebrate commercial fisheries (Boutillier et al. 1988). For aquaculture policy problems, dynamic multiobjective multilevel approaches have been developed by Sylvia (1992).

While the operational techniques related to the different multiple objective approaches vary, the modeling strategies fall into two general classes : (1) those strategies which are designed to ultimately identify a single policy optimum ; (2) and those strategies designed to identify only ranges of policy options. For most problems the first class of techniques are appropriate when the policy process is relatively well ordered, involves only a few decisionmakers, and is short-term in nature. In many cases this is consistent with a policy process driven by scientific management, i.e., a policy process which relies primarily on the decisions of a few select scientifically trained managers. This allows techniques like MUA which use multiple objective analysis, to identify the policymaker(s) derived utility function(s) through the use of strategic questionnaires and then to integrate this function with other elements of the policy problem in order to determine a single or narrow range of potentially optimal policy solutions. Note, however, that consistent with public choice theory, the utility functions generated by MUA are actually reduced form functions. The values on policy objectives generated from MUA may not represent the "true" values on the explicit policy objectives, but rather may include values on subjective goals not measured by the survey techniques. These goals may include such private objectives as increasing discretionary income or obtaining job promotions. Therefore, the derived utility function may be useful only in the short run since it will vary with respect to changes in the relationship of public policy objectives and the private welfare of the decision makers.

In contrast, approaches characterized within the second class may be more useful when the policy process is disorderly, when it involves many policy participants, and when it is characterized by extensive bargaining, i.e., a pluralistic process. Operational methods included under this approach such as generating techniques and multi-objective/multi-level programming would not be designed to determine an optimal policy position, but rather to reveal the implications of

policy options. This information would then be developed for helping decisionmakers and agency administrators explore the policy problem and structure the policy debate. The focus, therefore, is on information designed to improve the entire policy process, rather than the insular decisions of a select group of decisionmakers.

Multiobjective models also provide an important heuristic function : their operational design requires that the analyst explicitly choose which management objectives, regulatory policies, and operational constraints to include in the analysis. Their design also compels the decisionmakers and policy actors to explore important policy relationships and to recognize that selecting certain regulatory schemes implies relative values on social objectives. Finally, it forces policymakers to acknowledge the concept of policy frontiers, that is, that for any given set of relative management values, there are policy choices which can increase one objective, without necessarily decreasing the levels of other objectives.

## 4. THE DYNAMIC MULTIOBJECTIVE FISHERIES PROBLEM

Using the dynamic framework developed by Clarke and Munroe (1975), the relationship between single and multiobjective analysis for the fisheries problem can be illustrated where

$\delta$=discount rate,

h(t)=harvest level,

x(t)=stock size,

$\pi(h(t), x(t))$ = profit function [where $\pi_h > 0$, $\pi_{hh} \leq 0$, and $\pi_x > 0$, $\pi_{xx} \geq 0$],

$F(x)$ = the function describing the natural growth rate of the stock, [where $F_x \leq 0$, $F_{xx} < 0$],

and the state equation $\dot{x} = F(x) - h$.

The well known equilibrium solution to maximizing rents in the fishery is

$$F_x = \delta - \frac{\pi_x}{\pi_h}, \tag{1}$$

where at optimal equilibrium stock size (x*, h*) $F_x$, the marginal physical product of the resource stock equals the social discount rate ($\delta$) minus the "stock" effect, $\pi_x/\pi_h$.

If society's only interest, as represented by the decisions of scientific managers or the outcomes of a pluralistic processes was to maximize rents from the fishery, then the optimal stock size and harvest levels would equal x*, h* respectively. However, society could be interested in other objectives such as revenue. Such a case would occur where owners of capital live in areas distant from the location of the fishery and relatively isolated coastal communities are highly dependent on the direct and indirect income and employment impacts generated from the fishery. In this case society, through its representatives and decision makers, would be ambivalent regarding the "optimal solution" since maximizing either objective might lead to outcomes which were not considered to be in society's overall interests.

In this case, multiobjective analysis could provide information in a form consistent with the policy problem. This can be most easily demonstrated by reformulating the objective function :

$$Maximize: \int_t^{\infty} e^{-\delta t}[a\pi(x(t), h(t)) + bR(h(t))]\, dt\,. \tag{2}$$

where R(h(t)) is the revenue function and a and b are relative values on the objective of profits and revenues ($a + b = 1$ ; $0 \leq a, b \leq 1$). The Hamiltonian of the problem is :

$$H = E^{-\delta t}[a\pi(x(t), h(t)) + bR(h(t))] + \lambda(t)(F(x(t)) - h(t))\,, \tag{3}$$

where (t) is the adjoint variable or shadow price of the resource.

The optimality condition for an interior solution is :

$$e^{-\delta t} a\pi_h + bT_h - \lambda = 0\,, \tag{4}$$

the adjoint equation is equal to :

$$e^{-\delta t} a\pi_x + F_x = -\dot{\lambda} \tag{5}$$

and the transversality conditions include $e^{-\delta T} \lambda \geq 0$, $e^{-\delta T} \lambda X \geq 0$, and $H(T = \infty) = 0$. Taking the time derivative of (4), equating with (5) and substituting in for $\lambda$ from (4), and solving for long run equilibrium where $\dot{x}$ and $h = 0$ (i.e. $e^{-\delta T} \lambda X = 0$, where $T = \infty$) yields :

$$F_x = \delta - \left[ \frac{a\pi_x}{a\pi_h + bR_h} \right]. \tag{6}$$

The optimal equilibrium marginal growth rate of the stock is equal to the discount rate minus the "stock effect". The "stock effect" now includes the relative values on profit and revenues, and the marginal "supply costs" include the weighted value of marginal revenues. As the relative value on profits approaches one ($a \rightarrow 1$) and the value on revenues approaches zero ($b \rightarrow 0$) the optimal level of stock ($x^{**}$) and harvest ($h^{**}$) approaches $x^*$, $h^*$. In contrast as b1 and a0, the "stock effect" approaches zero and the marginal product of the stock approaches the discount rate, i.e. the solution where use of the resource is assumed costless.

## 5. THE MULTIOBJECTIVE MARINE AQUACULTURE PROBLEM

Similar to the fisheries case, marine aquacultural policy issues will inevitably involve multiple policy objectives. Commonly, however, the policy issues will focus on the negative externalities, rather than the positive social benefits which marine aquaculture (Sylvia, 1992) may generate. The policy problem, therefore, is to determine the effectiveness of policy instrument(s) in controlling externalities, while generating other aquaculture benefits including profits, employment, income, or consumer surplus.

For example, suppose that two primary objectives are profits and water quality. Note that in many cases the debate will focus on the amount of effluent, but not necessarily the welfare losses generated from effluent since this relationship may not be well understood. In these cases multiobjective analysis can generate values on effluent and demonstrate the costs of effluent control in terms of foregone profits, revenue, or employment (or any other positive objective that may be generated by the industry).

The aquacultural objective function may be formulated as :

$$Maximize : \int_0^{\infty} e^{-\delta t} [a\pi(Y(t), E(t)) - bE(t)]\, dt \tag{7}$$

$$\text{s.t. } \dot{E} = G(Y(t), E(t)) \tag{8}$$

where $\dot{E}$ = effluent and $G(Y(t), E(x))$ is the effluent state equation. In this case the effluent stock is increased by greater fish production ($G_y > 0$, $G_{yy} \leq 0$) but decreases due to natural physical and biological forces acting on the effluent stock ($G_E < 0$, $G_{EE} \leq 0$). The profit function is not only a function of production ($\pi_y < 0$, $\pi_{yy} \leq 0$) but also a function of effluent which is assumed to negatively impact fish growth ($\pi_E < 0$, $\pi_{EE} \leq 0$). The control variable or policy instrument is the allowable level of fish production.

The Hamiltonian is :

$$H = e^{-\delta t}(a\pi(Y(t), E(t))) - bE(h(t)) + \lambda G(Y(t), E(t)) . \tag{9}$$

The optimality condition for an interior solution is

$$e^{-\delta t} a\pi_y + \lambda G_y = 0 , \tag{10}$$

and the adjoint equation is equal to

$$e^{-\delta t} a\pi_E - e^{-\delta t} b - \lambda G_E = -\dot{\lambda} . \tag{11}$$

Using these conditions and solving for the equilibrium solution (where $\dot{Y}$ and $\dot{E} = 0$) as the ratio of relative weights or marginal social prices yields :

$$\frac{b}{a} = \pi_y \frac{(G_E - \delta)}{G_y} - \pi_{.E} \tag{12}$$

To help illustrate the solution suppose

$$\pi = pY - hY - kY^2 - qE , \qquad \text{and} \tag{13}$$

$$\dot{E} = uY - vE . \tag{14}$$

By substitution the ratio of marginal values of effluent and profit equals :

$$\frac{b}{a} = (p - h - 2kY^*) \frac{(\delta + v)}{u} - q , \tag{15}$$

or rearranging terms :

$$Y^* = \frac{p - h}{2k} - \frac{qu}{2k(\delta + v)} - \frac{b}{a}\left(\frac{u}{2k(\delta + v)}\right) , \tag{16}$$

$$E^* = \frac{u}{v} Y^* . \tag{17}$$

The optimal level of fish production and effluent is a function of the set of parameters associated with profits and the state equation, but also includes the ratio of weights on effluent and fish production. The right hand side of (16) includes three sets of terms : the first term shows the effects on optimal equilibrium production as a function of the parameters directly related to fish production ; the second term shows the indirect effects on fish production as a result of costs related to effluent production ; and the third term shows the effects on production due to the relative weights or "values" on profit and effluent. Unambiguously, as the value on effluent approaches unity (b1, a0) the equilibrium level of fish production and effluent decrease ; conversely as the value on profit increases (b0, a1) the last term in (16) vanishes and the optimal fish production equals the level which maximizes the firm's profits.

## 6. THE POLICY FRONTIERS AND THEORIES OF RESOURCE MANAGEMENT

Three types of policy frontiers are generated by parameterizing on policy weights and repetitively solving the dynamic fisheries or aquaculture multiobjective policy problem : 1) a single equilibrium frontier ; 2) a single capitalized frontier, and ; 3) a set of dynamic frontiers. These frontiers are illustrated in Figures 1-3. The capitalized frontier (Figure 1) demonstrates the highest aggregated discounted levels of achievable objectives given sets of alternative weights. Associated with each position on the frontier is a unique set of policy goals, weights, and instruments. Positions within the frontier are inferior since higher levels of either objective are possible given the admissible set of policy instruments. The equilibrium policy frontier (Figure 2), represents the combinations of objectives achievable in long run equilibrium (if an equilibrium exists). The position and shape of this frontier can be compared with solutions generated by more conventional static multiobjective programming approaches to determine how discount rates, initial conditions, and permissible approach paths affect policy goals. Figure 3 shows the dynamic frontiers, i.e., policy frontiers which shift through time. These dynamic frontiers show the combination of objectives achievable at each time period for each set of policy weights. If policy instruments are allowed to vary through time, associated with each point on each dynamic frontier is a unique set of policy instruments. If points across time periods are connected according to common weights, the dynamic changes for each set of weighted objectives can be traced out as they approach the equilibrium frontier. While Figures 1-3 show generalized frontiers, the precise shape of these frontiers will depend on the particular features of the problem, including the characteristics of the state equations, the autonomy of the problem, the degree of non-linearity in controls and states, and the initial conditions.

These frontiers can be used to illustrate the relationship between analytical approaches and alternative theories of resource management. For example, if the management process was driven by the decisions of scientific managers, multiobjective techniques such as multiattribute utility analysis could be used to identify a single position on the frontier consistent with maximizing the manager(s) utility (for example, point A). Alternatively, if management involved a small group of decisionmakers with different utility functions (represented by point A and point C), various compromising techniques could be used to reach consensus at, for example, point C (Nijkamp, 1979). In most cases, however, fisheries and aquaculture policy problems will be resolved within a process dominated by pluralism. The "best" modelling approach would not be designed to locate a single position (on the frontiers), but to demonstrate the shapes and positions of the frontiers. The information represented by these frontiers would then be used to facilitate the policy process and compel policymakers and policy actors to recognize choices which are clearly "irrational" or inferior (e.g., sacrificing "large" amounts of marginal profits to achieve "small" amounts of marginal revenue or marginal water quality ; or selecting an inferior position such as point D relative to point A in Figure 1).

## 7. THE PROBABILITY OF POLICY ADOPTION

There may be cases where policymakers believe that certain policy instruments have a low probability of adoption. For example, suppose that in our fisheries problem the probability of selecting harvest levels was a function of the associated stock size (e.g., policymakers or groups of policy actors are reluctant to select harvests levels which result in relatively "small" stock levels). Using the approach developed by Zeckhauser (1981), the dynamic multiple objective problem can incorporate these probability functions. In our generalized multiobjective fisheries problem, revenue would now be a function of stock size :

$$Maximize : \int_t^{\infty} e^{-\delta t}[a\pi(x(t), h(t)) + bR(h(t), x(t))]\, dt . \tag{18}$$

Taking the appropriate conditions and solving yields an equilibrium solution of the form :

$$F_x = \delta - \left[ \frac{a\pi_x + bR_x}{a\pi_h + bR_h} \right] . \tag{19}$$

If $\pi = ph\rho(x) - c(x)h\rho(x)$ and $R = ph\rho(x)$ where $\rho(x)$ is the probability of adopting any harvest level as a function of the stock size ($\rho_x > 0$, $\rho_{xx} \gtreqless 0$) then,

$$F_x = \delta + F\left[\frac{ac_x}{a(p-c)+bp} - \frac{\rho_x}{\rho}\right]. \tag{20}$$

For all weighted objectives the marginal growth rate of the equilibrium stock is now smaller than the case where the probabilities of adoption are not included in the analysis. The term $\rho_x/\rho$ which describes the rate of change in the probabilities of policy adoption as a function of marginal changes in stock size, causes the policy frontier to shift in. The position and shape of the new frontier would depend on how changes in the stock size affects the probability of adopting various harvest rates. This shift could be significant if policy actors including biologists were, for example, uncertain about the relationship of stock size and recruitment, or if the stock was perceived to be important to other fisheries or other species, including species which may be considered threatened or endangered.

In using a Zeckhauser approach, however, the economist, may inadvertently limit policy outcomes. The Zeckhauser approach may be valuable when the policy debate involves only a few groups or individuals, e.g., where the debate is dominated by scientific management. However, in a more pluralistic process, it may be difficult to estimate with any precision the probabilities associated with selection of policy instruments such as harvest levels, especially if the timing and availability of information can affect the policy outcome. The analyst, therefore, could ultimately affect policy outcomes by limiting the availability of the policy information.

An alternative approach more consistent with a pluralistic process would be to demonstrate to policy actors how their "attitudes" toward policy instruments could affect the potential levels of achievable policy goals. For example, if stock levels have some "value" other than for the fishery in question, this value can be expressed by expanding the multiple objective framework to include the stock level explicitly. Our multiple objective fisheries model would now take the form :

$$Maximize: \int_0^T e^{-\delta t}[a\pi(x(t), h(t)) + bR(h(t)) + cx(t)]\,dt \tag{21}$$

$$\text{s.t. } \dot{x} = F(x(t) - h(t))$$

where c is the relative value on stock (a+b+c=1 ; $0 \leq$ a, b, c $\leq 1$). Setting up the Hamiltonian and using the first order conditions yields the following equilibrium solution :

$$F_x = \delta - \left[\frac{a\pi_x + c}{a\pi_h + bR_h}\right]. \tag{22}$$

As the value on stock increases (c$\rightarrow$1, a, b$\rightarrow$0), a and b decrease and the second term on the right hand side of (22) approaches infinity. Therefore, as the value on stock increases, harvest rates decrease, stock size increases, and both profit and revenue decrease.

Including three objectives results in a three dimensional policy frontier. In two dimensions the frontier can be represented as a set of isoquants. Figure 4 illustrates the case for the capitalized policy frontier where isoquants are generated for fixed weights on stock size but varying weights on profit and revenue (this is analogous to having alternative probability distribution functions associated with harvest levels). The isoquants show the loss in revenues and profits for increasing "gains" in stocks. In this form, decisionmakers and policy actors must address the relevant tradeoffs and determine whether the marginal loss in terms of other social objectives are "worth" the gains in stock size. Therefore what was an internal issue under a Zeckhauser approach, now becomes an important economic question that can be addressed within the pluralistic public policy debate.

## 8. CONCLUSION

Multiobjective techniques applied to fisheries and marine aquaculture policy problems provide important analytical tools for broadening analysis beyond traditional cost-benefit approaches. Rather than attempting to identify a single or narrow

set of solutions for a select groups of decisionmakers, this information can provide "functional" policy information to improve the effectiveness of the bargaining process. Information can be developed in the form of dynamic and equilibrium policy frontiers which can help the managers guide the policy debate while constraining "unreasonable" policy choices.

If used effectively multiobjective approaches also have the potential for addressing management issues related to allocation of formal and informal property rights in fisheries and aquaculture.

Multiobjective analysis can help analysts uncover the implicit tradeoffs implied by initial allocation of property rights to alternative user groups. Multiobjective analysis also has the potential to help understand how different institutional arrangements can affect bid prices by focusing on the types of social returns which alternative user groups may seek to maximize.

In summary, multiobjective approaches in fisheries and aquaculture provide a valuable tool for helping decisionmakers understand the policy problem and guide the policy debate. While these approaches are characterized by the same limitations that confront all bioeconomic analysis, their most important attribute is that their structure is consistent with the nature of the policy process. These approaches can provide the analyst with important tool for addressing the difficult management issues which will confront decisionmakers in fisheries and aquaculture during the last decade of the 20th century.

## REFERENCES

**Boutillier D. N., D. Noakes, D. Heritage, and J. Fulton** (1988). Use of multiattribute utility theory for designing invertebrate fisheries sampling programs. *North American Journal of Fisheries Management* **8 :** 84-90.

**Candler W., J. Fortuny-Amat and B. McCarl** (1981). The potential role of multilevel programming in agricultural economics. *American Journal of Agricultural Economics* **63 :** 521-531.

**Charles A. T.** (1989). Bio-socio-economic fishery models : labor dynamics and multiobjective management. *Canadian Journal of Fisheries and Aquatic Sciences* **46** (8) : 1313-1322.

**Christy F.T.** (1977). The Fishery Conservation and Management Act of 1976 : management objectives and the distribution of benefits and costs. *Washington Law Review* **52 :** 657-680.

**Clarke C.W. and G.R. Munroe** (1975). The economics of fishing and modern capital theory : a simplified approach. *Journal of Environmental and Economic Management* **2 :** 92-106.

**Crutchfield J.A.** (1972). Economic and political objectives in fishery management. In : *World Fisheries Policy : Multidisciplinary Views,* ed Brian J. Rothschild, Seattle :University of Washington Press.

**Cohen J.L. and D.H. Marks** (1975). A review and evaluation of multiobjective programming techniques. *Water Resources Research* **11 :** 208-220.

**Dorcey A.H.** (1986). *Bargaining in the governance of Pacific coastal resources : research and reform.* Westwater Research Center, University of British Columbia, Vancouver B.C.

**Drynan R.G. and F. Sandiford** (1985). Incorporating economic objectives in goal programming for fishery management. *Marine Resource Economics* **2 :** 175-195.

**Edwards W. and J.R. Newman** (1982). *Multiattribute evaluation.* Sage University Papers, Series : Quantitative Applications for the Social Sciences, Sage Publications, Beverly Hills, Ca. Freshwater Fisheries Committee Ministers. 1986. National policy goals for Canadian aquaculture.

**Fricke P.** (1985). Use of sociological data in the allocation of common property resource. Marine Policy **9 :** 39-52.

**Healey M.C.** (1984). Multiattribute analysis and the concept of optimum yield. *Canadian Journal of Fisheries and Aquatic Sciences* **41 :** 1393-1406.

**Healey M. C.** (1985). Influence of fishermen's preferences on the success of commercial fishery management regimes. *North American Journal of Fisheries Management* **5 :** 173-180.

**Hennessey T. and D. Robadue** (1986). Adaptive implementation and coastal ecosystem management : the Rhode Island Coastal Resource Managment Council, 1971-1986. Paper presented to the American Political Science Association Annual Meeting, Washington D.C., August 27.

**Hilborn R. and C.J. Walters** (1977). Differing goals of salmon management on the Skeena River. *J. Fish. Res. Board Can.* **34 :** 64-72.

**Jacobson J., D. Conner and R. Tozer** (1985). *Federal fisheries management : a guidebook to the Magnuson Fishery Conservation and Management Act.* Ocean and Coastal Law Center. University of Oregon Law School, Eugene, Oregon.

**Keeney R.L. and H. Raiffa** (1976). *Decisions with multiple objectives.* John Wiley and Sons. New York, NY.

**Keeney R.L.** (1977). A utility function for examining policy affecting salmon on the Skeena river. *Journal of the Fisheries Research Board of Canada* **34 :** 49-63.

**Nijkamp P.** (1979). *Multidimensional spatial data and decision analysis.* John Wiley and Sons. London.

**Rausser Gordon C.** (1978). Active learning control theory and agricultural policy. *American Journal of Agricultural Economics* **60** (3) :476-490.

**Stokes R. L.** (1983). Fisheries economics and fisheries managament. In : *Economic Analysis for Fisheries Management Plans,* ed L. Anderson. Michigan :Ann Arbor Science Publishers.

**Sylvia G.** (1992). An economic policy model for net-pen salmon farming. In : *Economic Models for Aquaculture Development,* eds Upton Hatch and Henry Kinnucan. Westview Press, Los Angeles.

**Willis C.E. and R.D. Perlack** (1980). Comparison of generating techniques and goal programming for public investment, multiple decision making. *American Journal of Agricultural Economics* **62 :** 62-74.

**Niskanen W.R.** (1975). Bureaucrats and politicians. *Journal of Law and Economics.* Dec : 617-643.

**Scott A.** (1979). Development of economic theory on fisheries deregulation. *Journal of the Fisheries Research Board of Canada* **36 :** 725-741.

**Simmons R.T. and W.C. Mitchell** (1984). Politics and the new resource economics. *Contemporary Policy Issues* **5 :** 1-13.

**United States Congress** (1976). *Fishery Conservation and Management Act of 1976.* (PL 94-265, April 13). Washington D.C.

**Zeckhauser R.Z.** (1981). Preferred policies when there is a concern for probability of adoption. *Journal of Environmental Economics and Management* **8 :** 215-237.

**FIG. 1.**
**THE CAPITALIZED POLICY FRONTIER.**

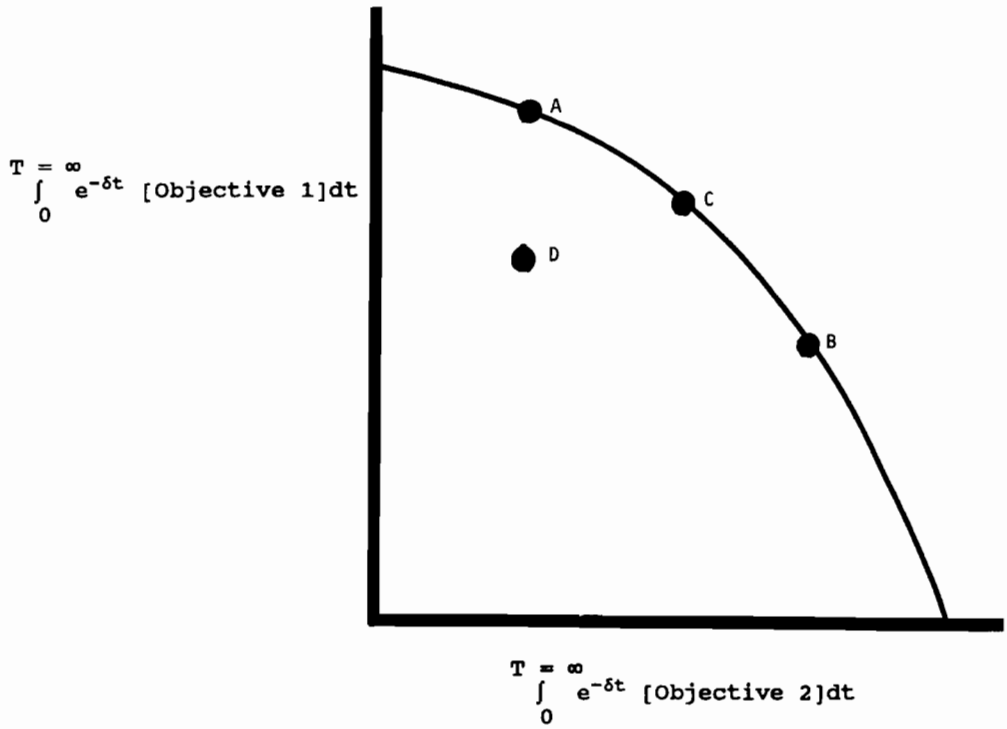



**FIG. 2.**
**THE EQUILIBRIUM POLICY FRONTIER.**

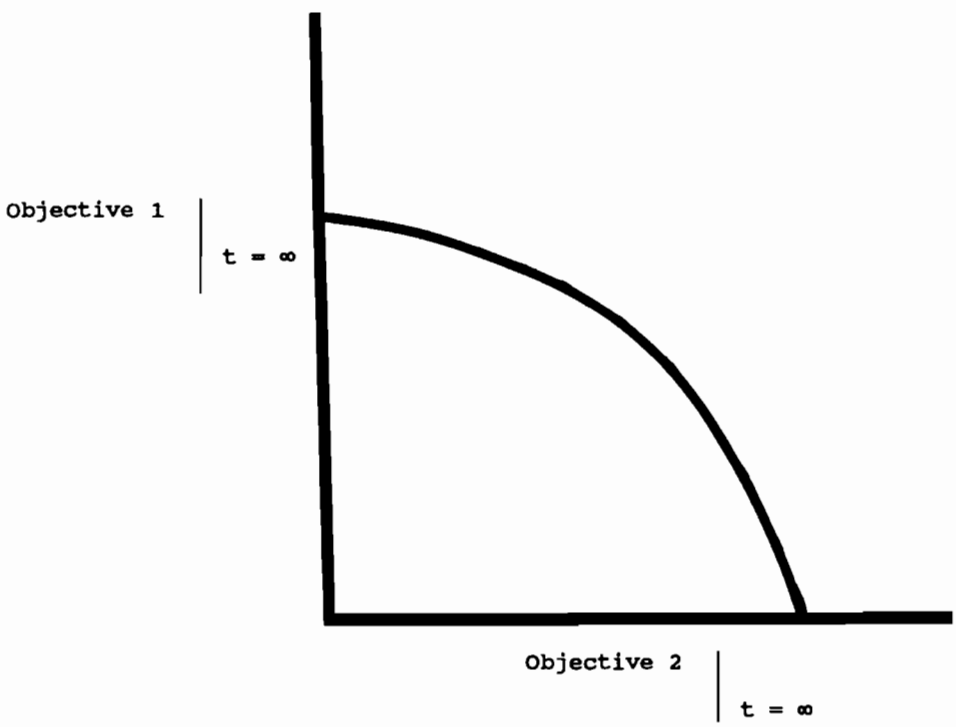


FIG. 3.
THE DYNAMIC POLICY FRONTIERS.

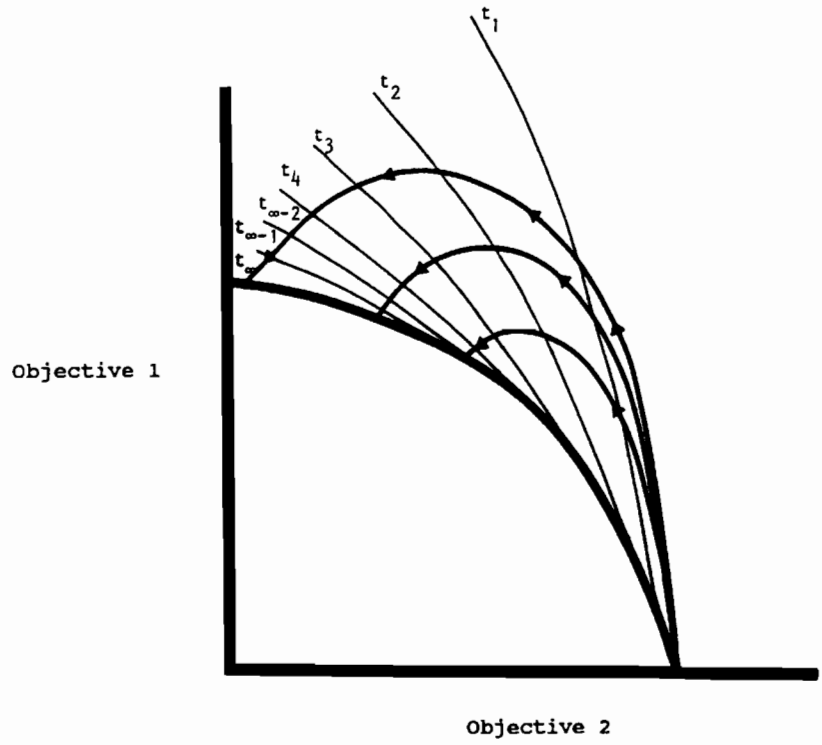
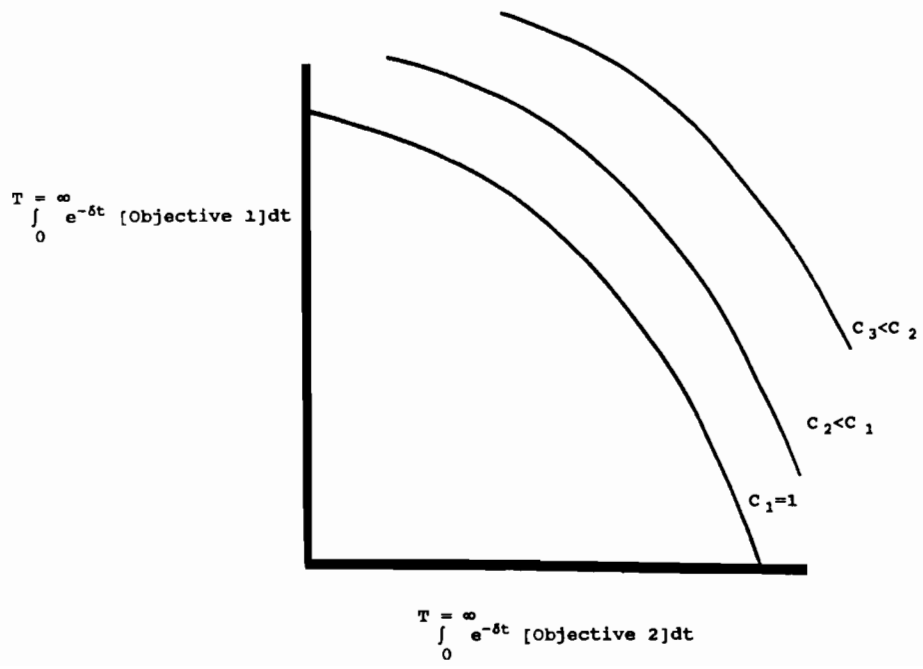



FIG. 4.
SHIFTING CAPITALIZED FRONTIERS FOR THE CASE WHERE FIXED WEIGHTS ($c_1$, $c_2$, $c_3$) ON A THIRD OBJECTIVE DECREASE IN VALUE.



# Bioeconomic Multispecies Modelling of the Barents Sea Fisheries

**Arne Eide and Ola Flaaten**

Norwegian College of Fishery Science, University of Tromsø, Breivika, N-9037 Tromsø, Norway

ABSTRACT

*The aim of this paper is to present a multispecies and multifleet model which integrates biology, harvesting, and economics. The model, ECONMULT, is designed, developed and implemented as a management tool for the Barents Sea fisheries. The economic part of the model includes several homogeneous fleet segments ; each has a specific species, or cohort, as its main target, and other species as bycatch. Fleet productivity coefficients and costs as well as ex-vessel fish prices are input data. The economic part of the model may be linked to any biological multispecies model whose stocks are described by a biomass vector. Present value of net economic benefit from different harvesting paths is computed.*

*A preliminary two-species model of cod and capelin, MULTSIMP, developed by the Institute of Marine Research, Bergen, has been used for model experiments with ECONMULT. The combined model, ECONSIMP, has been implemented on a SUN computer using Mathematica software.*

*Preliminary simulations with MULTSIMP indicate that for current Norwegian effort costs and fish prices, the combined harvesting of cod and capelin is more profitable than harvesting just one of the two species.*

## 1. INTRODUCTION

This paper describe an economic multifleet harvest industry model which together with a biological multispecies model is integrated into a bioeconomic multispecies model. This model is called ECONMULT, first outlined in Eide and Flaaten (1991) and fully documented in Eide (1991 and 1992). The bioeconomic model will be used for simulation of past and future fisheries, as well as for optimization of the fisheries. With respect to the latter point, the aim is to develop the bioeconomic model into a useful tool for fisheries management in Norway. In the design and the development of ECONMULT special consideration has been taken to the development of biological multispecies models by the Institute of Marine Researach, Bergen (IMR), to the actual structure of the Norwegian fishing fleet operating in the Barents Sea/Norwegian coast area, and to the availability of data. However, ECONMULT is designed so generally that it can be applied to other fisheries as well.

The theory of optimal management of renewable resources is fairly well developed within the single species context ; see e.g. Munro and Scott (1985) for a review of the fisheries economics litterature. Several authors have extended single species analysis to include multispecies interactions and harvesting, for example :

i) Theoretical analysis of management of competing species and predator-prey systems, e.g. Clark (1976) ch. 9, Hannesson (1983), May et al. (1979), Silvert and Smith (1977), Flaaten (1989 and 1991) and Getz (1979). The latter is especially concerned about the optimal path towards the long run steady state harvesting regime.

ii) Analysis of harvesting interactions, e.g. Clark (1976) ch. 9, Clark (1985) ch. 5, Lipton and Strand (1989) and European Communities (1987). The latter is especially concerned about particular fisheries and of assessment methods.

iii) Applied studies on interacting species, e.g. Conrad and Adu-Asamoah (1986) on competing species of tuna and Flaaten (1988) on plankton feeders-fish-sea mammals interactions.

This paper reports on applied work that include species interactions and harvesting interactions, i.e. groups b and c. Flaaten (1988) studied the Barents Sea fisheries on a highly aggregated level with a three-species model without harvesting interactions, whereas we have developed a more detailed model that allow bycatches and several vesselgroups fishing each stock. Similarities and differences in the economic solutions from the use of different types of vessels and gear are analysed, and the implications for management are derived.

The next section of this paper gives a brief review of the ecosystem of the Barents Sea. Then the ECONMULT-model is presented, followed by a section on the integration of this model with a cod-capelin testmodel, MULTSIMP, from the Institute of Marine Research, Bergen. Discussion and conclusions conclude the paper.

## 2. THE ECOSYSTEM OF THE BARENTS SEA

The Barents Sea occupies 1.405 million square km between the coast of North Norway, Svalbard, Novaja Semlja and the Murman Coast. The southwestern part of the Barents Sea never freezes to ice, and the northern and eastern parts are ice-free for part of the year.

The total number of zooplankton species of the Barents Sea is relatively few, consisting of 145 species (Zenkevitch, 1956). The copepoda make up the main zooplankton biomass : 90 % in the southwestern part of the sea. As in other seas of the world, the copepods are the basic food components for fish and other inhabitants. In addition to the zooplankton, there is another important main source of food for the fish : the benthos inhabiting the sea bottom.

There are 114 known species of fish inhabiting the Barents Sea, of which the commercially most important families are : the cod family (12 species) and the flounder (11 species). There are especially two species of zooplankton preying fish which have been of great commercial value : capelin (*Mallotus villosus*) and herring ( *Clupea harengus*). The pelagic fish species are important food sources for larger fish species, sea mammals and birds. So also is krill (*Euphauciacea*), feeding primarly at the second trophic level. In the transference of energy from phytoplankton through the food web to fish, krill is an important link (Mauchline and Fisher, 1969).

Larger fish of high commercial value are cod (*Gadus morhua*), haddoc (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*). On average for the years 1950-1990, these three species yielded approximately 90 % of the total annual catch of demersal and semipelagic species (excluding pelagic species like herring, capelin and polar cod). Other demersal species of commercial value are : red fish (*Sebastes sp.*), halibut (*Hippoglossus hippoglossus*), Greenland halibut (*Reinhardtius hippoglossoides*), plaice (*Pleuronectes platessa*). Of high-valued species, deep water prawn (*Pandalus borealis* ) and salmon (*Salmo salar*) are the most important ones.

The main food sources of cod are known consisting of small pelagic fishes such as herring, capelin, young cod, haddock and polar cod and large planktonic crustaceans. (see e.g. Zenkevitch, 1956 and Mehl, 1989).

The 7 species of seals of the Barents Sea and adjacent areas are great consumers of fish, krill, zooplankton, benthos, etc. The most important species for commercial purposes has been harp seal (*Pagophilus groenlandicus*). Its opportunistic feeding behaviour is probably a very important explanation of the large stock to be found in the Barents Sea, including the White Sea.

Fish and seals occupy the Barents Sea area all the year round, whereas 17-18 species of whales utilize the area through intensive feeding in summer. Since the early 1930s the minke whale (*Balaenoptera acutorostrata*) has been the most important commercially exploited whale species. Aslo the minke whale is an opportunistic feeder, consuming several species of fish, krill and zooplankton.

In the mid 1980s the Institute of Marine Research, Bergen (IMR), started a systematic research on multispecies interactions in the ecological system of the Barents Sea and adjacent area. The aim was to make this work an integrated part of IMR's research and to design and implement a detailed multispecies model for this area. The model, named MULTSPEC, is documented in Tjelmeland and Bogstad (1989). Even long before this particular multispecies research started, Norwegian, Russian and other scientists have investigated different parts of the Barents Sea ecological system (for references, see Flaaten, 1988). The MULTSPEC model is probably too detailed to be used for management purposes, therefore aggregated versions will be developed, and a preliminary one, MULTSIMP, already exist (Tjelmeland, 1990). The IMR's multispecies models will include (1) plankton preying species, especially capelin and herring, (2) carnivore fish species, especially cod, and (3) fish consuming sea mammals, especially harp seal and minke whale.

The economic multifleet, multispecies model presented in the following section will be integrated with one or more of the biological models from IMR, with the aim of developing better management tools for the Barents Sea fisheries.

## 3. THE ECONMULT MODEL

ECONMULT is a simulation and optimization model with several groups of homogenous fishing vessels. Each group may harvest one or more of the fishstocks and each stock includes one or more cohorts. A vector of cohort biomasses is an important interface between the biological and the economic part of the model. Alltogether there are u cohorts and s stocks, with $s \leq u$, as shown in figure 1. A fishery is defined as a combination of one vesselgroup and its main targeted fish stock. However, every cohort may in principle be caught in every fishery, either as being part of the main targeted stock or as bycatch. With m vesselgroups there are alltogether $m \cdot s$ fisheries in the model, and $m \cdot s \cdot u$ types of catches. Future extensions of the model may include geographical distribution of the fish stocks.

In figure 2 is shown a general outline of the ECONMULT-model. For a specific objective funtion the fisheries should be managed to maximize the objective. The harvest rates for the cohorts in one period will be deducted from the cohort biomasses before the start of next period. The cohort biomasses and catches thus are very important links between the biological and the economic part of the multispecies model.

In the presentation of the mathematical equations of the model the following symbols are used.

*List of variables and parameters*

| | |
|---|---|
| i | Refers to stock |
| j | Refers to vesselgroup |
| k | Refers to cohort |
| $a_{ijk}$ | Price function's constant term |
| $b_{ijk}$ | Price function's variable term constant |
| $cm_{ij}$ | Contribution margin |
| $d_{ijk}$ | Cohort's areal distribution and availability for catch |
| $e_{ij}$ | Days of fishing per vessel (fishing effort per vessel) |
| $fc_{ij}$ | Fixed costs |
| $h_{ijk}$ | Vessel catch of one cohort |
| $h_{ij}$ | Vessel catch of all cohorts in a given stock |
| $q_{ijk}$ | Catchability parameter |

| | |
|---|---|
| m | Number of vesselgroups |
| $n_{ij}$ | Number of vessels in each fishery group |
| $p_{ijk}$ | Ex-vessel price of fish |
| s | Number of stocks |
| $tc_{ij}$ | Total vesselcosts |
| $tr_{ij}$ | Total vesselrevenues |
| u | Number of cohorts in the model |
| $vc_{ij}$ | Variable vessel costs (costs per day of fishing) |
| $x_{ij}$ | Biomass of one cohort |
| C | Priceaffecting catch |
| $E_{ij}$ | Total fishingeffort of the vesselgroup |
| $H_{ijk}$ | Vesselgroup's catch of given cohort |
| $H_k$ | Total catch of cohort |
| $\alpha_{ijk}$ | Effort - output elasticity |
| $\beta_{ijk}$ | Stock- output elasticity |
| $\delta$ | Discount rate |
| $\pi_{ij}$ | Vesselprofit |
| $\Pi_i$ | Vesselgroup profit |

All the variables are related to specific periods of time. Some parameters are constants, other may vary between periods. To simplify the notation, subscripts are omitted in the equations that follow.

### *3.1 Catch*

The catch of a specific cohort in a given fishery is modelled by a Cobb-Douglas harvest function :

$$H = q\, E^{\alpha}\, x^{\beta} \tag{1}$$

where $E = n\, e$. Catch per vessel is

$$h = H/n = q\, e^{\alpha}\, n^{\alpha-1}\, x^{\beta}. \tag{2}$$

### *3.2 Price*

Ex-vessel price of fish is either constant or a linear function of a specific segment of the catch :

$$p = a - b\, C, \tag{3}$$

where C includes relevant catch of one or more cohorts from the vessels in one or more fisheries. The pricefunction may be on stock basis or on cohort basis.

### *3.3 Revenue*

The revenues of the vessels come from the sale of fish :

$$tr = p\ h \tag{4}$$

*3.4 Costs*

The harvesting costs consist of fixed costs, which is mainly capital costs, and variable costs, which are proportionate to the number of fishing days.

$$tc = fc + vc \cdot e. \tag{5}$$

This means that the average total costs of fishing effort is decreasing with increasing effort per vessel.

*3.5 Contribution margin and profit*

With constant ex-vessel prices of fish the contribution margin per vessel in a given fishery is

$$cm = p \cdot h - vc \cdot e, \tag{7}$$

and the profit is

$$\pi = cm - fc. \tag{8}$$

In case of elastic demand the constant price in equation (7) should be substituted by the price function (3).

The total profit of a given fishery is

$$\Pi = n \cdot \pi, \tag{9}$$

and the present value of the profit is

$$PV = \int_0^\infty e^{-\delta t}\, \Pi(t)dt. \tag{10}$$

*3.6 Simulation*

The fisheries of ECONMULT may be simulated by using one of the following combinations of management means :

i) fishing effort per vessel (e) and catch per vessel (h),

ii) fishing effort per vessel (e) and total catch (H),

iii) number of vessels (n) and fishing effort per vessel (e),

iv) number of vessels (n) and catch per vessel (h),

v) number of vessels (n) and total catch (H).

In the short run the number of vessels are fixed and the procedure i) or ii) may be the most relevant. In the long run, however, the number of vessels are not fixed, and the procedures iii) - v) may be more useful. The details of the simulation procedures are explained in Eide (1992).

*3.7 Optimization*

With a deterministic biological multispecies model and constant economic parameters ECONMULT as well is deterministic. This implies that long run equilibrium may be attained, with stocks of fish and number of vessels being

constant. Sustainable profit in a given fishery therefore in principal is a function of the number of vessels in all vesselgroups and fisheries. However, since only the most costeffective vesselgroup will be used to fish each stock, this fact is useful in the numerical optimization procedure described in detail in Eide (1991a). The simplest cases arise when there are no bycatches and zero discount rate. Such an example with maximization of sustainable economic rent in an applied bioeconomic model is given in the next section.

## 4. SIMULTATIONS WITH THE COD-CAPELIN MODEL ECONSIMP

The model ECONSIMP has been tested by using a simple cod-capelin model, MULTSIMP, made by IMR for experimental purposes. The integrated model is named ECONSIMP and it consist of 24 vesselgroups in the cod fisheries and 4 in the capelin fisheries. The data used for the 28 vesselgroups are given in table 1 and table 2.

### *4.1 The Multsimp model*

The biological model MULTSIMP is more aggregated than models currently used for management of the Barents Sea fisheries. Even though the MULTSIMP stocks are divided into yearclasses, catches are not. Recruitment may be deterministic or stochastic, however, in this paper only the former version is used. The recruitment of cod is constant, whereas that of capelin is an increasing, concave funtion of the spawning biomass. Agespecific individual weight for capelin is constant, while that of cod is an increasing function of the available food, the capelin biomass. For capelin the mortality is an increasing function of the predator stock, the cod biomass, while the natural mortality of cod is constant. The parameterized equations of MULTSIMP is shown below, where the following symbols are used :

| | |
|---|---|
| $N^{cap}$ | Number of capelin, in billions of individuals. |
| $N^{cod}$ | Number of cod, in billions of individuals. |
| $SB^{cap}$ | Spawning biomass of capelin, in thousand tons. |
| $R^{cap}$ | Capelin recruits, in billions of individuals. |
| $w^{cap}$ | Vector of age specific (1-5 years) capelin weights, in gram. |
| $w^{cod}$ | Individual weight of cod, in gram. |
| k | Refers to yearclass. |
| t | Refers to year. |

The recruitment of capelin is

$$R^{cap}(t) = \frac{2000.0\ SB^{cap}(t - 1)}{500.0 + SB^{cap}(t - 1)} \tag{11}$$

and the recrutiment of cod is constant :

$$R^{cod} = 0.500. \tag{12}$$

For a given yearclass of cod the number of individuals decreases over time due to constant natural mortality and fishing :

$$N^{cod}(t) = N^{cod}(t\text{-}1)\exp\text{-}[0.2 + F^{cod}(t)]. \tag{13}$$

For a given yearclass of capelin the decrease in numbers also come from predatory mortality :

$$N^{cap}(t) = N^{cap}(t\text{-}1)\ \exp\text{-}[0.636 + M^{pred}(t) + F^{cap}(t)] \tag{14}$$

where $M^{pred}(t) = 0.000325\ B_{pred}(t)$ and $B_{pred}(t)$ is the capelin eating fraction of the cod biomas, i.e. ages 3 years and above.

The agespecific weights of 1 - 5 years old capelin are constant :

f

$$w^{cap} = (3.4,\ 12.4,\ 22.8,\ 21.0,\ 21.0). \tag{15}$$

Individual weights in a given yearclass of cod depend to some extent on the availability of capelin as food :

$$w^{cod}(t) = w^{cod}(t-1)\left(1.0 + \frac{0.2(B_{prey}(t) - 4.000.0)}{4000.0}\right), \tag{16}$$

where $B_{prey}(t)$ is the eatable fraction of the capelin biomass, i.e. ages 1 year and above.

### *4.2 Simulation results*

According to the mutual agreements between Norway and the Russian Republic the Barents Sea cod stock is shared equally between them, and the capelin is shared 60-40 % in the favour of Norway. In this analysis we assume that the two parties have mutually interests and apply the same means. However, the reported figures are always that of Norway's, and we shall report on the results from 9 different simulation runs. Starting with stocklevels estimated by IMR for January 1, 1989, using reported catches for 1989, 90 and 91, the proper simulation period commences with estimated model stocks January 1, 1992 and runs for another 27 years. The number of vessels in each vesselgroup in the constant effort period are related to 1989 or 1990 figures for the cod fisheries and to 1991 for the capelin fisheries (cfr. table 1), due to the 1987-90 moratorium for the latter. The number of vessels are held constant during the 27 years simulation period, and a constant 7 % p.a. social rate of discount has been used. The effort used in each of the nine simulations and the present value of the corresponding resource rent is shown in table 3.

Of the nine simulations no. 5 gives the best economic result. This is for constant fishing effort 50 % higher than the 1990-effort for the cod fisheries and 50 % higher than the 1991-effort for the capelin fisheries. For the Barents Sea fisheries 1990 was a very bad year with no capelin quota and a record low quota of cod. It is obvious from the results in table 3 that interior solutions with simultanous fishing of cod and capelin are better than no harvesting of either of the two stocks. The worst result appear when there is no fishing of the cod stock in simulation 9, and the second worst in simulation 8 with no capelin harvest.

### *4.3 Maximizing economic rent*

Using only the bioeconomic most costeffective vesselgroups within the cod and the capelin fisheries, respectively, maximization of sustainable economic rent gives the results in table 4. Of the total profit of 1.85 billion Nkr. per year 70 % comes from the cod fishery. Increasing the price of cod 25 %, ceteris paribus, increases both the total profit and the cod fishery's share. Increasing the price of capelin, ceteris paribus,also increases the total profit compared to the basic case. In this case the optimal effort level in the capelin fishery increases 20 % and the effort level in the cod fishery increases 8 %. The latter result helps decreasing the cod stock, thus saving more of its prey, the capelin, for profitable harvesting.

## 5. DISCUSSION AND CONCLUSION

An important reason why the best result of the 9 simulations includes some harvesting of capelin, is the 100 % postspawning mortality of capelin in the MULTSIMP model. In reality some fraction of the spawning biomass is belived

to survive, but how much is disputed. In simulation 9, which is the worst case, the increased cod stock preys so heavily on the capelin that this stock is extinct with a constant fishing effort 50 % above the 1991 level. Even without harvesting of capelin the MULTSIMP model of the Institute of Marine Research is such that in the long run the capelin stock approaches zero if the cod stock is not harvested. Future biological research will probably reveal whether this is an appropriate characteristic of a cod-capelin model of the Barents Sea, or not.

Within the cod fisheries the cost effectiveness of trawl compared to other gear depend, to some extent, on the stock - output elasticities. For trawl in the Barents Sea there hardly exist significant estimates of such elasticities. In this work we have assigned trawlfishing a stock - output elasticity in between those estimated for longline and gillnet. Future work should investigate these problems more thoroughly.

The analysis of this paper has shown that whether one should harvest cod or capelin, and to what extent, depend on parameters such as the relative harvest prices of the two species. Based on another biological model Flaaten (1988) came to a similar result, in addition to the conclusion that harvesting sea mammals contribute significantly to the profitability of the cod and the capelin fisheries. Together, these works indicate that to maximize total profit from the fisheries the managers should encourage relatively weaker exploitation of capelin than of cod. However, one should not put too much emphasis on fine tuning the relative rate of exploitation before more reliable bioligical models are developed and implemented. Since some species of seals and whales are important predators on and competitors to fish in the Barents Sea, these stocks will be included in the coming models from the Institute of Marine Research, and in our bioeconomic research.

## REFERENCES

**Anon** (1989). Aktivitets- og strukturanalyse for fiskefartøyer 13 m l.l.og over, 1987. Fiskeridirektoratet. Bergen.

**Anon** (1990). Ressursoversikt 1990. *Fisken og Havet, særnummer 1,* 1990. Havforskningsinstituttet, Bergen.

**Clark C.W.** (1976). *Mathematical bioeconomics : the optimal management of renewable resources.* (Second edition 1990). New York. John Wiley & Sons.

**Clark C.W.** (1985). *Bioeconomic modelling and fisheries management.* New York - Singa pore. John Wiley & Sons.

**Conrad J.M. and R. Adu-Asamoah** (1986). The case of tuna in the Eastern Tropical Atlantic. *Journal of Environmental Economics and Management,* Vol.13, pp.50-68.

**Eide A.** (1991). ECONSIMP, Econmult-beregninger basert på biologimodellen Multsimp. Arbeidsnotat, 6.6.1991. Norges Fiskerihøgskole. Tromsø.

**Eide A.** (1991a). Optimalisering i ECONSIMP (in Norwegian). Norges Fiskerihøgskole, Universitetet i Tromsø, Desember, 1991.

**Eide A.** (1992). *Econmult 3.0,* Manual (in Norwegian). Tromsø. Norges Fiskerihøgskole, Universitetet i Tromsø.

**Eide A. og O. Flaaten** (1991). ECONMULT ver.2.1. Et utkast til modelldesign. NFFR's Flerbestandsprogram/Norges Fiskerihøgskole. Bergen/Tromsø. SEFOS.

**European Communities** (1987). *Assessment of technical interactions in mixed fisheries.* Commission of European Communities. Brussels.

**Fasmer E.** (1990). Inntekter og kostnader for norske fiskefartø yer etter redskap. Budsjettne mndas sesongdata for 1989. FTFI-arbeidsnot at, økonomigru ppen, Bergen.

**Flaaten O.** (1988). *The economics of multispecies harvesting - theory and application to the Barents Sea fisheries.* Studies in Contemporary Economics. Berlin - Tokyo. Springer-Verlag.

**Flaaten O.** (1989). The economics of predator-prey harvesting. In : *Rights Based Fishing* (eds. P.A.Neher, R.Arnasson and N.Mollett) 485-503. Dortrecht-London. Kluwer Academic Publ.

**Flaaten O.** (1991). Bioeconomics of Sustainable Harvest of Competing Species. *Journal of Environmental Economics and Management,* **20** : 163-180.

**Getz W.M.** (1979). On harvesting two competing populations. *J. Optim. Theory Appl.* **28** (4), 585-602.

**Hannesson R.** (1983a). Optimal harvesting of ecologically interdependent species. *Journal of Environmental Economics and Management,* **10**, 329-345.

**Lipton D.W. and I.E. Strand, Jr.,** (1989). The effect of common property on the optimal structure of the fishing industry. *Journal Environmental Economics and Management* **16,** 45-51.

**Mauchline J. and L.R. Fisher** (1969). The biology of euphausiids. *Adv. in Mar. Biol.,* Vol. **7**, *1-454.*

**May R.M., J.R. Beddington, C.W. Clark, S.J. Holt and R.M. Laws** (1979). Management of Multispecies Fisheries. *Science,* Vol. **205** : 267-277.

**Mehl S.** (1989). The Northeast Arctic cod stock's consumption of commercially exploited prey species in 1984-1986. Rapp. *P.-v. Reun. Cons. Int. Explor. Mer,* **188 :** 185-205.

**Munro G.R. and A.T. Scott** (1985). The economics of fisheries management. In A.V. Kneese and J.L. Sweeney (eds) : *Handbook of Natural Resource and Energy Economics.* Amsterdam. Elsevier Science Publishers B.V.

**Silvert W. and W.R. Smith** (1977). Optimal exploitation of a multi-species community. *Mathematical Biosciences,* Vol. **33** : 121-134.

**Tjelmeland S.**(1990). MULTSIMP : A simplified multispecies model for the Barents Sea. Working paper. Institute of Marine Research. Bergen.

**Tjelmeland S. and B. Bogstad** (1989). MULTSPEC : The manual. Institute of Marine Research. Bergen.

**Zenkevitch L.** (1956). 1963 : *Biology of the seas of the USSR.* London. George Allen & Unwin Ltd.

**TABLE 1.**
**DATA USED IN ECONSIMP. VESSELGROUPS NO. 23, 26, 27 AND 28 ARE IN THE CAPELIN FISHERIES, AND ALL OTHERS ARE IN THE COD FISHERIES.**

| Vessel group no. | Type of gear | Vessel length (m o.a.l.) | Number of vessels 1989[a] | 1990[b] | 1991[c] | Catchbility coefficient[d] ($q \cdot 10^3$) | Stock-output elasticity[e] ($\beta$) | Season length[f] (days) | Fixed seasonal costs[g] (N.kr.) | Variable costs[g] (N.kr./day) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Gillnet | < 16.0 | 750 | 650 | 650 | 0.0034 | 0.73 | 100 | 109530 | 649 |
| 2 | Gillnet | 16.0 - 18.0 | 150 | 130 | 130 | 0.0071 | 0.73 | 87 | 155410 | 1527 |
| 3 | Gillnet | 19.0 - 21.9 | 76 | 76 | 76 | 0.0126 | 0.73 | 99 | 331967 | 2164 |
| 4 | Gillnet | 22.0 - 24.9 | 34 | 34 | 34 | 0.0137 | 0.73 | 91 | 422898 | 2430 |
| 5 | Gillnet | 25.0 - 30.9 | 20 | 20 | 20 | 0.0130 | 0.73 | 85 | 371358 | 3526 |
| 6 | Longline | < 16.0 | 184 | 130 | 130 | 0.0701 | 0.35 | 99 | 129961 | 1707 |
| 7 | Longline | 19.0 - 21.9 | 20 | 20 | 20 | 0.0998 | 0.35 | 66 | 224243 | 4004 |
| 8 | Autolongline | < 16.0 | 8 | 8 | 8 | 0.0657 | 0.35 | 110 | 201384 | 973 |
| 9 | Autolongline | 16.0 - 18.9 | 6 | 6 | 6 | 0.1382 | 0.35 | 34 | 127172 | 3040 |
| 10 | Autolongline | 31.0 - 36.9 | 82 | 82 | 82 | 0.2962 | 0.35 | 48 | 375458 | 6997 |
| 11 | Autolongline | 37.0 - 42.9 | 26 | 26 | 26 | 0.3462 | 0.35 | 56 | 644672 | 7314 |
| 12 | Danish seine | < 16.0 | 120 | 90 | 90 | 0.0236 | 0.44 | 80 | 99902 | 686 |
| 13 | Danish seine | 16.0 - 21.9 | 64 | 60 | 60 | 0.0441 | 0.44 | 87 | 155125 | 815 |
| 14 | Danish seine | 19.0 - 21.9 | 48 | 48 | 48 | 0.0558 | 0.44 | 83 | 239036 | 1732 |
| 15 | Danish seine | 22.0 - 24.9 | 20 | 20 | 20 | 0.0504 | 0.44 | 80 | 257880 | 1321 |
| 16 | Danish seine | 25.0 - 30.9 | 4 | 4 | 4 | 0.0474 | 0.44 | 82 | 220735 | 1336 |
| 17 | Bottom trawl | 22.0 - 30.9 | 5 | 5 | 5 | 0.0688 | 0.50 | 87 | 320073 | 2099 |
| 18 | Bottom trawl | 25.0 - 30.9 | 9 | 5 | 5 | 0.0905 | 0.50 | 61 | 342035 | 3336 |
| 19 | Bottom trawl | 31.0 - 36.9 | 9 | 5 | 5 | 0.1991 | 0.50 | 86 | 1300428 | 7272 |
| 20 | Bottom trawl | 37.0 - 42.9 | 10 | 5 | 5 | 0.2593 | 0.50 | 47 | 748695 | 13571 |
| 21 | Bottom trawl | 43.0 - 48.9 | 10 | 6 | 6 | 0.2771 | 0.50 | 207 | 3444489 | 14525 |
| 22 | Bottom trawl | > 48.9 | 9 | 5 | 5 | 0.4847 | 0.50 | 290 | 1126376 | 26234 |
| 23 | Purse seine | > 48.9 | 0 | 0 | 103 | 1.6667 | 0.50 | 30 | 689772 | 10319 |
| 24 | Hand-line | < 16.0 | 620 | 500 | 500 | 0.0151 | 0.44 | 84 | 62053 | 353 |
| 25 | Hand-line | 16.0 - 18.9 | 12 | 12 | 12 | 0.0092 | 0.44 | 105 | 82623 | 431 |
| 26 | Pelagic trawl | 43.0 - 48.9 | 0 | 0 | 33 | 1.0100 | 0.50 | 40 | 212283 | 2576 |
| 27 | Purse seine | 19.0 - 21.9 | 0 | 0 | 36 | 0.5000 | 0.50 | 40 | 89102 | 18 |
| 28 | Purse seine | 22.0 - 24.9 | 0 | 0 | 36 | 0.4000 | 0.50 | 40 | 139424 | 1583 |

a. Calculated from Anon. (1989).
b. Calculated using catch data from 1990 (Anon., 1990), assuming the catch efficiency of each vessel to be the same as in 1989.
c. Reported number of vessels in vessel group no. 23, 26, 27 and 28. The number of vessels of the other groups are assumed to be the same as in 1990.
d. Calculated using the catch, and stock size of 1989 (Anon., 1990) and the effort (number of vessels in 1989 multiplied with season length) and the stock-output elasticity of this table.
e. The stock-output elasticity of trawl and purse seine fishing is assumed to be 0.50. The other values are from Flaaten (1987).
f From Fasmer (1990).
g. Calculated from Fasmer (1990), using the calculation procedure of Eide and Flaaten (1991).

**TABLE 2.**
**EX-VESSEL PRICES OF FISH (NKR/KG, 1989 PRICES).**

| Type of fishery and | | Vesselgroups no. | Price (Nkr./kg) |
|---|---|---|---|
| Cod fisheries | Other gear | 1 - 16, 24, 25 | 7.26 |
| | Bottom trawl | 17 - 22 | 4.73 |
| Capelin fisheries | | 23, 26 - 28 | 0.60 (for consumption) |
| | | | 0.43 (for reduction) |

**TABLE 3.**
**NINE SIMULATIONS WITH 27 YEARS CONSTANT FISHING EFFORT, IN NUMBER OF VESSELS, AND OUTCOME, IN PRESENT VALUE OF RESOURCE RENT, FROM 30 YEARS OF FISHING.**

| Simultation no. | Number of vessels 1992 - 2021 | | 1989 present value of resource rent (Billion N.kr.) |
|---|---|---|---|
| | The cod fisheries | The capelin fisheries | |
| 1 | as in 1990 | as in 1991 | 15.886 (3) |
| 2 | as in 1989 | as in 1991 | 15.751 (4) |
| 3 | as in 1990 | Purse seine as in 1991, summer fishing | 14.651 (5) |
| 4 | as in 1989 | Purse seine as in 1991, summer fishing | 14.102 (6) |
| 5 | as in 1990 + 50% | as in 1991 + 50% | 16.605 (1) |
| 6 | as in 1990 + 50% | Purse seine as in 1991, + 50% summer fishing | 13.899 (7) |
| 7 | as in 1990 | as in 1991 + 50% | 16.441 (2) |
| 8 | as in 1990 + 50% | Nil | 12.443 (8) |
| 9 | Nil | as in 1991 + 50% | 3.220 (9) |

**TABLE 4.**
**RESULTS OF MAXIMIZING TOTAL SUSTAINABLE ECONOMIC YIELD IN ECONSIMP.**

| | | Basic case 1989-prices | Basic case +25% increase in cod price | Basic case +25% increase in cape-lin price |
|---|---|---|---|---|
| Effort (in % of basic case) | Fishing for spawning capelin | 100 | 88 | 120 |
| | Cod-gilnet fishing | 100 | 100 | 108 |
| Profit (Billion Nkr) | Total | 1.85 | 2.52 | 2.09 |
| | Cod-gillnet fishing | 1.28 | 2.01 | 1.14 |
| Stock level (Thous. tons) | Capelin | 3897 | 4034 | 3963 |
| | Cod | 2297 | 2358 | 2032 |
| Harvest (Thous. tons) | Capelin | 1473 | 1315 | 1778 |
| | Cod | 364 | 367 | 358 |

**FIGURE 1.**
**THE RELATIONSHIP BETWEEN THE ECONMULT-CONCEPT OF STOCK AND COHORTS. THE NUMBER OF COHORTS IN EACH STOCK MAY VARY.**

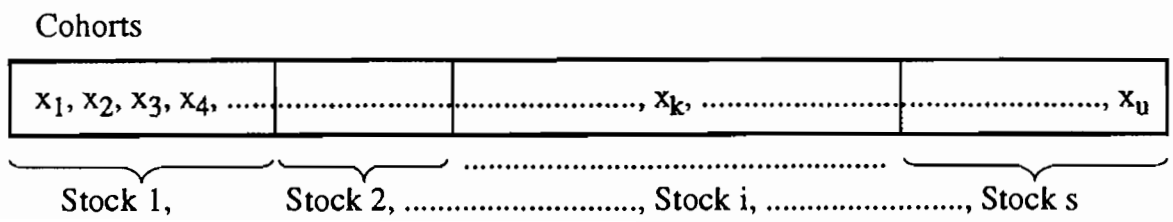
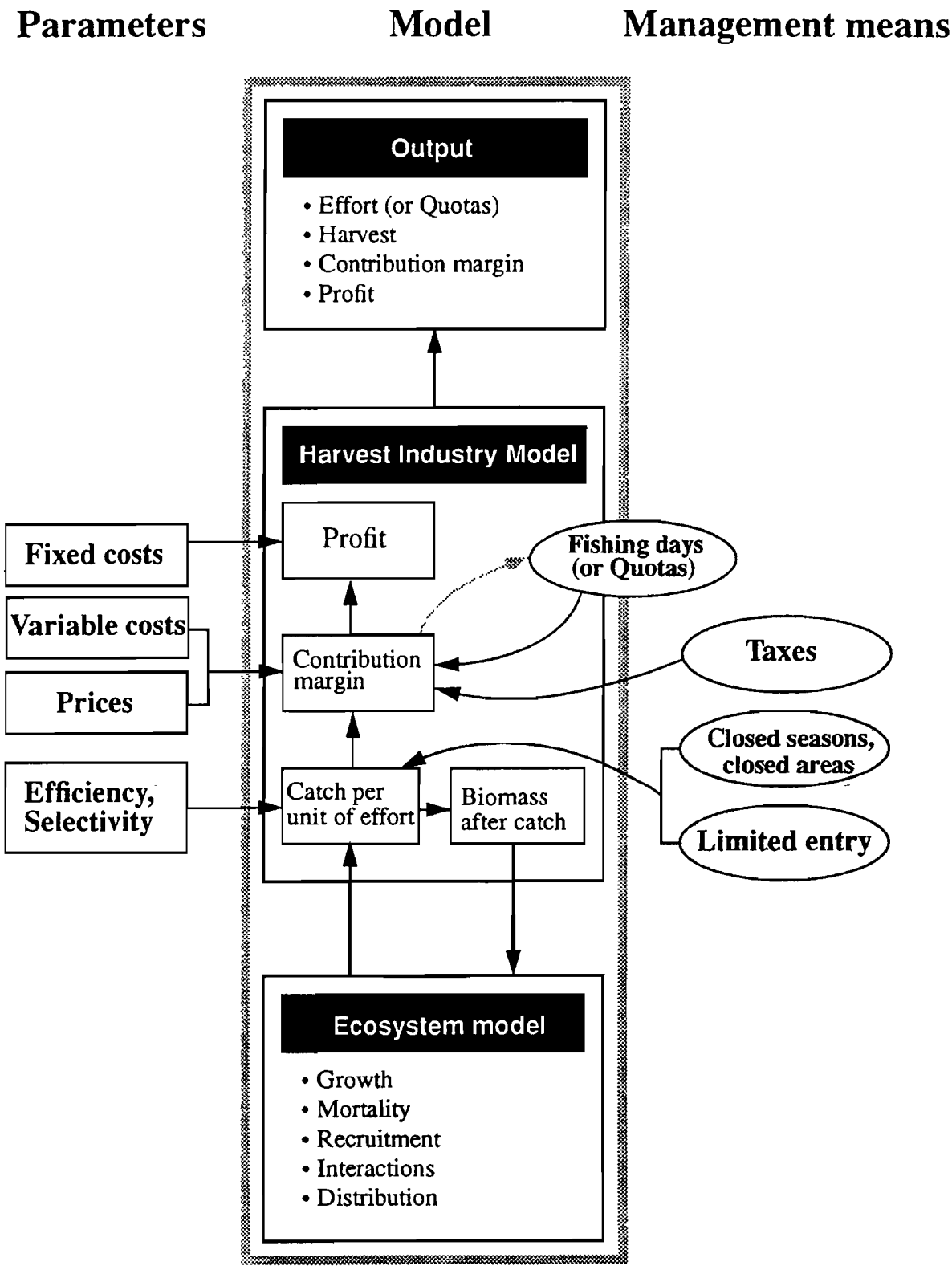


FIGURE 2.
THE STRUCTURE OF THE ECONMULT MODEL.



# A Bioeconomic Model for Fish Harvest Technology

**David B. Sampson***

Oregon State University, Coastal Oregon Marine Experiment Station, Newport,
Oregon 97365, United States of America

ABSTRACT

*The catches and profits in a fishery depend on the technology employed, on the utilization of human and capital resources, on the abundance and distribution of the fish stock, and on the prices for fish, fuel, and labor. Here a harvest function is constructed that includes parameters for the main technical components of the fishing process : travel to the fishing grounds, catching fish, and handling those that have been caught.*

*The fishery system does not have the same sensitivity to each technical parameter. Furthermore, small changes in a parameter can result in catastrophic alteration of the system's dynamics. Fishing technology in part determines the behavior of the fishery system ; the technology in turn evolves in response to changes in the fishery. It is argued that fishing technology will tend to evolve more rapidly in those components that have the greatest impact on the flow of fishing profits.*

## 1. INTRODUCTION

During this century there have been dramatic improvements in the methods used for harvesting fish. However, the literature on fisheries economics gives little regard to the technical details of the fishing process and their influence on the dynamics of fishery systems. The yield from a fishery depends in general on the fishing technology, the rate of application of human and capital resources, and the current size of the fish stock. Most fisheries models incorporate these

* This paper is the result, in part, of research sponsored by Oregon Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, under grant no. NA89AA-D-SG108 (project no. R/ES-16) and from appropriations made by the Oregon State Legislature. The U.S. Government is authorized to produce and distribute reprints for governmental purposes, notwithstanding any copyright notation that may appear hereon.

elements into a production or harvest function that links the economics of fishing with the population dynamics of the fish. Fishing technology influences the behavior of the system through the harvest function. The status of the system, in turn, determines the suitability of different technologies.

In this paper I construct a harvest function that explicitly includes parameters for the three major technical components of the fishing process and I show that these different components do not exert the same influence on the stability and dynamic behavior of the fishery system. My objective is to develop a framework for examining the evolution of fishing technology and fishery systems. For a given set of conditions, what forms of technological change have the greatest impact on profitability ?

## 2. A GENERALIZED HARVEST FUNCTION

The harvest function in a bioeconomic model of a fishery should account for the full variety of human activities required for the production of catches of fish. In most fisheries the basic time span of the production cycle is the fishing trip (Doll, 1988), and each trip involves three distinct activities : traveling to and from the fishing grounds, operating the fishing gear on the grounds, and handling the catch. Improvements in fishing technology can affect any or all of these activities.

Consider the catch that accumulates while a fisherman deploys his gear on the fishing grounds. Assume that the fish encounter the gear randomly and that the encounter rate is jointly proportional to the number of fish near the gear and to the amount of time spent fishing. During the short interval of a fishing trip the average the number of fish caught is given approximately by

$$C_N \approx N \cdot q \cdot tF,$$

where N is the number of fish initially available to the gear, q is a technical parameter that measures the instantaneous probability of capturing a particular fish (the catchability coefficient), and tF is the amount of time the gear is fishing. This is a simplified version of the standard catch equation of fisheries (Gulland, 1983). If the diffusion of individual fish on the grounds is sufficiently rapid, then the number of fish within range of the gear and the catch rate at any particular location are both proportional to the total stock of fish on the grounds (Sampson, 1991a).

The definition of time spent fishing (tF) depends on the type of fishing technology. For trawl fisheries it is the amount of time the net drags through the water. For purse seine fisheries it is the time spent searching for suitable schools of fish. For a hook and line fishery it is the time a baited hook is in the water. Similarly, the meaning of the catchability coefficient (q) also differs with the type of technology. With a trawl it corresponds to the rate at which the net strains water. With a purse seine it is a measure of the fisherman's proficiency at locating fish schools. For a hook and line fishery it corresponds to the ability to attract and hook a fish.

The equation above ignores some important activities : fishermen spend time traveling to and from the grounds ; they spend time handling and processing their catch. For convenience let the term "travel" refer to those activities whose duration is independent of the size of the catch ; e.g., travel, vessel maintenance, sleeping and eating ; and let the term "handling" refer to those activities that inhibit the catch of additional fish and whose duration is proportional to the size of the catch ; e.g., sorting and icing the catch from a trawl, pumping out a purse seine, or removing fish from the hooks of a longline.

Let tF denote the time spent fishing, let tH denote the time spent handling the catch, and let tO denote travel time and all other time expenditures. The total duration of a fishing trip is

$$T = tF + tH + tO.$$

Note that the different activities do not occur simultaneously. This time partitioning is inappropriate for fishing operations in which the catch is taken by unattended gear, e.g., the trapping of lobsters or the capture of salmon in weirs.

The average number of fish caught during a trip is approximately equal to $N \cdot q \cdot tF$ ; if different sized fish are equally vulnerable to capture, then the weight of the catch is

$$C \approx B \cdot q \cdot [T - (tH + tO)],$$

where B is the biomass of the fish stock on the fishing grounds (N times the average weight of a fish). If each unit of fish biomass that is caught requires a handling time of h, then the total time spent handling the catch is tH = C . h and

$$C \approx B \cdot q \cdot [T - tO] / [1 + B \cdot q \cdot h].$$

Let $\tau$ be the ratio tO/T and let T shrink to zero. This results in a differential equation that describes the instantaneous catch rate for a single fishing operation,

$$dC = \frac{B \cdot q \cdot (1 - \tau)}{1 + b \cdot q \cdot h}.$$

If there are E independent and identical fishing operations, which act concurrently, competitively, and without interference, then the total catch rate by the fleet (the yield) is

$$Y = dC \cdot E = \frac{B \cdot q \cdot (1 - \tau)}{1 + B \cdot q \cdot h} \cdot E.$$

This form of equation, with $\tau = 0$, has been used for modeling the capture of schooling fish (Paloheimo and Dickie, 1964), for modeling whaling operations (Beddington, 1979a), and for modeling hook and line angling (Deriso and Parma, 1987).

The graph of catch rate as a function of fish biomass is a rectangular hyperbola (Figure 1, upper panel). Catch rate increases with increasing biomass, but at a decreasing rate. The catch rate per vessel has a slope of $q \cdot (1 - \tau)$ at the origin, and it approaches $(1 - \tau)/h$ at high levels of abundance. Changing the number of fishing operations alters the scale of the vertical axis, but does not otherwise affect the shape of the curves.

Parameters q, $\tau$, and h characterize the fishing technology, but each has a different effect on the relationship between catch rate and fish biomass. Parameter h exerts a major influence over the asymptotic catch rate. Parameter q determines the rate of approach to the asymptotic catch rate. Parameter $\tau$ modifies both the level and the rate of approach to the asymptote.

## 3. A STATIC EQUILIBRIUM ANALYSIS

Assume that the fish stock's biomass dynamics are governed by logistic growth and that, in the absence of fishing, the stock's instantaneous growth rate is given by

$$G = r \cdot B \cdot (1 - B/K),$$

where r is the intrinsic growth rate and K is the environmental carrying capacity (Schaefer, 1954 ; Pielou, 1974). The exploited fish stock will be at equilibrium if the rate of removals by the fishery exactly balances the stock's natural growth. The lower panel of Figure 1 illustrates this by the points of intersection between the growth curve and the different yield curves. Notice that the fishery system can develop an unstable equilibrium if there are enough active fishing vessels in the fleet. At such an unstable point of equilibrium any perturbation to the fish biomass will force the stock either to the origin and extinction, or towards the other stable point of equilibrium.

The instability in this fishery system is a direct consequence of the curvature in the yield function. Several authors have discussed this system and its properties (e.g., Beddington, 1979b ; Condrey, 1984 ; Clark, 1985). However, in order to understand fully this system's behavior we need to consider the dynamics of the fishing fleet (below).

## 4. THE SHORT-RUN ECONOMICS OF FISHING

In the shortrun the captain of a fishing vessel cannot readily alter the technical characteristics embodied in his vessel and gear. Instead, the captain controls the production process by deciding whether or not to go fishing. We can expect that he will not knowingly engage in fishing if he will lose money by doing so. Unless the revenues generated by a fishing trip exceed the costs of making the trip, no fishing will occur.

We can use the harvest function to construct an equation for the flow of fishing revenues. However, it is more problematic to derive an equation for the flow of fishing costs. Although there are numerous published accounts from cost and earning surveys, there have been few detailed studies of the factors that determine fishing costs. As a consequence, it is difficult to assess the suitability of any particular cost function. If fish density varies with distance from port, then the most profitable distance for fishing depends on fish abundance and fish price, and the flow of fishing costs changes with variation in either of these external variables (Sampson, 1992, 1991b).

For simplicity assume that operating costs (e.g., wages, food, and fuel) are incurred whenever a fishing trip is made and that the flow of these costs is constant. These operating costs, although fixed per trip, only accrue if a trip is made ; they are the variable costs of production. Also assume the following : (1) the members of the crew receive a share of the catch in addition to their wages ; (2) the captain of the fishing vessel is also its owner ; (3) the captain pays the operating costs from his share of the catch ; and (4) each captain must accept the going price for fish. Given these assumptions, the flow of net income to the captain is described by

$$I = p \cdot (1 - S) \cdot dC - oc$$

where p is the price for fish, 1 - S is captain's share of the catch, and oc is the rate of flow of the operating costs.

Unless the flow of net income is positive, the captain will not operate his vessel. As a consequence, for a given level of fish biomass, the price for fish must be greater than some minimum supply price or the vessel stays in port,

$$p_{min} = \frac{oc \cdot (1 + B \cdot q \cdot h)}{(1 - S) \cdot (1 - \tau) \cdot B \cdot q}$$

Alternatively, for a given price for fish, the biomass of the fish stock must exceed the minimum economic biomass or fishing will not occur,

$$B_{min} = \frac{oc}{q \cdot [p \cdot (1 - S) \cdot (1 - \tau) - h \cdot oc]}$$

The upper panel of Figure 2 illustrates these relationships.

Provided the price for fish is greater than the minimum supply price, the captain goes fishing and supplies fish at a rate determined by the level of fish biomass. The short-run supply curve is perfectly inelastic (Doll, 1988).

## 5. THE LONG-RUN ECONOMICS OF FISHING

There are several important long-run features of a fishery for which the short-run model makes no provision. Fishing operations must pay the fixed costs of the vessel. The captain may be able to modify the technical characteristics of his operation. The number of active fishing vessels may change in response to variations in profitability.

The profit flow to the captain is given by

$$\pi = \begin{cases} -fc & \ldots \text{ if } p < p_{min}, \\ I - fc & \ldots \text{ otherwise}, \end{cases}$$

where fc is the flow of fixed costs, the sum of all the fixed costs divided by the vessel's working lifespan. If the fish price is less than the minimum supply price (and B < Bmin), then the captain does not go fishing and losses accrue at the rate of flow of the fixed costs. If the price for fish is greater than the minimum supply price (and Bmin < B), then the captain makes a profit (or loss) at a rate equal to the difference between the flow of net income and the flow of fixed costs. Profit flow is zero when the fish biomass is at the break-even biomass level,

$$BB = \frac{oc + fc}{q \cdot [p \cdot (1 - S) \cdot (1 - \tau) - h \cdot (oc + fc)]}.$$

Given a fixed price for fish, the profit flow per vessel varies with the fish stock's biomass (Figure 2, lower panel). If fish biomass is greater than the break-even level, participating vessels will make super-normal profits which will encourage others to join the fishery. If fish biomass is less than the break-even level, vessels will incur losses and some will leave this fishery and find alternative employment. If the fish stock is at the break-even level, the fleet will be at equilibrium.

## 6. THE DYNAMICS OF THE FISHERY SYSTEM

Assume that the rate at which fishing vessels enter (or exit) the fleet is proportional to the current profit flow per vessel ;

$$dE / dt = e \cdot \pi$$

where parameter e is the entry (exit) coefficient ; and assume that the rate of growth of the fish stock is determined by

$$dB/dt = G - E \cdot dC.$$

These coupled differential equations govern the dynamics of the fishery system. We can deduce the behavior of the system by examining the ratio dE/dB ; we can represent solutions to this ratio as curves in the {B,E} plane, the phase plane.

When any solution crosses the fleet isocline (the set of points {B,E} for which dE/dt is zero, the break-even biomass level), it must move parallel to the B axis because the size of the fleet is constant whenever B = Bmin. By similar logic, when any solution crosses the biomass isocline (points for which dB/dt is zero), it must move parallel to the E axis. The intersections of the two isoclines depict equilibria.

The biomass isocline has a discontinuity if B is less than or equal to Bmin because the catch rate dC is zero under these conditions. If B is greater than Bmin, the biomass isocline is

$$EE = (1 - B/K) \cdot (1 + B \cdot q \cdot h) \cdot r / [q \cdot (1 - \tau)]$$

and the graph of EE(B) is a quadratic with roots at

$$B = K \text{ and } B = - 1/(q \cdot h)$$

The (local) maximum value for EE occurs when B is equal to

$$BmaxEE = 1/2 \cdot [K - 1/(q \cdot h)]$$

The location of BmaxEE relative to the break-even biomass (BB) determines whether the fishery system has a stable equilibrium point (if BmaxEE < BB), or instead has a stable limit cycle (if BB < BmaxEE). Figure 3 shows the alternate forms of the system. In the upper left panel, break-even biomass (the vertical dashed line) is to the right of the local maximum of the biomass isocline (the solid curved line), and the system has a stable equilibrium point. In the upper right panel, break-even biomass is left of the local maximum of the biomass isocline, and the system has a stable limit cycle. In this example a small (15 %) improvement in handling induces a significant alteration in the system's behavior.

Notice the relationship between the phase plane diagrams at the top of Figure 3 and the corresponding static equilibrium analyses at the bottom. In particular, observe that the unstable equilibrium point shown in the lower right panel generates a limit cycle for the system, rather than the possible extinction of the fish stock suggested by the static analysis.

## 7. THE EVOLUTION OF FISHING TECHNOLOGY

Certain forms of technological change will be more advantageous than others. It seems reasonable to assume that fishermen will prefer to adopt those innovations that have the greatest positive impact on the flow of profits. Although there are numerous factors that affect a fishermen's decision to invest in new fishing technology (Whitmarsh, 1990), it may be possible to anticipate developments in fishing technology by examining the sensitivity of profit flow to the different technical parameters.

Let X denote the set of technical parameters (q, $\pi$, h) that determine the harvest function. The profit flow to the captain (and owner) of a fishing vessel is determined by

$$\pi = R(\underline{X}) - [oc(\underline{X}) + fc(\underline{X})],$$

where R denotes the flow of revenues, and oc and fc denote the flow of operating and fixed costs. We can measure the relative sensitivity of profit flow to a particular technical parameter X by means of an elasticity coefficient,

$$s(X) = \pi'(X) \cdot X/\pi = (d\pi/\pi) / (dX/X),$$

$$s(X) = [R'(X) - oc'(X) - fc'(X)] \cdot X / \pi.$$

For the harvest function developed earlier the partial derivatives of the revenue function are

$$R'(q) = R / [q \cdot (1 + B \cdot q \cdot h)],$$

$$R'(\tau) = -R / (1 - \tau), \text{ and}$$

$$R'(h) = -B \cdot q \cdot R / (1 + B \cdot q \cdot h)$$

If we assume for simplicity that the potential improvements in the different technical parameters all require the same increase in flow of costs, then we can examine how the relative sensitivities vary as the fishery system changes. Figure 4, for example, compares two fishery systems, one (on the left) with a large value for the handling time parameter (h) versus one with a small value for h. The bottom panels show how the relative sensitivities change through time as a fishery develops on a stock that is unexploited initially. The system on the left is most sensitive to the handling time parameter (h) and least sensitive to the catchability coefficient (q). The system on the right, however, is most sensitive to q and the sensitivity to h versus $\tau$ depends on the size of the fish stock.

## REFERENCES

**Beddington J.R.** (1979a). On some problems of estimating population abundance from catch data. *Rep. Int. Whal. Comm.* **29,** 149–154.

**Beddington J.R.** (1979b). Harvesting and population dynamics. In: *Population Dynamics,* pp. 307–320. Ed. by R.M. Anderson, B.D. Turner, and L.R. Taylor. Symp. Brit. Ecol. Soc. 20. Blackwell Scientific Publications, Oxford. 434 pp.

**Clark C.W.** (1985). *Bioeconomic Modelling and Fisheries Management.* John Wiley & Sons, New York. 291 p.

**Condrey R.E.** (1984). Density-dependent searching time: implications in surplus-production models. *Fish. Bull.* **82,** 449–453.

**Deriso R.B. and A.M. Parma** (1987). On the odds of catching fish with angling gear. *Trans. Am. Fish. Soc.* **116,** 244–256.

**Doll J.P.** (1988). Traditional economic models of fishing vessels : a review with discussion. *Mar. Res. Econ.* **5,** 99–123.

**Gulland J.A.** (1983). *Fish Stock Assessment ; A Manual of Basic Methods.* John Wiley and Sons, New York. 233 pp.

**Paloheimo J.E. and L.M. Dickie** (1964). Abundance and fishing success. *Rapp. P.-v. Reun. Cons. int. Explor. Mer* **155,** 152–163.

**Pielou E.C.** (1974). *Population and Community Ecology : Principles and Methods.* Gordon & Breach Science, Publ., New York. 424 pp.

**Sampson D.B.** (1991a). Local per unit effort as an index of global fish abundance. In : *Catch Effort Sampling Strategies : Their Application in Freshwater Fisheries Management,* pp. 275–284. Ed. by I.G. Cowx. Fishing News Books, London. 420 pp.

**Sampson D.B.** (1991b). Fishing tactics and fish abundance, and their influence on catch rates. *ICES J. Mar. Sci.* **48,** 291–301.

**Sampson D.B.** (1992) Fishing technology and fleet dynamics : predictions from a bioeconomic model. *Mar. Res. Econ.* **7**, 37-58.

**Schaefer M.B.** (1954). Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bull. Inter-Amer. Trop. Comm.* **1,** 25–56.

**Whitmarsh D.** (1990). Technological change and marine fisheries development. *Mar. Policy* **14** (1) : 15–22.

FIG. 1.
THE RELATIONSHIP BETWEEN CATCH RATE PER VESSEL AND FISH BIOMASS (UPPER PANEL) IS CONTROLLED BY THREE TECHNICAL PARAMETERS (q, τ, h). BECAUSE OF THE CURVATURE IN THE YIELD FUNCTION, THE FISHERY SYSTEM (LOWER PANEL) CAN HAVE BOTH STABLE AND UNSTABLE EQUILIBRIA.

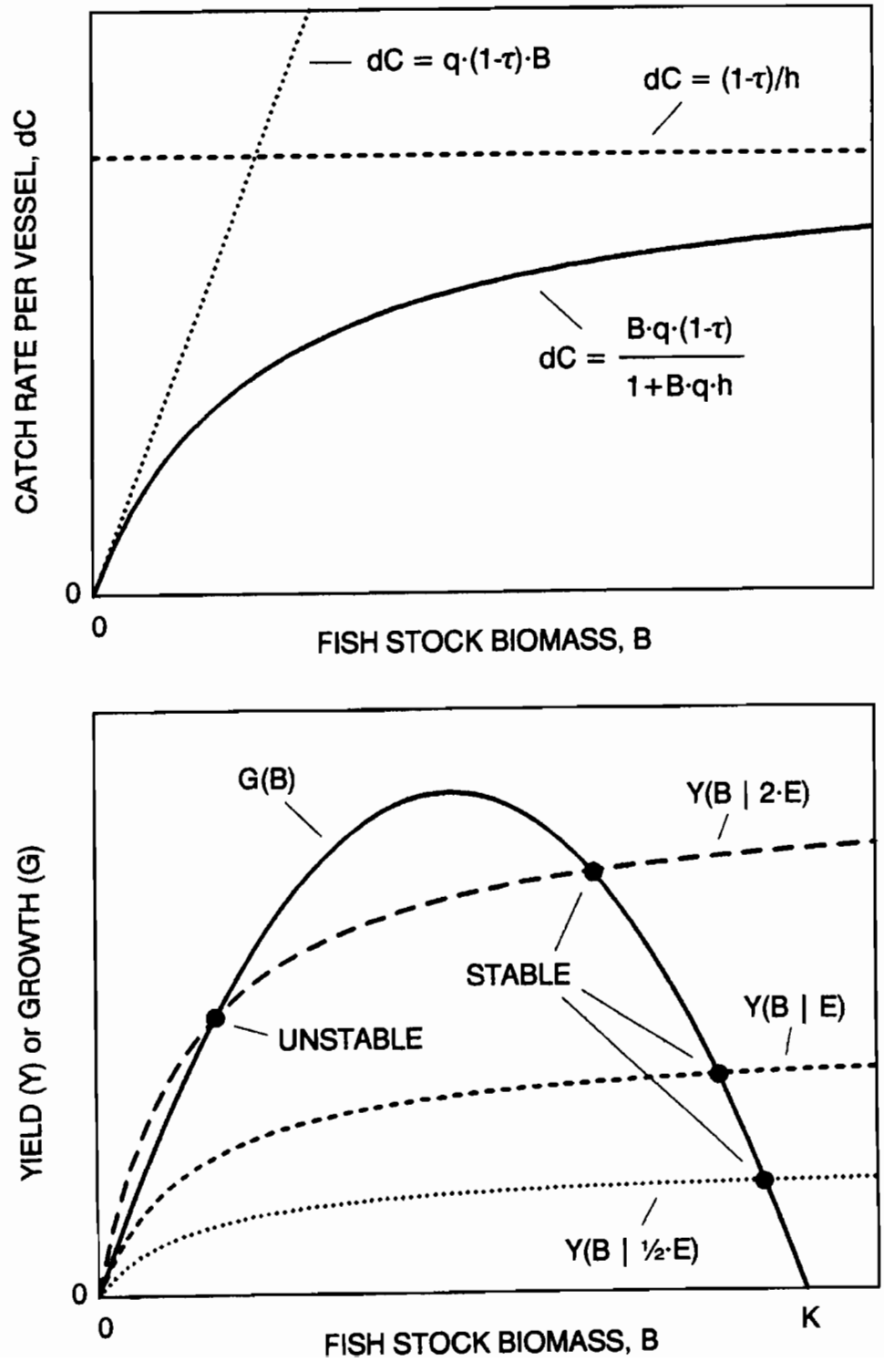
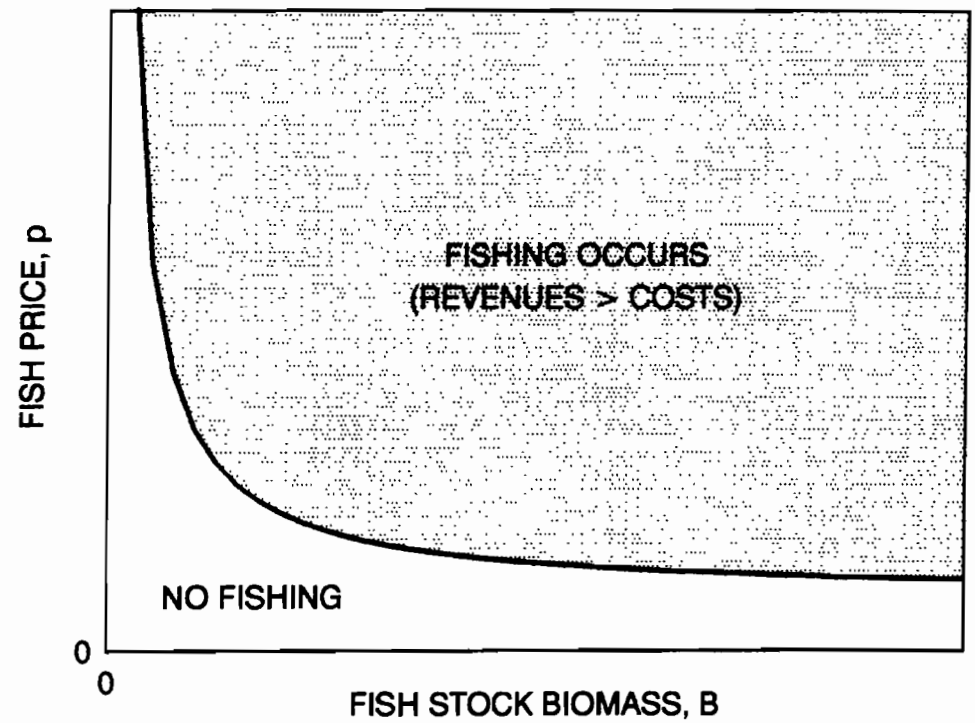


**FIG. 2.**
**WHETHER OR NOT FISHING OCCURS DEPENDS ON THE PRICE FOR FISH AND THE BIOMASS OF THE FISH STOCK (UPPER PANEL). THE FLOW OF PROFITS PER FISHING VESSEL VARIES WITH THE BIOMASS OF THE FISH STOCK (LOWER PANEL).**



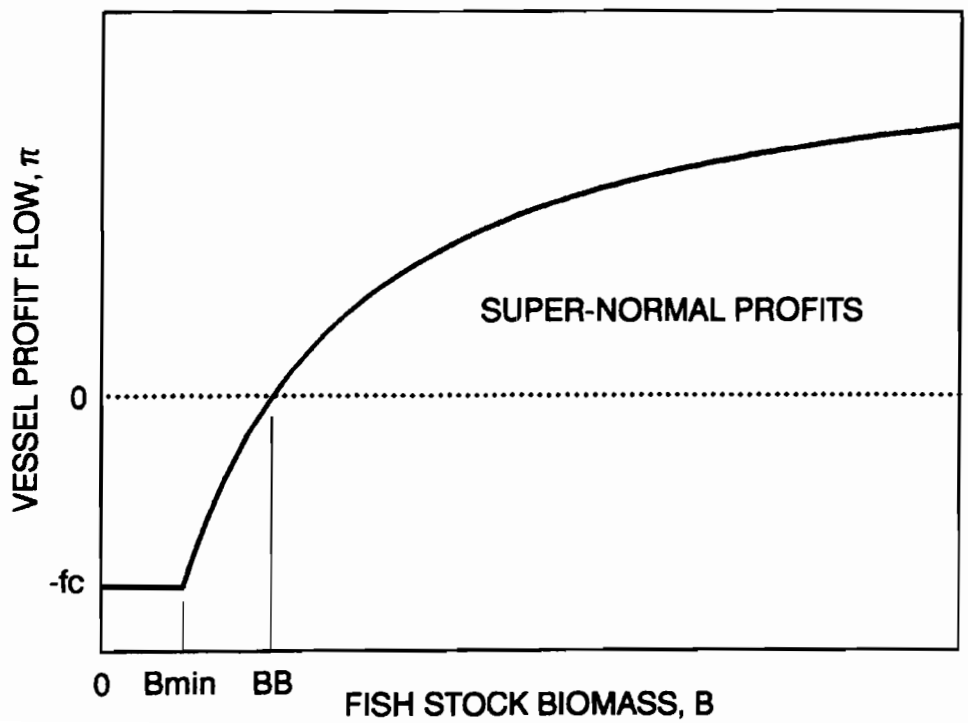



FIG. 3.
SMALL TECHNOLOGICAL CHANGES CAN ALTER THE FISHERY SYSTEM'S BEHAVIOR. THE SYSTEM ON THE LEFT HAS A SINGLE STABLE EQUILIBRIUM POINT ; THE SYSTEM ON THE RIGHT HAS A STABLE LIMIT CYCLE.

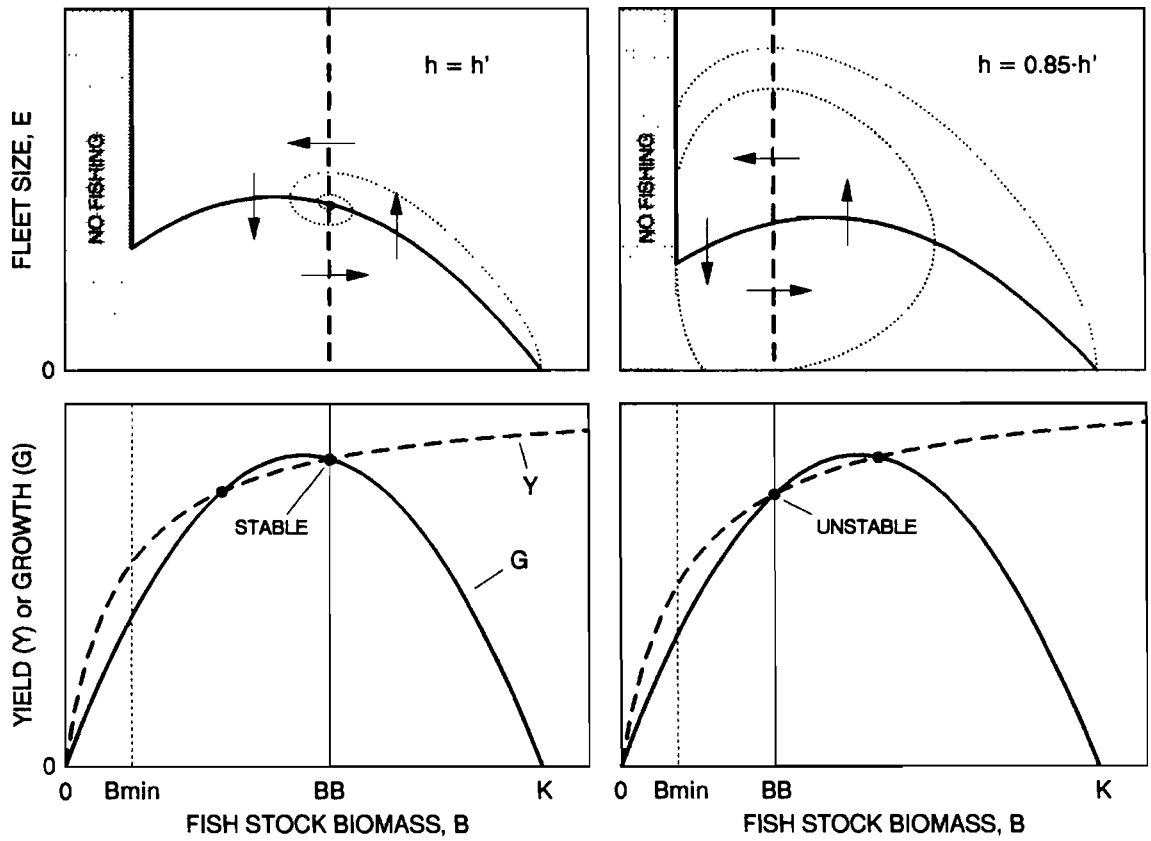
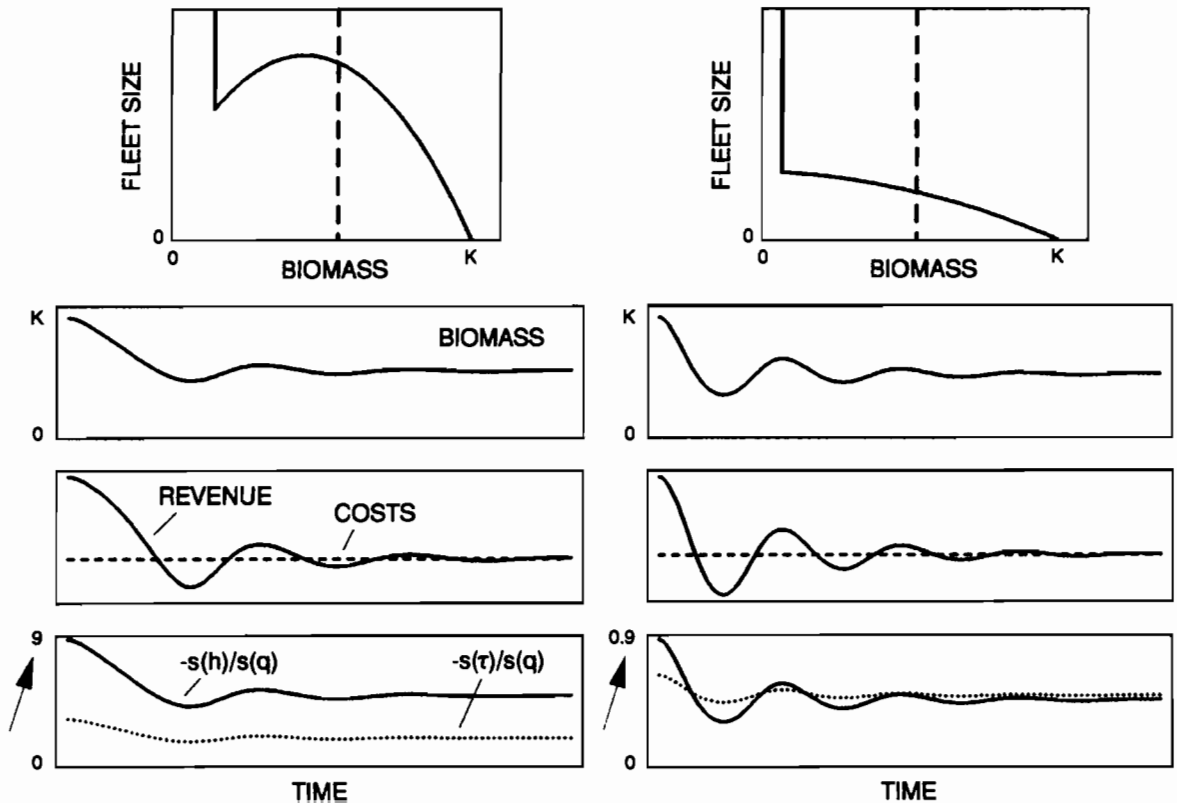


**FIG. 4.**
**FISHERY SYSTEMS CAN VARY IN THEIR SENSITIVITY TO DIFFERENT FORMS OF TECHNOLOGICAL CHANGE. THE SYSTEM ON THE LEFT IS MOST SENSITIVE TO CHANGES IN HANDLING TIME AND LEAST SENSITIVE TO CHANGES IN CATCHABILITY ; THE SYSTEM ON THE RIGHT IS MOST SENSITIVE TO CHANGES IN CATCHABILITY.**



# Dynamics of Resource and Fishermen Behaviour in Coastal Invertebrate Fisheries

**Juan Carlos Seijo [a] and Omar Defeo [a, b]**

[a]Centro de Investigación y de Estudios Avanzados del IPN. A.P. 73-Cordemex, 97310 Mérida, Yucatán, México.

[b]Instituto Nacional de Pesca, Constituyente 1497, Casilla de Correo 1612. 11200 Montevideo, Uruguay.

ABSTRACT

*In sessile and sedentary invertebrates the assumptions underlying traditional population dynamics are not always valid, mainly due to the heterogeneous distribution of the stock and the corresponding allocation of fishing intensity. Consequently, strategies for managing invertebrate fisheries differ from those employed in finfish populations. This study reports an application of the systems simulation approach for short and long-run analysis of the intertidal yellow clam Mesodesma mactroides fishery of Uruguay. A non-linear and stochastic model was built to represent the short-run spatial dynamics of fishing intensity. The space-time distribution of fishing effort is represented in an indicative way as a function of estimates of the dynamic catch per unit effort in alternative grounds, their distances from different localities, the perceived probability of finding species at profitable levels, and the corresponding net revenues of the previous fishing trip. The long-term dynamics of the fishery considers time lags in spawning, hatching and settlement processes, as well as in fishermen entry and exit to the fishery. The distributed delay model is applied for this purpose. A density-dependent function characterizes the dynamics of the stock-recruitment relationship. Because of relatively low total costs, the bioeconomic equilibrium is estimated at high levels of fishing effort, which in turn increases the risks of exhausting this highly vulnerable sedentary species. Simulation experiments with alternative management strategies are conducted to observe the effect on fishery performance.*

## 1. INTRODUCTION

The modern approach to fisheries management is to characterize and predict the behaviour of a stock and the fishing effort exerted, through comprehensive mathematical models (Walters, 1986 ; Charles, 1989). Since the 50's these have been designed for finfish populations (Schaefer, 1954 ; Beverton and Holt, 1957 ; Pella and Tomlinson, 1969). An important characteristic of these models is that they consider the stock as a closed, self-sustaining unit of population with

uniform distribution over the whole area, so that the effect of fishing effort (also assumed to be uniformly distributed) is absorbed by the whole stock through recruitment and/or redistribution of organisms (Ricker, 1944 ; 1975). Hence, fluctuations in stock size may be reflected by the size of the catches (Hancock, 1979).

In sessile and sedentary organisms, the above assumptions are not always valid: the patchy distribution of populations (Elliott, 1977) and their relative or null mobility, introduce important restrictions on the application of traditional finfish models. Mollusks cannot redistribute themselves quickly over a fishing ground, and thus gaps in patches are produced as a result of a sequential depletion pattern produced by the heterogeneous allocation of fishing effort (Hancock, 1973, 1979 ; Caddy, 1975 ; Conan, 1984 ; Orensanz *et al.*, 1991). In addition, their population dynamics is extremely dependent on environmental conditions and biological interactions even between small distances, thus making a high short-term variability in stock size and availability for harvesting (Conan, 1984). Consequently, strategies for managing invertebrate fisheries differ from those employed in finfish populations. As a result, for this type of species, it has been considered appropriate to relax the assumption of spatial homogeneity of resource distribution. Extensive fishing grounds with variability in environmental conditions and related heterogeneity in abundance, growth and mortality patterns, can be divided into smaller areas which are considered as independent units (Caddy, 1975, 1989a, 1989b ; Hall, 1983 ; Sluczanowski, 1986). A comprehensive approach may be used to integrate the results obtained by the discrete analysis.

In this paper we report an application of the systems simulation approach for short and long run analysis of the intertidal yellow clam *Mesodesma mactroides* fishery of Uruguay. Biological, environmental and economic factors are integrated in a comprehensive model, also incorporating some of the more important features of resource management under uncertainty.

## 2. MATERIAL AND METHODS

### *2.1 The study region*

The study was conducted on a 22 km sandy beach of the eastern coast of Uruguay comprised between Barra del Chuy (33°40'S, 53°20'W) and La Coronilla (33°50'S, 53°27'W). This dissipative beach (*sensu* McLachlan, 1990) has the highest values in species richness and diversity among Uruguayan sandy beaches, being the yellow clam *M. mactroides* dominant in biomass terms in the macrofauna community (Defeo *et al.*, 1992a). Artisanal exploitation of species such as the yellow clam and penaeid shrimps constitutes a regional source of employment (Defeo, 1989).

### *2.2 Sampling design : field procedure and fishery statistics*

Sampling was done seasonally between March 1983 and March 1991, along the 22 km of sandy beach where this clam is fished. One transect per km perpendicular to the shore was defined, and samples were collected every 4 m across the beach (down to the limit of the clam bed) with a 1/16 $m^2$ cylinder. Sampling continued in the downshore direction until at least two successive empty quadrats had been sampled. The sediment collected to a depth of 50 cm was sieved through a 0.5 mm mesh and the organisms retained in each quadrat were measured and weighed in the laboratory with 0.5 mm and 0.01 g of precision.

The full range of sizes were covered (i.e. 1 to 76 mm). A recruit was defined as the organisms included between the length interval 1 - 10 mm, and thus have been resident in the benthic population for some time. Adults were all organisms greater than 43 mm, the mean size at first maturity according to Masello and Defeo (1986).

Taking into account the alongshore population structure variability along the 22 km of beach (Defeo *et al.*, 1986), the study beach was divided into four zones, with the boundaries set at right angles to the coast line : zone A, from km 1 to km 5 ; B, from km 6 to km 10 ; C, between km 11 and 15 ; and D, from km 16 to km 22. Population structure and abundance, as well as daily catch/effort data, were examined discriminately by zones. Thus, statistical fishing areas coincided with those selected as independent units for research purposes.

### *2.3 The fishery model*

The systems simulation approach as applied to fisheries (Seijo, 1986 ; 1989) was employed to build and implement a dynamic, non-linear and stochastic bioeconomic model for the yellow clam fishery. The general components of the

fishery were disaggregated in order to specify the interdependencies of relevant ecologic, economic and resource management variables. Using such scheme, the corresponding sets of equations were developed for the main processes involved in the fishery system:

### 2.3.1 Dynamics of population structure

The age-structured population through time was estimated separately for each fishing ground. Growth parameters of von Bertalanffy growth equation were used (Defeo *et al.*, 1992b). Values of $L_\infty$, K and $t_0$ were respectively 75.47 mm, 0.9 1/year and -0.04 year. A length-weight relationship of the form $W=aL^b$ ($a=5.88*10^{-5}$ ; b=3.03 ; n=2839 ; r=0.97 ; $p<0.0001$) was employed for biomass estimations.

The dynamics of the population structure for *M. mactroides* was modeled applying the main concepts of Life Tables (Begon *et al.*, 1990). This method is based on the dynamic accounting of inflows and outflows of individuals to each cohort a of the population structure. The number of individuals in each cohort in ground g was obtained in time t+DT, $(N_{ga}(t+DT))$, by integrating in the interval [t,t+DT] the number of individuals of age *a-1* that survive and grow into cohort *a* in time *t*, minus the total mortality rate (*sensu* Gulland, 1983) of individuals of cohort *a*, $(A_{ga}(t))$, minus the rate at which organisms surviving cohort *a*, $(SR_{ga}(t))$, are incorporated into cohort *a+1* in the time *t*. For a set of initial conditions of the population structure in time t=0, the above is expressed in equation (1) as follows :

$$N_{ga}(t+DT) = N_{ga}(t) + \int_t^{t+DT} (SR_{ga-1}(\tau) \cdot N_{ga-1}(\tau) - (SR_{ga}(\tau) + A_{ga}(\tau)) \cdot N_{ga}(\tau))\, d\tau \qquad (1)$$

$SR_{ga-1}(t)$ denotes the survival rate (*sensu* Gulland, 1983) of organisms of age *a-1* in ground *g* over time t. The survival rate was expressed as :

$$SR_{ga-1}(t) = 1 - [MR_{ga-1}(t) + FR_{ga-1(t)}] \qquad (2)$$

being $MR_{ga-1}(t)$ the rate of natural mortality and $FR_{ga-1}(t)$ the rate of exploitation (*sensu* Gulland, 1983). Both rates were derived from previous determinations of the corresponding coefficients of natural and fishing mortality. The fishing mortality coefficient of organisms of age *a* in ground *g* over time t ($F_{ga}(t)$) was estimated by multiplying the age/site specific catchability coeficient ($q_{ga}$) by the fishing intensity implemented by fishermen from the locality *p* in site *g* over time ($f_{pg}(t)$). A dynamic and density-dependent natural mortality ($M_g$) was estimated as a function of the initial density of settlers and salinity at settlement time in each fishing ground *g*.

Given equations 1 and 2, the spatial dynamics of the population structure was implemented in the computer model using Euler numerical integration (Cheney and Kincaid, 1985) as follows :

$$N_{ga}(t+DT) = N_{ga}(t) + DT \cdot [SR_{ga-1}(t)\, N_{ga-1}(t) - N_{ga}(t)] \qquad (3)$$

Recruitment density was spatially generated over time by Table Look-up functions (Ruckdeschel, 1981 ; Cheney and Kincaid, 1985) which have adult density (number/$m^2$) as the independent variable. Peak recruitment time within a year occurs as specified by Defeo *et al.* (1992b) and is distributed using the distributed delay model (gamma function of order 3) in accordance to the corresponding recruitment period (Manetsch, 1976). Observations related to the main spawning and recruitment periods were obtained from Masello (1987) and Defeo *et al.* (1992b).

### 2.3.2 Short-run spatial dynamics of fishing intensity

The effective fishing effort (man-hours/day) per fishing ground, effective fishing days/month, and average daily catches per fishermen, were used to model fishermen behaviour over time. The number of fishable days per month and effective fishing hours per day were available from 1985 on. The fishery was closed to fishing operations between April 1987 to December 1989.

In this paper, fishing intensity $f_{pg}(t)$ was estimated spatially over time, taking into account fishermen locality of origin $p$, the distances between these localities and the alternative fishing sites, the perceived probability of finding the target species in economically feasible amounts, and the net revenues obtained in the previous fishing day in those grounds :

$$f_{pg}(t + DT) = f_{pg}(t) + \int_{t}^{t+DT} SAE_{pg}(\tau) \,.\, DAYS \,.\, FISHER_{p}(\tau)\, d\tau \tag{4}$$

where :

$FISHER_p(t)$ = number of fishermen from locality $p$ allocating their fishing effort to *M. mactroides* in time t.

$SAE_{pg}(t)$ = a (0,1) daily optimum spatial distribution of fishermen from locality $p$ into grounds $g$ in time t.

DAYS = Average number of fishing days per month.

$SAE_{pg}(t)$ was estimated by the following equation :

$$SAE_{pg}(t) = \frac{\dfrac{\pi_{pg}(t) \,.\, PROB_{g}}{D_{pg}^{n}}}{\sum_{g} \dfrac{\pi_{pg}(t) \,.\, PROB_{g}}{D_{pf}^{n}}} \tag{5}$$

Short-run (daily or per fishing trip) net revenues $\pi_{pg}(t)$ obtained by fishermen of locality $p$ in site $g$, were estimated considering the unit cost of effort and the returns obtained. $D_{pg}^{n}$ is the distances from each locality to each fishing ground where $n$ is the corresponding friction of distance parameter. Short-run net revenues per locality and fishing ground $\pi_{pg}(t)$ were estimated by :

$$\pi_{gp}(t + dt) = \pi_{gp}(t) + \int_{t}^{t+dt} [TR_{gp}(\tau) - TC_{gp}(\tau)]\, d\tau \tag{6}$$

where $TR_{gp}(t)$ and $TC_{gp}(t)$ are respectively the total returns perceived and total costs incurred by the fishermen of the locality $p$ harvesting in ground $g$ over time. This equation was also implemented in the computer model using Euler numerical integration.

The uncertainty, inherent to fishermen decision-making concerned with the spatial allocation of fishing effort over time, and space-time resource variability, was modelled using the catch standard deviations estimated for each season. Random variables (with zero mean) were generated with an observed exponentially autocorrelated probability density function and added to the catch equation obtained for the different fishing grounds.

### 2.3.3 Long-run dynamics

In the long-run, the effort dynamics (number of fishermen from locality $p$ present in the fishery over time) is modelled by spatially applying Smith (1969) equation :

$$\frac{dV_p}{dt} = \delta \cdot \sum_{g} \pi_{pg}(t) \tag{7}$$

where $\delta$ is a positive constant. Equation (7) states that in the long- run, if the sum of net revenues obtained from all fishing grounds is positive, there will be entry to the fishery. Exit is expected to occur if net revenues are negative. If profits are equal to zero, the fishery will be in bioeconomic equilibrium and there will be no stimulus for entry or exit to the fishery.

Price of the yellow clam for the local market was estimated in 1 dollar/kg ; opportunity cost of labor (Pearce, 1981) was estimated in US$ 6 per day, and operating costs in 160 US$ per year.

Simulation experiments were conducted with three management strategies to observe the dynamic impact on performance variables. The impact of three policy vectors were simulated and compared with the base run representing the current management scheme (minimum size restriction of 50 mm, and 50 fishing licenses). The policy vectors were the following : 1) the current management scheme plus a catch quota of 50 ton/year ; 2) a minimum size restriction of 43 mm (size at sexual maturity) and 150 fishing licenses ; 3) 150 fishing licenses and minimum size restriction of 50 mm.

### 2.3.4 Model assumptions

Some of the most important assumptions of the above described simulation model are the following :

i) Recruitment is assumed to be dome-shaped as the classic Ricker function (Ricker, 1954). The distribution of recruits within the recruitment period, modelled with the distributed delay method, is not assumed to occur in a single point in time, but within a period with certain distribution.

ii) The spatially disaggregated dynamic natural mortality is assumed constant for all ages. Fishing mortality is made a function of catchability, selectivity at age (Sparre *et al.*, 1989), fishing intensity, and dynamic age specific resource abundance in each ground.

iii) The spatial allocation of fishing intensity of fishermen from different localities, is assumed to be a function of the probability of finding the target species at profitable levels, the net revenues obtained from different fishing grounds in previous trips, and the distances to alternative fishing grounds.

iv) For long-run effort dynamics, the estimated time lag of fishermen entry or exit to the fishery is assumed to be six month. For short-run effort dynamics (within the fishing season), the estimated average time lag (mean of the probability density function describing the delay process) to enter the seasonal fishery is two weeks.

v) Gear characteristics are assumed constant. In this case, all fishermen harvest the yellow clam by means of shovels.

vi) Fishermen price-taking behaviour is assumed for prices of yellow clam.

vii) Costs of inputs needed per fishing trip remain constant along the fishing season.

### 2.3.5 Stability and validation analyses

Concerning model stability, an appropriate value for the time increment (DT) was determined. This value was selected taking into account the numerical integration operations involved in the computer model (Cheney and Kincaid, 1985). After the stability condition was satisfied, DT was reduced to a size that allowed to achieve a specified numerical integration error.

The model was validated through the comparison between observed and estimated values. The non-parametric Kolmogorov-Smirnov test (K-S) for two samples was applied to test the null hypothesis of equality of distributions (Graybeal and Pouch, 1980).

## 3. RESULTS

### *3.1 Population fluctuations*

Abundance of adults and recruits varied markedly through time. Mean densities of adults reached maximum values in 1984 and 1985, and decreased dramatically between 1986 and 1987, from which a closed season was established (Fig. 1).

A rapid recovery of the resource was observed from 1988 on, as a result of a heavy recruitment in absence of adults (Fig. 2). Statistical comparison of the actual and simulated annual densities of the spawning stock and recruits did not reveal significant differences (K-S test : $p > 0.1$ in both cases).

### *3.2 The fishery : short and long term variability*

The fishery showed a strong seasonal component. A marked increase in fishing intensity during summer and spring was a common pattern observed during the study period (Table 1). A decline in demand for consumption in the local market (Defeo, 1989) and a reduced availability of the resource because of downward migration towards the infralittoral (Defeo *et al* ., 1986) explains the diminished catches in autumn and winter. As a result of the seasonal behaviour of the resource and the fishery, catches were always greater during spring and summer (Table 1).

Figure 3 shows the comparison of the historical trend of recorded annual landings from 1983 to 1990, with respect to predicted landings. No significant differences were found between these two sets of data (K-S test ; $D=0.14$ ; $p > 0.5$). Total landings fluctuated between 62 ton from 1981 to a peak of 219 ton in 1985. From 1985 to 1987, declining yellow clam abundance produced an important fall in landings, and a temporal closure of the fishery between 1987 and 1989. Since the reopening of the fishery in 1990, catches are constrained by an overall quota which did not exceed 50 ton in 1990 and 1991 (Fig. 3).

### *3.3 Spatial variability of the resource and the fishery*

The four grounds differed in terms of abundance and population structure. Adults of yellow clam were prevalent in the central zones (i.e. B and C, see Fig. 4a), while it was always lower in zone D. Water salinity (recorded at the time of settlement) showed gradients towards both margins of the study area, but the stronger one was observed in zone D (Fig. 4b). Concerning this variable, exceptionally low values were recorded for 1986 during the settlement period (i.e. from February to May), coinciding with the major decreasing trend in population abundance (see Fig. 4a). In this year, as well as in 1987, the salinity-induced natural mortality was the main source of natural deaths in the yellow clam population in the four fishing grounds.

Spatial fluctuations in catches and fishing intensity showed the same trend as the above mentioned space-time variability of the stock, i.e. zones B and C had a major amount of fishing activity (Fig. 4c).

### *3.4 Simulation of management strategies*

Results of the simulation experiment of alternative management strategies are shown in Table 2. With policy 1, final catch increased 8 % and economic rent raised in the order of 10 %. Adult density did not change significantly. With policy 2, which allowed harvesting of organisms reaching the size at maturity, a substantial increase in harvest and economic rent resulted in a tradeoff of adult density, which decreased 17 %. With policy 3, that kept minimum size restriction 7 mm above sexual maturity, a more modest increase in harvest and economic rent is observed with non-significant reductions in adult density.

## 4. DISCUSSION

### *4.1 Short term model*

The spatially disaggregated analysis of the resource and the fishery resulted a useful approach in interpreting the behaviour of this exposed sandy beach population.

Spatial decisions concerning the use of sedentary marine resources (Caddy, 1975), are made in the short-run. It is every day or, more precisely, before every fishing trip, that artisanal fishermen consider three decisions : (1) to go fishing next

day or not, (2) if fishing is the choice, to select the target species, and (3) to select the fishing site to harvest such species (Bockstael and Opaluch, 1983 ; Eales and Wilen, 1986). Therefore, to correctly represent the spatial dynamics of fishing intensity, the analyst must make an effort to model the short-run behaviour of fishermen concerning site selection. In the long-run, a spatial pattern of fishing intensity can be depicted but only as a result of short-run resource behaviour and spatial decisions of fishermen.

In the present study, the short-run behaviour of fishermen concerning site selection was correctly represented through the validation of the spatial dynamics of fishing intensity and catches. It can be stated that the magnitude of catches and thus the economic rent obtained in previous days in certain fishing ground, was a good indicator of the future location of fishing effort (see also Eales & Wilen, 1986).

Moreover, even though in the present study the distance between localities did not constitute a key factor (only 22 km), in most artisanal fisheries the friction of distance could be a more significant variable in explaining fishermen behaviour.

### *4.2 Long-term model*

The long-term field study conducted at Barra del Chuy beach suggest two cycles of population variation of different magnitude, governed by overcompensatory changes (*sensu* Fogarty *et al.*, 1991) in recruitment success. The long term model put in evidence that the yellow clam population is "recruitment conditioned", with increments/decrements in recruitment strength defining future adult population sizes (Roughgarden *et al.*, 1985 ; Hughes, 1990). Moreover, unexpected heavy recruitment occurred in the presence of lower adult densities (e.g. 1983-1988 cohort) and *vice versa*. Considering the mobility of exposed sandy beach organisms, space could not be regarded as a limiting resource (McLachlan, 1988 ; 1990). Thus, the overcompensatory mechanism of population regulation suggested is that adults filter larvae out of the water column, as mentioned by Woodin (1976) and André and Rosenberg (1991) for suspension feeders of soft-bottom communities.

Simulation of alternative management strategies also suggests that, if the population is closed to fishing activities for a long period, high adult densities would inhibit recruitment success and hence the magnitude of the stock available for fishing. In this sense, human impact due to fishing also affected the population regulation of *M. mactroides*, mainly between 1983 and 1987, when the increase in fishing effort and catches leading to decreasing values of CPUE and stock size (Defeo, 1989), and the closure of the fishery (austral autumn of 1987). Because of very low levels of unit cost of effort, bioeconomic equilibrium was estimated at very high levels of fishing intensity.

Furthermore, a variable incidence of environmental driven variability due to salinity fluctuations through time (e.g. 1986 and 1987) was also an important source of population oscillations, already mentioned by Defeo *et al.* (1986).

Considering the above mentioned factors, the observed long-term trends in population fluctuations should be explained by a combination of biotic factors (density-dependent recruitment), environmental variability (salinity), and fishing pressure. In this sense, the constructed dynamic and non-linear model allowed us to verify this kind of interdependencies for the first time in a long-term study of an exposed sandy beach population.

An optimal harvest strategy (*sensu* Parma, 1990) could be used to minimize the effects of density-dependence effects, as well as those of fishing intensity.

### *4.3 Spatial dynamics of the resource and the fishery*

Density gradients were observed in the alongshore distribution of *M. mactroides*, as well as in fishing intensity and catches.

Spatial heterogeneity in stock distribution was explained by a differential response of the species to differences in habitat quality, defined in terms of the marked gradient in salinity through the 22 km sandy beach. In this sense, spatial salinity fluctuations coincided in their continuous gradient with respect to both adults and recruits abundance.

As a result, the fishing effort is usually focussed primarily on central grounds (zones B and C). Such characterisitics of the resource and fishermen behaviour were successfully reproduced by the model. Considering the marked seasonality in stock abundance and availability, as well as in catches and fishing intensity, a spatial management scheme based upon

an optimum rotation of fishing grounds were proposed as a feasible option to manage the fishery (Defeo, 1989 ; Defeo *et al.*, 1991). Fishing grounds A and D can be selected as exploitation units for seasons of low demand of clams (i.e. autumn and winter), whereas the central sections B and C can be preserved for periods of higher demand.

*4.4 Impact of alternative management strategies*

Assuming a stable environment, simulation of alternative management strategies suggested a great capacity of population recovery following human perturbation (fishing pressure) due to : 1) an overcompensatory response, i.e. the occurrence of heavy recruitment at low levels of parental stock, and a density-dependent natural mortality; 2) the fact that the size at first capture is greater than the size at maturity. As observed in Fig. 4a, the incorporation of organisms to the adult population (i.e. > 43 mm) usually occurs in austral summer, but this fraction reaches the minimum legal size commercially harvested during winter (i.e. two seasons after), characterized by very low exploitation levels and less accesibility to hand-gathering exploitation because of downward migration to lower intertidal levels (Defeo *et al.*, 1986). Results obtained in this study highlighted the concepts proposed by Caddy (1990), in the sense that this strategy increases the reproductive potential of the population, spawning at least once before capture. The rotation of areas with the periodicity mentioned above, constitutes a good complement of this management strategy.

## REFERENCES

**Andre C. and R. Rosenberg** (1991). Adult-larval interactions in the suspension-feeding bivalves *Cerastoderma edule* and *Mya arenaria. Mar. Ecol. Prog. Ser.* **71 :** 227-234.

**Begon M., J.L. Harper and C.R. Townsend** (1990). *Ecology. Individuals, populations and communities.* Blackwell Sci. Publ., Boston.

**Beverton R.J.H. and S.J. Holt** (1957). On the dynamics of exploited fish populations. *Fish. Invest. London.* Ser. II. **19 :** 1-533.

**Bockstael N. and J. Opaluch** (1983). Discrete modelling of supply response under uncertainty : the case of the fishery. *J. Environ. Econ. Manag.* **10 :** 125-136.

**Caddy J.F.** (1975). Spatial model for an exploited shellfish population, and its application to the Georges Bank scallop fishery. *J. Fish. Res. Bd. Can.* **32 :**1305-1328.

**Caddy J.F.** (1989a). A perspective on the population dynamics and assessment of scallop fisheries, with special reference to the sea scallop *Placopecten magellanicus* Gmelin. In : Caddy, J.F. (ed.), *Marine invertebrate fisheries : their assessment and management.* J. Wiley & Sons, N.Y. : 559-590.

**Caddy J.F.** (1989b). Recent developments in research and management for wild stocks of bivalves and gasteropods. In Caddy, J.F. (ed.), *Marine invertebrate fisheries : their assessment and management.* J. Wiley & Sons, N.Y. :665-700.

**Caddy J.F.** (1990). Options for the regulation of Mediterranean demersal fisheries. *Nat. Res. Model.* **4 :** 427-475.

**Charles A.T.** (1989). Bio-socio-economic fishery models : labour dynamics and multi-objective management. *Can J. Fish. Aquat. Sci.* **46 :** 1313-1322.

**Cheney W. and D. Kincaid** (1985). *Numerical mathematics and computing.* Brooks Cole Publishing Company, Monterey, California.

**Conan G.Y.** (1984). Do assumptions commonly used for modelling populations of finfish apply to shellfish species ? ICES, Shellfish Committee, C.M. 1984/K : **49 :** 21 pp.

**Defeo O.** (1989). Development and management of artisanal fishery for yellow clam *Mesodesma mactroides* in Uruguay. *Fishbyte* **7** (3) :21-25.

**Defeo O., C. Layerle and A. Masello** (1986). Spatial and temporal structure of the yellow clam *Mesodesma mactroides* population in Uruguay. *Medio Ambiente, Chile* **8** (1) :48-57.

**Defeo O., J.C. Seijo, E. Euan and M. Liceaga** (1991). Dinámica espacial del esfuerzo pesquero en una pesquería artesanal de la costa atlántica uruguaya. *Inv. Pesq. (Chile)* **36 :** 17-25.

**Defeo O., E. Jaramillo and A. Lyonnet** (1992a). Community structure and intertidal zonation of the macroinfauna in the Atlantic coast of Uruguay. *J. Coast. Res.* **8** : 830-839.

**Defeo O., E. Ortiz and J.C. Castilla** (1992b). Growth, mortality and recruitment of the yellow clam *Mesodesma mactroides* in Uruguayan beaches. *Mar. Biol.* **114** : 429-437.

**Eales J. and J.E. Wilen** (1986). An examination of fishing location choice in the pink shrimp fishery. *Mar. Res. Econ.* **2 :** 331-351.

**Elliott J.M.** (1977). Statistical analysis of samples of benthic invertebrates. *Freshwater Biological Association, Scientific Publication* N°25.

**Fogarty M.J., M.P. Sissenwine and E.W. Cohen** (1991). Recruitment variability and the dynamics of exploited marine populations. *TREE* **6 :** 241-246.

**Graybeail W. and U.W. Pooch** (1980). *Simulation : principles and methods.* Winthrop Publishers, Inc., Cambridge.

**Gulland J.A.** (1983). Fish stock assessment : a manual of basic methods. FAO/Wiley, *Series on Food and Agriculture I.*

**Hall M.A.** (1983). A spatial approach to the population dynamics of the manila clam *Tapes philippinarum.* Ph.D. Dissertation, University of Washington : 241 pp.

**Hancock D.A.** (1973). The relationship between stock and recruitment in exploited invertebrates. *Rap. P.-V. Reun. Cons. Int. Explor. Mer* **164 :** 113-131.

**Hancock D.A.** (1979). Population dynamics and management of shellfish stocks. *Rapp. P-V Reun. Cons. Int. Explor. Mer* **175** : 8-19.

**Hughes T.P.** (1990). Recruitment limitation, mortality, and population regulation in open systems : a case study. *Ecology* **71 :** 12-20.

**Manetsch T.J.** (1976). Time-varying distributed delays and their use in aggregative models of large systems. IEEE Transactions on Systems, *Man and Cibernetics* **6 :** 547-553.

**Masello A.** (1987). Consideraciones sobre crecimiento y biología reproductiva de la almeja amarilla *Mesodesma mactroides* (Deshayes, 1854). B.Sc. Thesis, Universidad de la República (Uruguay) : 121 pp.

**Masello A. and O. Defeo** (1986). Determinación de la longitud de primera madurez sexual en *Mesodesma mactroides* (Deshayes, 1854). *Com. Soc. Malac. Uruguay* **6** : 387-392.

**McLachlan A.** (1988). Behavioural adaptations of sandy beach organisms : an ecological perspective. In Chelazzi, G. & Vannini, M. (eds.), *Behavioural adaptation to intertidal life.* Plenum Publishing Corporation : 449-475

**McLachlan A.** (1990). Dissipative beaches an macrofauna communities on exposed intertidal sands. *J. Coast. Res.* **6 :** 57-71.

**Nisbet R.M. and W.S.C. Gurney** (1982). *Modelling fluctuating populations.* J. Wiley & Sons, New York.

**Orensanz J.M., A.M. Parma and O.O. Iribarne** (1991). Population dynamics and management of natural stocks. In : Shumway, S.E. (ed.), Scallops : biology, ecology and aquaculture. *Developments in Aquaculture and Fisheries Science,* **21 :** 625-713.

**Parma A.M.** (1990). Optimal harvesting of fish populations with non-stationary stock-recruitment relationships. *Nat. Res. Model.* **4 :** 39-76.

**Pearce D.W.** (1981). *The dictionary of modern economics.* The MIT Press, Cambridge, Mass.

**Pella J.J. and P.K. Tomlinson** (1969). A generalized stock production model. *Bull. Inter-Amer. Trop. Tuna Comm.* **13 :** 421-496.

**Ricker W.E.** (1944). Further notes on fishing mortality and effort. *Copeia* **1 :** 23-44.

**Ricker W.E.** (1954). Stock and recruitment. *J. Fish. Res. Bd. Can.* **11 :** 559-623.

**Ricker W.E.** (1975). Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd. Can.* **191 :** 382 p.

**Roughgaden J., Y. Iwasa and C. Baxter** (1985). Demographic theory for an open marine population with space-limited recruitment. *Ecology* **66 :** 54-57.

**Ruckdeschel F.R.** (1981). *Basic scientific subroutines, volume II.* McGraw-Hill Publications, New York.

**Schaefer M.B.** (1954). Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bull. Inter-Amer. Trop. Tuna Comm.* **1 :** 27-56.

**Seijo J.C.** (1986). Comprehensive simulation model of a tropical demersal fishery : red grouper (*Epinephelus morio*) of the Yucatan Continental Shelf. Ph.D. Dissertation. Michigan State University : 210 pp.

**Seijo J.C.** (1989). The systems simulation approach to tropical fisheries management. In : CHAVEZ, E.A. (ed.), *Proceedings of the workshop Australia- Mexico on marine sciences* : 279-288.

**Sluczanowski P.R.** (1986). A disaggregate model for sedentary stocks : the case of South Australian abalone. In : Jamieson, G.S. and Bourne, N. (eds.), North Pacific Workshop on stock assessment and management of invertebrates. *Can. Spec. Publ. Fish. Aquat. Sci.* **92 :** 393-401.

**Smith V.L.** (1969). On models of commercial fisheries. *J. Polit. Econ.* **77 :** 181-198.

**Sparre P., E. Ursin and S.C. Venema** (1989). Introduction to tropical fish stock assessment. Part I. Manual. *FAO Fish. Tech. Pap. N°* **306/1 :** 337 p.

**Walters C.J.** (1986). *Adaptive management of renewable resources.* McMillan Publ. Co., New York, NY : 374 pp.

**Woodin S.A.** (1976). Adult-larval interactions in dense infaunal assemblages : patterns of abundance. *J. Mar. Res.* **34 :** 25-41.

**TABLE 1.**
**YELLOW CLAM FISHERY OF URUGUAY. SEASONAL COMPARISON OF ACTUAL AND PREDICTED CATCHES (TON) AND FISHING INTENSITY (FINT : # OF TRIPS) (K-S TEST : $p > 0.1$). FROM AUTUMN 1987 TO SPRING 1989, THE FISHERY WAS CLOSED (SEE TEXT).**

| Year | Season | Catch | | FINT | |
|---|---|---|---|---|---|
| | | Obs. | Pred. | Obs. | Pred. |
| 1983 | Autumn | 14 | 0 | | 0 |
| | Winter | 5 | 14 | | 212 |
| | Spring | 36 | 29 | | 592 |
| 1984 | Summer | 61 | 54 | | 977 |
| | Autumn | 19 | 25 | | 272 |
| | Winter | 9 | 25 | | 212 |
| | Spring | 77 | 69 | | 592 |
| 1985 | Summer | 124 | 103 | 1030 | 977 |
| | Autumn | 21 | 20 | 242 | 271 |
| | Winter | 19 | 20 | 128 | 212 |
| | Spring | 56 | 55 | 545 | 593 |
| 1986 | Summer | 66 | 83 | 885 | 979 |
| | Autumn | 14 | 17 | 257 | 273 |
| | Winter | 7 | 14 | 200 | 212 |
| | Spring | 21 | 36 | 346 | 592 |
| 1987 | Summer | 11 | 42 | 321 | 641 |
| 1990 | Summer | 12 | 12 | 85 | 37 |
| | Autumn | 6 | 12 | 29 | 32 |
| | Winter | 12 | 10 | 68 | 25 |
| | Spring | 20 | 27 | 110 | 72 |
| 1991 | Summer | 27 | 39 | 129 | 120 |
| | Autumn | 9 | 5 | 44 | 0 |
| | Winter | 7 | 3 | 23 | 25 |
| | Spring | 16 | 9 | 80 | 73 |

TABLE 2.
IMPACT OF ALTERNATIVE RESOURCE MANAGEMENT STRATEGIES IN THE YELLOW CLAM FISHERY OF URUGUAY. % DENOTE PERCENTAGE OF CHANGE WITH RESPECT TO BASE VALUES.

| Performance Variable | Policy 1 (%) | Policy 2 (%) | Policy 3 (%) |
|---|---|---|---|
| Adult density (ind/m2) | -2.5 | -16.9 | -0.2 |
| Catch (ton/yr) | 7.7 | 135.8 | 91.5 |
| Economic rent Locality 1 (US$) | 10.7 | 100.2 | 58.9 |
| Economic rent Locality 2 (US$) | 10.1 | 92.0 | 53.8 |

FIGURE 1.
MODEL VALIDATION. COMPARISON OF ACTUAL AND PREDICTED ANNUAL MEAN DENSITIES OF THE YELLOW CLAM POPULATION.

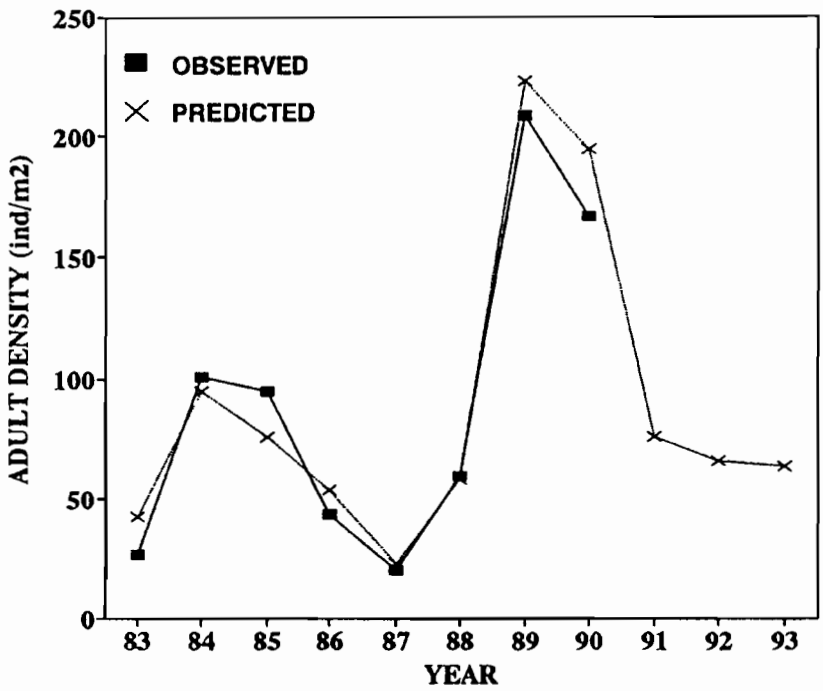


FIGURE 2.
SEASONAL FLUCTUATIONS IN OBSERVED MEAN DENSITIES OF ADULTS AND RECRUITS OF THE YELLOW CLAM POPULATION.

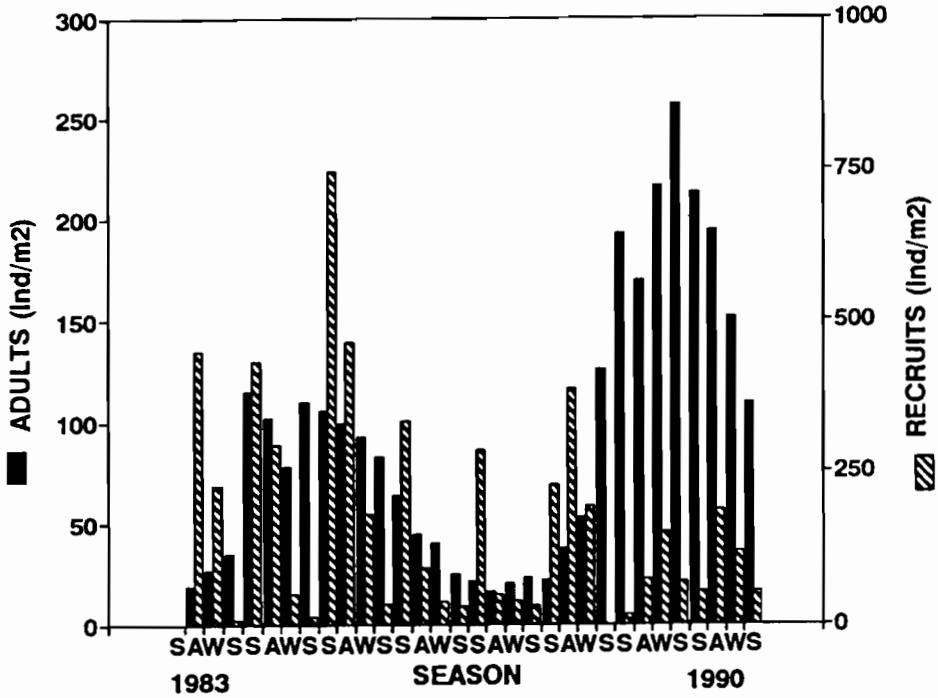



FIGURE 3.
COMPARISON OF ESTIMATED AND OBSERVED ANNUAL CATCHES FOR THE YELLOW CLAM FISHERY.

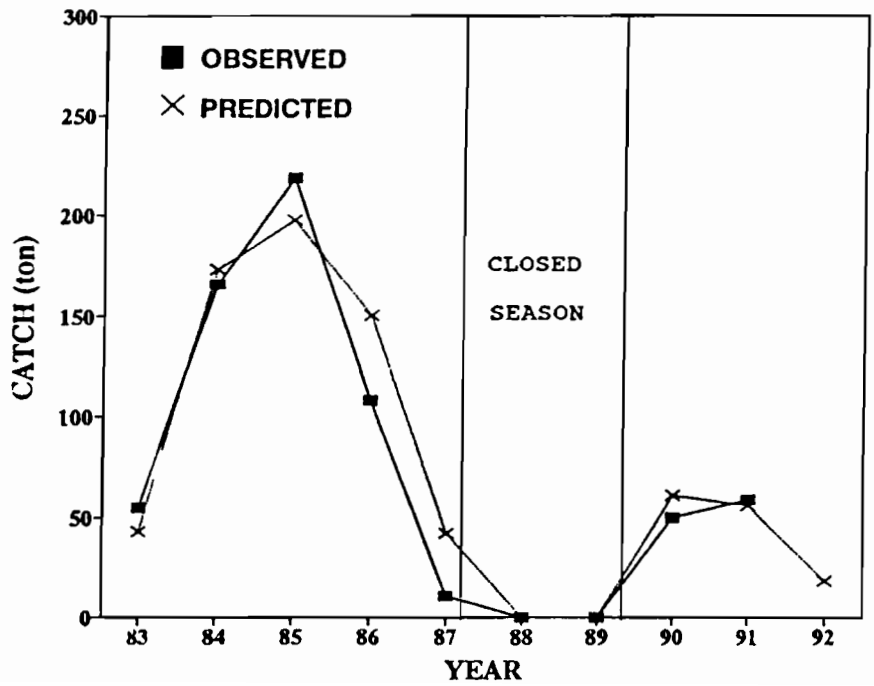
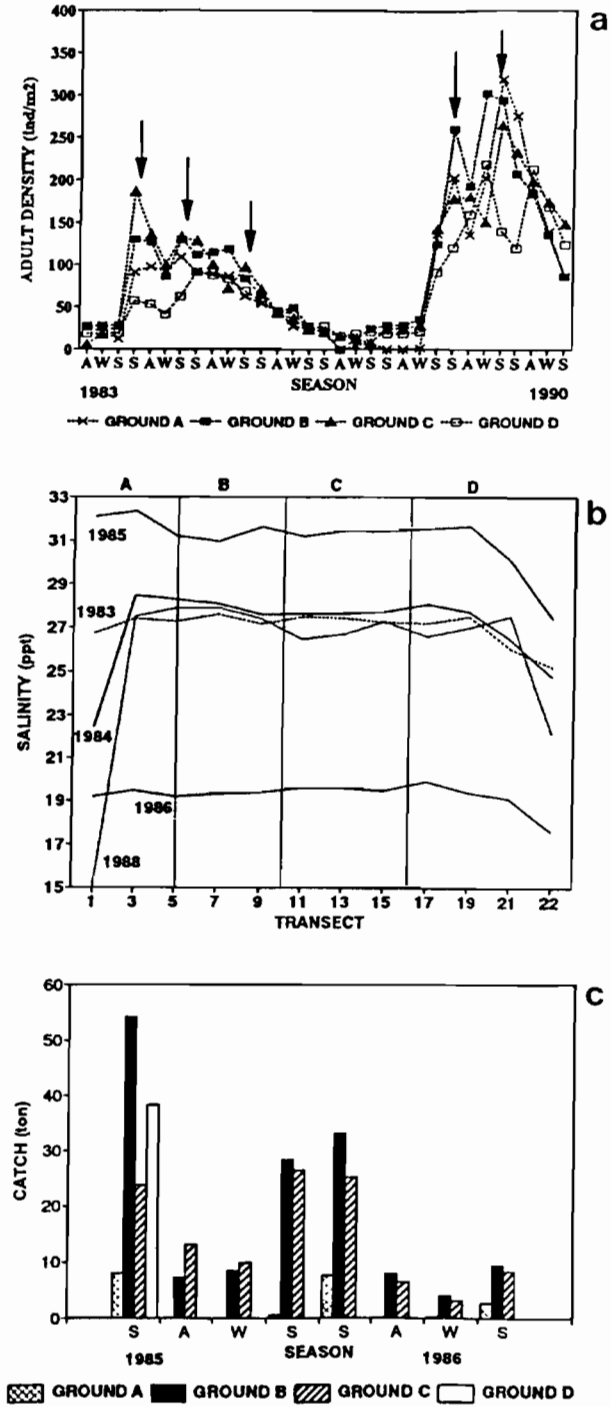


**FIGURE 4.**
**SPATIAL VARIABILITY IN : a) MEAN SEASONAL DENSITY OF ADULTS PER GROUND BETWEEN 1983 AND 1990. ARROWS INDICATE MAJOR RECRUITMENT TO THE ADULT POPULATION (SUMMER) ; b) SALINITY PER GROUND AT SETTLEMENT TIME (1983-1986 AND 1988) ; c) SEASONAL VARIABILITY IN RECORDED LANDINGS PER GROUND (1985-1986).**



# Analysis of Some Management Options for a Small Pelagic Fishery in Central Philippines

**Jose E. Padilla[a] and Parzival Copes[b]**

[a]International Center for Living Aquatic Resources Management Management, MC, P.O. Box 2631 Makati, Philippines

[b]Institute of Fisheries Analysis Simon Fraser University, Burnaby, B.C., Canada V5A 1S6

ABSTRACT

*This paper explores a possible approach to the management of a multispecies and multigear fishery in the circumstances of a developing country. The analysis is applied to the small pelagic fishery of Guimaras Strait and adjacent parts of the Visayan Sea in central Philippines. It is carried out in three stages. In the first, a biological model is developed, using a dynamic pool approach to represent the population dynamics of the stocks. The status of the stocks is evaluated on the basis of yield-per-recruit measures for selected important species. The second stage of the analysis models optimal allocation of the fish catch across competing gears or fleets, having regard for distributional considerations. The allocation process explicitly considers the technological interactions in harvesting, as well as optimization in the pursuit of two conflicting objectives, namely maximizing employment and maximizing vessel operating profits. In the third stages alternative management schemes are explored. The regulatory regimes considered are those potentially applicable in the institutional environment of the Philippine region in which the fishery takes place.*

*The results of the analysis indicate that, on the basis of the criteria used, the optimal fleet size would amount to a relatively small fraction of the existing fleet size. The displacement of a large number of vessels and fishers that such optimization would involve, would represent an enormous social problem. Calculation of increased target yields that could be achieved through the regulation of fishing selectivity, shows that the resulting increase in the optimal fleet size would not be significant. The reason for this is that the current level of exploitation is close to that producing the maximum yield-per-recruit. The results confirm that overemployment and overcapitalization in the fishery are considerable. The paper concludes with discussion of an agenda for exploration of further management alternatives appropriate to the social and economic policy objectives of a developing country.*

## 1. INTRODUCTION

Tropical fisheries are complex resource systems. First, fishery resources in the tropics are mostly multispecies. The degree of biotic diversity and interaction between species is more complex in tropical environments than in their

temperate counterparts (Pauly, 1989). Second, there tend to be significant technological interrelationships in the harvesting process. Most of the large number of fishing gears being used have limited selectivity and every haul of the net is likely to yield a mix of many targeted and nontargeted species. All of there contribute to the complexity of the fishery resource system and, consequently, to a limited understanding of the fishery.

Most tropical fisheries are in developing countries where there are serious economic and social problems. Fish resources here are used to achieve various ends. FAO (1983) classifies the objectives in the exploitation of fishery resources into three groups - maintaining the resource, economic performance and equity (social needs). In addition to the above, other authors (Charles, 1988 ; Regier and Grima, 1985 ; Copes, 1969) include, among others, the following : food production, maintaining employment for fishers and the well-being and viability of fishing communities. Often, the objectives are non-complementary and this poses difficulties in managing the resource.

As most tropical fisheries are already overexploited, fishery programs should be directed increasingly toward improved resource management rather than further development of fishing operations. However, tropical fishery resource systems should be understood first to be able to design proper management programs. The multispecies and multigear nature of tropical fisheries and the pursuit of several objectives in the exploitation present difficulties in understanding the system and in the formulation of appropriate management plans. This paper attempts to develop a methodology that takes into account such characteristics of the fishery. The model is then applied to a specific fishery.

## 2. METHODOLOGY

The model that is formulated consists of several sub-models that accomplish the following tasks : the estimation of fishery yields, the allocation of these yields to competing fishing fleets and the analysis of alternative management schemes. The biological model used to describe stock dynamics is an adaptation of the dynamic pool model developed by Beverton and Holt (1957) :

$$Y_t = FRe^{-M(t_p - t_r)} W_\infty \sum_{n=0}^{3} \frac{\Omega_n e^{-nKt_p}}{F + M + nk} \qquad (1)$$

where $t_p$ is the age-at-first-capture, $t_r$ is the recruitment age, K is a curvature parameter which indicates the speed at which fish approaches the maximum possible weight attainable ($W_\infty$), R is recruitment and $\Omega_n$ is equal to 1, - 3, + 3, - 1 for n equal to 0, 1, 2, 3, respectively. In equation 1, $t_0$ is assumed to be zero.

The above equation gives the yield for each species over the exploitable life span of a given year-class. It also gives the annual yield for all cohorts if recruitment is assumed constant and yearly. The yield-per-recruit is a function of the following parameters : R, M, F, $t_p$, $T_r$, K and $W_\infty$. Of these, only F and $t_p$ may be manipulated and are considered policy variables.

Most of the applications of the Beverton-Holt model of stock assessment as enumerated above are on temperate and sub-temperate fishery stocks. Pauly (1989) noted that the M/K ratio is generally higher for tropical stocks than for temperate stocks. This has implications with regard to the kind of management advice that can be designed for the fishery when using yield-per-recruit stock assessment models in tropical environments.

Most tropical fisheries support a large number of gears whose biological impact (effectiveness in catching fish) and economic performance vary. In this regard an important task is determination of the optimum size of each fleet to be supported by the fish stock. In the process of determining the optimal fleet size, the goals of fishery management need to be considered. Multi-objective mathematical programming may be employed to determine the desirable allocation of fishery yields while pursuing several fisheries management objectives.

Following Evans (1984), the allocation problem is that of selecting the values of a vector of decision variables $f = (f_1, f_2,..., f_n)$ in order to optimize $p$ ($p \geq 2$) objective functions $h_1(f)$, $h_2(f)$,..., $h_p(f)$ subject to a constraint matrix imposed on the decision variables expressed as $f \in \Phi$ . Mathematically, the allocation problem is stated, in general form, as

$$\text{Max } h(f) = [h_1(f), h_2(f),..., h_p(f)] \qquad (2)$$

subject to $f \in \Phi$

Here f is the vector of standardized fishing efforts for the n fishing fleets and $\Phi$ represents the set of feasible values of f. It is implicit in the constraint matrix that f should be nonnegative.

A solution which maximizes each of the objective functions simultaneously is called a superior solution. Since at least two objectives in a multi-objective programming problem are typically conflicting in nature, a superior solution rarely exists. Hence, the concern is on generating the set of efficient or nondominated solutions. There are several methods of generating the set of nondominated solutions. One, the weighting method, transforms the multi-objective problem into a single objective programming format and then, by variation of the parameters used to effect the transformation, the set of nondominated solutions can be generated. A complete listing and description of methods to generate the nondominated set is found in Goiceochea et al. (1982).

It may be that the number of efficient solutions is large and that narrowing down the set to a more manageable number of alternatives is necessary. However, the methods for reducing the number of efficient solutions involve an articulation of the preferences of the decision maker. To avoid any subjectivity in the modeling process, an evaluation of a number of extreme points may be done and their characteristics compared. Some sort of a "menu" may be prepared from which the decision maker chooses the "desired" allocation. This becomes clearer in section 4.

To date, the applications of multi-objective programming to fisheries analysis are rather few. One of the earlier works is by Bishop *et al.* (1981) although they just outlined the procedure. Kendall (1984) outlined a multi-objective approach to regional resource management planning but without an empirical application. Healey (1984) developed a multi-objective fisheries model by considering conservation, economic development and social development goals. He used multi-attribute analysis, specifically, a linear utility model to assess the optimality of alternative yield strategies. He then applied the model to the New England herring fishery and the Skeena River salmon fishery.

## 3. AN APPLICATION OF THE MODEL

The model developed here is applied to the small pelagics fishery of Guimaras Strait and the Visayan Sea in the central Philippines. The fishery is multispecies, multigear and based on Philippine fisheries policy. Several objectives are pursued in its exploitation. The application of the model considers only two management objectives explicitly ; hence the problem becomes a special case of multi-objective programming. There are several advantages of a bicriteria programming model. First, numerical results may be easily derived and the tradeoffs between objectives may be clearly shown. Second, the procedure can be run in most linear programming packages and, hence, can be easily applied without use of specialized computer packages. More importantly, such formulation is adequate in representing the fisheries problem at hand.

In the case of the small pelagics fishery of Guimaras Strait and the Visayan Sea, the following objectives have been selected as appropriate for analysis in this paper : maximization of fishing enterprise profits (in respect of capital inputs), maximization of fishing employment (in respect of labor inputs), catch optimization (in respect of resource utilization), and provision of equal access to competing groups of fishers (in respect of equity). Of the possible fishery management objectives, the first two objectives remain as objective functions while the others are captured in the constraints. The rationale is that the other two objectives (catch optimization and equity) may be more conveniently expressed as constraints.

The two objectives in the programming model are as follows :

$$\text{Max } h_1(f) = \Sigma_i \Sigma_j \Sigma_s p_i q_{ijs} f_{js} - \Sigma_j \Sigma_s c_{js} f_{js} \quad (3)$$

$$\text{Max } h_2(f) = \Sigma_s \Sigma_j l_{js} f_{js} \quad (4)$$

Equation 4 specifies the maximization of fishing profits where *i* denotes species of fish and *j* the fleet (gear) while *s* is the sector ("municipal", i.e., small inshore vessels, or "commercial", i.e., larger offshore vessels). $P_i$ is the unit price of the *i*th species and $c_{js}$ is the unit cost of standardized effort for gear *j* in sector *s*. The objective of maximizing employment in the fishery may be expressed in equation 4 where $l_{js}$ is the labor component for every unit of standardized fishing effort.

The constraints imposed in the allocation process are :

$$H_i = \Sigma_j \Sigma_s q_{ijs} f_{js} \leq Y_i \quad (5)$$

$$f_{j1}/f_{j2} = CR_j \text{ for all j, and} \quad \Sigma_j f_{j1}/\Sigma_j f_{j2} = CR \quad (6)$$

$$f_j \leq \min (f_j) \quad (7)$$

In equation 5, catches for each species are limited to the biological potential of the resource. Total catch (H) for a given species, *i*, is the sum of the catches (or fishing mortalities) generated by all fleets 1, 2,..., *j* in each of two sectors *s* (commercial and municipal). It must be less than or equal to $Y_i$, the target yield for each species group.

Equity constraints are captured in equation 6. Since fishery rationalization entails an inevitable displacement of vessels and fishers, an important issue to resolve is from which fleet and sector (municipal and commercial) this reduction should come. For equity purposes it is considered that management regulation should not favor any group of fishers. Hence in the allocation process the current proportion of fishing effort exerted by the two sectors ($f_1$ and $f_2$) in each fleet ($CR_j$) and for the entire fishery (CR) should be maintained.

Equation 7 imposes minimum fleet size constraints to prevent the elimination of certain fleets in the optimal solution. The elimination of any fleet reduces the flexibility in adapting to changes in the course of managing the fishery in the future.

The $q_{ij}$ in equation 5 is the catchability coefficient for species *i* taken in fishery *j* and by sector *s*. In a mixed species fishery, the $q_{ij}$ or the coefficient of proportionality between landings and fishing effort varies across $q_{ij}$ species and fleets, owing to differences in the availability of the various species and their vulnerability to the gear.

Fishing effort captured in the f vector is standardized. It is a production function involving fishing inputs, labor (measured by crewdays - CD) and capital (represented by the gross tonnage of the vessel - GRT). Dummy variables are added to include seasonal effects. A Cobb-Douglas specification is selected as it incorporates the restriction of separability in the production technology. The fishing effort index is expressed as follows :

$$f = e^{\beta 0}(GRT)^{\beta 1}(CD)^{\beta 2} e^{\Sigma i \sigma i Si} \quad (8)$$

where f is standardized effort, $\beta_i$s and $\varsigma_i$s are the parameters to be estimated and $S_i$s are the seasonal dummies.

Although the small pelagic fishery is exploited by a large number of gears, only five are included in the model. These are the Danish seine, encircling gill net, purse seine, trawl and gill net fleets. The combined landings of these gears are at least 80 % of the total catch for each small pelagic species group specified below. The small pelagic fishery draws on seven major families and in each family are several species.

The biological parameters were estimated for dominant species in each category. The following species accounted for the largest share in each category of small pelagics : *Sardinella gibbosa* (sardines), *Rastrelliger brachysoma* (mackerels), *Selaroides leptolepis* (crevalles), *Stolephorus indicus* (anchovies), *Decapterus macrosoma* (round scads), *Dussumieria acuta* (round herring), *Selar crumenupthalmus* (big-eye scads). The parameters required by the Beverton-Holt equation and the bicriteria programming model are estimated by Padilla (1991). An important assumption with regard to the population dynamics parameters is that of knife-edge selection of the sample gear.

## 4. EFFICIENT ALLOCATION OF FISHING EFFORT : BASE CASE RESULTS

The Interactive Mathematical Programming System (IMPS) (Love and Stringer, 1987) was used. The weighting method is employed to generate the set of efficient solutions. The corner or pivot points of the feasible region in decision space, i.e., in terms of the composition of fleet, are first identified. From these pivot points, the efficiency frontier is derived in objective space, i.e., in terms of the values of the objective functions. Target yields set equal to the average annual landings for the period 1978-1987 constitute the base case model.

The feasible region and the efficiency frontier, drawn in objective space, show the trade-offs between the two objectives (Figure 1). The frontier indicates where the fishery can operate optimally depending on the desired combination of profits and employment. No specific point will be suggested as such decision is political. Instead, a "decision menu" will be presented to the decision maker from which a desired point may be chosen. The extreme points of the efficiency frontier and one intermediate point may adequately describe the set of efficient solutions, hence these constitute the menu. The characteristics of each menu item are described below.

The decision menu consists of corner points on the efficiency frontier A and C and the intermediate point B, all of which are corner points. Point A corresponds to profit maximization ($P_{max}$) where total fishery profits amount to 416.9 million pesos (P 416.9 M) and incidental employment generated is 3.50 million crew-days. At C, on the other hand, employment is at a maximum at 3.93 million crew-days and profits equal P 374.5 M. Point B is where the values of profits and employment are in between their respective minimum and maximum values. Between $P_{max}$ and B, and B and $L_{max}$, respectively, profits decrease by 2.72 % and 7.64 % while labor utilization increases by 3.98 % and 7.96 %.

The output from the bicriteria programming model is the standardized fishing effort for each fleet. These provide values for the following variables : total catch, number of vessels, investments in fishing assets and the number of fishers, given information on the temporal operations of sample vessels. The three points on the efficiency frontier are compared with respect to these variables. The values are found in the first column of figures in Table 1.

The point $L_{max}$ offers the highest catch at over 76.03 million tons although the difference in catch with the other corner points is only a few million tons. The catch is valued at about 931.78 million pesos at $P_{max}$ and 975.24 million pesos at $L_{max}$. The target yields are not fully utilized at the various points of the efficiency frontier. At $P_{max}$, the limiting species are sardines, mackerels and anchovy while at $L_{max}$ these are sardines, mackerels and crevalle. Less than half of the target yields for round scads, round herring and big eye scads are utilized at all corner points in the efficiency frontier. However, that part of target yields not caught by the fleets included in the model does not represent waste to the extent that these are caught by the other fleets not included in the model.

There exist surplus vessels in the Danish seine and trawl fleets in both commercial and municipal sectors while more vessels are required over their current levels for the rest of the fleet. A transfer of the excess vessels from the Danish seine and trawl fleets to other fleets can only partially offset the significant reduction in the number of vessels in other fleets at each corner point. Along this line, the results of this regional study on small pelagics support the findings of Dalzell *et al.* (1987) in a nationwide study on the small pelagics fishery.

The preceding discussion shows that there are excess inputs in the fishery. Such is not an aberration as economic theory predicts that an open-access fishery has a tendency to attract input resources, especially capital, beyond what is optimal. The small pelagics fishery of Guimaras Strait in its present state is not an exception. The estimated investment in fishing equipment for the nine fleets is currently about 614 million pesos, more than half of which is accounted for by the Danish seine fleet. Indeed the corner points of the efficiency frontier prescribe capital resource withdrawal from the fishery by as much as 52 % of the present level.

The resulting distribution of fishers across fleets maximizes labor utilization (crewdays) as specified in the employment objective. The fishery currently provides part-time and full-time employment to about 76,000 fishers from the provinces of Iloilo and Negros Occidental. (On top of this number are fishing operators, shore-based workers, fish traders and other allied workers who depend largely on the fishing industry for employment.) The points on the efficiency frontier, however, call for a considerably smaller number of fishers. Up to 50,375 (66 %) of the current number of fishers will be displaced from the fishery or conversely 34 % (25,845) will remain in the fishery.[1] This occurs at $P_{max}$. The largest number of fishers that may be optimally accommodated is 31,616 (41.5 % of total) which corresponds to $L_{max}$.

The displacement of a large number of fishers creates the greatest difficulties. But is the inevitable consequence of the process of rationalizing the fishery. Although employment-sharing arrangements have been observed in the study area, the employment effects of such would not be substantial. At most, such arrangements could only provide temporary employment to displaced fishers but at the expense of reducing the length of participation of those left in the fishery. However, there are other possible adjustments, e.g., regulating other components of fishing effort, that may be implemented to reduce the negative employment effects of rationalization.

1. Optimal employment is underestimated if the unutilized yields of some species are harvested by other fleets not included in the model.

## 5. ANALYSIS OF ALTERNATIVE FISHERIES MANAGEMENT SCHEMES

The fishery regulations analyzed in this section (regulations of F and $t_p$) may be considered complementary to a licensing scheme. The latter may be viewed as the primary regulatory scheme for the fishery, while the former are instruments that may be implemented to "fine tune" the fishery to the desired status.

### *5.1 Fishing mortality regulations*

Regulations targeting two particular levels of fishing mortality are examined. The first aims at $F_{0\,1}$ mortality, which corresponds to an effort level at which the marginal yield-per-recruit (from an additional unit of effort) is 0.1 of the yield-per-recruit at very low levels of fishing. The basis of $F_{0.1}$ is arbitrary. Its merit is that it is conservation-oriented by comparison with a fishing strategy aiming at maximum (sustainable) catches. An alternative fishing mortality target is $F_{max}$, which corresponds to the fishing intensity that gives the maximum yield-per-recruit for each species. However, $F_{max}$ may not be an appropriate target for the small pelagic stocks as it occurs at a high fishing mortality. This may lead to extremely low stock biomass and to recruitment failures if there is a strong stock-recruitment relationship. Nevertheless, $F_{max}$ is often regarded to be a management strategy worth considering.

Total fishery yield corresponding to $F_{0.1}$ is 93,475 tons while at $F_{max}$ it is 113,667 tons. While these are greater than the current fishery yield of about 90,146 tons, the yields of species (sardines and mackerels) which are binding biological constraints in the allocation model have actually declined, but only at $F_{0\,1}$. The largest increase in yield is for anchovy since current exploitation gives a very low yield-per-recruit which is less than half of that at $F_{0\,1}$ and at $F_{max}$.

The values of the key indicators (Table 1) have actually declined for $F_{0\,1}$ because of the reduction in yields of the constraining species. For $F_{max}$ the values have generally increased compared to the base case figures. Hence, the two regulations of fishing mortality cause changes in the optimal composition of the fleet. A more interesting result is that in the process of maximizing fishery profits or labor utilization in the fishery, neither of the yields corresponding to the two target mortality rates can be obtained simultaneously across species. As in the base model, at least two species are fully exploited while there are surpluses in some species.

The efficiency frontiers are plotted in Figure 2. Only the frontier is drawn to show the full extent of the shifting. The two regulations increase the range of efficient points although the number of corner points is not changed. This means that the decision makers have a wider range of choices particularly at $F_{max}$ which represents a substantial increase in profits and labor utilization in the fishery. This also allows an increase of about 19 % in the number of vessels and the number of fishers at $L_{max}$. The employment effect will be greater if the unharvested yields by the fleets under study can be captured by other fleets. However, the levels of displacement of vessels and fishers remain large at about 39 % and 51 %, respectively.

### *5.2 Mesh size regulations*

Regulations restricting mesh size of fish gears involve changes in the biological constraints following the concept of eumetric yield (Beverton and Holt, 1957). A given yield for each species would be the maximum yield for a specific mesh size. However, the estimation of these yields requires selection data for each mesh size by species and by gear, which is not available.

To examine the effects of mesh size regulations, a simplifying assumption is made. The results in this section, based on this assumption, are illustrative in nature. Fishery yields are estimated by looking at a uniform fish length across species where each length is assumed to correspond to a specific mesh size. Three arbitrary lengths are considered and target fishery yields are computed given the yield per recruit curves and recruitment.

Combined fishery yield is at a maximum at 10-cm length and decreases with time (or length). This is because for most species, the gain from individual growth is outweighed by loss in natural mortality beyond the 10 cm length. The lengths (10 and 12 cm) considered give a larger yield-per-recruit for the two constraining species, sardine and mackerel. The inclusion of 14 cm length in the analysis is to show that there are limits of increasing the target length for the small pelagic fishes.

The values of the important indicators of fishery performance are given in Table 2. The values of the two objective functions increase for the 10 and 12 cm lengths. The efficiency frontier is illustrated in Figure 3. For the 10 and 12 cm lengths, the number of corner points remains at three, while for the 14 cm fish length the number of corner points is two. Only two of mesh sizes considered yield an improvement over the base results in terms of employment. The number of fishers increased although the results are mixed with regard to the number of vessels. However, the increase in the number of fishers is rather insignificant and there would still be a large displacement of labor from the fishery. Optimizing yields with mesh size regulations alone does not reduce significantly the capital and labor displacement from the fishery.

## 6. POLICY RESPONSE AND FURTHER MANAGEMENT ALTERNATIVES

This paper has developed a framework for evaluating management options in multispecies multigear fisheries and has applied it illustratively to the small pelagics fishery of Guimaras Strait and the Visayan Sea, which is typical of many fisheries in tropical developing countries. From a productivity perspective, the paper confirms severe overcapitalization and overemployment in the fishery. This is a common finding for open access fisheries in regions with low alternative employment opportunities.

For the fishery under review, the calculations of this paper suggest that an efficient allocation of fishing effort would displace much more than half of the current labor force, along with a correspondingly large number of vessels, which would thus also reduce the level of capital investment considerably. However, capital invested in this fishery, generally, appears to be earning healthy returns. This may signify a high opportunity cost for capital, owing to its relative scarcity and mobility. It may also reflect monopsonistic access for fishery entrepreneurs to a large supply of cheap, underemployed labor in fishing communities. Given the foregoing, one may well expect government policy to give greater weight to employment maximization than to profit maximization in balancing these dual objectives.

Some specific management alternatives were modeled in the paper and tested for their ability to improve the fishery's performance in meeting the twin objectives of profit and employment maximization, subject to resource productivity and equity constraints. The results were not greatly encouraging. The base case modeled in this paper set target catches equal to the historical average yield for 1978-1987. Results were also modeled for two alternative regulated mortality levels. Catch regulation to meet the $F_{0.1}$ mortality criterion gave decidedly poorer results than the base case. The conservationist impact of $F_{0.1}$ management strategies has given reasonably good results with fisheries on longer-lived species in danger of stock depletion. With the shorter-lived species under consideration here, $F_{0.1}$ criteria appear inappropriate.

The model of this paper was also used to test the results of an $F_{max}$ strategy, aimed at maximum yield-per-recruit for each species. Indeed, the calculations based on this strategy offered the prospect of decidedly higher maxima for profits and employment than obtained in the base case. However, as noted above, the pursuit of $F_{max}$ in a small pelagics fishery, with relatively short-lived species, is of dubious merit because the high level of mortality it calls for may involve a significant risk of recruitment overfishing and stock collapse. Given the foregoing considerations, neither the $F_{0.1}$, nor the $F_{max}$ strategy warrants a recommendation for policy adoption.

A biologically low-risk management strategy is to regulate mesh size, with the aim of optimizing size-at-first-capture, in order to maximize annual net growth in the stock and thereby increase the surplus available for harvesting. Calculations showed, indeed, that modest improvements in the maxima for profits and employment could be achieved with mesh sizes targeting fish of 10-12 cm length. It is suggested that government give consideration to a policy of optimal mesh size regulation, after detailed study to determine the precise biological and economic impacts, as well as the costs and benefits of effective enforcement.

Probably the greatest dilemma in most fisheries rationalization schemes is how to deal satisfactorily with the question of employment levels in the fishery (Copes, 1987). The pursuit of economic efficiency, narrowly defined, almost always calls for a substantial reduction in labour inputs to the fishery. But, in very many cases, there are few realistic prospects for alternative jobs, at least in the short to intermediate term. This makes any substantial reduction in the number of fishers employed socially unacceptable and politically unrealistic. Such appears to be the case also in the fishery studied in this paper. The question then arises whether it is possible to achieve some improvement in economic efficiency without reducing the number of workers participating in the fishery.

What is required is a more labor-intensive fishing strategy. This does not (necessarily) mean any regression to a less advanced technology, but it does suggest a reduction in capital inputs relative to labor inputs. It should be noted that labor

inputs in this case are measured in terms of the *number* of workers employed and not (necessarily) the number of *worker-days* expended. The reduction in investment should be reflected in both capital and operating cost savings, with a corresponding improvement in net earnings for the fishery. Essentially the approach suggested is one in which much the same amount of fish is caught as before, with the same number of workers, but with much less equipment. The precondition of overcapitalization in the fishery should make this a feasible proposition.

A number of approaches may be considered. The possibility of "employment sharing" has already been mentioned above. This could be achieved by reducing the number or vessels and running them with alternate crews. Undoubtedly there would be transaction costs involved in setting up and maintaining such an arrangement. On the other hand, with shorter individual working-times, there would be opportunities to enhance incomes with greater inputs to household production.

Another approach would be to maintain existing fishing units with their full crews, but to reduce their operating costs by rationing gear use and/or fishing time. Gear rationing could be achieved, for instance, by limiting permissible headline lengths on trawls, numbers and sizes of traps used, fathoms of gillnet allowed, number of hooks permitted, and length of longline authorized. Time rationing could be achieved either by periodic closures of the entire fishery or (if this caused undesirable interruptions in supply) by requiring different fleet components to fish in alternate periods.

The foregoing discussion suggests that there is room for exploration of additional approaches to achieve more effective management of fishery resources, with better returns to those dependent on the fishery for their livelihood. There are particularly severe difficulties in determining optimal management techniques in the complex case of multispecies and multigear fisheries. The authors hope that the model developed in this paper will prove capable of adaptation and expansion, to make it a useful tool in testing new management designs for complex fisheries and in evaluating the prospects for successful implementation.

## REFERENCES

**Beverton R.J.H. and S.J. Holt** (1957). On the dynamics of exploited fish populations. *U.K. Min. Agric. Fish. Fish. Invest. (Ser.2)* **19 :** 533 p.

**Bishop R.C., D.W. Bromley and S. Langdon** (1981). Implementing multi-objective management of commercial fisheries : a strategy for policy-relevant research. pp. 197-222. *In* Anderson, L.G. (ed.) *Economic Analysis for Fisheries Management Plans.* Ann Arbor : Ann Arbor Science.

**Charles A.T.** (1988). Fishery socioeconomics : a survey. *Land Economics* **64** : 276-295.

**Copes P.** (1969). Government policy and investment in the fishing industry of Newfoundland, Rome, International Conference on Investment in Fisheries, Food and Agricultural Organization of the United Nations, *FAO Fisheries Reports,* No. 83, Vol. 2.

**Copes P.** (1987). Resource management and the development of small-scale fisheries. pp. 55-59. Opening address to panel discussions, in *Proceedings of the International Conference on Fisheries,* vol. 3. Rimouski : Groupe d'étude des ressources maritimes and International Institute of Fisheries Economics and Trade.

**Dalzell P., P. Corpuz, R. Ganaden and D. Pauly.** (1987). Estimation of maximum sustainable yield and maximum economic rent from the Philippine Small Pelagic Fisheries. *BFAR Fisheries Technical Paper Series 10(3),* Quezon City : Bureau of Fisheries and Aquatic Resources and International Center for Living Aquatic Resources Management.

**Evans G.W.** (1984). An overview of techniques for solving multi-objective mathematical programs. *Management Science* **30**(11) : 1268-1282.

**FAO** (1983). Report on the expert consultation on the regulation of fishing effort (fishing mortality). *FAO Fisheries Report No. 289.* Rome : Food and Agriculture Organization of the United Nations.

**Goicoechea A., D.R. Hansen and L. Duckstein** (1982). *Multi-objective decision analysis with engineering and business applications.* New York : John Wiley and Sons.

**Healey M.C.** (1984). Multiattribute analysis and the concept of optimum yield. *Can. J. Fish. Aquat. Sci.* **41 :** 1393-1406.

**Kendall S** (1984). Fisheries management planning : and operational approach to adaptive management of a renewable resource for multiple objectives using qualitative information. *Can. J. Regional Sci.* **7** (2) : 153-180.

**Love C.E. and J. Stringer** (1987). *Interactive mathematical programming system : users guide. Burnaby,* B.C. : Simon Fraser University.

**Padilla J.E.** (1991). Managing tropical multispecies fisheries with multiple objectives. Ph.D. Dissertation (unpublished). Simon Fraser University.

**Pauly D.P.** (1989). Biology and management of tropical marine fisheries. *Resource Management and Optimization* **6**(3) : 253-271.

**Regier H.A. and A.P. Grima** (1985). Fishery resource allocation : an exploratory essay. *Can. J. Fish. Aquat. Sci.* **42 :** 845-859.

TABLE 1.
MAJOR INDICATORS OF FISHERY PERFORMANCE FOR BASE CASE MODEL AND VARIOUS REGULATIONS OF FISHING MORTALITY (F).

| Item | Base case model | Fishing mortality | | Percent change from base | |
|---|---|---|---|---|---|
| | | F0.1 | Fmax | F0.1 | Fmax |
| Fishing profits (mil. pesos) | | | | | |
| Pmax | 416.87 | 397.17 | 517.37 | -4.73 | 24.11 |
| Intermediate point | 405.51 | 376.27 | 489.15 | -7.21 | 20.63 |
| Lmax | 374.55 | 330.17 | 436.82 | -11.85 | 16.63 |
| Employment (mil. crewdays) | | | | | |
| Pmax | 3.498 | 3.164 | 3.937 | -9.55 | 12.55 |
| Intermediate point | 3.638 | 3.421 | 4.283 | -5.98 | 17.73 |
| Lmax | 3.927 | 3.852 | 4.773 | -1.92 | 21.53 |
| Number of fishermen | | | | | |
| Pmax | 25,845 | 20,345 | 24,844 | -21.28 | -3.87 |
| Intermediate point | 29,734 | 27,502 | 34,510 | -7.51 | 16.06 |
| Lmax | 31,616 | 30,305 | 37,691 | -4.15 | 19.21 |
| Total catch (tons) | | | | | |
| Pmax | 73,853 | 69,960 | 86,696 | -5.27 | 17.39 |
| Intermediate point | 72,335 | 67,204 | 82,974 | -7.09 | 14.71 |
| Lmax | 76,027 | 72,671 | 89,180 | -4.41 | 17.30 |
| No. of vessels | | | | | |
| Pmax | 4,795 | 3,124 | 3,623 | -34.85 | -24.44 |
| Intermediate point | 6,168 | 5,650 | 7,034 | -8.40 | 14.04 |
| Lmax | 6,726 | 6,481 | 7,977 | -3.64 | 18.60 |
| Gross tonnage | | | | | |
| Pmax | 10,527 | 9,700 | 12,045 | -7.86 | 14.42 |
| Intermediate point | 10,600 | 9,835 | 12,228 | -7.22 | 15.36 |
| Lmax | 11,056 | 10,514 | 12,998 | -4.90 | 17.57 |
| Total capitalization (million pesos) | | | | | |
| Pmax | 256.07 | 219.45 | 282.13 | -14.30 | 10.18 |
| Intermediate point | 275.16 | 254.59 | 329.52 | -7.48 | 19.76 |
| Lmax | 267.45 | 243.13 | 316.30 | -9.09 | 18.26 |

**TABLE 2.**
**MAJOR INDICATORS OF FISHERY PERFORMANCE FOR VARIOUS REGULQTIONS ON MESH SIZES (INDICATED BY LENGTH AT FIRST CAPTURE).**

| Item | Base case model | Length at first capture | | | Percent change from base | | |
|---|---|---|---|---|---|---|---|
| | | 10 cm | 12 cm | 14 cm | 10 cm | 12 cm | 14 cm |
| Fishing profits (mil. pesos) | | | | | | | |
| Pmax | 416.87 | 451.27 | 457.50 | 268.17 | 8.25 | 9.75 | -35.67 |
| Intermediate point | 405.51 | 437.16 | 444.56 | | 7.80 | 9.63 | |
| Lmax | 374.55 | 415.11 | 441.50 | 247.09 | 10.83 | 17.87 | -34.03 |
| Employment (mil. crewdays) | | | | | | | |
| Pmax | 3.498 | 3.711 | 3.788 | 2.321 | 6.08 | 8.28 | -33.66 |
| Intermediate point | 3.638 | 3.884 | 3.946 | | 6.77 | 8.48 | |
| Lmax | 3.927 | 4.090 | 3.975 | 2.426 | 4.15 | 1.22 | -38.22 |
| Number of fishermen | | | | | | | |
| Pmax | 25,845 | 26,574 | 27,046 | 15753 | 2.82 | 4.65 | -39.05 |
| Intermediate point | 29,734 | 31,415 | 31,479 | | 5.65 | 5.87 | |
| Lmax | 31,616 | 32,749 | 31,665 | 19962 | 3.58 | 0.15 | -36.86 |
| Total catch (tons) | | | | | | | |
| Pmax | 73,853 | 77,896 | 77,780 | 53,032 | 5.47 | 5.32 | -28.19 |
| Intermediate point | 72,335 | 76,039 | 76,073 | | 5.12 | 5.17 | |
| Lmax | 76,027 | 78,650 | 76,436 | 50,385 | 3.45 | 0.54 | -33.73 |
| No. of vessels | | | | | | | |
| Pmax | 4,795 | 4,739 | 4,822 | 2,689 | -1.17 | 0.56 | -43.92 |
| Intermediate point | 6,168 | 6,447 | 4,364 | | 4.52 | -29.25 | |
| Lmax | 6,726 | 6,842 | 6,442 | 4,250 | 1.72 | -4.22 | -36.81 |
| Gross tonnage | | | | | | | |
| Pmax | 10,527 | 11,078 | 11,107 | 7,313 | 5.23 | 5.51 | -30.53 |
| Intermediate point | 10,600 | 11,171 | 11,191 | | 5.39 | 5.58 | |
| Lmax | 11,056 | 11,495 | 11,236 | 7,265 | 3.97 | 1.63 | -34.29 |
| Total capitalization (million pesos) | | | | | | | |
| Pmax | 256.07 | 271.47 | 277.67 | 153.09 | 6.01 | 8.43 | -40.22 |
| Intermediate point | 275.16 | 295.18 | 298.97 | | 7.28 | 8.65 | |
| Lmax | 267.45 | 289.99 | 298.25 | 170.95 | 8.43 | 11.52 | -36.08 |

FIG. 1.
FEASIBLE REGION IN OBJECTIVE SPACE: BASE CASE MODEL.

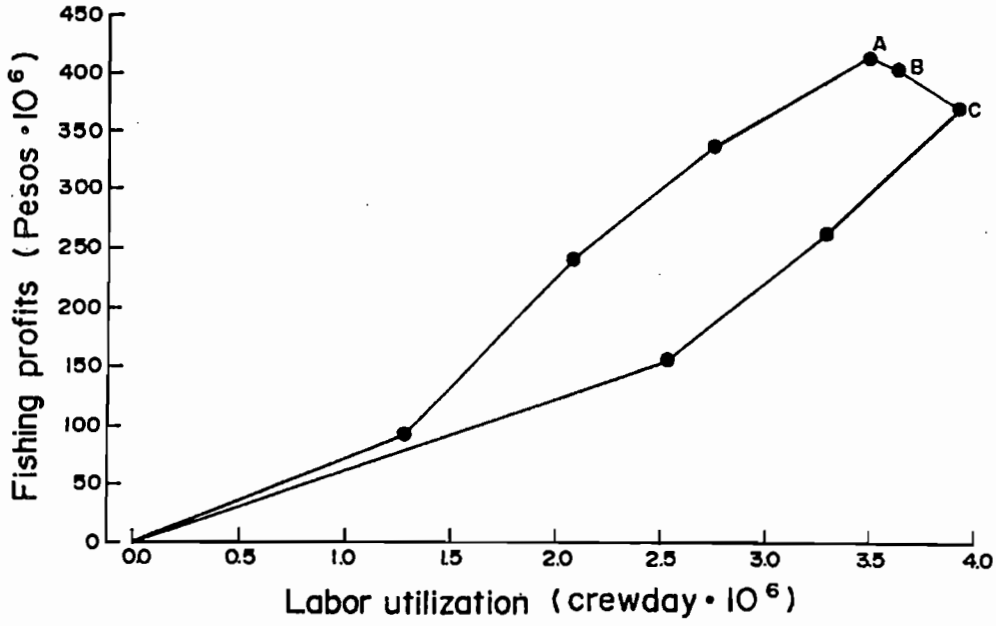



FIG. 2.
EFFICIENCY FRONTIER IN OBJECTIVE SPACE FOR VARIOUS REGULATIONS REGULATIONS OF FISHING MORTALITY (F).

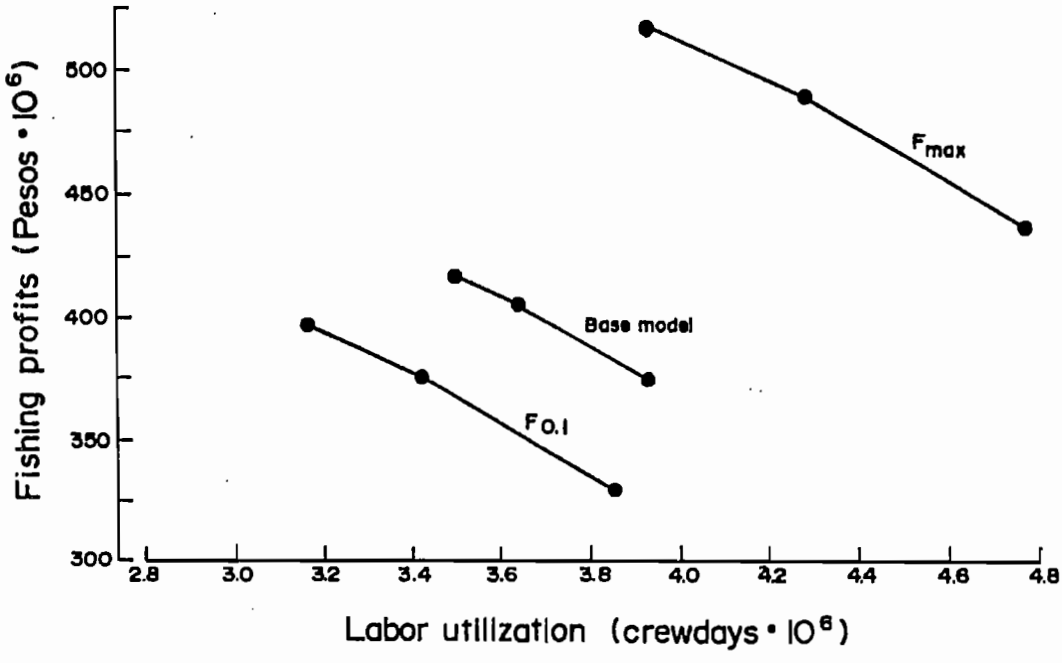
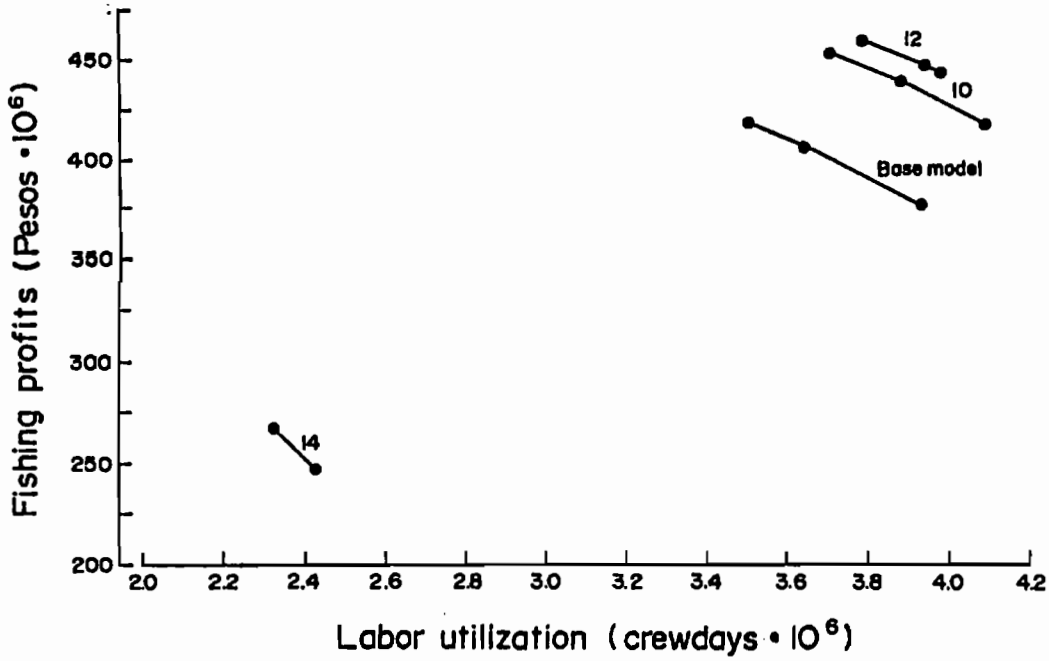


**FIG. 3. EFFICIENCY FRONTIER IN OBJECTIVE SPACE FOR VARIOUS LENGHTS AT FIRST CAPTURE (TP).**



# The Usefulness of Bioeconomic Models under biological Uncertainty : a Case Study of the Australian Southern Shark Fishery

**Sean Pascoe, Tony Battaglene and David Campbell**

Australian Bureau of Agricultural and Resource Economics GPO Box 1563 Canberra ACT 2601, Australia

ABSTRACT

*An common feature of fisheries management is the need to make management decisions in the presence of uncertainty. Much of this uncertainty arises because information about the true biological state of the resource is incomplete. Fisheries scientists, conscious of their lack of a full understanding of the stock dynamics, have been hesitant in providing firm advice to fishery managers, and often present a range of biological scenarios. Where uncertainty is high, managers have been reluctant to impose strict management controls because these would cause economic hardship for some fishers.*

*There has been evidence of this recently in relation to the management of Australian southern shark fishery. Despite general agreement between biologists that the stock was severely overexploited, uncertainty as to the sustainable level of catch resulted in managers not imposing firm controls.*

*To examine the likely economic outcomes of various management options, ABARE developed a bioeconomic model of the southern shark fishery. The several management options were examined under a range of alternative biological assumptions. While the magnitude of the economic effects changed if these management options changed with different biological assumptions, the relative effects remained fairly consistent for most of the alternative biological assumptions. The costs of imposing an "optimal" policy based on the wrong biological assumptions was also estimated. As a result, a risk minimising/profit maximising strategy was developed for management of the fishery.*

## 1. INTRODUCTION

Unlike most other resource managers, fishery managers are expected to formulate policies for the optimal utilisation of an often unseen and mobile resource. In many cases, information on the resource is limited to historic catch records, the

accuracy of which may have been influenced by previous management policies. While most Australian fishers record details of their catch and effort in logbooks, this is not mandatory in all fisheries. Where a fishery covers waters under several different jurisdictions, requirements for keeping logbooks may vary between operators. Consequently, complete and consistent information is not always available.

As a result, fisheries researchers may not have enough information to accurately assess the biological state of the resource. Fisheries scientists have been cautious in providing firm advice to fishery managers, and often present them with a range of biological scenarios. Where uncertainty is high, managers have often been reluctant to impose strict management controls because the imposition of such controls would lead to certain economic hardship for some fishers.

There has been evidence of this recently in the management of the Australian southern shark fishery. This fishery includes Commonwealth waters as well as the waters of three states. Logbook requirements differ between the states, resulting in only partial catch records being obtainable. Available logbooks are not always complete or consistent, resulting in further difficulties in obtaining information on the stock. Despite these difficulties, most biologists are in general agreement that the shark stock is severely overexploited. However, uncertainty as to the true state of the resource and the sustainable level of catch has made managers hesitate before imposing firm controls.

Fisheries management in Australia, however, is concerned with more than just maximum sustainable catch rates. A requirement of all Australian Commonwealth fisheries management plans is to ensure that the resource is harvested at the level that results in the greatest returns to society over time. An optimal management strategy under this criterion may require catch rates below the maximum sustainable level. To examine the likely economic outcomes of various management options, ABARE developed a bioeconomic model of the southern shark fishery. The various options were examined under a range of alternative biological assumptions. Decision criteria under uncertainty were employed to establish an optimal management strategy.

## 2. THE SOUTHERN SHARK FISHERY

The southern shark fishery, located in waters off south-eastern Australia (figure 1), produced a catch of around 3000 tonnes carcass weight (about 4500 tonnes liveweight) valued at over $15 million in 1990.

The fishery is based primarily on catches of gummy shark (*Mustelus antarcticus*), which make up just over 40 per cent of the catch, and school shark (*Galeorhinus australis*), which also make up just over 40 per cent of the total catch. Other shark species, such as common saw shark (*Pristiophorus cirratus*), southern saw shark (*Pristiophorus nudipinnis*) and elephant fish (*Callorhynchus milii*) account for most of the remainder of the catch.

Most of the shark is caught using either gillnets or long lines, although some shark are also captured as a by-catch of trawlers operating in the south-east trawl fishery. The shark fishery is managed jointly by the Commonwealth and state governments, with most of the catch being taken by Commonwealth licensed boats.

Concerns have been raised about the status of the shark stocks in the southern shark fishery for a number of years. Catch per unit effort in the southern shark fishery over the past decade has declined markedly. This decline has been largely attributed to over-fishing (Southern Shark Restructuring Task Force 1991).

In December 1990, the Southern Shark Assessment Group suggested that the fishery faced collapse unless catches in the fishery were immediately reduced to 500-800 tonnes carcass weight (less than one third of the 1990 catch level). Scientists advised managers to reduce the number of nets by at least half. Fishery leaders, however, argued that there was too much uncertainty in the models to undertake such a drastic reduction. As a result, management measures were introduced in 1991 that were designed to reduce the number of nets in the fishery by about a third rather than by a half.

## 3. MAKING DECISIONS IN AN UNCERTAIN ENVIRONMENT

The hesitancy of fishery managers to reduce catch levels in the southern shark fishery is understandable given the amount of uncertainty that still remains about the status of the biological stocks. This uncertainty arises because of incomplete data from commercial fishers and less than complete knowledge about the biology of the fishery. On the other hand, managers are well aware that reducing catch levels will most likely cause financial hardship for a number of operators.

Much of what is known about the fishery is open to a number of equally plausible explanations. These explanations, however, have implications which differ significantly. Two models have been proposed by biologists to explain the historic patterns of fishing effort and catch. The basic difference between the models arises from their assumptions about the degree of migration of the shark. If the shark are highly migratory throughout the fishery as suggested in model 1, there is a single breeding stock of each species of shark, since areas would be restocked through migration. The alternative assumption, associated with model 2, is that the sharks are not highly migratory, and that when regional breeding stocks are depleted, they will not be replenished readily through in-migration.

Under the assumptions of model 1, both school and gummy shark stocks have been significantly depleted. To save the fishery from collapse, catch needs to be reduced. The exact level of the reduction is not known, however, given the uncertainty about the values of some of the key biological parameters. Again, alternative values result in different estimates of sustainable catch rates.

Model 2 is based on the possibility of a series of regional stocks that have progressively been fished down to a sustainable level. Under this alternative set of assumptions, the gummy shark component of the fishery is not in danger of collapse, and is likely to be sustained at its current level of catch. This is because there is thought to be a breeding stock of gummy shark off southern Tasmania that has previously been unexploited due to being located in water which is too deep or too rough to fish. This stock is thought to be supplying a constant recruitment of juvenile gummy shark to Bass Strait (J. Prince, Southern Shark Research Group, personal communication, 25 October 1991). The school shark stock, however, may have been severely depleted in some regions. Under model 2, some reallocation of effort may be desirable to protect breeding stocks, resulting in current catch levels being sustained, at least for gummy shark.

Both models are capable of explaining (to some extent) changes in the historical pattern of catch and size distribution of the sharks. Eliciting from scientists the probability of each model being the correct one is difficult. Most scientists believe strongly in either one model or the other, and acknowledge only a scant possibility that the other model is correct.

Despite this uncertainty, managers need to decide now on the future management of the fishery. In the absence of 'reasonable' subjective probabilities[1] , managers will need to employ decision criteria that do not require any knowledge of the states of nature (Anderson, Sweeny and Williams 1982). Most of the formal decision criteria under uncertainty are based on extreme adverse outcomes that may arise from the decisions (Hinchy, Jones and Thorpe 1992). For example, the maximin criterion attempts to identify the option that has the best worst-case outcome. Similarly, the minimax criterion identifies the option that results in the least cost if the wrong decision is made.

As part of the research effort in assessing future management options, a bioeconomic model of the fishery was developed by ABARE. The model was used to estimate the fleet structure, catch rates and net present value of total fishery profits over time for a number of possible policy options. The model was run with the alternative biological assumptions. The criteria for decision making under uncertainty were applied to the results of the simulations to indicate the optimal management strategy.

## 4. THE BIOECONOMIC MODEL OF THE SOUTHERN SHARK FISHERY

The bioeconomic model of the southern shark fishery draws on the biological relationships developed by Olsen (1984), Walker (1991) and the South Australian Department of Fisheries (1991). Economic and physical features that affect, and are affected by, fishery management decisions are imposed on these biological relationships. The model can be used to examine the impact of various management options on both the profitability of the fishery and the biological state of the fishery. Complete technical details of the model are given in Pascoe, Battaglene and Campbell (1992).

Previous biological models of the fishery have highlighted the need for urgent action to protect the resource. While effective biological tools, these models can only be used to estimate the consequences of applying given amounts of fishing effort in a fixed sequence. They cannot be used to estimate the best sequence to achieve certain objectives, except through trial and error. Furthermore, they exclude the effects of management decisions on the economic performance of the commercial operators in the fishery.

1. Subjective estimates of probabilities are considered 'reasonable' if there is a low variance in the probabilities assigned by acknowledged experts on the events in question (Hinchy, Jones and Thorpe 1992).

The ABARE model, in contrast, is an optimisation model, which means that it can be used to maximise an objective, such as profit, subject to a set of constraints such as the relationships between fishing effort, catches and biological stocks. In this case, the model is used to estimate the number and types of boat, the type of gear used and the timing of fishing (that is, in which years the boats fish) that will maximise the net present value of either profits, gross margins or revenue over time, given the constraints imposed by the shark stock and by management action.

The principal components of the model are shown in figure 2. Together these components enable the user of the model to estimate the biological, economic and physical outcomes for the fishery under different management strategies.

### *4.1 Biological characteristics*

The biological features of the model include the parameters of growth, mortality, catchability, size selectivity, and reproduction. Most of these parameters for gummy shark were derived by Walker (1991). Olsen (1954, 1984) derived similar biological parameters for school shark.

The model focuses on the two major target species – school and gummy shark. For the purpose of the analysis, school shark were considered to be asexual, but gummy shark were divided into males and females. This is because male and female gummy shark grow to substantially different sizes and at different rates, whereas male and female school shark are similar in size and weight at a given age. Other shark species are considered as by-catch in the model. While the catch of these other species is included in the model through a simple by-catch/target catch ratio, the biological implications associated with their catch are ignored.

Sharks age in the model, and this affects their catchability, weight and fecundity. Sharks are not usually caught until they are three years old, a function of both the behaviour of the juvenile shark and gear selectivity. The starting stock of shark in 1992, by age, was estimated using 'SharkSim' (South Australia Department of Fisheries 1991) with historical and 1991 estimated effort levels. As the population age structure changes over time, the survival rate of juvenile shark (less than three years old) is affected. The juvenile mortality rate, which affects the survival rate, increases as the number of older shark in the population increases (a density dependent mortality effect). While the exact cause of this increase is not certain, competition for food and cannibalism have been suggested. Juvenile sharks, being physically limited (due to their smaller size) in the range of food that they can eat may be more affected by competition arising from increased population size than older sharks, which have a broader food base. The reproductive capacity of the stock is also affected by changes in the age structure over time.

The catchability of shark may also be related to the number of shark in the fishery. A constant catchability coefficient (the link between the amount of effort and the level of fishing mortality) would be associated with catch rates which decreased in proportion to a decreasing stock size. However, as shark tend to aggregate into schools, catch rates do not necessarily decrease in direct proportion to the decrease in stock size. This feature is captured in the model by having the catchability coefficient increase as the number of recruited sharks decreases.

### *4.2 Physical and economic characteristics of the fleet*

Boats in the southern shark fishery can be divided into five main types, an outcome of the management regime that has been in place since 1988. Commonwealth endorsed boats fall into three categories – A10, A6 and B. The A10 boats are limited to fishing with a maximum of ten nets, while A6 boats are limited to six nets. The B class boats are limited to between one and five nets, depending on their historic involvement in the fishery. While a small number of Commonwealth endorsed boats operate using longlines rather than gillnets, for the sake of simplification all of these boats are assumed to use nets. The remaining two groups are comprised of state endorsed boats. These boats may use either nets or hooks, and their historic choice of gear determines the group to which they belong.

The main physical information used in the model was the number of boats in each group, the amount of effort employed by each boat (in thousands of hook lift hours or kilometre net lift hours), types of fishing gear used and the selectivity of each type of gear. The different types of effort (hook and net effort) are standardised in the model through the use of relative fishing power. This measure of the relative catching efficiency of vessels is based on the relative catch per unit of effort from the different types of fishing gear.

Information on the cost of fishing in 1988-89 was collected from an economic survey of the southern shark fishery. The key economic information used in the model includes: the variable cost per unit of effort and the fixed cost of operating in the fishery, for each boat type, and the average price received for shark.

The main variables examined using the model were catch and effort levels and the net present value of fishery profits over time. For the purposes of the analyses, profits were defined as total returns less all cash costs, including an allowance for owner operators. No allowances were made for non-cash costs such as the opportunity cost of the capital or depreciation.

While many shark boats are endorsed to operate in some other fisheries, such as in the southern rock lobster fishery, shark boats are still prevented from operating in most other fisheries. Even when they do hold endorsements to operate in other fisheries, the ability of operators to increase their income from those fisheries is limited because these fisheries are heavily fished. Consequently, the opportunity cost of the boats used to catch shark is low, and was assumed to be zero.

## 5. MANAGEMENT OPTION SIMULATIONS

ABARE's bioeconomic model of the southern shark fishery was used to estimate the likely outcomes of a number of different management strategies proposed for the fishery by the fishing industry, by fisheries scientists and by fisheries managers. These options included: a continuation of the existing management plan; total or partial closure of the fishery to allow stocks to recover; or a reduction of the catch to 1200 tonnes, 800 tonnes or 400 tonnes. A number of key areas of uncertainty were also identified and the effect of varying these parameters was investigated. Each option was simulated under a range of alternative biological assumptions.

The baseline simulations, based on model 1, used a 'best guess' set of biological parameters that were current in early 1991. These parameters are very similar to those used in the 'SharkSim' model (South Australia Department of Fisheries 1991). Recent analyses of the biological status of the fishery suggest that the biomass of the fishery may be twice as large as was assumed in the baseline simulations (Reichelt and McLoughlin 1991). The effect of this on the results of the ABARE model was tested by doubling the starting stock size in the model and rerunning the simulations. The options were also examined assuming alternative density dependent mortality and growth rate assumptions to those used in the baseline model.

Not all options were examined using model 2, in which there is assumed to be a series of regional stocks in varying degrees of depletion. It has been suggested that one such stock of gummy shark may exist off southern Tasmania that has previously been underexploited due to being located in water either too deep or too rough to fish. It is further postulated that this breeding stock may result in a relatively constant recruitment of juvenile gummy shark to the Bass Strait region of the fishery (J. Prince, Southern Shark Research Group, personal communication, 25 October 1991). This possibility was modelled by splitting the bioeconomic model into two distinct parts – one each for gummy and school sharks. Each part was optimised separately.

As the number of variables increases rapidly with a longer time frame, the simulations were restricted to a thirty year period[2]. Thirty years represents about one complete life cycle of school sharks and about two life cycles of gummy sharks. The longer life cycle of school sharks may result in some longer term effects being inadvertently excluded from the analysis.

## 6. COMPARISON OF THE MANAGEMENT OPTIONS

Under model 1, using the baseline simulations, closure of the fishery for between 8 and 12 years will result in the greatest net present value of profits despite the uncertainty associated with the biological parameters (figure 3). However, when

2. The model could be run successfully over a longer time period only if the fishing activities were excluded. For example, the model was run over a 40 year period as part of the validation process for the biological component (Pascoe, Battaglene and Campbell 1992). Running the model with the fishing activities over a longer period resulted in problems with both resource constraints and infeasible solutions.

the starting stock size is doubled (the higher stock size assumption), the net present value of profits associated with a total closure is not substantially greater than that obtained by reducing the catch to 400 tonnes (figure 3). Given that the higher stock level is thought to be more accurate than the stock level used in the baseline simulation, there may be little to be gained from a total closure of the fishery.

Assuming that the gummy shark component of the fishery can sustain the current catch level of 1500 tonnes (model 2), then the optimal fleet configuration will be about twenty boats, each catching about 75 tonnes. This will result in an annual profit of about $3 million, giving a net present value over thirty years of about $48 million. Closing the school shark component of the fishery for a period of twelve years will result in further profits in the future. Under current price and cost conditions, this would result in a net present value of profits of about $24 million, and involve a small number of additional boats (between four and ten) once the fishery re-opens. Based on model 2, the optimal use of the fishery may result in a net present value of profits of about $72 million over the next thirty years.

It is unlikely that these levels of profitability could be realised under the current management plan irrespective of the true biological state of the fishery. The lack of adequately defined property rights for fishers over the fish stock results in most (if not all) profits being dissipated through unnecessary (from an economic perspective) competition between fishers. Continuing with the current management plan is likely to eventually result in the school shark stock being depleted below the point of commercial viability, even if the operators concentrate on the gummy shark fishery. While some short term profits may accrue, these are likely to be short lived as the school shark stock continues to be fished down.

For the school shark, the optimal management policies derived from model 1 and model 2 are quite similar. However, for the gummy shark, the two models yield very different results. Under model 1, the optimal strategy would be to close the entire fishery for 8 to 12 years. Under model 2, the optimal strategy would be to keep the gummy shark fishery open at around the current catch level and to prevent further catches of school shark for 8 to 12 years. In the absence of reasonable subjective probabilities on which model is correct, the minimax or the maximin decision criteria may provide useful guidance to managers on which model to accept and, hence, on what management action to take.

Under the maximin criterion, the decision maker would choose the option that had the best outcome under a pessimistic (worst case) scenario (Anderson, Sweeney and Williams 1982). Model 1 with higher juvenile mortality rates represents the worst case scenario for all uncertain biological parameters (figure 3). Based on the maximin criterion, the 'best' option would be to close the fishery for about 8 years (assuming the higher current stock level).

Under the minimax criterion, the decision maker would choose the option that results in the least opportunity loss or regret if an alternative scenario were discovered to be the true state (Anderson, Sweeney and Williams 1982). If model 1 is correct, the potential loss from keeping the gummy shark component of the fishery open may not be great. Under the baseline simulation of model 1 the gummy shark fishery contributed only $3 million out of a net present value of $27 million over 30 years. Conversely, the cost of closing down the gummy shark fishery, if model 2 is correct, may be as much as $3 million a year. The cost of maintaining the current management policy is the forgone potential profits from closing the fishery. This may be $35 million over the next thirty years if model 1 and the higher stock assumption are correct, or $70 million if model 2 is correct. Based on this, the manager using the minimax criterion would accept model 2, and choose to reduce boat numbers and prevent further catches of school shark.

The maximin criterion represents extreme risk aversion (Meyer 1975). In cases where uncertainty is high and the outcomes are irreversible, the maximin criterion may well be appropriate. However, fisheries management decisions may be reviewed on an ongoing basis as more information comes to light, and are likely to be reversible unless stocks have been reduced to a very low level. As a result, the stock can usually be expected to recover if the wrong decision is made as long as it is recognised in time. Consequently, the minimax criterion is more appropriate in this circumstance and model 2 may be the best model on which to base management decisions.

The optimal strategy derived from model 2 is to prevent further catches of school shark for 8 to 12 years while maintaining the catch of gummy shark at around current levels. However, in practice it is very difficult to catch gummy shark without catching some school shark. Depending on the mesh size used, at least 20 per cent of the catch is likely, on average, to be school shark, even when gummy shark are targeted. Since it is unlikely that catches of school shark can be prevented without a total closure of the fishery, the catch of gummy shark may need to be reduced well below the current catch level to ensure that the school shark component of the fishery can recover.

Ongoing monitoring of the fishery will provide more information on which biological model is more likely to be correct. As a result, management decisions can be reviewed as this information becomes available.

## 7. DISCUSSION AND CONCLUSIONS

The advantage of using models in policy analysis is that they can improve our understanding of the ways in which a system is likely to behave in circumstances where it is not possible (for economic, technical, political or moral reasons) to experiment with a real world situation (Lee 1980). In the case of the southern shark fishery, the alternative to modelling is experimentation through trial and error in the fishery. If model 1 is correct, error could mean the further depletion of the resource and a fishery which produces much lower profits than otherwise.

While management decisions need to be made in the light of uncertainty, these decisions are not necessarily final. Ongoing evaluation and revisions to the biological models will reduce the uncertainty and management decisions can then be reviewed in the light of the new information.

The purpose in this paper was to demonstrate how bioeconomic models may be useful management tools even with biological uncertainty. Although biologists generally do not like using models that contain a high degree of uncertainty, management decisions need to be made on the basis of the information that is currently available. In the case of the southern shark fishery, the cost of keeping the gummy shark component of the fishery open even if the constant recruitment assumption of model 2 is wrong is substantially less than the cost of closing the entire fishery if the constant recruitment assumption is correct. Based on this, a risk minimising/profit maximising strategy is to reduce effort on the gummy shark component of the fishery whilst preventing, or at least reducing, capture of school sharks.

## REFERENCES

**Anderson D.R., D.J. Sweeney and T.A. Williams** (1982). *An Introduction to Management Science : Quantitative Approaches to Decision Making*, West Publishing Company, USA.

**Hinchy M.D. and B. S. Fisher** (1991). *A Cost-Benefit Analysis of Quarantine*, ABARE Technical Paper 91.3, AGPS, Canberra.

**Hinchy M.D., B. Jones and S. Thorpe** (1992). *Reducing Greenhouse Gas Emissions from the Energy Sector*, ABARE Research Report 92.3, AGPS, Canberra.

**Lee C.** (1980). *Models in Planning,* Urban and Regional Planning Series, vol. 4, Pergamon Press Great Britain.

**Meye J.** (1975). 'Increasing risk', *Journal of Economic Theory* **11** (1) : 119-32.

**Olsen A.M.** (1954). 'The biology, migration and growth rate of the school shark *Gaeleorhinus australis* (Macleay 1881) (*Carcharhinidae*) in south-eastern Australian waters', *Australian Journal of Marine and Freshwater Research* **5** : 353-410.

**Olsen A.M.** (1984). Synopsis of biological data on the school shark *Gaeleorhinus australis* (Macleay 1881), FAO Fisheries Synopsis No.139, Food and Agriculture Organisation of the United Nations, Rome.

**Pascoe S., T. Battaglene and D. Campbell** (1992). *A Bioeconomic Model of the Southern Shark Fishery*, ABARE Research Report 92.1, AGPS, Canberra.

**Reichelt R. and K. McLoughlin** (1991). Bureau of Rural Resources Report on Southern Shark Assessment – Response to CSIRO interim report, 14 December, Canberra.

**South Australian Department of Fisheries** (1991). *SharkSim 1 : A Computer Graphics Model of Australia's Southern Shark Fishery*, Adelaide.

**Southern Shark Assessment Group** (1990). *Report of the Southern Shark Assessment Workshop No. 6,* Marine Science Laboratories, Queenscliff, Victoria, Bureau of Rural Resources, Canberra (mimeograph).

**Southern Shark Restructuring Task Force** (1991). Minutes of Meeting No. 2, Melbourne, 11 February.

**Walker T.I.** (1991). 'Fishery simulation model for shark applied to the gummy shark, *Mustelus antarcticus* Gunther, from Southern Australian Waters', in *Southern Shark Database Project : Final FIRDTA Report, April 1991*, Marine Science Laboratories Internal Report No. 189. Department of Conservation and Environment, Queenscliff, Victoria.

**FIGURE 1.**
**THE AUSTRALIAN SOUTHERN SHARK FISHERY**

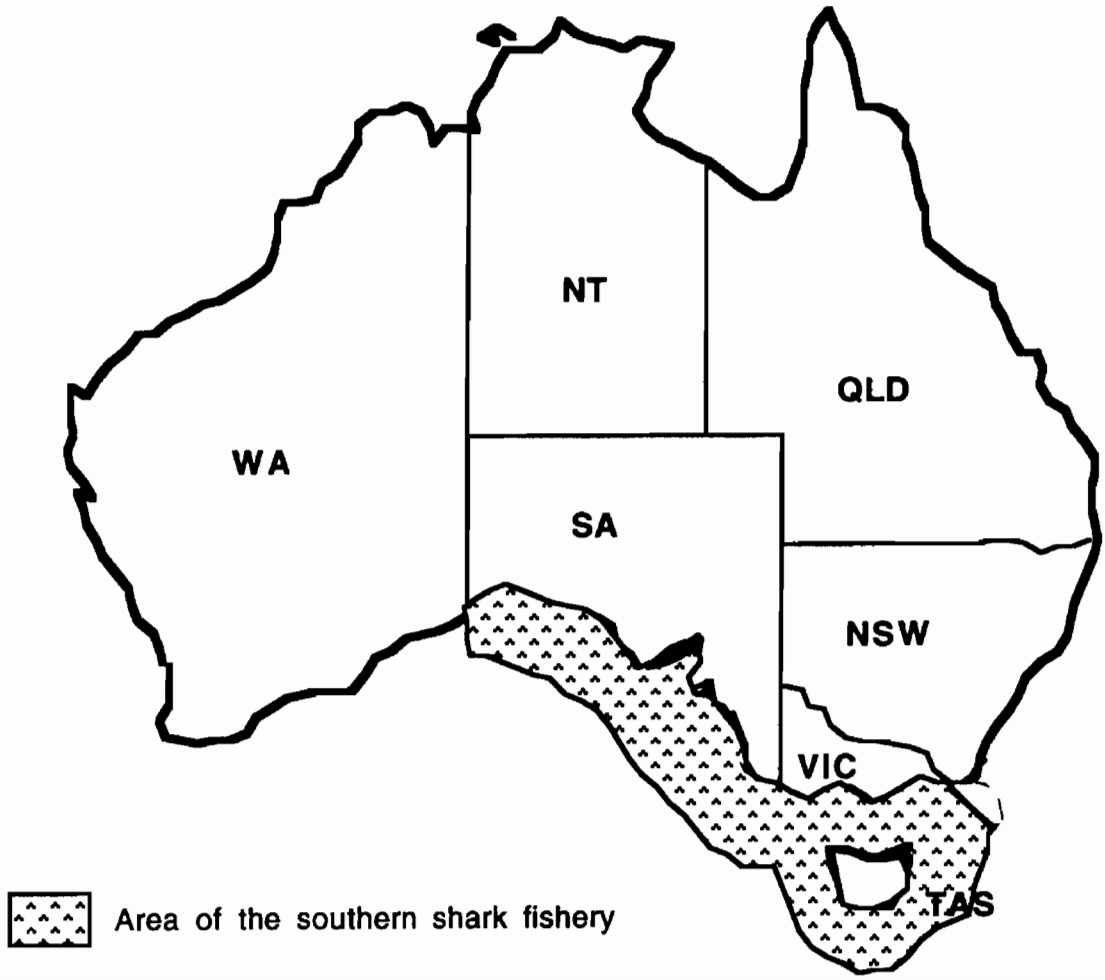


**FIGURE 2.**
**DIAGRAMMATIC REPRESENTATION OF ABARE'S BIOECONOMIC MODEL OF THE AUSTRALIAN SOUTHERN SHARK FISHERY**

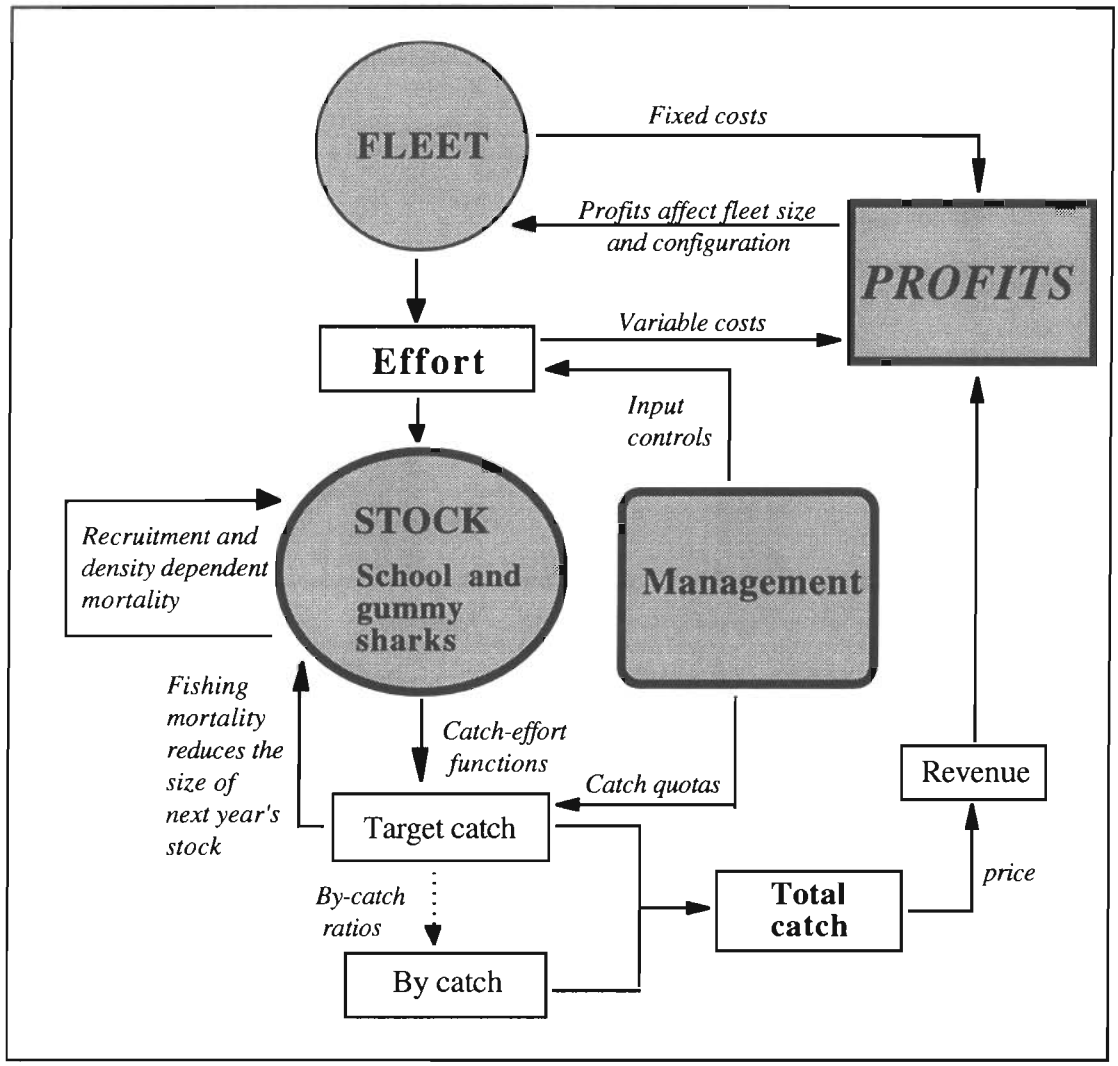
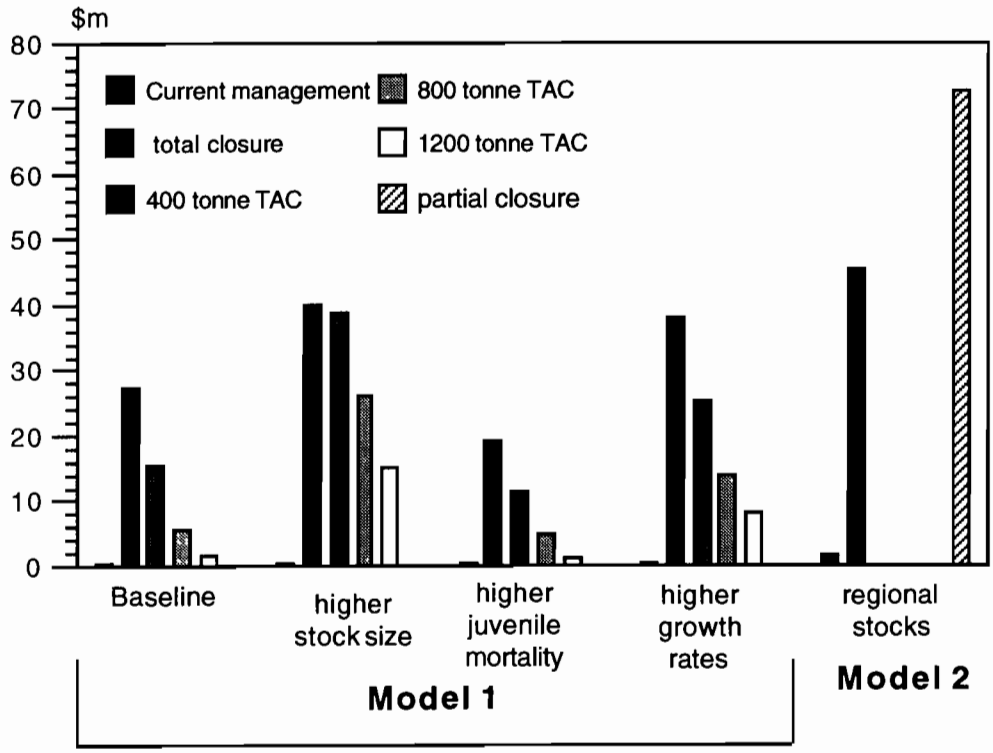


**FIGURE 3.**
**NET PRESENT VALUE OF PROFITS ACCRUING TO THE AUSTRALIAN SOUTHERN SHARK FISHERY UNDER DIFFERENT FISHERY MANAGEMENT POLICIES**



# Simulation Model of Factory Trawler Operation

**Ingólfur Arnarson and Páll Jensson**

Faculty of Engeenering, University of Iceland 15-107 Reykjavik Iceland

ABSTRACT

*Simulation models have proved useful in analyzing operations of complex systems, in particular if the decision problems are of dynamic and stochastic nature. In these cases, optimization models are often too far from the reality, whereas simulation can be more credible to the decision makers and serve them in a better way.*

*The operation of a fishing vessel can certainly be characterized as being subject to both a high degree of randomness and dynamic decision processes. During a fishing trip of several days or weeks, the captains often observe great fluctuations in catches and weather. Many decisions have to be made on the basis of these observations, regarding fish finding and on board processing.*

*The paper describes a model which simulates a factory trawler, haul by haul and trip by trip. The case of a factory trawler is chosen because it has both the catching and the processing operations. A LP model is embedded to plan the processing of each haul's catch. Among the many potential applications of the model, the two discussed in the paper are the testing of decision support systems and an analysis of the impacts of different fisheries management schemes on the individual firms.*

## 1. INTRODUCTION

A great and an increasing deal of fish, at least in the more developed fisheries of the world, is caught by trawlers. These are mainly stern trawlers, towing the trawl from the stern of the ship. Typically, the trawl is towed for few hours, and then hauled and emptied and set again, possibly after some relocation of the vessel. Trawlers with onboard processing capabilities (beyond gutting and heading) are called factory trawlers. Examples of the products processed are various types of frozen fillets or surimi. The main production stages in fillet production are gutting, heading, filleting, skinning, trimming, packing and freezing. Some or even most of these stages (except freezing) can be skipped, and therefore many products are possible, differing in price and in processing speed. In surimi production, different operations strategies can result in different quality grades of the surimi products, and different prices.

Factory trawlers can vary in size from 200 to 5000 BRT (metric tons), and in crew size from 15 to 150 men. Similarly, the length of trips varies from say 20 days to many months. The average catch rates are also very different at the various

fishing grounds of the world, and might range between 0 and more than 100 tons/hour. In most cases, the freshness of the raw material is important for the processing. Hence, the catch of one haul is usually processed while the next haul is being towed, even though some storage time is possible.

The operation of a modern factory trawler is a complex management process. In addition to the better known tasks like navigating and fish finding, the captain frequently has to make important decisions regarding the onboard processing. After each haul, he must decide if time should be taken to produce the most valuable, however usually also the most time consuming products, or if "faster" but less valuable products should be chosen.

The random fluctuations in catch rates, and in many cases also weather conditions, add to the complexity of the management process. Low catches could trigger the steaming to other fishing grounds, despite the cost of fuel and lost time in catching. During high peaks in catch rates, the captain might consider synchronizing his catching with the processing rate of some chosen product.

These decisions are highly dependent on whether the vessel has open access to the fishing grounds, or it is constrained by, say, an individual quota, i.e. on the fisheries management scheme applied. Many different schemes are either being discussed or have been implemented. These schemes can have different impact on operations fishing vessels.

Because of the stochastic and dynamic nature of the operations of factory trawlers, it was decided to build a simulation model. By this, we hope to be able to study the decision processes in a more realistic way than an optimization model would allow. Also, the model should enable us to study the impacts of the various fisheries management methods on the firms.

Sigvaldason et al. 1969 describe a similar model of a wet fish trawler, with the main purpose of studying the supply of raw material to freezing plants in Iceland, and comparing vessels of different sizes. In Jensson 1981, a simulation model of a fishing fleet is reported, emphasizing the decisions regarding the choice of harbor and congestion problems. Digernes 1982 and Arnarson 1986 discuss the value of time, when captains are making decisions about cruising speed and choosing fishing grounds. The value of time also enters the following discussion, when the product mix, as described in Jensson 1988 for freezing plants, is being decided. Many of the scenario assumptions for the case studied here, the cod fishery in Iceland, are based on Arnarson 1984, as well as on Andrason 1990 and Teitsson 1990, which describe work on the first prototypes of the model.

In the next section, the main logic of the model is described. Three of the most significant modules are then described in a more detailed way : The random catch generator, the important concept of the value of time, and the product choice module. As the product mix problem is a reasonably well defined decision problem, we embed a linear programming unit to simulate the decision behavior of a rationally thinking captain.

In section 6, we show an example of the possible applications of the model, in this case for analyzing the impact of introducing individual quotas in a fishery. In the concluding remarks, other potential applications are suggested.

## 2. MODEL DESCRIPTION, MAIN LOGIC

The simulation model is programmed in PASCAL (TURBO-PASCAL 5.5) and runs on PC computers. The main reasons for the choice of PASCAL, a general programming language, instead of some special purpose simulation language or package (like GPSS, SIMULA, SIMSCRIPT etc.), are the following :

(i) More flexibility in modelling and report design

(ii) The need to call a fast simplex routine for a speedy solution to the product mix problem after each haul (note that thousands of hauls may be trawled each year)

(iii) The simulation can be characterized by "time slice incrementing (haul for haul)", as opposed to the common "event driven" simulation, which in turn is made much easier by using simulation languages.

The overall structure of the model is as follows :

FACTORY TRAWLER SIMULATOR : A Structure Chart :

READ assumptions (from files and/or keyboard).

INITIALIZE parameters.

WHILE Years < Number of years to be simulated
DO NEXT YEAR :

WHILE Accumulated Catch < Individual Quota (infinite if none)
AND Elapsed Time of Year < One Year
DO NEXT TRIP :

Revise an OPERATIONS PLAN for the rest of the year, providing a framework plan for the (next) trip. See section 4.

[CHOOSE fishing grounds. Planned for a multi species/grounds version]

SAIL to the fishing grounds.

WHILE Accumulated Production < Fish Hold Capacity
AND Elapsed Time of Trip < Maximal Trip Length
DO NEXT HAUL :

GENERATE CATCH and time span of the haul, see section 3.

Revise the VALUE OF TIME, i.e. the processing strategy (reflecting how much emphasis should be put on time versus price value of products). See section 4

Solve the PRODUCT MIX (product choice) problem, i.e. what to do with the catch of the haul. Here it is solved as a linear program, with a simplex outine embedded in the simulation. See section 5.

UPDATE time elapsed, accumulated catch, production and other statistics influenced by the results of each haul.

NEXT HAUL ->

END of Trip :

[CHOOSE harbor to land the catch]
SAIL to harbor
LAND the catch [Refill supplies, repair work etc.]
UPDATE Trip Statistics (Catch,Time,Income,Costs,...)
WRITE Trip Report (if requested by user)

NEXT TRIP ->

END of year :
UPDATE Year Statistics
WRITE Year Report (if requested)

NEXT YEAR ->

END of Simulation :
UPDATE Totals and Averages
WRITE Totals and Averages, for all years simulated.

END.

This main structure is composed of modular units, in a flexible manner so that additional units can be included. Some of the planned units are shown in brackets above.

Many of the units are trivial or plain programming work and not of interest here. Those deserving further discussion are explained in the following three sections.

## 3. THE CATCH GENERATOR

Because of the extensive use of the modular features provided by PASCAL 5.5, it is relatively easy to change the model and replace modules, to adapt to different types of factory trawlers and fisheries. In this paper, the case considered is, as said before, the cod fishing in Iceland. The following description will be based on that case.

The probability distribution for hourly catches was estimated by sampling statistics from reports of some Icelandic trawlers, which are required to keep and send to the Icelandic fisheries authorities a diary recording information (date, start of haul, trawling time in minutes, fishing grounds, depth, and catches in kg by species) on every haul.

The statistical work is described in Teitsson 1990. The Log-Normal, LN(a,b), distribution was found to be a convenient model of catches per hour. It is interesting to note that Sigvaldason et al. 1969 used the LN distribution for catches per day, which was the unit of time in their study. The daily catch of a trawler is simply the sum of catches from several (a fluctuating number) hauls, however probably too few to give the daily catch a typical Normal distribution form.

Another and even a more likely explanation for this is the high egree of autocorrelation observed in the catches from haul to haul. The catch per hour series was modelled as a 1. order autoregressive process :

$$\text{Catch}(t) = A^* \text{ Catch}(t-1) + \text{Residual}(t) \quad (1)$$

The Least Squares Estimate for the coefficient A is the correlation coefficient, in this case estimated to be 0.26. This would also be the Maximum Likelihood estimate if the residuals were normally distributed, which however is not the case here. Higher order coefficients were found not to be significantly different from zero.

The residuals provide the random fluctuations in the process above. By using the well known relationship between LN and Normal distributions, see for example Derman et al. 1973, we can generate the fluctuating catches by (1) and :

$$\text{Residual}(t) = \text{EXP}( \text{Mean}(t) + \text{StDev}(t) * \text{Normal}(0,1)) \quad (2)$$

where

Normal(0,1) is a realization of the standardized normal distributionwith mean = 0 and standard deviation = 1. This is generated bycalling and summing 12 uniformly (0 to 1) distributed numbers andsubtracting 6 to get a mean of 0.

Mean(t) is the mean value of the normal distribution, which will give the desiredmean value of the Log-Normal according to seasonal catch fluctuations scenario described in Arnarson 1984.

StDev(t) is the standard deviation of the normal distribution calculated in a similar way as the mean value.

The high autocovariance in catch rate from hour to hour makes it more difficult to plan the production and smooth out the randomness. Also, it is in accordance with the fact that the captains often change fishing grounds rather frequently, as soon as they observe low catches. This is simulated in the model by a threshold criteria, such that whenever catch rate lower than the threshold is observed, the vessel is relocated,which takes time from fishing. This time is simulated by an exponential distribution, so that moving the vessel short distances is most common.

The trawling time for each haul is dependent on the catch rate. Modern techniques allow the captains to "see" on a graphical computer screen approximately how much is in the trawl. When catch rate is high, he will haul the trawl earlier, sometimes even after one or two hours of trawling. If catch rates are low, however not under the threshold criteria, he might trawl for say 4 to 6 hours. This is modelled by a set of rules, reflecting the behavior of captains found by examining the diary recordings.

## 4. THE CONCEPT OF TIMEVALUE

The concept of "Timevalue", as applied to decision making in fisheries, was introduced by Digernes 1982, see also Arnarson 1986. A thorough discussion on the concept is out of range of this paper. In short, the timevalue is the expected opportunity cost of time, "bought" from the future, or the expected shadow price of future time.

In the references cited above, the concept was proposed to help making short term decisions about cruising speed, for example when steaming to the fishing grounds. Intuitively, if no use can be made of the next hours, because the weather is too bad for fishing, or reported catch rates are very low, then time has no or low value, and the captain should choose low cruising speed. The opposite case could justify maximal speed.

Also, the timevalue enters more long term decisions. Consider planning a fishing trip of several days or weeks, and comparing two alternatives (choosing between different fishing grounds), that differ in length of trips as well as net revenues. Then, the question rises how to evaluate the time from the finish of the shorter trip until the longer trip is finished. A long term timevalue is then suggested to make the two alternatives comparable. This will depend on the quota left and the remaining time of the year, as well as on expected catch rates for the time interval considered.

In our model, we apply an expected opportunity cost of future time, or timevalue, to describe how the captain trades processing speed with product prices. This will become clearer in the next section. In the following, we discuss the difficult problem of assessing the timevalue.

The assessment of a long term (however within a year'shorizon) timevalue can theoretically be regarded as an evaluation of the shadow price of a time constraint in an optimization model. This model, which will be discussed in another paper, describes an aggregate plan for the operations of the vessel for there maining part of a year, with a given quota left, and subject to forecasted catch rates, prices and costs throughout the year.

In the simulation model, a more pragmatic and heuristic approach was used, based on a study of how the operators actually plan the fishing trips in real life. After all, the purpose of building this simulation model is to be able to study a wide range of questions, all however based on a realistic description of the actual decision behavior of the operators and the captains.

The approach used is as follows :

### *4.1 Revision of an OPERATIONS PLAN for the remaining part of the year*

This is done at the beginning of each trip :

(i) Plan Number of Trips Left, NTL :

NTL = (Year - Time Elapsed of year)/Maximal Trip Lengthround up (unless excess time is very small if rounded down).

(ii) Find Average Quantity per Trip, AQT (tons) :

AQT = (Vessel Quota - Accumulated Catch)/NTL

If AQT < Minimum, then reduce NTL by 1 and do 1.2 again. This means one or more trips will be skipped. If AQT > Maximum, then use the maximum value.

This could be the open access case, where vessel quota is infinite, or a case where the annual vessel quota cannot be reached.

(iii) Modify AQT with a seasonal (by months) Index of Catch Rates ICR(t), describing how the next month is compared to the remaining months of the year. This gives the Planned Quantity for the (next) Trip, PQT (tons) :

PQT = AQT * ICR(t)

### *4.2 Revision, after each haul of the EXPECTED VALUE OF TIME for the next haul :*

(i) Find the Planned Processing Rate for the remaining part of the trip, PPR (tons/hour), in accordance with the operations plan and the planned quantity for the trip :

PPR = (PQT - Accum. catch of trip)/Time left of trip

PPR is, however, never less than a given minimum rate.

(ii) Revise, if necessary, according to possible changes in prices and variable costs, the Net Revenue per ton of Fish caught, NRF (IKR/ton) [1] :

NRF = Reference Sales Price * Yield Coverage - Variable Costs

(iii)Estimate the Expected Catch Rate, ECR (tons/hour), for the next few hours, on basis of the last hauls. Here, various sophisticated forecasting methods could be applied. In the simulation model, we simply use the last haul :

ECR = Catch rate observed in last haul

(iv) Revise the Expected Value of Time, EVT (IKR/hour) :

EVT = NRF * MIN( PPR, ECR )

In this way, the long term plan PPR "sets the pace" for the assessment of the time value, unless it is so high (or the catch rates so low) that the catch rates, in short term, become a bottleneck.

## 5. PRODUCT MIX PLANNING

Each time when a trawl has been hauled onboard, the captain has to make two closely related decisions regarding the processing of the catch of the haul :

i) How much time should be allocated to the processing, i.e. should he wait to start the next tow, or should he allocate the expected trawling time for the next haul and go onwith continuing catching ?

ii) What product, or products should he chosen for the processing, considering that they can differ a great deal in prices and labor requirements ?

Given a certain expected value of time EVT, this is a reasonably well defined decision problem. Here, we assume that the captain is a rational optimizer, and we model the decision behavior by solving a linear program (LP), similar to the one reported in Jensson 1988. In fact, modelling an irrational behavior seems rather difficult.

Decision variables in the LP model are :

X(j) : Quantity produced of final product j (tons of product)

time : Time allocated for processing (hours)

Coefficients :

P(j) : Sales Price for product j (IKR/ton)

W(j) : Work Requirement in processing for product j (man hours/ton of product)

R(j) : Raw Material Requirement for product j, i.e. the reciprocal of the yield coverage (tons of fish/ton of product)

F(j) : Filleting Machine Time Requirement for product j (machine hours/ton). This is zero for whole frozen fish.

EVT : Expected Value of Time, see last section (IKR/hour)

MEN : Crew size on shift working in processing

RAW : Raw Material, i.e. catch of last haul (tons of fish)

FIL : No of Filleting Machines

1. USD = 55 IKR

FRC : Freezer Capacity (tons of products/hour)

ETT : Expected Trawl Time for next haul, here simply equal to the trawl time of last haul (hours)

The model maximizes the sales value of the products minus the opportunity cost of time, with respect to manpower, raw material, filleting and freezer capacity :

max z = SUM(j : P(j) * X(j) ) - EVT * time (IKR)

Manpower : SUM(j : W(j) * X(j) ) <= MEN * time (man hours)

Raw mat : SUM(j : R(j) * X(j) ) <= RAW (tons of fish)

Filleting : SUM(j : F(j) * X(j) ) <= FIL * time (machine hours)

Freezing : SUM(j : X(j) ) <= FRC * time (tons of products)

Time : time >= ETT (hours)

X(j) >= 0

Data for our case is given in Table 2. This is a simplified version of the model, whereas a full version has the following additional features :

- *Size grading of the fish, which affects filleting time and work requirements.*
- *The possibility of calling extra people, not on duty, to work.*
- *Aging of the raw material, as the yield coverage and labor requirement get worse after rigor mortis.*

Although the full version was the original one, it was later simplified as it showed to be difficult to justify and collect data on these features, when studying the real life closer. One the other hand, the time was not introduced as a decision variable in the first version.

These last remarks are examples of the value of being able to test ideas of decision support tools in a simulated environment, while developing them. A simulation model like this serves as a laboratory, where experiments can be made without the costs of real life.

## 6. ANALYZING THE IMPACT OF INDIVIDUAL QUOTAS

In most fisheries of the world, methods for managing the fishing in one way or another have been implemented or are at least being discussed. One of many different management schemes is the individual quota system (IQ), i.e. each vessel is allocated (given or sold) an annual quota for each the most important species. In some cases, the quotas are transferrable (ITQ).

They can be leased or sold. Open access to the fisheries, possibly with a Total Allowable Catch (TAC), can be regarded as the special case of infinite IQ.

In Iceland, all fishing vessels have had IQs since 1984. Here, we will focus on the cod fishery, the most important species in terms of export value. Every year, a TAC is set for the cod stock. Then, if all vessels were alike, and there were N vessels, the individual quota would be

$$IQ = TAC / N$$

Of course, the vessels are different, and so are the IQs. However, if we consider the factory trawlers per se, we have a relatively homogeneous fleet. Then the question arises : Is it most economical to have as few trawlers as possible, with as high IQ as possible ? Most economists and other specialists have, implicitly or explicitly, said yes to this question. Some have stated that the number of vessels in the Icelandic fishing fleet should be cut down by 30 - 40 %.

This result would certainly be correct if the net revenue earned by a vessel would be a linear function of the IQ allocated. Then, a "bang-bang" type of solution would appear : Either full IQ or 0. In the literature of fisheries economics, this seems to be one of the basic assumptions, even though some practitioners in the fishing industry do not agree by intuition.

It is therefore of interest to study the linearity of the net revenue with respect to the IQ. We restrict ourselves to Icelandic factory trawlers fishing cod. In the following, we will see how the simulation model was used to provide answers to this and other fundamental questions regarding fisheries management.

In Table 1, the data for the model trawler is given, while Table 2 shows data for the onboard processing, i.e. the various products that the trawler can produce, as well as production capacity data. Data for the cod fishing and it's seasonal pattern is in Table 3.

The model was run 20 times for each value of IQ allocated, in order to get reliable results. Each run spanned a year, or less if all the quota was caught before the end of the year.

Net annual revenue is defined here as the sales value of all products produced in the year, minus variable costs, which are of two types :

(i) Costs associated with each trip (fuel for steaming to grounds etc.)

(ii) Costs associated with each day at sea.

The results are presented graphically in figures 1, 2, 3.

The simulations reveal that the revenue function is not linear with IQ. The reason can be seen in fig. 3 : The product mix changes as more IQ is given to the trawler. So does the average net price per kg of fish, see fig. 2.

The implications of these results are outside the scope of this paper. At present, the effects on fisheries economics and fisheries management theories are being studied. Suffice to point out here, that the state of the markets for fish products must be considered when deciding individual quotas. In case of one product, or all products having similar sales price per kg of fish (accounting for yield coverage), the revenue increases linearly with IQ. The more the products differ in this respect, the greater is the concavity of the revenue function, and the more erroneous are the theories and results, that are based on the linear form.

The results are useful for the fisheries managers, when analyzing the impacts of different quotas for the vessels. Also, the operators of the vessels can use the results for decision making. To take an example, the marginal price per kg of fish, fig. 2, tells them how much they could pay for additional quota.

## 7. CONCLUSIONS

As some readers may have concluded, a more analytical (optimization) approach could have been used to the problem presented in this paper, however at the risk of loosing some important aspects of this dynamic and stochastic reality. The product mix problem, with stochastic raw material quantity from each haul, may be regarded as a "Wait and see" problem (the "passive method") in Stochastic Programming, see Jensson 1975. It would, however, be difficult to grasp the essence of the decision behavior of the captains with such an approach. Also, our experience tells us that with a simulation model, it is easier to gain the confidence of the decision makers, as reality can be modelled more closely.

In the last section, we have seen an example of the possibilities of the simulation model. Following is an overview of the various potential users :

i) Naval architects and engineers, comparing alternative design of equipment and production facilities onboard.

ii) Operators of factory trawlers, planning the year or single trips, or deciding whether to invest in a certain processing line or not, or to buy more quota.

iii) Fisheries management authorities, evaluating the consequences of quotas or other management schemes for the firms and the sectors of the fisheries.

iv) Educators and trainees in fisheries operations management. By using simulators, principles of management can be taught and trained.

v) Researchers in fisheries management and economics, and developers of decision support systems for operators and captains.

Several additions to the model have been planned, like adding more fish species and fishing grounds, and introducing the decisions of choosing grounds. Also, more model runs are planned to study various important aspects of fisheries management, and to test ideas to decision tools. The model has shown it's value by serving as a laboratory, where ideas and methods can be tried out without the costs associated with making real life errors.

## REFERENCES

**Sigvaldason H. et al.** (1969). *"A Simulation Model of a Trawler as a Raw Material Supplier for Freezing Plants in Iceland"*, Techn. Report, Univ. of Iceland (in Icelandic).

**Digernes T.** (1982). *"An Analytical Approach to Evaluating Fishing Vessel Design and Operation"*, Dr. Ing. Thesis, NTH Trondheim, Norway (in Norwegian).

**Jensson P.** (1981). *"A Simulation Model of the Capelin Fishery in Iceland"*,in Applied Operations Research in Fishing, ed. K. B. Haley, Plenum Press.

**Arnarson I.** (1984). *"Economical Analysis of Fishing Vessels. A Comparison between Stern Trawlers and Longliners"*, MSc Thesis, Norwegian College of Fishery Science Tromsø, Norway (in Norwegian).

**Arnarson I.** (1986). *"A Decision Support System for Fishing Skippers"*, Techn. Report, FTFI Trondheim, Norway (in Norwegian).

**Jensson, P.** (1988). "Daily Production Planning in Fish Processing Firms", *European J. of Operations Research Vol. 36,* No. 3.

**Andrason Th. I.** (1990). *"Production Management onboard on Factory Trawlers"*, Final Thesis, Engin. Fac. Univ. of Iceland (in Icelandic).

**Teitsson A.** (1990). *"Processing onboard on Factory Trawlers"*, Techn. Report, Icelandic Fisheries Laboratories (in Icelandic).

**Derman C., L. Gleser and I. Olkin** (1973). *"A Guide to Probability Theory and Application"*. Holt, Rinehart and Winston.

**Jensson P.** (1975). *"Stochastic Programming. Vol. I : Models"*, PhD thesis IMSOR, Techn. Univ. of Denmark.

**TABLE 1.**
**FACTORY TRAWLER DATA.**

| | |
|---|---|
| Annual quota in metric tons | 1.000-6.000 |
| Maximum trip duration in days | 24 |
| Number of years simulated | 1 |
| Maximum number of operating days per year | 350 |
| Fish hold capacity in metric tons. | 250 |
| Crew size. | 24 |
| Average fuel costs in free speed pr trip, '000 IKR. | 200 |
| Misc. var. costs pr operating day pr. man '000 IKR. | 2.3 |
| Other var. costs pr operating day. '000 IKR | 317 |
| Sales price pr kilogram quota. IKR/KG. | 30 |
| Number of factory workers pr. shift. (MEN) | 8 |
| Vessel share of gross revenue. | 0.75 |
| Maximum number of workers on extra shift. | 3 |
| Number of workers handling fishing gear. | 5 |
| Extra cost pr man on extra shift, IKR. | 500 |
| Time in rigor mortis, minutes. | 165 |
| Time spend on fishing gear prior rigor mortis, min. | 35 |
| Time spend on fishing gear post rigor mortis, min. | 15 |
| Average time spent in free running speed, days. (To first and from last fishing ground including stay in harbor between trips). | 3 |
| Percent of the catch in size grade 1. | 0.2 |
| Percent of the catch in size grade 2. | 0.4 |
| Percent of the catch in size grade 3. | 0.3 |
| Percent of the catch in size grade 4. | 0.1 |
| Fileting capacity, fish/minutes. (FIL) | 34 |
| Freezing capacity, kg/minutes. (FRC) | 49 |
| In effective time in fileting, min pr shift. | 10 |
| In effective time in freezing, min pr shift. | 15 |

**TABLE 2**
**PRODUCTS AND PROCESSING DATA.**

Product = Name Of The Product
Price ... = Sales Price For The Product
Con2 = Percent Of Production Produced To Minced Blocks %.
Con3 = Lower Bounds On Processing Time.
Con4 = Labor Requirements On Labor. Min/Kilogram Of Product.
Con5 = Labor Requirements On Fileting Machines. Number Of Fish Per Us Product.
Con6 = Labor Requirements Freezing. -1 If Frozen 0 If Not.
Con7 = Raw Material Requirements Kg Mol/Kg Product

| Product | Price P(j) | Con2 | Con3 | Con4 W(j) | Con5 F(j) | Con6 | Con7 R(j) |
|---|---|---|---|---|---|---|---|
| AM11 | 350.3 | 0.16 | 0.0 | 2.79 | 1.13 | 1.0 | -2.67 |
| RL11 | 213.3 | 0.05 | 0.0 | 2.56 | 1.13 | 1.0 | -2.26 |
| RB11 | 193.6 | 0.04 | 0.0 | 2.26 | 1.13 | 1.0 | -2.22 |
| OSN1 | 149.0 | 0.0 | 0.0 | 0.41 | 1.13 | 1.0 | -1.96 |
| IS11 | 0.0 | 0.0 | 0.0 | 0.13 | 0.0 | 0.0 | -1.0 |
| HEI1 | 69.0 | 0.0 | 0.0 | 0.13 | 0.0 | 1.0 | -1.0 |
| MAR1 | 97.0 | -1.0 | 0.0 | 0.17 | 0.0 | 1.0 | 0.0 |
| KAS1 | -30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -1.0 |
| FRIV | -500.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| VINN | 0.0 | 0.0 | -1.0 | -8.0 | -34.0 | -49.0 | 0.0 |

**TABLE 3**
**CATCH RATES.**

| **Month** | **Mean Catch rate (Kg pr trawling hour).** |
|---|---|
| January | 858 |
| February | 942 |
| Mars | 1177 |
| April | 1139 |
| May | 1369 |
| June | 1184 |
| July | 1256 |
| August | 1385 |
| September | 1020 |
| October | 941 |
| November | 882 |
| December | 799 |

FIG. 1.
ANNUAL NET REVENUE FOR THE TRAWLER,WITH INCREASING QUOTA (IQ).

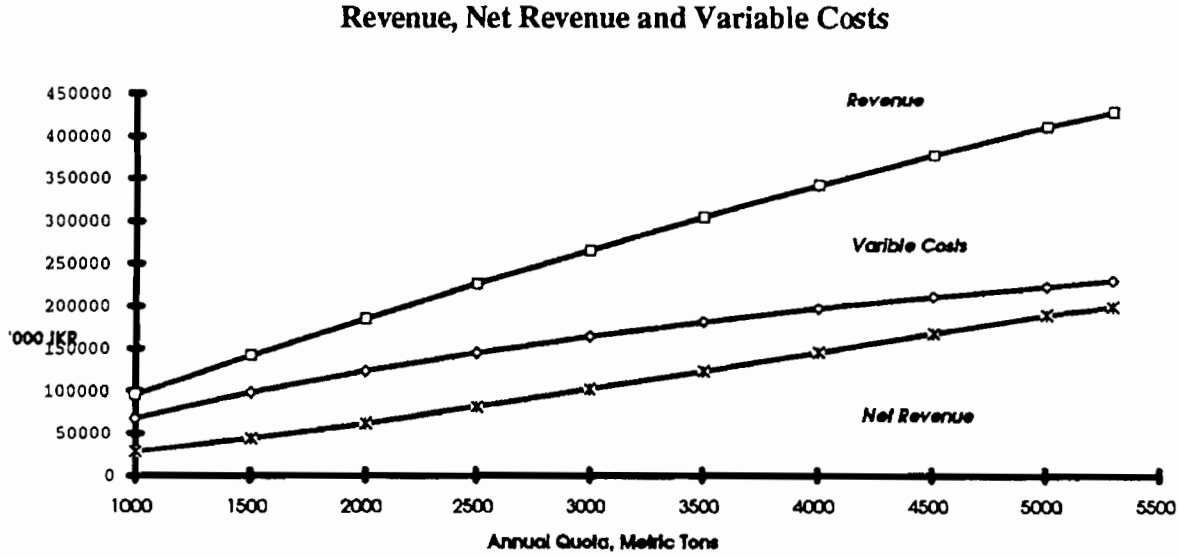



FIG. 2.
AVERAGE AND MARGINAL NET PRICE PER KG OF FISH, WITH INCREASING IQ.

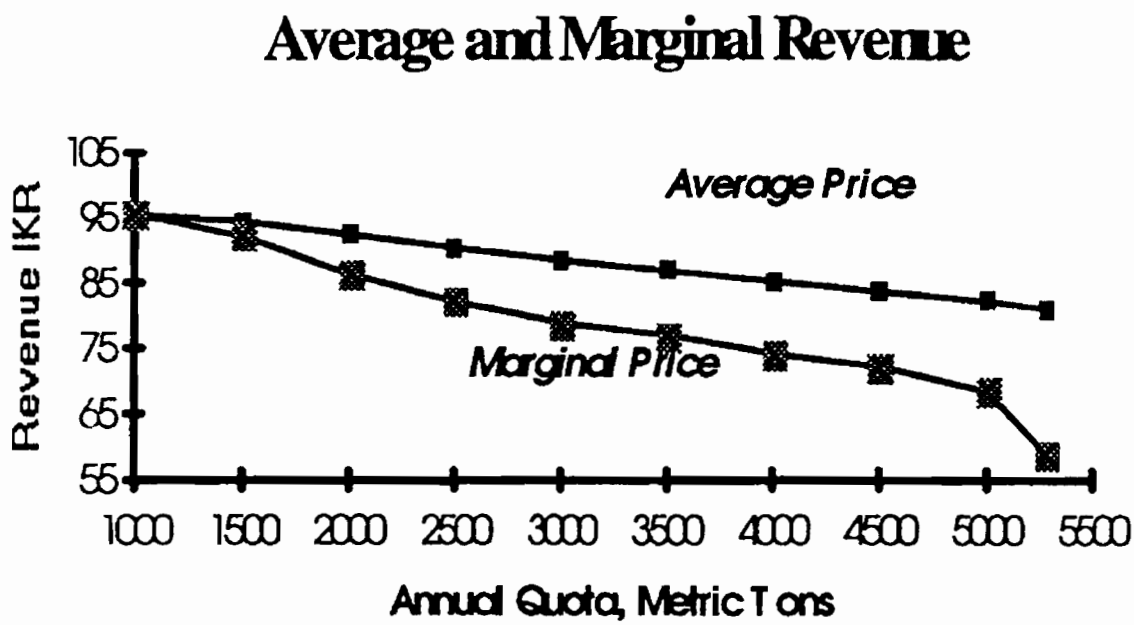
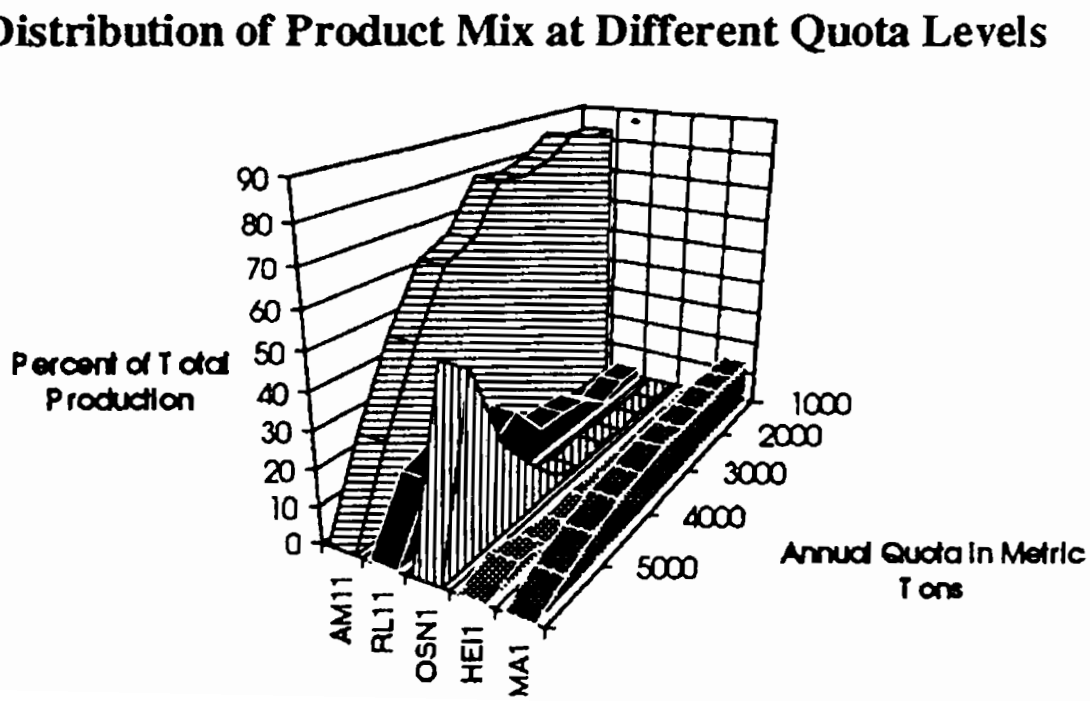


FIG. 3.
PRODUCT MIX FOR DIFFERENT IQ.



# The Nordic Fisheries Management Model - The model and the data for the Icelandic version

**Asgeir Danielsson**

National Economic Institute, Kalkofns vegw 1, 150 Reykjavik, Iceland

ABSTRACT

*The paper describes the main features of the Nordic Fisheries Management Model (NFMM). This model has been developed by P. Helgason, S. Olafsson,, S. Wallace, R. Arnason, A. Danielsson and others. The aim of the model is to simulate the economic and biological consequences of different methods for manging the fisheries. The model simulates the vessels choice of fishery, their catches the production decisiosn of the processing plants, the market for wet fish, and for catche-quotas, the profits of the firms and the biological consequences of their activity.*

*The paper describes also the collection/construction of data for the Icelandic version of the NFMM. As the basic unit in the model are actual firms it requires data on the production costs of the different products in the model, i.e.it needs input/output coefficients for every fishery and every boat as well as input/output coefficients for each production line in the processing plants of the firms.*

## 1. INTRODUCTION

In most countries fisheries management has changed radically during the last two decades. A variety of administrative controls have been introduced. In some countries efforts are being made to use market mechanisms to control the fisheries through individual transferable catch quotas. In the North Atlantic area Iceland has had from Jan. 1, 1991, a system where fishing of the 11 most important species is almost completely managed with individual, transferable catch quotas which are allocated to fishing vessels[1]. In Canada and Norway individual quota schemes have been used together with other systems for managing the fisheries. The European Community and its member states, on the other hand, rely on total quotas and technical controls.

1. There is no regulation of the fishing of other species than cod, haddock, saithe, redfish, greenland halibut, plaice, capelin, herring, shrimp, scallop and lobster.

In most countries the advantages and the disadvantages of the different management systems are intensively debated among the fishermen and their organizations and in the scientific community. The Nordic Fisheries Management Model is to be a tool for making comparisons of the different management systems. This model originates from efforts to develop a model to simulate the effects of different quota management schemes for the Norwegian demersal fisheries which started in 1988 at the Christian Michelsen Institute in Bergen, Norway. These efforts were a follow-up of a modelling of the pelagic fisheries done earlier at the same institute.[2] Some use was also made of the experience from a simulation model for the Icelandic demersal fisheries.[3] This modelling activity was carried out during 1988-1990 at the Haugesund Maritime College, Norway, and has been documented in several reports.[4]

From mid-1990 this modelling activity has been supported by a grant from the Nordic Council of Ministers under a special program on multi-species research. At the same time the main modelling activitiy has been transfered to the Fisheries Research Institute at the University of Iceland. The Icelandic Ministry of Fisheries is co-sponsoring the project, principally the data collection and the adaptation to the Icelandic case. This aspect of the project is also supported by the National Economic Institute and the Marine Research Institute in Iceland. The Nordic grant is to cover only those general aspects of the modelling work which will be useful for modelling fisheries in all Nordic countries. It is this Icelandic version of the Nordic Fisheries Management Model (NFMM for short) which will be discussed in this paper.

A number of researchers have been involved in the work on the NFMM. Those most involved in the construction of the model have been T. Helgason and S. Olafsson from the University of Iceland and S.W. Wallace from the Norwegian Institute of Technology, Trondheim. Others who have contributed include : R. Arnason and A. Einarsson from the University of Iceland, K. Skarphedinsson from the Ministry of Fisheries in Iceland, A. Danielsson from the National Economic Institute, G. Stefansson from the Marine Research Institute and Ö.D. Jónsson from the Fisheries Research Institute at the University of Iceland. E. Hvannberg from the University of Iceland has been in charge of the software design and data management. A. Danielsson has been responsible for the collection/construction of economic data for the model and G. Stefansson has been responsible for the collection/construction of the biological data, the selectivity of the gear and the catch per unit of effort of the fishing vessels in the model.

In the work on the NFMM the author of this paper was primarily responsible for the economic data for the model. This paper will therefore discuss the collection/construction of the economic data in some detail. But first it is necessary to give a summarized description of the model.

## 2. THE MODEL [5]

The NFMM is a simulation model which is designed to simulate the behaviour of an entire fishing fleet, the related processing and the exploited biological fish-stocks for a period of some years. The simulation encompasses both biological and economic behaviour. The model is designed to give maximum flexibility so that it can be adapted to the special conditions in individual countries. It allows that existing modules are changed and new one added as more information and experience is gathered. Much effort has been put into the design of a user-friendly software to run the model. This software makes it easy to use and allows visual respresentation of some standard output data from the model as well as giving the output data in tabular form in a spreadsheet.

The NFMM is intended as a practical tool to study the effects of different methods for managing the fisheries. The model is therefore designed to allow the user to define in the model the management rules which he wants to study. He can choose between effort quotas, common catch quotas for a group of vessels, individual vessel-quotas with unrestricted transferability, individual non-transferable vessel-quotas, or individual vessel quotas with limited transferability where

2. See S.D. Flåm, A. Hilstad and S.W. Wallace : Artiklar om norsk industrifiske. CMI-rapport 832555-5, Christian Michelsen Institute, Bergen, Norway, 1983.
3. See T. Helgason and S. Olafsson : An Icelandic fisheries model, in European Journal of Operational Research no. 33, 1988, pp. 191-199.
4. See especially S.W. Wallace and T. Helgason : A quota model for fisheries ; General outline. NROU Working paper 90/4, Haugasund Maritime College, 1990.
5. For a more complete and a more detailed description of the model see Nordic Fisheries Management Model - A Comprehensive Description, Nordisk Seminar- og Arbejdsrapporter 1992 :501. See also T. Helgason and S.W. Wallace : Nordic Fisheries Management Model - A short description, Science Institute, University of Iceland.

the limits are defined by the user who defines which vessels are allowed to engage in trade in quotas.[6] The model allows the user to choose whether some specific features which are used in the fisheries management in the nordic countries are included or not. The user can e.g. choose if half of the catch on longline during the period from November to February should not be counted as part of the quota of the vessel as is done in Iceland, or he can choose not to allow this. The user determines the TACs for each specie and each period [7] and it is allowed that he defines subsidies which are given to the firms to influence their financial and competitive positions. For each set-up which the user chooses the model will simulate the catches, the size and composition of the fleet, the cost of the fishing industry, the aggregate profits of the fishing industry, the size and the age-distribution of the fish-stocks, the regional development of the fishing industry etc.

The NFMM is a disaggregated model. The basic economic entities in the model are actual firms which own vessels and/or processing plants. It is believed that the model will be somewhat more realistic and more flexible through the modelling of the firms in the real world. The cost of this realism is that it is necessary to obtain, store and handle a large quantity of data in the simulations with the model. In the Icelandic version of the NFMM there are 389 firms involved in processing, each producing on the average 4.19 processed products. In the model there are more than 700 fishing vessels choosing on the average between 2.3 different options for gear and location.

In most cases it will be necessary to limit the size of the model in terms of number of firms and products by aggregating firms to some extend. In the Icelandic model some 1500-1700 small boats which are owned by independent fishermen have been aggregated into a few 'boats'. [8] It is assumed that each of these aggregated 'boats' are owned by one firm which operates it according to the rules of the model. These aggregate 'boats' are big in terms of number of vessels, but the catch of these vessels amounts to only 5-10 % of the total catch.

### *2.1 The biology*

The NFMM is developed under a Nordic program on multi-species research. It is, however, outside the scope of the work on the NFMM itself to develop a model for species interactions and other ecological effects. When such models are available they can be included in the NFMM, but as such a model is not available for the biological species in the sea around Iceland, the present version of the NFMM uses a single specie biology where the size of the stock at some period of time is a function of the size of the same stock in the previous period, recruitment figures, natural mortality rate and fishing mortality rate for this stock and the average weights to get the biomass in tonns from the numbers. This year the Marine Research Institute in Iceland started an ambitious project of multispecies research. When this project produces reliable results these will be included in the Icelandic version of the NFMM.

### *2.2 Technology*

The model assumes Leontief technology of fixed input-output coefficients for each product. From the economic point of view the level of aggregation used in the definition of the products in the model are arbitrary, but the biological part of the model requires that each specie which is included in the biological part of the model is treated as a separate entity. It follows that the maximum aggregation of products permissible in the processing part of the model is up to the point where all different products of each specie are aggregated into one product. So if cod and haddock are separate species in the biological part of the model the processing plants have to produce at least one cod-product and at least one haddock-product and there have to be input-output coefficients for each of these products. The typical freezing plant produces some cod-products, some haddock-products, some saith-products, etc., so there will therefore have to be input-output coefficients for each of these products. A salting plant will produce salted cod-products, etc.

Fishing is an activity which often produces many products at the same time. The input-output coefficents of the vessels therefore describe the volume of input needed for one unit of effort, e.g. per day at sea rather than per unit of output. As different gear and different location of the fishing activity produces different catches of different species it follows that

6. E.g. if quotas are to be transferable only within a region then the user will define a market in quotas which only allows vessels registered in this region to participate.
7. Or he specifies a rule for determining the TAC's on the basis of the size of the stock.
8. At least one such 'boat' will be operating in each region.

for each vessel the model requires data on the coefficients which show the use of input per day at sea for each gear/location available for that vessel. In this way it is possible to detemine the cost of each fishing trip. The catches and the income side of the fishing trip are determined through gear-selectivity coefficients for each vessel and coefficients which show the catch per unit of effort. The latter coefficients are defined as stochastic variables.

### *2.3 Behavioural assumptions*

It is assumed that the firms use their vessels and processing plants to maximize the firm's profit, possibly subject to some restrictions. The firms are assumed to decide on the basis of this maximization which fisheries open to their vessels they should engage in, where to sell the fish they catch or how to process the fish they catch (or buy wetfish from other firms for processing) and which quotas to buy and which quotas to sell. With the constant input-output coefficients and the constraints of production capacity being constants as well, this maximization is a problem for linear programming.

### *2.4 Markets*

The model assumes that the firms take the prices of their products as given on the market and that the wage rate and the prices of variable inputs other than wetfish are assumed given. Other prices, i.e. the prices of wetfish, the prices of quotas and the prices of vessels (or physical capital in general) are determined by the model itself. For these goods there are defined markets, which may be country-wide or regional (i.e. markets where only those firms located in certain region are allowed to trade). These markets are open on certain market days. The markets for wetfish are open most frequently, but the markets for physical capital are open once a year. These markets operate as Walrasian auction-markets. The market authority signals a vector of prices, the firms update their plans and calculate their net demand for each good on the market and send this information to the market authority. The market authority then adjusts the prices so as to reduce the excess demand for the goods. This interaction continues until the market authority has found a vector of prices which is tolerably close to the vector of market clearing prices. These prices will then be the effective prices for the trading in the market.

### *2.5 The balance sheets of the firms*

The model starts to simulate from a point in time when the value of the assets of the firms, their debt and therefore their net wealth is known from their balance sheets. [9] During the simulations the model will calculate a profit or loss each year which changes the net wealth of the firm. A firm is assumed to meet a loss by increasing their bank-debt which is the only form of financing in the model. It is assumed that the firm is able to borrow at an exogenously given rate of interest up the point where its net wealth as a percentage of its total debt is below a certain minimum. When this happens and the next period's outlook does not indicate any improvement, then the firm will go bankrupt and all its assets will be sold. A firm may also choose zero-activity or it may decide to sell all its assets and cease to exist in the model.

## 3. THE ECONOMIC DATA

The economic data for the NFMM can in principle be obtained through different routes. One method would be to send a questionnaire to each firm and ask them directly about the cost per unit of output of the different products in their sortiment and about their production capacity. At least some of the larger firms in processing have reliable data on at least some of the cost of production of the different products in their sortiment. It is, on the other hand, uncertain how reliable data could be obtained from the smaller firmst. And as for the fishing very little information is availale on the cost of different fishing methods. It was therefore decided to estimate the input-output coefficients through indirect methods, i.e.

9. As the balance sheets sometime reflect the tax law better than they reflect the value of the assets of the firms some revaluation of these assets have been made. This primarily concerns the value of the vessels and the value of the quota-rights of the vessels.

through some kind of regression analysis on the basis of information which had already been collected and stored in a computer. However, information on these input-output coefficients which could be obtained directly from the firms would be used where it was believed to improve the estimates.

### *3.1 Estimation of the input-output coefficients for processing*

The information which is used for estimating the input-output coefficients for the processing consists of two parts. Firstly there are the operating accounts of firms in fish-processing collected by the The National Economic Institute (NEI). These operating accounts are usually highly aggregate. Sometimes there is one operating account for freezing groundfish, one for freezing shrimp, one for salting groundfish and one for salting herring, etc., but sometimes there is only one operating account for the processing of a firm which produces frozen and salted groundfish, frozen shrimp and salted herring as well. Table 1 shows how well the operating accounts for 1990 in the sample of operating accounts of 142 processing firms [10] which the NEI collected are disaggregated into the seven main processing categories traditionally reported. The first column shows the percentage of income which is declared in the correct processing division. 98.2 % of all income from freezing groundfish is declared as a part of the income of divisions which are mainly involved in freezing groundfish. 1.8 % of the income for freezing groundfish is reported as a part of the income of divisions which are mainly involved in salting groundfish, freezing shrimp, etc. As much as 92.7 % of the income from drying is declared as a part of the income of divisions which are not mainly involved in drying, while only 7.3 % of the income is declared as a part of the income of divisions primarily involved in drying.

The second column in Table 1 shows the shares of the income of the processing divisions of the 142 firms in NEI's sample which come from the main product produced in these divisions. 84.6 % of the income of the divisions which were mainly concerned with producing frozen groundfish came from freezing groundfish etc.

Table 1 shows that even the limited disaggregation which is reported in the accounts of the firms is far from complete. Even when the processing of one specie is reported in a separate operating account (salting of herring and freezing of shrimp and scallop) this reporting is not complete. But most importantly, there are no separate accounts for the freezing of individual groundfish species, or for the salting of individual groundfish species which is what the NFMM needs. These accounts have to be constructed through the use of some additional information. This second set of information about the processing firms consists of data on the purchases of wetfish for processing by each firm which are collected by the Fisheries Association of Iceland (Fiskifélag Íslands). These data show for each processing firm the volume of each specie allocated to freezing, the volume of each specie allocated to salting, the volume of each specie allocated to drying and the volume of each specie allocated to the production of fishmeal and oil. These data possess the degree of disaggregation which the NFMM needs.

The idea now is to use regression analysis on the data to get estimates of the costs of production which are not available directly in the firms accounts. After some experimentation the following method was believed to be best.

Let $V_{jk}$ be the volume of wetfish which is allocated for the production of product j (frozen cod is product number 1, frozen haddock is product number 2, salted cod is product number 10, etc.) in firm k,

let $A_{jk}$ be the cost of a certain type [11] which is associated with product j in firm k,

let $a_j^2$ be the average cost per unit of wetfish of this type wich is associated with the production of product j and

let $C_k$ be the total cost of this type in the operatinal accounts of firm k.

We now assume that the firm-specific coefficients $A_{jk}/V_{jk}$ are square-root normal, i.e. if we assume that $(A_{jk}/V_{jk})^{.5}$ is normally distributed around $a_j$ with some standard deviation which is to be estimated from the data [12]. The estimates are then the solutions of the following optimization problem :

10. These 142 firms received 75.6 % of all wetfish which was allocated for processing in Iceland. The firms which are in the sample of the National Economic Institute are the biggest firms. The 247 firms which are not included in the sample received only 24.4 % of all wetfish allocated for processing in Iceland.
11. Or income of certain type or the volume of input or the volume of output.
12. By this assumption the distribution of the firm specific coefficients, $A_{jk}/V_{jk}$, is skewed to the right which seems reasonable. The estimation procedure described below gives estimates of $A_{jk}$ which are independent of the choice of units used for measuring the volume of wetfish ($V_{jk}$). It is therefore possible to use the volume of certain species measured in tons og kilos, while others are aggregated into a composite commodity and measured in kronas or cod-equivalent tons.

$$\underset{A_{jk},a_j}{\text{Min}} \quad \text{SUM(j,k)}\{V_{jk}[(A_{jk}/V_{jk})^{.5} - a_j]^2\},$$

$$\text{subject to SUM(j)}\{A_{jk}\} = C_k \text{ , } k=1,2,...,n_k \tag{1}$$

The Lagrange function for this problem is :

$$L = \text{SUM(j,k)}\{V_{jk}[(A_{jk}/V_{jk})^{.5} - a_j]^2\} + \text{SUM(k)}\{l_k[C_k - \text{SUM(j)}\{A_{jk}\}]\} \tag{2}$$

where $l_k$, $k=1,2,...,n_k$ are Lagrange multipliers.

Expanding the expression in (2), rearranging the terms and using the restrictions in (1) gives that :

$$L = \text{SUM(k)}\{C_k\} + \text{SUM(j)}\{a_j^{\,2}\text{Sum(k)}\{V_{jk}\}\} -$$

$$2\text{Sum(j)}\{a_j\text{Sum(k)}\{(V_{jk}\,A_{jk})^{.5}\}\} + \text{SUM(k)}\{l_k[C_k - \text{SUM(j)}\{A_{jk}\}]\} \tag{2'}$$

Differentiating (2) with respect to the unknown variables, $A_{jk}$, gives :

$$\frac{\delta L}{\delta A_{jk}} = -\,a_j\,(V_{jk}/A_{jk})^{.5} - \lambda_k = 0, \quad j = 1, 2, ..., n_j \quad \text{and} \quad k = 1, 2, ...,n_k \tag{3}$$

which implies that the ratio of the coefficients for cost (or income) per unit of wetfish allocated, specific to firm k ($A_{jk}/V_{jk}$, $j=1,2,...,n_j$) and the average for the industry ($a_j^2$) is the same for all products which the firm produces. This means that it is implicitly assumed in the estimation that the firm is equally efficient in the use of a certain input relative to the industrial average in the production of all the products in their sortiment.

(3) and the restrictions in (1) give that :

$$A_{jk} = [a_j^2 V_{jk}/\text{Sum(i)}\{a_i^2 V_{ik}\}]\,C_k \tag{4}$$

Differentiating (1) with respect to $a_j$ and solving for $a_j$ from the first order conditions gives :

$$a_j = \text{Sum(k)}\{(V_{jk}A_{jk})^{.5}\}/\text{Sum(k)}\{V_{jk}\} \tag{5}$$

Iterating between (4) and (5) gives a reasonably efficient algorithm for the solution of the optimization problem in (1).

In the estimation of the coefficients for the processing it was decided to allow for 20 products. These products are listed in table 2.

The 142 processing firms in the NEI's sample produced on the average 5.7 products so defined, so it was necessary to estimate 20 $a_j$ and 807 $A_{jk}$ coefficients for each cost/income item. For the NFMM three coefficients were estimated for each product : the coefficients for the income from each product, the labour cost and other variable cost associated with that product. In the estimation it was decided to include only those firms where all firm-specific coefficients $(A_{jk}/V_{jk})^{.5}$ deviate less than 3 standard deviations from the $a_j$. The justification for this procedure is that there are obvious errors in the data, especially in the data for the smaller firms. As it turned out this excluded very little of the processing in terms of volume (usually less than 1-2 % in unrestricted estimation) and somewhat more in terms of number of firms from the estimation.

The method above is most efficient in estimating input-output coefficients for those products which are largest in terms of volume and those which are relatively much produced in firms which produce only that one product. But for products like freezing of capelin and herring where the product is only a small part of the total production of the firms involved in this production and where there are no firms which specialize in this production, then the method above is not very efficient. The table 3 shows the differences between the estimates from the unrestricted estimation and the values which are believed to be the correct ones.

To improve these estimates it was decided to use direct information from the firms. In the estimation of the coefficients for income the relative values of 10 $a_j$ were fixed in advance and estimated together while the other 10 $a_j$ where estimated without restrictions. In the estimation of the coefficients for labour cost the relative values of 12 $a_j$ were fixed in advance and estimated together while the other 8 $a_j$ where estimated without restrictions. In the estimation of the coefficients for 'other variable cost' the relative values of 14 $a_j$ were fixed in advance and estimated together while the other 6 $a_j$ where estimated without restrictions.

In the estimation of the data for the NFMM which have been done up to now only data for 1990 have been used. Using data for more than one year in the estimation would probably improve the estimates.

It is rather difficult to get an idea about the efficiency of the estimates of the input-output coefficients as the correct figures are not known. One method was though close to hand, i.e. to estimate the division of the operating accounts which the firms reported from the aggregate account and compare the results with those reported by the firms. As the data for the shrimp allocated for processing are unreliable[13] operating accounts for the other 6 divisions were added into one aggregated operating account and then this aggregated account was divided into division-accounts with the aid of the wetfish data. The table 4 shows the results for those firms which reported operating accounts for more than one division.

The big errors in the estimation of the income and costs related to drying are mainly due to incorrect reporting of the volume of wetfish allocated to drying. The errors in the estimation of the income and costs related to salting herring are at least partly due to the fact that this production takes place during the winter months and there are large stocks at the end of the year. The errors in the estimation of the income and costs of a division of a specific firm are of course bigger than the errors in the estimation of the aggregates for a number of firms. The fact that there was only one firm which reported freezing of scallop together with some other activity in its operational accounts explains the errors in the estimation in that case.

This study showed two things : Firstly that the more important the division, the smaller is the error of estimation. And, secondly, the larger is the firm, the smaller is the error. For those firms which reported operating accounts for more than one division the average error in the estimation of the firm specific coefficients ( $_{jk}/V_{jk}$) for income from the largest product, freezing groundfish, was 2.1 % and for the largest firms which had together 50 % of the volume the average error was only 1.8 %. The average error in the estimation of coefficients for income from the second largest product, salting groundfish, was 10.4 % and for the largest firms which had together 48 % of the volume the average error was 4.4 %. The average error of estimation for the less important division of drying was very large. This indicates that much of the error in the estimation of the coefficients are due to errors in the data, rather than errors in the estimation. That firms often report incorrectly their internal allocation of the same specie between different methods of processing is an important source of error. Some of the error is also the result of a difference in the time period which is reported in the operational accounts and the time period for which is reported in the data on the allocation of wetfish for processing. These differences explain why the value of the wetfish which a firm puchased is not always the same in these two set of data and make it necessary to adjust the data on the allocation of wetfish for processing so that the value of the raw material used in the processing according to these reports are equal to the value of the raw material reported in the operational accounts before the estimation of the coefficients.

The errors in the estimation of the coefficients for labour cost and the coefficients for 'other variable cost' were larger than the errors in the coefficients for income. The average error for the labour cost per unit of wetfish in freezing was 8.5 % and in the case of other variable cost it was 8.1 %. In a factory with many divisions it is obviously much easier to record separately the income from the different divisions than it is to record separately all the costs which are specific to one division and not another. Labour can be moved from one division to another without anybody exactly recording it. Different firms have different policies in this respect. In the operational accounts of some firms the reported accounts for individual divisions are conscientiously done and reliable, but the cost side of the subdivision in the operational accounts of some other firms may be quite worthless [14]. It was therefore decided to use the information in reported subdivision of the operational accounts only in the estimation of the coefficients for income but to ignore it in the estimation of the cost items, except when there was a special account for the freezing of shrimps or for the production of fishmeal and oil. If the firms reported operational accounts for other divisions then the cost item in these accounts were summed up and the sum used in the estimation.

13. The figures do include raw shrimp bought directly from a fishing vessel in Icelandic harbour, but do not include imported raw shrimp.
14. This does not necessarily imply that the aggregate operational accounts of these firms are not accurate.

The data on capacity in the fish-processing were in most cases obtained through finding the maximum volume of production during 1988-1990.

### *3.2 Estimation of cost coefficients for fishing*

The income side of the fishing is closely related to the biology of the model and the selectivity of the gear which is used. This will not be dealt with in this paper. The cost side of fishing on the other hand is of pure economic nature and will be dealt with subsequently. The NFMM needs coefficients which show the use of different inputs (or cost items) per day at sea for each vessel, gear and location defined in the model. There is one such coefficient for the cost of oil, and one for the other variable cost, excluding the salaries of the fishermen which are detemined by the value of the catch according to a formula specified in the contracts between the federation of vessel-owners and the fishermen's unions.

Operating accounts of fishing vessels are collected by the NEI and the Fisheries Association of Iceland. Together these institutions collected operating accounts for 402 vessels in 1990. The value of the catch which these vessels landed was around 75 % of the value of all landings.

To estimate the cost coefficients for each gear/location it was decided to utilize data on days at sea collected by the Fisheries Associations of Iceland. In the estimation of the coeffcients for costs per days at sea it was decided to define 11 gear/location which the vessel can choose (see table 5).

It is obvious that these cost coefficients are usually larger for the larger vessels than for the smaller ones. It is therefore necessary to adjust for the size of the vessel. After some experimentation it was decided to estimate the cost per days at sea multiplied by the size of the vessels in GRT. This means that in the estimation procedure described above $V_{jk}$ becomes the number of days at sea when the vessels utilized gear j multiplied by the size of vessel k in GRT. The 402 vessels in the sample utilized 982 gear/location. This means that the estimation involved estimating 982 $A_{jk}$ and 11 $a_j$.

The average gear/location per vessel was 2.4 in 1990, which is much lower than the average number of products per processing firm. It is also not uncommon that a vessel utilizes only one gear/location. For these reasons it is to be expected that the estimates of the coefficients for fishing are better than the coefficients for processing. In the estimation of the coefficients for the NFMM only the $a_j$-coefficients for catching with bottom trawl were restricted. These coefficients were restricted so that their relative values were fixed and they estimated together while the other 8 coefficients were estimated without restrictions.

The data on capacity of a vessel in terms of the number of days at sea are easily obtainable. It is simply the total number of days in the year minus the days they have to be in harbour for landing the catch minus the days they have to be in harbour for maintenance minus the days they have to be in harbour because of the weather. Nowadays the last subtraction is relevant only for the smaller boats.

## 4. THE CONSTRUCTION OF DATA FOR MISSING DATA

Almost a quarter of the processing in Iceland takes place in firms which are not in the NEI's sample. Hopefully this number will decrease later, but there will always be some firms for whom there are no operational accounts and no balance sheets available. The only available information about the processing in these firms is the information about the volume of wetfish allocated for processing. To complete the set of data for the NFMM it was decided to generate the input-output coefficients for the processing in these firms with a random number generator assuming that the distribution of the $A_{jk}/V_{jk}$-coefficients is square-root normal with mean and standard deviation equal to the estimated values. In almost all cases the ratio of mean of $(A_{jk}/V_{jk})^{.5}$ to the standard deviation was so large that the probability of some $(A_{jk}/V_{jk})^{.5}$-coefficients becoming zero or negative is zero. In most cases this ratio was 30-40 for the coefficients of income in processing, 12-16 for labour cost and 8-10 for 'other variable cost'. For the cost of oil in fishing the ratio was in the 6-9 range, and for 'other variable cost' in fishing the ratio was in the 4-5 range.

The items on the balance sheets of these firms were constructed in a similar manner. The production capacity of these firms was determined in the same manner as the production capacity of the firms in NEI's sample.

The cost-coefficients for those vessels where there were no operational accounts were constructed in the same way as the missing input-output coefficients for the processing plants.

## REFERENCES

**Flåm S.D., A. Hilstad and S.W. Wallace** (1983). Artiklar om norsk industrifiske. CMI-rapport 832555-5, Christian Michelsen Institute, Bergen, Norway.

**Helgason T. and S. Olafsson** (1988). An Icelandic fisheries model, *European Journal of Operational Research no. 33 :* 191-199.

**Helgason T. and S.W. Wallace.** Nordic Fisheries Management Model - A short description, Science Institute, University of Iceland.

**Olafsson S. , T. Helgason and S.W. Wallace a.o.** (1992). *Nordic Fisheries Management Model - A Comprehensive Description,* Nordisk seminar - og arbejdsrapporter 1992, 501.

**Wallace S.W. and T. Helgason** (1990). A quota model for fisheries ; General outline. *NROU Working paper 90/4,* Haugasund Maritime College.

TABLE 1.

| | The percentage of income declared in the correct processing division | The percentage of income of a processing division coming from 'its own' product |
|---|---|---|
| Freezing | 98.2 | 84.6 |
| Salting | 78.3 | 87.3 |
| Drying | 7.3 | 46.8 |
| Fishmeal and oil | 91.1 | 97.9 |
| Salting herring | 67.4 | 49.3 |
| Freezing shrimp | 94.8 | 91.7 |
| Freezing scallop | 87.0 | 74.9 |

TABLE 2.
PRODUCTS

| | | |
|---|---|---|
| 1. Freezing of cod, | 2. Freezing of haddock, | 3. Freezing of saithe, |
| 4. Frozen redfish, | 5. Frozen greenland halibut, | 6. Frozen capelin, |
| 7. Frozen herring, | 8. Frozen lobster, | 9. Other frozen products, |
| 10. Salted cod, | 11. Salted saith, | 12. Other salted products, |
| 13. Dried cod, | 14. Other dried products, | 15. Fishmeal and oil from capelin, |
| 16. Fishmeal and oil from herring, | | 17. Other fishmeal and oil, |
| 18. Salted herring, | 19. Frozen shrimp, | 20. Frozen scallop. |

TABLE 3.
DIFFERENCES BETWEEN THE ESTIMATES FROM THE UNRESTRICTED ESTIMATION AND THE VALUES BELIEVED TO BE THE CORRECTIONS

| | Income | Labour cost | Other variable cost |
|---|---|---|---|
| Freezing of cod | 2.3% | 27.5% | -54.3% |
| Freezing of haddock | 8.6% | -21.1% | 15.5% |
| Freezing of saithe | 2.3% | -18.3% | 312.1% |
| Frozen redfish | -0.9% | -24.0% | -50.3% |
| Frozen greenland halibut | -6.1% | -100.0% | 19.0% |
| Frozen capelin | -22.7% | 251.1% | 274.2% |
| Frozen herring | -32.2% | -68.7% | 51.7% |
| Frozen lobster | 46.4% | 35.6% | 96.3% |
| Other frozen products | -22.6% | -15.0% | 217.0% |
| Salted cod | 1.8% | 9.0% | 5.6% |
| Salted saith | 6.7% | 0.1% | 7.0% |
| Other salted products | 51.9% | -100.0% | -100.0% |
| Dried cod | -24.6% | -4.0% | -31.1% |
| Other dried products | -18.0% | 35.9% | -100.0% |
| Fishmeal and oil from capelin | -0.9% | -85.2% | 161.4% |
| Fishmeal and oil from herring | 0.0% | 14.3% | -8.8% |
| Other fishmeal and oil . | 55.8% | 158.7% | 260.2% |
| Salted herring | -38.4% | 0.3% | -11.9% |
| Frozen shrimp | 0.1% | -0.5% | 7.8% |
| Frozen scallop | -12.4% | -2.5% | -73.3% |

TABLE 4.
THE PERCENTAGE DIFFERENCE BETWEEN THE ESTIMATED INCOME/COST AND THE REPORTED INCOME/COST. [1]

| | Income | Labour cost | Other variable cost | Number of firms | Share in total income |
|---|---|---|---|---|---|
| Freezing | 1.1% | 5.1% | 3.5% | 23 | 50.6% |
| Salting | 2.7% | -8.5% | -7.4% | 21 | 32.4% |
| Drying | -99.9% | -99.9% | -99.9% | 1 | 7.7% |
| Fishmeal and oil | 1.7% | 11.8% | -4.0% | 9 | 36.6% |
| Salting herring | -31.9% | -62.9% | 3.1% | 13 | 78.1% |
| Freezing of scallop | -15.3% | -26.0% | -38.2% | 1 | 9.0% |

1. It should be kept in mind when one evaluates these errors in the estimation that the reported figures are not necessarily the correct ones. It is easy to point out examples of incorrect separation of costs between operational divisions of the firms in the operational accounts which are reported.

# Sources of Variance in the Economic Performance of New England Otter Trawl Vessels

**Iswanie J. Anwar[a], Philippe Lallemand[b] and John M. Gates[b]**

[a] Bank Bumi Daya, Jatinegara Branch, LT9 Jl Imam Bonjol , 61, Jakarta, Indonesia

[b] Department of Resource Economics, University of Rhode Island,Kingston, RI 02881-1630, USA

ABSTRACT

*This study updates and extends work initiated and described in working papers by Crutchfield and Gates (CG) (1983) and Gates et.al.(1984). The objective of the research was to monitor the economic performance of the fishing fleets ; an objective achieved by combining information from different sources. This paper is concerned with total revenue aspects of the research. The results are consistent with the CG results which found measurable, persistent differences between vessels. These disparities illustrate why it is rational for "highliners" to oppose, for example, an ITQ system based on mean performance. It would be of interest if such differences were diminishing, since such a trend might lessen antipathy toward policies widely regarded by economists as rational. Such a trend would also be consistent with weak versions of optimizing behavior based upon Darwinian survival. The results show persistent differences in revenue per vessel month which are not explained by measured variables.*

## 1. INTRODUCTION

The maximization of returns (MOR) hypothesis has a long and controversial history in economics (Friedman, 1953, pp.22-23), and Simon (1968). That two Nobel laureate economists disagree on this hypothesis is indicative of the periodic dispute about the universality and usefulness of the "maximization of returns"(MOR) hypothesis. This paper reports results which may be of interest for analysts of fishing industries and for the MOR dispute. We begin from observations of persistent differences in the performance of vessels which are not explained by measured inputs. The residual variance is hypothesized to be associated with suboptimizing behavior ; to "non-maximization of returns" or NMOR. With respect

to MOR, it must be noted that the hypothesis has a number of variants- long run versus short run, with or without risk aversion etc. This renders MOR particularly amenable to what Lakatos has termed "immunizing strategies" (Blaug, 1980, ch.1).

The existence of qualitative variables such as skill and experience of fishers are often asserted but never measured in fisheries economics (Gates, 1984). It is a conventional wisdom that these qualities strongly influence success in "fishing for dollars, not species". Loan officers of banks indicate that the captain's skill in landing dollars is the single most important question in loan evaluation. Such qualitative factors imply the existence of generalized Ricardian(qualitative) factor rents. The implications of such differentials for the "standard model" in fisheries management have been explored by Copes(1972).

In the New England Otter Trawl fleet the number of vessels increased by approximately 60 percent from 1976 to 1982. This investment in physical capital stock also required a commensurate increase in number of captains or "skippers". A good captain may have the benefit of years of experience which is a form of "human capital" and cannot be created overnight. Given these events as background, it would not be surprising to find differences in skill during the 1976-1981 period and that is what Crutchfield and Gates(CG) reported in 1984. This study updates their work. However, we have made several procedural changes and presently do not have the pre 1982 data.

## 2. THE DATA

The data were obtained from the National Marine Fisheries Service, Northeast Fisheries Center, and include only New England landings by vessels using a specific gear, which is otter trawl (gear code 050). During each year, "trip records" for vessels are obtained by the National Marine Fisheries Service(NMFS). A trip record includes information summarizing a specific trip by a specific vessel. It includes such pertinent data as days absent, catch, landed value, etc. The trip records are aggregated by NMFS staff by vessel and month which resulted in annual files with approximately 9000-12000 records per file. Measured variables include vessel home port, vessel characteristics and intensity of vessel use. The measured characteristics of vessels include length and gear type used. Intensity of vessel use is measured by days absent from port per vessel-month.

## 3. THE MODELS

Five categories of captain's skill were defined in descending order (following CG), viz., High Liner(HL), High Average (HA), Average (A), Low Average (LA), and Low Liner (LL). Skill can be considered as measurable performance differences between vessels in terms of (1) gross revenue, (2) catch, (3) price or (4) cost. This paper is concerned with (1). We estimated "skill" measures for revenue, catch and price but will report only on revenue skill in this paper, since it combines both quantity and price related skills. It was found that the data set in the post 1988 period will not support more than three clusters, which we label "Lowliner"(or LOW), "Average" (Ave) and "Highliner"(or HIGH).

A log-log model was fitted for each year from 1982 to 1990 using the form in equation 1,(initially without the RFOS) variables :

$$LY = \alpha_0 + \alpha_{pi}\, HOMEPORT_k + \alpha_{mi}\, DMONTH_n + \alpha_{si}\, LRFOS_l + \alpha_1\, LLENG + \alpha_2\, LQLENG + \alpha_3\, LDA + \alpha_4\, LQDA + u_t \quad (1)$$

All continuous variables are in Naperian logarithmic form, indicated by an "L" prefix :

Definition of variables :

Continuous variables :

Y ≡ LN(GROSS STOCK) in dollars /vessel-month

$RFOS_l$ ≡ relative frequency with which a given vessel is classified in SKILL category l=1,2,..,L.

LENG ≡ vessel length in feet ;ln ≡ Naperian logarithm.

DA ≡ days absent per vessel-month

LQLEN,LQDA ≡ squared values of LLENG and LDA, respectively

$u_t$ ≡ heteroscedastic, Gaussian error term.

Qualitative variables

$HOMEPORT_k$ ≡ Home port of vessel= qualitative variables ; k ≡ 14,

$DMONTH_n$ ≡ MONTH qualitative variables ; n ≡ 12,

SKILL ≡ qualitative variables ; may be TRCLUSTER, QCLUSTER or PCLUSTER, for revenue, catch and price, respectively.

The model stated by equation 1 was applied to 1982-1991 monthly data for the New England otter trawl fishery which is a multispecies, multijurisdictional fishery.

## 4. PROCEDURES

The estimation procedure we used had six stages. In the first stage, an unweighted general linear model regression procedure was used to estimate equation 1 without the RFOSS variables. In stage two, the residuals of stage 1 estimation were analyzed using Glejser procedures (Gujarati, 1988), to detect the presence of heteroscedasticity terms. Since the residuals were not homogeneous, output(predicted values of residuals) from the Glejser model was used as a weighting factor in a weighted OLS estimate of model 1. This was stage 3. Weighted least squares(WLS) is a special case of Generalized Least Squares(GLS). (Kmenta,1971, pp. 264-265). If the Glesjer procedure succeeded, the residuals from the stage 3 model would be Gaussian white noise having been purged of any variance patterns in stage 2. However, an analysis of the residuals from the stage 3 model showed a pattern of "fat tails" ; i.e. normality was violated.

One interpretation of such patterns is that the data is drawn from heterogeneous normal densities. Cluster analysis (PROC FASTCLUS in SAS) was used to partition the residuals into a user defined number of clusters. The stage 2 use of a Glesjer procedure reduces the chances of spurious clustering around heteroschedasticity induced by measured variables such as vessel size, port, month or intensity of vessel use. SAS clustering procedures can be used to cluster the observations or the variables in a data set. The cluster analysis uniquely allocates each residual to one of the clusters.

There are no fully satisfactory methods for determining the correct number of population clusters for any type of cluster analysis (Everitt 1979, 1980 ;Hartigan 1985 ; Bock 1985). That is partly because the notion of a "cluster" is itself vague. It was found that the data set in the post 1988 period did not consistently support five clusters. The marginal clusters either cannot be created by the clustering algorithm used or the marginal clusters which result become so sparse that numerical instabilities are induced. A minimum cluster size of 30 was imposed which caused the clustering algorithm to find only three clusters which we will call "Low", "Average" and "High". In 1982, only two clusters were found. This produces somewhat anomalous results for 1982 which we are still investigating.

The clusters were then used to construct the "Relative Frequency of Skill" (RFOS) variables. Construction of the RFOS variables entailed tabulation of the number of times the observations on a given vessel (FOS) were classified in SKILL category i by the FASTCLUS procedure. Because the value of FOS differs between vessels, use of RFOS variables may induce heteroschedasticity which will be addressed below in stage 5. The total number of observations on a given vessel was used as a denominator to calculate the RFOS variables by dividing the FOS variables by observations per vessel. Note that the RFOS variables are ratio variables which necessarily lie between zero and unity and which sum to unity for a given vessel.

In stage four, the stage three model is re-estimated exploiting information gleaned from the cluster analysis. CG created qualitative variables corresponding to the clusters. This has avoidable consequences. First, since the qualitative variables

are derived from the cluster analysis, which is, in turn, driven by the residuals from earlier stages, it is difficult to claim independence. Secondly, the structure does not address ambiguities associated with the fact that a given vessel's records may be spread across more than one cluster. To avoid these consequences, the relative frequencies(RFOS) with which a vessel is classified in each cluster were calculated. Because the number of vessel records varies considerably, the same relative frequency can result from widely different per vessel sample sizes. Because landings at different ports appear as different records, the number of monthly records is not bounded by twelve per vessel ; some vessels have as much as thirty-six records per year. This inequality of sample sizes may reintroduce heteroschedasticity to be addressed in Stage five, but should tend to reduce dependence.

In stage four, the stage one model is re-estimated but inclusive of the relative frequencies just described. The descriptive labels are assigned based on the relative magnitudes of the means of residuals by cluster.

In stage five, the Glejser procedure is re-applied to the residuals of the stage 4 model to detect whether heteroscedasticity has been reintroduced by the inclusion of frequency of skill variables. In model 6, the OLS model of stage 4 is re-estimated using weighted OLS with the Glejser estimator from stage five as weights.

## 5. RESULTS

A summary of the cluster analysis results appears in Table 1. In general, the clusters appear quite stable, but two caveats are noted. First, as noted earlier, PROC FASTCLUS was able to create only two clusters in 1982 given the restriction on minimum cluster size(30 records). There are small numbers of extremely skewed observations which, if too many clusters are requested, can cause numerical instabilities. There is some indication that the frequency of such outliers is less in recent years ; a point to be kept in mind in evaluating the MOR hypothesis.

On average, coefficient (elasticity) estimates for relative frequency of "skill" (RFOS) variables in all years were statistically significant at ≤1 % LOS ; the persistence in error terms has been quantified via these variables(Table 2).

On average the $R^2$ was about 80 percent. The goodness of fit results can be compared with goodness of fit for the Stage 1 or 3 gross stock models of 65 percent ; a forty percent reduction in residual variance through inclusion of the frequency of skill variables. This improvement in goodness of fit is not surprising ; otherwise the clustering algorithm would be expected to have difficulty converging on clusters which differ statistically from each other. However, including the RFOS variables in the model 6 regression recasts the results of the cluster analysis in a useful form as part of a general linear model.

Variables for which parameters were estimated include qualitative variables for month and home port and continuous variables for vessel length and days absent per month. We have not reported these results since it results in a much larger Table wich is mostly irrelevant to the focus of this paper. All conditional mean parameter estimates in model 6 showed better results in terms of narrower confidence intervals compared to models 1 and 4. Reductions in standard errors of estimation are of course the intent of GLS procedures so this result is not surprising.

From the summary of results in Table 2, it can be seen that significant differences existed between the highest and the lowest skill level for revenue. The RFOS variables are tautological in that they describe the expected effect on monthly revenue of a change in the relative frequency with which a given vessel is classified in a particular skill category. However, we think it better to be tautologous than to ignore the obvious.

## 6. DISCUSSION OF RESULTS

The existence of differences between managers is widely accepted by investigators who have a "managerial" or "business" orientation (Farrell, 1957 ; Seitz, 1970). Although economists have figured prominently in the above literature, other economists have disputed the relevance of such differences. The dissenting view asserts that MOR would erase such differences or, if MOR failed, that any empirical differences are irrelevant because they must be due to pursuit of other or conflicting objectives(Stigler, 1976). Simon's critique of Friedman's casual empiricism is consistent with his

research program on "bounded rationality". Since neither is at pains to define their terms, let us define what we presume is meant by MOR, in its various forms. We define MOR1 to mean that all producers are always maximizing profits. In this extreme form we doubt that many would believe the hypothesis. Simon believes that producers would like to maximize profits but may not know how to achieve such a complicated task. Friedman's weak ("survival") rationale for profit maximization would predict a tendency for disappearance of sub maximal skills. This weaker version we term MOR2. As far as we can tell, the MOR2 hypothesis says nothing about relative rates of convergence(whereas MOR1 denies that there are differences to disappear). The MOR2 hypothesis predicts an upward drift by the submaximal vessels as the experience of survivors grows and or the inexperience of non survivors is purged through attrition. There would be a tendency for the skill variables to become less significant with the passage of time and to become more "compressed" so that some skill categories would become statistically indistinguishable from one or more adjacent clusters.

A version(MOR3) even weaker than MOR2 would recognize learning by new entrants. This "stochastic process" version could, under stable conditions, lead to a stable *distribution* of skills due to equilibrium of entry and exit processes. This would be one way of rationalizing the logical structure proposed by Houthakker(1956) to derive aggregate production functions from micro premises. Of course, in a fluctuating, uncertain environment rates of entry and exit vary and the FOS variables may also vary over time. This weakest version of MOR is very difficult to test directly, since it "forbids" so little and is so easily immunized(by noting unanticipated environmental fluctuations, for example).

We stress that the skill variables measure *relative* differences between vessels in the same year ; not absolute differences or levels. We may regard the skill clusters as metaphorical "waves" while mean performance level is the "tide". In this metaphor, waves (skill differences) may persist or dissipate regardless of the level of the tide. MOR2 holds that the waves would diminish in amplitude due to learning and attrition (of the troughs) ; MOR1 deny the existence of waves. MOR3 acknowledges the waves but suggests that they "tend" toward a stable distribution. Note that the "tide" may rise(fall) due to a uniform rise(fall) in skill, price or stock abundances ; our real world counterparts of the tidal metaphor. MOR3 allows for the possibility that individual waves may dissipate but, if constantly replaced by new entrants, a stable population of waves may evolve and persist.

The skill clusters are measured from a reference point independent of aggregate stock or market dynamics. Thus, while stocks have declined during the study period, all captains had access to the same stocks(although not necessarily the same knowledge). The dissipation of heterogeneity says nothing about the background level ; for that we must examine the time trend of the regression intercepts.

Figure 1 addresses graphically the hypotheses of skill convergence by showing the "relative frequency of skill" (RFOS) coefficients by year and skill level for all skill levels. For category i=1,2,3, RFOS(i) indicates the proportion of times a given vessel is classified in category i. The associated coefficient indicates the elasticity of monthly vessel revenue with respect to RFOSS(i).

The zero reference point in Figure 1 is, ex hypothesis, what one would expect for an "average" vessel ; that is, an increase in the frequency of average performance would be expected to have no effect on the performance of an average vessel. The RFOS coefficient for the average category is statistically insignificant. The RFOS coefficients for Low and High categories are non-zero, have the expected signs(by construction) and show no evidence of convergence toward zero as implied by MOR2.

The non-convergence in Figure 1 is sufficiently clear and space is limited so we will not present statistical tests of nonconvergence, although we did construct them.

## 7. SUMMARY AND CONCLUSIONS

The gross stock model, yielded "good" estimates of gross revenue for the simulator. In this equation, month, homeport, and "skill", as qualitative variables were highly significant statistically and economically important for estimating monthly gross stock. Inclusion of these qualitative variables, along with such continuous variables as length of vessel and days absent from port narrowed substantially the confidence intervals for conditional predictions of individual fisher's gross stock (gross revenue) during 1982-1991. This result is consistent with CG. The results do not support either the MOR1 or MOR2 hypotheses. The results do not conflict with the MOR3 hypothesis but, as noted earlier, MOR3 is broadly compatible with almost any time series data.

The results of the dynamic analysis of skill levels suggest that profit maximization and/ or Darwinian survival have diminished the skill differences but have not eliminated them. Under the MOR3 hypothesis, we should not expect their elimination. Entry-exit can be viewed as a stochastic process. If we presume that entrants will be skewed toward the low skill end of the spectrum, and a 20-30 year life cycle, then very simple stochastic processes imply a steady state which is heterogeneous with respect to skill.

In our interpretation, MOR is another relevant characteristic of (some) vessel operators and is a component of "skill". If two individuals have available the same resource opportunities, markets and technology but one makes better product mix decisions (for example), is this not part of "good management" ? This interpretation has the advantage of suggesting that differences are not immutable ; that data, information and communication can improve the status quo and, by implication, can contribute to the demise of such differences.

Also of interest are the effects of these skill variables on cost equations. There could be underlying differences in engine horsepower, electronic equipment or fishing time per day absent ; differences which would have some effects on costs. Another set of compensatory mechanisms exists in the lay system. Differences may exist between skill level and the lay system employed and in the opportunity costs of labor and management.

Do the skill levels matter to economists ? We would certainly not suggest that all analyses attempt such detail. There are contexts where the detail may be useful ; perhaps essential. It matters in advising individuals ; the Marshallian fiction of a "representative firm" is potentially disserving when the question at hand is individual and specific rather than generalized and abstract. Also, in fisheries management there are many contexts(e.g. individual catch rights) in which distributional issues are very important and skill differences are one dimension of such issues.

Another set of issues may arise in estimation. A good introduction to regression analysis will include a fallacious example in which a regression curve is fitted to two distinct clusters of data. The results will often indicate a non-zero slope when the nature of the problem is merely one of differing, discontinuous means. Under such circumstances, analysis of variance (use of qualitative variables) is a more appropriate tool because it eschews the assumption of continuity.

The interpretation of cluster differences as "skill" is debatable since managerial skill is approached via residuals ; whatever cannot be explained via measured inputs is attributed to "management" or "skill". It seems likely that some, if not all of the observed differences are explainable via product mix decisions in response to relative prices and abundances. That is a premise of duality approaches (Squires, *op cit.* ; Kirkley and Strand, *op cit.*).

Statistical estimation is ideal if all follow the same behavioral rule and observation units are technically homogeneous. As a matter of logic, however, if it is admitted that some follow NMOR, then there is no compelling reason to suppose( which duality does), that suboptimal units are technically efficient but allocatively inefficient. The converse is equally possible and a mixture of inefficiencies seems (to us) a more plausible characterization of humanity ; there is an infinity of ways to suboptimize. An allocatively inefficient, technically efficient solution is always equivalent in terms of net income, to (many) technically inefficient solutions. It would be interesting, therefore, to examine the stability of duality estimations across clusters and time periods. We have no desire to criticize duality theory per se. However, we do wish to note that regression analysis in the presence of clusters *could* give results which are spurious in part or in total. Possible pathologies could include violation of second order necessary conditions etc. Recognition of skill differences may alleviate such problems but at a price of acknowledging that some fishers operate on the interior of the revenue possibilities set rather than at different points on the frontier.

## REFERENCES

**Aigner D., C.A. Knox Lovell and P. Schmidt** (1977). "Formulation, estimation of stochastic production frontier models," *J. Econometrics* **6** (July) : 21-37.

**Blaug M.** (1980). *The Methodology of Economics,* New York : Cambridge University Press, 296 pp.

**Carroll R.J. and D. Ruppert** (1988). *Transformation and Weighting in Regression*, New York : Chapman and Hall.

**Copes P.** (1972). "Factor rents, sole ownership, and the optimum level of fisheries exploitation," *The Manchester School of Social and Economic Studies* **40 :** 145-163.

**Crutchfield S.R. and J.M. Gates** (1984). "The Importance of Skill and Experience in Commercial Fisheries". Staff Paper No., Department of Resource Economics, URI. Kingston, RI 02881.

**Crutchfield S.R.** (1984). "An Econometric Model of the Market for New England Groundfish," *Northeast J. Agr. & Resource Econ.* **14** (2) : 128-143.

**Everitt B.** (1980). *Cluster Analysis*, London : Heneiman Educational Books.

**Farrell M.J.** (1957). "The measurement of productive efficiency," *J. Royal Stat. Soc.*, ser A, **120** (3) : 253-281.

**Friedman M.** (1953). *The Methodology of Positive Economics*, Chicago :The University of Chicago Press, 328 pp.

**Gates J.M.** (1984). "Principal Types of Uncertainty in Fishing Operations," *Marine Resource Economics*, **1** (1) : 31-49.

**Glesjer H.** (1969)."A new test for heteroschedasticity," *J. Amer. Stat. Assoc.* **64 :** 31 6-323.

**Goldberger A.S.** (1964). *Econometric Theory,* New York : John Wiley & Sons,Inc.

**Goldberger A.S.** (1968). *Topics in Regression Analysis*, London : The Macmillan Company.

**Gujarati D.** (1988). *Basic Econometrics*, New York : McGraw-Hill Book Company.

**Houthakker H.S.** (1956). "The Pareto distribution and the Cobb-Douglas production function in activity analysis," *Rev. Econ. Stud.* **23 :** 27-31.

**Johnston J.** (1972). *Econometric Methods,* New York : McGraw-Hill Book Company.

**Jondrow J., C.A. Knox Lovell and I.S. Materov** (1982). "On the estimation of technical inefficiency in the stochastic frontier production function model," *J. Econometrics* **19** (August) : 233-238.

**Kirkle J. and I.E. Strand** (1988). "The technology and management of multispecies fisheries," *Applied Econ.*, **20 :** 1279-92.

**Kmenta J.** (1971). *Elements of Econometrics,* New York : MacMillan Co., 655 p.

**Leibenstein H.** (1966). "Allocative vs. 'X-efficiency," *Amer. Econ. Rev.* **56** (3) : 392-415.

**Seitz W.** (1970). "The measurement of productive efficiency," *Amer J. Agr. Econ.* **42** (3) : 505-511.

**Simon H.** (1968). "Theories of decisionmaking in economics and behavioral science," *Amer. Econ. Rev.* **63** (1) : 1-28.

**Squires D.** (1987). "Long run profit functions for multiproduct firms," *Amer. J. Agr. Econ.* **69 :** 558-69

**Squire D.** (1987). "Public regulation and the structure of production in multiproduct industries : an application to the New England otter trawl industry," *RAND J. Econ.* **18** (2) : 232-247.

**Stigler G.** (1976). "On the Xistence of X-efficiency," *Amer. Econ. Rev.* **66** (1) : 213-16

**Wetherill G.B.** (1986). *Regression Analysis with Applications* New York : Chapman and Hall.

**TABLE 1.**
**CLUSTER ANALYSIS SUMMARY.**

| | | | | | |
|---|---|---|---|---|---|
| Gear Code 050 | | Max Iter.= 100 | | | |
| Convergence=0.005 | | Min # Obs./cluster= 30 | | | |
| Max # Clusters= 3 | | | | | |
| Year-> | 1982 | 1983 | 1984 | 1985 | 1986 |
| Number of Obs. in data set | 11729 | 12196 | 12833 | 12479 | 11316 |
| Cluster ranks | 2,1,* | 3,2,1 | 3,2,1 | 2,1,3 | 2,1,3 |
| Residual variance accounted for by the clusters = R-Squared | 0.57 | 0.75 | 0.75 | 0.75 | 0.77 |
| Year-> | 1982 | 1983 | 1984 | 1985 | 1986 |
| Frequency of Skill(FOS): | | | | | |
| Cluster 1: | 6803 | 4360 | 4042 | 4035 | 3108 |
| Cluster 2: | 4515 | 5786 | 6258 | 5979 | 5424 |
| Cluster 3: | * | 1507 | 1891 | 1756 | 2091 |
| | 11318 | 11653 | 12191 | 11770 | 10623 |
| % of Obs. Usable: | 96 | 96 | 95 | 94 | 94 |
| Year-> | 1982 | 1983 | 1984 | 1985 | 1986 |
| Relative Frequency of Skill(RFOS): | | | | | |
| Cluster 1: | 60.11 | 37.42 | 33.16 | 34.28 | 29.26 |
| Cluster 2: | 39.89 | 49.65 | 51.33 | 50.8 | 51.06 |
| Cluster 3: | * | 12.93 | 15.51 | 14.92 | 19.68 |
| | 100 | 100 | 100 | 100 | 100 |
| Year-> | 1982 | 1983 | 1984 | 1985 | 1986 |
| Mean Residuals | 0 | 0 | 0.002 | 0.002 | 0.004 |
| Cluster 1: | 0.36 | 0.54 | 0.58 | 0.56 | 0.62 |
| Cluster 2: | -0.54 | -0.14 | -0.09 | -0.1 | -0.04 |
| Cluster 3: | * | -1.05 | -0.93 | -0.93 | -0.8 |
| Year-> | 1982 | 1983 | 1984 | 1985 | 1986 |
| Std.Dev. Residuals | | | | | |
| Cluster 1: | 0.34 | 0.29 | 0.29 | 0.29 | 0.28 |
| Cluster 2: | 0.44 | 0.21 | 0.2 | 0.2 | 0.19 |
| Cluster 3: | * | 0.47 | 0.42 | 0.43 | 0.37 |
| Year-> | 1982 | 1983 | 1984 | 1985 | 1986 |

Notes: * only 2 clusters in 1982
1987-1991 cont'd. next page

**TABLE 1 (CONTINUED).**

| Year-> | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|
| Number of Obs. in data set | 11059 | 11121 | 10147 | 9430 | 10315 |
| Cluster ranks | 2,1,3 | 1,2,3 | 3,1,2 | 2,1,3 | 3,2,1 |
| Residual variance accounted for by the clusters = R-Squared | 0.76 | 0.75 | 0.76 | 0.75 | 0.75 |
| Year-> | 1987 | 1988 | 1989 | 1990 | 1991 |
| Frequency of Skill(FOS): | | | | | |
| Cluster 1: | 3074 | 3154 | 3165 | 3091 | 2964 |
| Cluster 2: | 5402 | 5492 | 4855 | 4731 | 5012 |
| Cluster 3: | 1856 | 1724 | 1445 | 1453 | 1578 |
| | 10332 | 10370 | 9465 | 9275 | 9554 |
| % of Obs. Usable: | 93 | 93 | 93 | 98 | 93 |
| Year-> | 1987 | 1988 | 1989 | 1990 | 1991 |
| Relative Frequency of Skill(RFOS): | | | | | |
| Cluster 1: | 29.75 | 30.41 | 33.44 | 33.33 | 31.02 |
| Cluster 2: | 52.28 | 52.96 | 51.29 | 51.01 | 52.46 |
| Cluster 3: | 17.96 | 16.62 | 15.27 | 15.67 | 16.52 |
| | 100 | 100 | 100 | 100 | 100 |
| Refer to cluster ranks above to ascertain ranks each year | | | | | |
| Year-> | 1987 | 1988 | 1989 | 1990 | 1991 |
| Mean Residuals | 0.002 | -0.33 | 0.083 | 3e-04 | 0.005 |
| Cluster 1: | 0.62 | 0.63 | 0.62 | 0.61 | 0.63 |
| Cluster 2: | -0.06 | -0.7 | -0.1 | -0.1 | -0.07 |
| Cluster 3: | -0.84 | -0.91 | -0.48 | -0.97 | -0.93 |
| Year-> | 1987 | 1988 | 1989 | 1990 | 1991 |
| Std.Dev. Residuals | | | | | |
| Cluster 1: | 0.31 | 0.32 | 0.31 | 0.33 | 0.32 |
| Cluster 2: | 0.2 | 0.21 | 0.22 | 0.21 | 0.21 |
| Cluster 3: | 0.38 | 0.43 | 0.42 | 0.45 | 0.43 |

**TABLE 2.**
**SUMMARY BY YEAR OF CONDINIONAL MEAN ELASTICITIES WITH RESPECT TO RFOS VARIABLES.**

| RFOSS> | Low | Average | High | RANGE | Low | Average | High |
|---|---|---|---|---|---|---|---|
| YEAR | ESTIMATED COEFFICIENTS | | | | STANDARD ERRORS | | |
| 1982 | -0.17 | -0.03* | 0.18 | 0.35 | 0.006 | 0.008 | 0.006 |
| 1983 | -0.11 | -0.08 | 0.14 | 0.25 | 0.004 | 0.008 | 0.005 |
| 1984 | -0.11 | -0.02 | 0.144 | 0.254 | 0.004 | 0.007 | 0.004 |
| 1985 | -0.11 | -0.05 | 0.13 | 0.236 | 0.004 | 0.007 | 0.005 |
| 1986 | -0.12 | -0.02 | 0.12 | 0.24 | 0.004 | 0.008 | 0.005 |
| 1987 | -0.1 | -0.02 | 0.13 | 0.23 | 0.004 | 0.008 | 0.005 |
| 1988 | -0.11 | -0.05 | 0.124 | 0.234 | 0.005 | 0.009 | 0.005 |
| 1989 | -0.11 | -0.04 | 0.14 | 0.25 | 0.005 | 0.01 | 0.006 |
| 1990 | -0.11 | 0 | 0.133 | 0.243 | 0.005 | 0.01 | 0.006 |
| 1991 | -0.11 | -0.03 | 0.13 | 0.24 | 0.004 | 0.007 | 0.004 |
| AVERAGES | -0.12 | -0.03 | 0.137 | 0.253 | 0.005 | 0.008 | 0.005 |
| S.DEVs. | 0.019 | 0.023 | 0.016 | 0.001 | 0.001 | 0.001 | |

* MEAN VALUE USED

# A General Bioeconomic Simulation Model of the catching Sector of a Multispecies Fishery

**Philip Rodgers**

S.F.I.A., 10, Young Street, Edinburgh EH2 4JQ, United Kingdom

ABSTRACT

*This paper describes a general bioeconomic simulation model for the catching sector of a multispecies fishery. The objective of the model is to set out the economics of a fishery so that the final figure measured is the nett discounted present value of future value added from the fishery.*

*The model is comprehensive and is applicable to a fishery prosecuted by a number of countries with fleets using a variety of fishing methods. It accommodates multiple species fisheries over a multi-cohort span which permits landings by size category of fish to be simulated.*

*The model assumes that there is no more than one stock of a species since the intention was to concentrate on the economics of the fishery, but little extra programming would be required to allow for separate stocks of a species.*

*The model has two purposes. First, to act as a test bed for the mathematical structure of the system of equations used, so that a suitable optimisation method can be developed. Secondly, to offer a means by which fisheries managers can examine the impact of proposed measures on the different participants in a fishery.*

## 1. INTRODUCTION

Until now almost all economic models of fisheries have limited themselves to an examination of some aspect within the context of a single species fishery. This assumption has been necessary because of the need to understand the complex bioeconomic system on which the essentially economically-driven fishing activity takes place. While there are many such single species fisheries to be found, such models make no attempt to describe the complex interrelationships which exist where, because of the behaviour of the fish, only multi-species catches are possible, or where there are alternative fishing opportunities.

It has become apparent that there is now a need for a thorough-going model of a multi-species fishery that accommodates the variety of interactions between economic behaviour and biological factors.

## 2. THE OBJECTIVES OF THE MODEL

In planning the construction of any economic model the first question to determine is what task the model is required to perform. There are three functions a thoroughgoing bio-economic model can be asked to perform.

First, it can be asked to simulate the history of a fishery. The main purpose of this exercise is to test the specification of the model and validate the coefficients used.

The second is to predict ex ante the behaviour of the fishery and each of the variables included in the model. The model can be used to assess the impact of a range of events on the fishery. These events may be controllable, such as a change in regulatory limitations to fishing effort, or uncontrollable, such as failures in the recruitment of young fish to the stocks.

The third is to predict the level of activity which will maximise a variable such as profitability, value-added, or the size of stocks.

These functions are not mutually exclusive, and while the third of them requires different software from the first two in order to obtain a solution, the fundamental mathematical and economic structure of the model remains the same for all three tasks. Thus, my aim has been to describe a detailed general model of a fishery subject to exploitation by a number of countries by a variety of different methods aimed at a differing mix of the species available.

## 3. A GENERAL SCHEMATIC ANALYSIS OF THE DYNAMICS OF A FISHERY

The schematics of the model described in this paper are set out in Figure 1.

The relationships on the right hand side of most of the equations discussed below are almost wholly unknown. The mathematical specification of the equations has often merely been assumed in order to facilitate development of the strucure of the model. The functional form of the equations, the variables to be included and their dynamics, remain to be discovered.

In the formulation below all variables should be read as at time t unless otherwise specified. I have omitted the subscript t to avoid the formulae becoming unnecessarily cluttered. Given that the mathematical specification of the formulae remains to be discovered the philosophy of the systemic approach is more important than precise but possibly spurious specification. Similarly, I have omitted a number of identities which are merely summations necessary to move with mathematical exactitude between equations. This should not cause the reader any difficulty, but again has been done to avoid overcomplication. For the reader who wishes to check the detail, the computer program shows the exact summations needed.

The subscript c represents country, g fishing method, f species, a age cohort of fish, and s market size category of fish.

## 4. THE INVESTMENT FUNCTIONS

Thus for the purposes of the model it is postulated that investment is a function of injections and profitability, such that

$$I_{cg} = i0_{cg} + (i1_{cg} * PY_{cg}) \tag{1}$$

where I is investment, i0 is injected capital, and PY is profitability.

Profitability is the proportion of revenue accruing to profits, such that

$$PY_{cg} = \frac{PI_{cg}}{TR_{cg}} \tag{2}$$

where PI is the absolute level of profits and TR is the Total Revenue.

## 5. THE CAPACITY CONSTRAINTS

The capacity of the fleet is here defined as the maximum number of days fishing the fleet is capable of achieving. In the United Kingdom this normally means that a vessel is limited to about 200 days fishing a year. It would be possible for a vessel to be used much more heavily, subject to the mechanical wear and tear, by double or even triple crewing. It is necessary, therefore, that it is assumed in the model that there is no change to the pattern of crewing.

Capacity is here postulated to be a function of previous capacity, and investment such that

$$K_{cg} = K_{cgt-1}^{k1_{cg}} + (k2 * PI_{cgt-2}^{k3_{cg}}) \tag{3}$$

where K is capacity. The parameter k1 represents decay and

$$0 < k1_{cg} < 1 \tag{3a}$$

but k3 includes technological growth. The two period lag postulated for the impact of investment relates to the fact that it takes a considerable amount of time between earning profits and the launch of a new vessel. Usually commissioning the building of a new vessel involves staged payments as the work progresses. Further, there are other ways of investing such as the addition of a new piece of machinery to a vessel. Both these make the formulation postulated in equation 3 insufficient to describe accurately the true specification of capacity functions.

Capacity, however, need not be fully used. It is therefore a constraint on effort. Thus

$$E_{cg} = < K_{cg} \tag{4}$$

The formulation given in equation 3 assumes a given limit to capacity for each country and method. The model does not permit switching between methods which would increase the capacity available for one method at the expense of another. At this stage I do not believe this to be a significant weakness, though it is undoubtedly unrealistic. To over come the problem a series of constraints limiting the sums of capacity by country and method is needed. As these are specific to a given fishery I see no advantage in including them in the general model at this stage.

## 6. THE EFFORT EQUATIONS

Subject to the constraint expressed in equation 4, fishing effort expended may depend upon a number of factors.

Nominal fishing effort is postulated to be a function of a constant and the level of profitability of the method in that country in the previous time period

$$E_{cg} = e0_{cg} + (e1_{cg} * PY_{cgt-1}) \tag{5}$$

The adjustment period must remain a matter of conjecture until the hypothesis can be tested empirically. A one year lag was chosen because it seems unlikely that the reaction to a downturn would be immediate. There is little empirical evidence on which to base a postulation and an added advantage of a lag of some degree is that it facilitates computation by making the system recursive.

The question of switching effort from one method to another is similar in concept to that outlined in capacity above. Here it is perhaps more important but again because the structure of effort is specific to a fishery there is little to be gained in including effort switching inequalities at this stage.

## 7. THE STOCK EQUATIONS

The size of stock is fundamental to the viability of the economic activity based on it, and is a function in part of that activity. In the model there is assumed to be a single stock of each species. The stock equation used in the model calculates the numbers of fish in each age cohort and is

$$S_{fa} = (S_{f,\,a-1,\,t-1} * \exp(-M_{f,\,a-1} - F_{f,\,a-1,\,t-1})) + IM_{fa} - EM_{fa} \qquad (6)$$

for a > 1, assuming recruitment takes place at age 1.

where S is the stock, M is natural mortality, and F is fishing mortality.

Equation 6a is the standard Beverton-Holt model with the simple addition of terms for immigrants, IM, and emigrants, EM, to the stocks.

Fishing mortality is defined as :

$$F_{fa} = \ln\left(1 - \frac{CA_{fa}}{S_{fa}}\right) \qquad (7)$$

where CA is the catch in numbers, and

$$CA_{cgfa} = \frac{Q_{cgfa}}{MW_{fa} * D_{cgfa}} \qquad (12a)$$

Q is the quantity of landings by weight, MW the mean weight-at-age of a fish, and D the percentage rates of discard.

## 8. THE RECRUITMENT FUNCTIONS

It is assumed that recruitment is a constant. This has been done more for the potential use of the model in predicting the impact of management measures than to model the effect of fishing on the spawning stock and ultimately on stock size.

In some degree, this is unfortunate as the link between fishing and recruitment to the stocks is at the heart of fisheries management. The relationship appears to be so dependent upon a range of environmental factors, about the influence of which little is known, that models specifically designed to simulate the relationship have not yet been developed.

It is however possible to include actual recruitment data for the ex-post simulations. This overcomes the difficulty of including what must inevitably be a questionable functional form for the recruitment function and avoids also the problem of determining multi-species effects on recruitment.

The advantage in using a constant for recruitment is that a whole range of scenarios may be tried, and the effects of a single management measure determined given the unpredictability of future natural events. Thus

$$R_f = \bar{R}_f \qquad (8)$$

where R is recruitment. R is either mean, given, or actual recruitment depending on whether the model is running ex-post or ex-ante.

Where recruitment of young fish to all stocks is given as the mean historic level or some other constant, it should be noted that this model, and any which uses a similar assumption, is unable truly to replicate the extinction of a stock through overfishing. In the limiting case of their being no spawning stock there can of course be no subsequent recruitment. Any model using some form where recruitment is not a function of the spawning stock cannot replicate extinction.

A better alternative, which is not attempted for the reasons given above would be

$$R_f = R\left(SSB_{ft-1}, \sum_{i=1}^{f} Stock_i, ECC\right) \tag{8a}$$

where SSB is the spawning stock biomass. ECC is the environmental carrying capacity of the sea.

## 9. THE SPAWNING STOCK BIOMASS

Spawning in fish is related to size rather than age. Size is a function of food and space available. There would be no great difficulty in making the model accommodate fish by size but since the relationship of size as a function of food and space is unknown it has to be assumed constant. This leaves size as a function of age and simple substitution means that spawning can be treated directly also as a function of age.

Thus functions of the form

$$SSB_f = \sum_{i=4}^{a} S_{fi} \tag{9}$$

will suffice. Note that I have made no attempt to deduct those fish caught in each time period before they spawn. This leaves each time period split into three discrete sections ; recruitment, spawning, fishing.

## 10. THE CATCH EQUATIONS

Effort, given by equation 5, applied to the stocks results in the catch.

The Beverton-Holt model for catches is derived by substituting equation 6 into 7 and rearranging. This arithmetic manipulation gives

$$CA_{fa} = S_{fa} * (1 - \exp(-F_{fa} - M_{fa})) * \frac{F_{fa}}{F_{fa} + M_{fa}} \tag{10}$$

and

$$F_{fa} = E_{cg} * q0_{cgfa} \tag{11}$$

where q0 is a catchability parameter. Note that equation 10 contains no parameter representing stock density, and equation 11 has no parameter for diminishing returns to effort.

## 11. THE LANDINGS FUNCTIONS

Information about the levels of discarding is extremely limited and so given percentages are assumed to be discarded from each catch.

Those fish remaining after the unwanted fish in the catch are discarded provide the landings,

$$Q_{cgfa} = CA_{cgfa} * D_{cgfa} * MW_{fa} \quad (12)$$

The application of mean weights, MW, at this stage converts landings from numbers of fish to weights of fish.

To compute the quantity landed of each market size category it is necessary to multiply equation 12 by a matrix of mean size-at-age. Thus

$$Q_{cgfs} = Q_{cgfa} * SXA \quad (13)$$

where SXA is the mean size-at-age matrix.

## 12. THE PRICE FUNCTIONS

Quayside demand for fish is a derived demanded filtered by the needs of retailers, caterers, and processors who add value to the fish before it reaches the consumer. The model requires the demand schedule to be rearranged to form a price function.

The price function used is of the form :

$$P_{cfs} = p0_{cfs} + (p1_{cfs} * Q_{cfs}) + (p2_{cu} * Q_{cu}) \quad (14)$$

where P is price. u refers to the vector of substitute species for the one whose price is currently being estimated. The constant term p0 has subsumed within it the ceteris paribus assumptions relating to the vector of explanatory variables not determined endogenously.

It might have been preferable to include the prices of substitute species as explanatory variables instead of quantity but the use of price avoids the necessity to calculate prices simultaneously.

## 13. REVENUE

Revenue is calculated simply by multiplying the quantities by price :

$$TR_{cgfs} = P_{cfs} * Q_{cgfs} \quad (15)$$

where TR is total revenue.

## 14. THE COST EQUATIONS

Costs here relate to the costs of the whole fleet disaggregated by country and method. They include all costs including the cost of capital provided other than by the shareholders but excluding profits and wages.

Costs may be divided into fixed and variable costs. Fixed costs are a function of the size of the fleet. Variable costs are a function of the cost of fishing. In addition, many charges, such as harbour dues and salesman's commission are a percentage of the value of the catch landed.

The cost function used is therefore :

$$C_{cg} = (c1_{cg} * E_{cg}) + (c2_{cg} * TR_{cg}) + (c3_{cg} * K_{cg}) \quad (16)$$

where C is costs.

## 15. THE WAGE EQUATIONS

In the fishing industry in the UK crew remuneration is normally by one of two methods.
It may by proportionate to the value of the catch nett of running costs. The usual alternative to this means of payment is for the crew to be paid a basic wage, and some form of bonus as a proportion, w1, of the value of landings, so

$$W_{cg} = w0_{cg} + (w1_{cg} * TR_{cg}) \quad (17)$$

where b is a constant which represents the sum of basic wages by country and method, and

$$0 < w1_{cg} < 1 \quad (17a)$$

If any vessel at all for the country and method pays its crew a basic wage independent of the revenue from landings then the function for the country and method will include a non-zero intercept term.

## 16. THE PROFIT IDENTITIES

Profits are defined as

$$PI_{cg} = TR_{cg} - C_{cg} - W_{cg} \quad (18)$$

where PI represents profits.

## 17. VALUE ADDED AND THE DISCOUNTED VALUE ADDED

It is assumed in the model that the ultimate objective of society in having a fishing industry is to maximise value-added to society. In the catching sector of fishing the discounted value added from each method is

$$DVA_{cg} = (PI_{cg} + W_{cg}) * (1 - r)^t \quad (19)$$

where DVA is the nett discounted present value of value added, and r is the discount rate.
This completes the model.

## 18. THE SIMULATION MODEL

The structural model detailed above has been incorporated into a simulation model. The program is written in BASIC. BASIC is much derided by computer buffs but the flexibility it offers while one's thinking is developing in parallel with

the work has been an immense asset. The program is now some 7500 lines in length and as the importance of new factors has come to be understood it has been relatively easy to add sections to cope with their influence. At no stage have I felt constrained by the software in what I have wanted to model.

One limitation has been that the TurboBasic package used has insufficient memory to store all the calculated variables for output at the end of the simulation run. This constrains the output to be by time period, so that the memory can be overwritten, rather than by variable. It is less than ideal as it prevents ready access to the variables without needing to re-run the model in order to provide a particular set of results in time series format, but it is a question of presentation of output and not whether the output can be produced. The difficulty could easily be overcome by repeatedly running the model and retaining the values of one group of variables at each run for output at the end of the run. This is already done in the current program with Discounted Value Added.

However, the main objective of setting up the conceptual structure to answer the question of who gains and who loses has been achieved and transfer to a larger computer would enable all the output to be stored till the end with only minor changes to the program.

BASIC may prove unwieldy at some stage in the future if simultaneous solution of some of the equations is sort. At present, this limitation is negligible when set against the advantages the language's flexibility offers.

## 19. USE OF THE SIMULATION MODEL

The model can be used in a number of ways.

First, it can be used to test the correctness of functional forms. By examining the closeness of the simulation results to those historically observed the user will be able to develop a better understanding of the economic relationships existing in fisheries. In addition the user, by making small changes to the values of the coefficients, will be able to test the sensitivity of the economic system to a variable.

Secondly, it will be possible to run the model to determine what the effect of a suggested regulatory measure will be, including identifying the gainers and the losers, and the impact on the contribution of fisheries to the economy as a whole.

Thirdly, it will be possible to examine the vulnerability of the catching sector of the fishing industry to external factors, such as demand for fish, or the cost of fuel oil.

There are throughout the model assumptions which have had to be made. The decision criteria for these has been to select those which pull the model closer to reality so long as the basic theoretical framework of the model is not compromised.

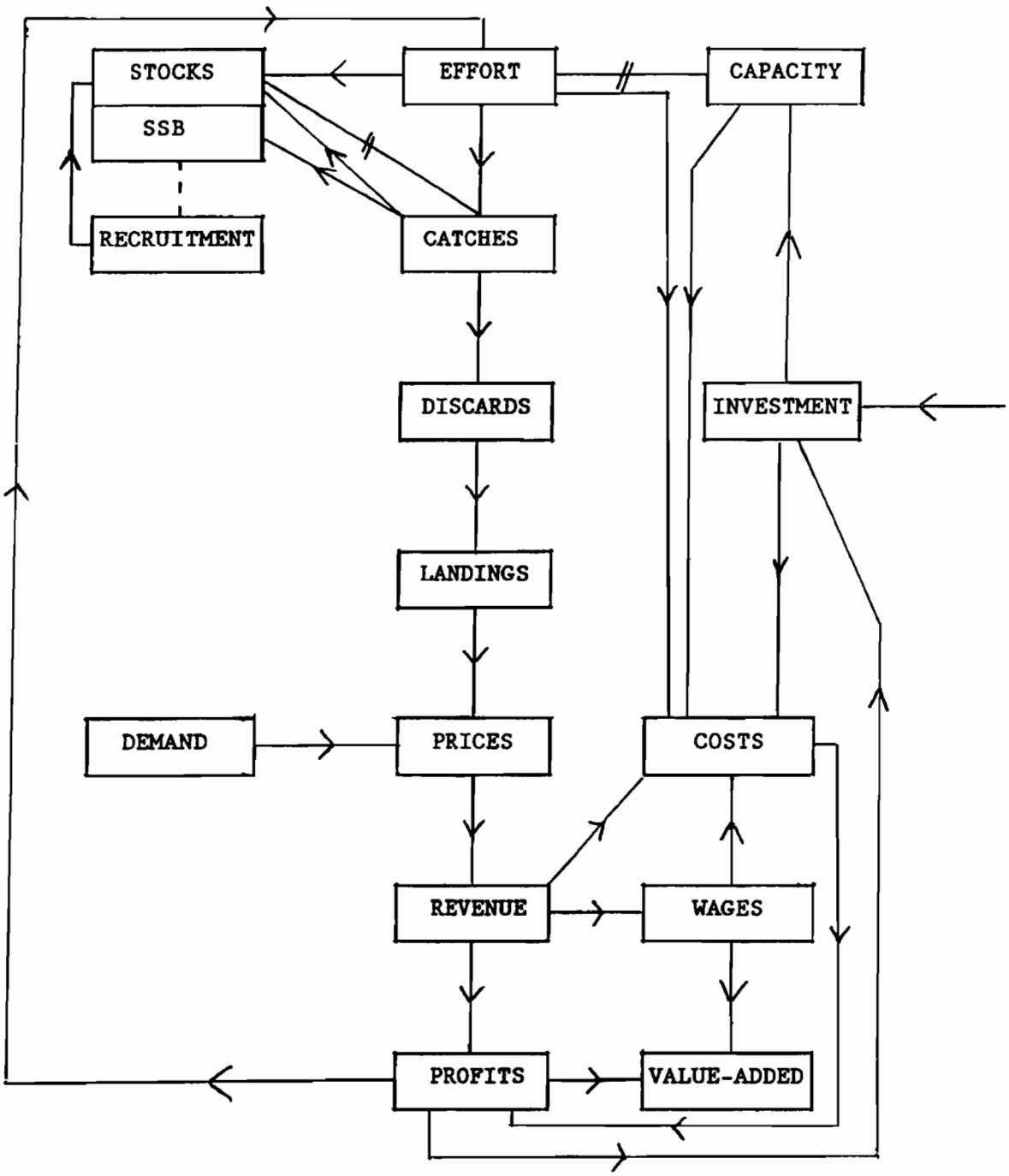
Even if we had perfect knowledge of all the economic parameters, there remains the problem of the apparently stochastic nature of recruitment.

This seems to me to be so fundamental a problem that any attempt to use this or any other bioeconomic model which includes it is bound to conclude with a series of "if... then..." comments.

## 20. CONCLUSION

What I have achieved here is twofold. First I have identified the conceptual structure of a thoroughgoing bioeconomic model. Secondly, I have shown what data is needed for such a model. The schematics show the true position of the stocks as constraints on economic activity and not an end in themselves. Capacity is also shown to be a constraint on effort and not causal.

**FIGURE 1.**
**SCHEMATICS OF THE BIOECONOMIC MODEL**



# BEAM 4 - A Bio-Economic Model for the Simulation of Space-Structured Multi-Species and Multi-fleet Fisheries

**Per Sparre[a] and Rolf Willmann[b]**

[a]Danish Institute for Fisheries and Marine Research, Charlottenlund Castle, 2920 Charlottenlund, Denmark

[b]Fisheries Department, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy

ABSTRACT

*The paper provides a summary of the elements and structure of a bio-economic model of fish harvesting and processing. BEAM 4 is the fourth in a series of bio-economic analytical models issued by the FAO Fisheries Department. The model allows to predict yield and a range of economic performance indicators as a function of fishery management measures such as fishing effort control, closed season, closed area and minimum mesh size regulation. BEAM 4 can deal with a fishery system of several stocks, several fleets, several areas (fishing grounds) and several processing plants, and can account for migration of the animals as well as seasonality in recruitment. The model behind BEAM 4 is an age-structured cohort-based fish stock assessment model combined with an economic model of both harvesting and processing.*

## 1. INTRODUCTION

This paper provides a summary description of BEAM 4 (Sparre and Willmann, 1992), the latest in a series of bio-economic analytical models issued by the FAO Fisheries Department [1]. BEAM 4 is a versatile tool for the analysis of space-structured multi-fleet and multi-species fisheries and can account for migration of the animals as well as seasonality in recruitment. The model behind BEAM 4 is an age-structured cohort-based fish stock assessment model combined with an economic model of both harvesting and processing sectors.

1. BEAM I and II by Coppola, Garcia and Willmann (1992), and BEAM III, the stochastic simulation model by Cochet and Gilly (1990).

The objective of BEAM 4 is to predict yield, value and a series of measures of economic performance as a function of fishery management measures such as fishing effort control, closed season, closed areas and minimum mesh size regulation. The measures of economic performance include profit, profitability, gross value added, net value added, national net value added, resource rent, employment, costs in foreign exchange and foreign exchange earnings.

BEAM 4 is primarily designed for the analysis of tropical mixed fisheries with penaeid shrimps as the target and finfish as the by-catch. It is, however, general, and in principle may be used to analyse any fishery. It is suitable for the analysis of resources shared between artisanal and industrial fisheries. It is a simulation model and has no routine for optimization.

BEAM 4 is implemented in TURBO PASCAL for IBM micro-computers. The system is user-friendly and menu-driven. It contains extensive data entry, file handling and output facilities as well as graphical presentation of results.

BEAM 4 consists of a biological/technical and an economic model which are described below.

## 2. THE BIOLOGICAL/TECHNICAL MODEL

Models used for fish stock assessment either deal with the analysis of historical data such as the Virtual Population Analysis, VPA, (Fry, 1949) or they deal with prediction of catches and stock sizes such as the Thompson and Bell model (1934). The series of BEAM models is of the latter type but their biological input parameters are usually estimated with VPA or similar methods. BEAM 4 works with numbers of fish/shellfish by age group as described by, for example, Beverton and Holt (1956).

There are two kinds of input data into the biological/technical model. The first kind include data on growth, migration and mortality by species which need to be obtained on the basis of stock assessment techniques such as VPA. The second kind are data on observed fish catches and fishing efforts by species, fleets and fishing grounds which are used to tune the model.

### *2.1 Number of Survivors*

The number of survivors of a cohort belonging to a stock is designated, N. With indices, the number of survivors reads :

N[s,t,ar,a] = Number of survivors of stock (species) s, at the beginning of time period t, in area ar, belonging to age group a.

Let NoS, NoT and NoA designate the numbers of species, time periods and areas, respectively : s = 1,2,..,NoS ; t = 1,2,..,NoT ; ar = 1,2,..,NoA. The number of survivors in area ar at the beginning of time period t is :

N[s,t,ar,a] = (The number at the beginning of previous time period in area ar, i.e. N[s,t-1,ar,a-1])
- (The number which died from fishing during period t-1)
- (The number which died from natural causes during period t-1)
- (The number which migrated out of area ar)
+ (The number which migrated into area ar)

### *2.2 The time step and the age group concepts of BEAM 4*

The smallest time step considered in BEAM 4 is called the "basic time step", and is designated "dt". BEAM 4 allows for the following options for the basic time step, dt : 1, 2, 3, 4, 6 or 12 months. The length of an age group may take the same values as the basic time step (but must be larger than or equal to the basic time step). The length of the age group of species s is designated DT[s].

The life span is, for the sake of simplification, assumed to be equal to the length of 12 time periods, or some multiplicity of 12 (that is 24, 36, 48,...). In the following it is assumed, for simplicity, that there are 12 age groups of each species.

*2.3 Recruitment*

"Recruitment" refers to the number of juvenile animals which enter the stock, i.e., the "incoming cohorts". That is, the numbers in the first age group. They are also called the "0-group" and assigned the index zero. N[s,t,ar,0], is the number of recruits to stock s in area ar at the beginning of time period t, t = 1,2,...,NoT. As an approximation to reality, the recruitment in BEAM 4 takes place at the beginning of the time period.

The number of recruitment batches per year is determined by the time step applied to model the different stocks. If a stock has a time step of 3 months it can have from 1 to 4 recruitment batches (or incoming cohort parts) per year. If a time step of one year is applied only one recruitment season per year can be considered. Thus, for short-lived species like penaeid shrimps, BEAM 4 can account for seasonality in recruitment, whereas seasonality is ignored for species with a life span of 12 (or more) years. The recruitment may occur in any sea area.

In BEAM 4, the number of recruits is an input parameter. As the number of specimens which can be caught by the fishery is proportional to the number of recruits, the simulation results are highly sensitive to this parameter. Many attempts have been made to find the relationship between the size of the parent stock (the so-called spawning stock biomass) and the subsequent recruitment. However, none of them appears to have much prediction power, and consequently, no stock and recruitment relationship is modelled in BEAM 4.

*2.4 The growth of a single animal*

Mean body length of species s as a function of the age group a, is given by the von Bertalanffy growth model (von Bertalanffy, 1934) :

$$LGT[s,a] = L_{\infty}[s]*\{1 - \exp( -K[s]*\{DT[s]*(a + 0.5)- T_0 [s]\})\}$$

where $L_{\infty}[s]$ is the asymptotic body length of species s, K[s] (per year) is the curvature parameter of species s, $T_0[s]$ (year) is the initial condition parameter of species s, DT[s] is the length of an age group (years) of species s. These four variables are input parameters.

The body weight is given by the equation :

$$W[s,a] = CF[s] * LGT[s,a]^{CE[s]}$$

where CF[s] is the condition factor and CE[s] is the condition exponent for species s ; these are input parameters to BEAM 4. The asymptotic body weight, $W_{\infty}$, of species s is derived from $L_{\infty}$ using the above equation.

*2.5 The area-based exponential decay model*

BEAM 4 assumes the sea area to be partitioned into a number of sub-areas (or fishing grounds). To begin with, however, the partitioning of the sea into areas is ignored and only the total number of the entire stock in all areas combined is considered :

$$N[s, t, . , a] = \sum_{ar = 1}^{NoA} N[s, t, ar, a]$$

i.e. the number of species, s, of age group a at the beginning of time period t. Note that the dot "." is used to indicate summation over an index.

The death process of BEAM 4 is modelled by the usual exponential decay model (see for example Sparre *et al.*, 1989) :

$$N[s,t+1,.,a+1] = N[s,t,.,a] * \exp( - Z_{stock}[s,t,a]*DT[s]), \text{ for } a = 0,1,2,...,10,$$

and where $Z_{stock}[s,t,a]$ (per year) is the total instantaneous mortality coefficient for the entire stock of species s.

The oldest age group, a = $A_{max}$ -1 is a plus-group, so after age $A_{max}$ - 1 the animals stay in age group $A_{max}$ - 1. For age group $A_{max}$ - 1 the model takes the form, in the case $A_{max}$ = 12 :

$$N[s,t+1,.,11] = N[s,t,.,10] * \exp( - Z_{stock}[s,t,10]*DT[s]) + N[s,t,.,11] * \exp( - Z_{stock}[s,t,11]*DT[s])$$

The total mortality is composed of fishing mortality, $F_{stock}$, and natural mortality, M, referring to the entire stock :

$$Z_{stock}[s,t,a] = F_{stock}[s,t,a] + M[s,a]$$

$F_{stock}$ is composed of the fishing mortalities created by each fishing fleet in each area. The non-aggregated fishing mortality, F[s,t,ar,fl,a] has five indices, where fl, is index of fleet and ar is index of area. $F_{stock}$ is related to the non-aggregated F in a rather complex way. As $Z_{stock}$ is composed of M and F, these features are similar for $F_{stock}$ and $Z_{stock}$.

The model of the death process for a single area is similar to that of the entire stock (as an example is used $A_{max}$ = 12) :

$$N[s,t+1,ar,a+1] = N[s,t,ar,a] * \exp( - Z[s,t,ar,a]*DT[s]), \text{ for } a = 0,1,2,...,10$$

$$N[s,t+1,ar,11] = N[s,t,ar,10] * \exp( - Z[s,t,ar,10]*DT[s]) + N[s,t,ar,11] * \exp( - Z[s,t,ar,11]*DT[s])$$

Here Z is the total mortality of the part of the stock which is in area ar. Z depends on the number of fishing boats which fish in area ar in addition to M. It should be noticed that the relationship between $Z_{stock}[s,t,a]$ and Z[s,t,ar,a] is not as simple as the relationship between N[s,t,.,a] and N[s,t,ar,a]. $Z_{stock}[s,t,a]$ can be derived from Z[a,t,ar,a] and the Ns :

$$Z_{stock}[s,\ t,\ a]*DT[s] = -\ln\left(\sum_{ar=1}^{NoA} \frac{\exp(-Z[s,\ t,\ ar,\ a]*DT[s])*N[s,\ t,\ ar,\ a]}{N[s,\ t,\ .\ ,\ a]}\right)$$

where "ln" stands for "natural logarithm".

This equation follows from the fact that total mortality for the entire stock is defined by the inverse exponential decay equation :

$$Z_{stock}[s,t,a] * DT[s] = - \ln( N[s,t+1,.,a+1]/N[s,t,.,a] )$$

The sum over areas gives number of survivors at the end of the period (if migration is ignored) :

$$N[s,\ t+1,\ .\ ,\ a+1] = \sum_{ar=1}^{NoA} \exp(-Z[s,\ t,\ ar,\ a]*DT[s])*N[s,\ t,\ ar,\ a]$$

The mean number of survivors in area ar during time period t is defined :

$$\overline{N}[s,t,ar,a] = (N[s,t,ar,a] - N[s,t+1,ar,a+1]) / Z[s,t,ar,a]*DT[s]$$

For an explanation of this formula, see for example, Sparre *etal.* (1989).

The mean number of survivors in the stock is calculated similarly :

$$\overline{N}[s,t,.,a] = (N[s,t,.,a] - N[s,t+1,.,a+1]) / Z_{stock}[s,t,a]*DT[s]$$

Notice that if the Zs vary between areas then :

$$\bar{N}[s, t, . , a] \text{ is different from } \sum_{ar=1}^{NoA} \bar{N}[s, t, ar, a]$$

Only if the Zs are equal in all areas will there be equality.

In BEAM 4, natural mortality, M[s,a] (per year), is a function of species s, and age group, a. Natural mortality is input to BEAM 4. Often, M is assumed to remain constant from age group to age group. The reason for this assumption is not that it represents a good approximation to reality. The reason rather reflects the lack of knowledge about M. The available knowledge suggests that M is a function of age indicating that there is in fact a very pronounced size dependency. One obvious explanation is that small specimens are more exposed to predation mortality than large specimens. BEAM 4, however, does not attempt to model natural mortality, or predation mortality along the lines of the so-called Multi-Species Virtual Population models and their prediction counterparts (see for example, Sparre, 1991).

BEAM 4 contains an option for a simple age dependent model of M, which reflects some of the findings from multi-species VPA :

$$M[s,a] = M_A[s] + 1/(a + M_B[s]),$$

where $M_A[s]$ and $M_B[s]$ are parameters. This is a reformulation of the model of Caddy (1991).

*2.6 Gear selectivity*

The number of fleets is designated NoF and fl is the index of fleet. E[fl,t,ar] denotes the effort of fleet fl exerted in area ar during basic time period t. Gear selectivity is modelled by the mathematical function :

$$f(x) = \frac{1}{1 + \exp(a - bx)}$$

where a and b are positive constants. It approaches zero when x takes high negative values and it approaches 1.0 when x takes high positive values. This mathematical function is called the "logistic" curve. It has been used to model the probability that a fish is retained by the meshes of a gear (notably codends of trawls) as a function of its body length. The probability that a fish if it enters the gear multiplied by the probability that the fish is available to the fishery (the so-called resultant selection curve) is in BEAM 4 given by the logistic function, the "selection ogive" (see for example Kimura, 1977) :

$$SO[s, fl, ar, a] = \frac{1}{1 + \exp(SP1[fl, ar, s] + SP2[fl, ar, s] * LGT[s, a])}, \quad \text{where}$$

$$SP1[fl, ar, s] = \frac{\ln(3) * L_{50\%}[fl, ar, s]}{L_{75\%}[fl, ar, s] - L_{50\%}[fl, ar, s]}, \quad \text{and}$$

$$SP2[fl, ar, s] = - SP1[fl, ar, s] / L_{50\%}[fl,ar,s]$$

These two parameters are derived from the input parameters $L_{50\%}[fl,ar,s]$ and $L_{75\%}[fl,ar,s]$ : 50 % and 75 % availability/retention length for species s in area ar caught by fleet fl.

### *2.7 Effort and fishing mortality*

The fishing mortality of fleet fl exerted in area ar on age group a of species s during time period t is designated F[s,t,ar,fl,a]. F is assumed to be proportional to the effort, E[fl,t,ar], and the factor of proportionality is the "catchability coefficient", Q[fl,s,ar].

BEAM 4 can use different measures for the effort of different fleets. Within a fleet, it is assumed that boats are identical. If a fleet contains a number of different boat types a unit such as "boat day" cannot be used if the boat types have different fishing power. Effort may then be expressed in "standard boat units" if estimates of fishing power are available. BEAM 4 allows for area-specific allocation of fishing effort in each time period considered.

The model for fishing mortality for species s, age group a, during time period t, caused by fleet fl in area ar is :

$$F[s,fl,t,ar,a] = Q[fl,s,ar] * E[fl,t,ar] * SO[s,fl,ar,a]$$

The tacit assumption behind this model is that the fish and the fishing vessels, irrespective of their numbers, are evenly distributed within the area. The area (the fishing ground) is assumed to be homogenous in all respects.

The total fishing mortality in area ar by all fleets is :

$$F[s, . , t, ar, a] = \sum_{fl=1}^{NoF} F[s, fl, t, ar, a]$$

Within an area, simple sums of fishing mortalities can be made, because of the homogeneity assumption. However, the overall fishing mortality by all fleets for the entire stock is not defined as a simple sum, but has to be calculated as a weighted sum as was the case for $Z_{stock}$ :

$$F_{stock}[s, t, a] = \sum_{ar=1}^{NoA} F[s, . , t, ar, a] * \bar{N}[s, t, ar, a] / \bar{N}[s, t, . , a]$$

The total mortality used to calculate number of survivors is the area-based mortality, the mortality for the part of the stock which is in area ar :

$$Z[s,t,ar,a] = M[s,a] + F[s,.,t,ar,a]$$

Fish caught may be either landed or discarded (returned to the sea). BEAM 4 assumes that all discarded fish die. Therefore, the fishing mortality can be separated into two components :

$$F[s,fl,t,ar,a] = F_{discards}[s,fl,t,ar,a] + F_{landings}[s,fl,t,ar,a]$$

### *2.8 Migration*

Inclusion of migration in age-based fish stock assessment has been suggested for many years, but there are few examples of practical use of the methodology. For a theoretical discussion of migration in connection with age based fish stock assessment the reader is referred to Quinn II *etal* (1990). These authors also discuss the estimation of migration parameters. In principle their model is the approach used in BEAM 4.

The types of migrations accounted for in BEAM 4 are only horizontal movements, i.e., along the coast, inshore and offshore or even between rivers/lagoons and marine areas.

BEAM 4 can deal with any number of areas (fishing grounds) and any migration route between the areas (within the limits of the memory capacity of the micro-computer). Migration is modelled in a time discrete manner and takes place at the end of each (species dependent) time period. The process of migration takes zero time. During a time period the fish/shrimps are assumed to be homogeneously distributed within the area (fishing grounds).

The "Migration Coefficient", MC, from area A to area B is defined as the fraction of the animals in area A which moves to area B. In this definition, migration includes the "movement" from area A to area A, i.e., the event that the animal does not migrate. The migration coefficient depends on (or has the indices) : ar (starting area) ; j (destination area) ; s (species) and a (age group). The sum of migration coefficients over destination areas always becomes 1.0, as the starting area is also considered a destination area :

$$C[s, fl, t, . , a] = \sum_{ar=1}^{NoA} F[s, fl, t, ar, a]* DT[s]* \bar{N}[s, t, ar, a]$$

*2.9 Number caught and yield*

The number caught of species s, age group a in area ar during time period t by fleet fl is given by the Baranov model (Baranov, 1918) used for only that part of the stock which is in area ar :

$$C[s,fl,t,ar,a] = F[s,fl,t,ar,a] * DT[s] * \bar{N}[s,t,ar,a]$$

The total catch in all areas by fleet fl is the sum :

$$C[s, fl, t, . , a] = \sum_{ar=1}^{NoA} F[s, fl, t, ar, a]* DT[s]* \bar{N}[s, t, ar, a]$$

The total catch from the stock by all fleets in all areas is

$$C[s, . , t, . , a] = F_{stock}[s, t, a]* DT[s]* \bar{N}[s, t, . , a]$$
$$= \sum_{fl=1}^{NoF} C[s, fl, t, . , a]$$

This is in accordance with the definition of overall fishing mortality by all fleets for the entire stock, $F_{stock}$.

The catch in weight, the yield, for fleet fl in area ar is :

$$Y[s,fl,t,ar,a] = C[s,fl,t,ar,a] * W[s,a]$$

The yield of species s age group a of fleet fl in all areas is :

$$Y[s, fl, t, . , a] = C[s, fl, t, . , a]* W[s, a] = \sum_{ar=1}^{NoA} Y[s, fl, t, ar, a]$$

and the total yield caught by fleet fl during the year becomes

$$Y[s, fl, . , . , a] = \sum_{t=1}^{12} Y[s, fl, t, . , a]$$

The last two equations form the basis for the calculation of the value of the yield which in turn produces the input for the economic analysis of the fishery.

The total yield of all age groups caught by all fleets during one year becomes

$$Y[s, ., ., ., ., ., .] = \sum_{fl=1}^{NoF} \sum_{a=0}^{11} Y[s, fl, t, ., a]$$

The yield of species s, caught by fleet fl in area ar during time period t summed over age groups is :

$$Y[s, fl, t, ar, .] = \sum_{a=0}^{11} C[s, fl, t, ar, a] * W[s, a]$$

These quantities will be used for comparisons of observed yields to simulated yields (predicted by the computer program).

### *2.10 Commercial size categories*

For many species, unit prices differ with the size of the animals whereby small fish or shrimps fetch lower prices in the market than larger ones. Prices are often quoted by commercial categories that have been defined in the market according to the specific nature of the product (species). For example, in shrimp fisheries, commercial size categories (counts) are defined as number of tails or animals per pound or kg.

As the biological model of BEAM 4 works on the basis of age groups, there is the need to convert commercial categories (or sizes) into the corresponding age groups and vice versa. The computer program BEAM 4 has a built-in facility to do this conversion.

### *2.11 Prices and value of yield*

For computational reasons, the value of the yield is calculated within the biological/technical part of BEAM IV. The value of the yield, Y[s,fl,t,.,a], of species s, age group a, taken by fleet fl during time period t, is expressed in terms of "ex-vessel value" and "wholesale value". The ex-vessel value is the gross revenue of the harvesting sector from selling the yield to the processing sector. The wholesale value is the gross revenue of the processing sector from sale of the processed yield.

The values are based on the prices :

PE[s,fl,a] : Ex-vessel price per weight unit of species s, age group a, caught by fleet fl

PW[s,fl,a] : Wholesale price per weight unit of species s, age group a, caught by fleet fl

Different species and sizes of fish generally fetch different prices in the market. In addition, fish of the same species and size may realize different prices because of differences in product qualities. The latter is often related to the handling and storage facilities on board of the vessels. In BEAM 4, price differentials may be due to species, size and/or technical characteristics of the fleets.

Wholesale prices are those received by the processing plant when selling the processed fish/shrimps to either the domestic or export market. Fish/shrimps of the same sizes and species are assumed to realize the same wholesale price in either the domestic or export market. However, fish/shrimps sold for export will earn foreign exchange.

The BEAM 4 model operates with constant fish prices because originally it was designed for shrimp fisheries where there are many suppliers and buyers in the international market and where no single shrimp fishery would have a significant impact on prices.

Combining all age groups gives the total ex-vessel value of species s caught by fleet fl during time period t :

$$VEF[s, fl, t] = \sum_{a=0}^{11} Y[s, fl, t, . , a]* PE[s, fl, a]$$

and the corresponding wholesale value becomes :

$$VWF[s, fl, t] = \sum_{a=0}^{11} Y[s, fl, t, . , a]* PW[s, fl, a]$$

In case discarding takes place, the discarded amounts are subtracted before the sum of products are calculated.

Summed over species and time periods the total value of the yield caught by fleet fl, VWF[.,fl,.,], is obtained. This, together with the effort figures are inputs into the economic analysis of fleet fl.

### *2.12 The links between the biological/technical sub-model and the economic sub-model*

For the economic analysis of each fleet and the entire harvesting sector, the following data are produced by the biological/technical sub-model : (i) annual landings ; (ii) ex-vessel value of the annual landings ; and (iii) effort per year and number of boats. To avoid any misunderstandings, the term "landings" has been introduced to account for the fact that the yield also includes discards. Landings are, therefore, defined as the yield minus discards.

For the economic analysis of the processing sector, the following data are produced by the biological/technical sub-model for each plant and for the entire processing sector : (i) annual landings delivered by each fleet ; (ii) ex-vessel and wholesale values of the annual landings delivered by each fleet ; and (iii) the share of the annual landings sold in the export and in the local markets.

## 3. THE ECONOMIC MODEL

The economic model of BEAM 4 calculates a range of economic performance criteria. Its principal input variables are cost data for the fishing fleets and processing plants plus aggregated results from the biological/technical model as described above.

### *3.1 Costs of fish harvesting*

In BEAM 4, there are three different types of harvesting costs, namely

(i) costs depending on fishing effort ;
(ii) costs depending on the number of fishing vessels ; and
(iii) costs depending on the value of the landings (i.e., ex-vessel value).

The first category of costs, also referred to as variable costs, is assumed to be linearly related to fishing effort and comprises fuel and lubrication, repairs and maintenance, ice, habour/landing fees, crew wages (independent of the ex-vessel value of the landings), and miscellanous costs. For a particular fleet the total of this cost category is calculated by multiplying the total number of units of effort expended per year with the total costs per unit of effort.

The costs depending on the number of boats refer to those costs which arise even though the vessels may not go out for fishing. They are also referred to as "fixed costs" and comprise depreciation of hull, engine and gear, insurance, interest, overheads and fixed licence fees. In BEAM 4, these costs are given on an annual basis. The total costs of this category for a certain fleet is given by multiplying the number of boats with the average total fixed costs per boat per year.

The third category of harvesting costs in BEAM 4 are those costs which depend on the ex-vessel value of the landings ; they comprise two elements, namely (i) crew remuneration and (ii) fish auctioning/marketing fees.

The common system of labour remuneration in fishing is different from that of other occupations. In fishing, crews are often paid a share of the value of the landings. Usually, certain variable or effort dependent costs such as fuel or repair and maintenance costs, etc., are deducted from the ex-vessel value prior to sharing the proceeds between the crew and the owner of the fishing vessel. In BEAM 4, the user can specify which costs are deducted before sharing.

Auctioning fees are determined as a share of the ex-vessel value of the landings (without prior deduction of costs).

The total harvesting costs of a particular fleet are obtained as the sum over all three cost categories. Obviously, total harvesting costs will not increase linearly with fishing effort because some costs depend on the value of the landings produced by that effort which changes with the intensity of exploiting the fishery resource. The total costs of the entire harvesting sector are given as sum over the costs of each fleet.

### *3.2 Processing costs*

The BEAM 4 model is constructed in such a way that all fish caught is also processed, although it may be processed in different plants and in different ways, i.e., drying, freezing or canning, etc., (including discarding in a pseudo processing plant). Different processing techniques (and plants) are reflected by differences in processing costs. The case of no processing can be modelled by putting all processing cost items to zero. The user is free to determine for each fleet and for each age class or commercial size category of each species the type of desired processing.

Processing cost items include power and water, packaging, wages, depreciation, insurance, interest, etc. They also include the ex-vessel value of the landings. Costs are given per ton of raw material processed. This implies that processing costs are independent of the intensity of utilization as processing capacities are automatically adjusted to the amount of fish harvested by the fishing fleet(s).

### *3.3 Foreign exchange costs*

Each of the cost elements and items presented above may entirely or partially be incurred in hard currency. Fuel, for example, needs often to be imported and paid for in foreign exchange. Similarly, equipment such as engines, hulls, echosounders, etc., frequently have to be imported.

In joint-venture fisheries, crew remuneration may occur in hard currency because the vessels may be manned by foreign fishermen. Further, interest and insurance payments may need to be settled in foreign exchange. In these cases, the respective foreign exchange costs are entered in a separate category in the BEAM 4 model that is referred to as "transfers abroad". Profits can also be transferred.

### *3.4 Opportunity costs*

The opportunity cost concept is used to better reflect the costs to the economy of using a production input in one activity rather than in another one. In fisheries, remuneration of labour is often based on a sharing system. It is unlikely that the system results in a "price" of labour that is equal to its opportunity cost. Therefore, BEAM 4 allows the user to adjust crew remuneration so as to reflect better the cost to the economy of using labour in fishing rather than in its next best alternative occupation.

The other important production factor that may need to be adjusted through opportunity cost is capital. In the definition of Gittinger (1982 :490) it is "The opportunity cost of using investment resources in a project rather than in their next best alternative use, usually expressed in the form of an interest rate." In BEAM 4, two kinds of opportunity cost of capital are considered. One type is as described above by Gittinger.

The second type of opportunity cost of capital refers to depreciation of capital equipment. Once a fishery has expanded to the point where economic and possibly biological over-fishing occurs, the fleet size may be reduced and vessels retired.

If there is no other alternative use for the vessels in other fisheries or in other activities such as transportation, the costs of using them in the fishery are low or zero. Adjustments to costs of depreciation may also be called for if the initial capital investment was subsidized (or taxed) by the government.

### *3.5 Taxes and subsidies*

Taxes are payments from private individuals or companies to the government. Subsidies are negative taxes, i.e., tax rebates or payments from government to private individuals or companies. Therefore, both taxes and subsidies are transfers of income rather than costs to the economy.

In BEAM 4, taxes and subsidies are considered explicitly only in the case of fuel and lubricants (harvesting), power and water (processing) and of repair and maintenance (harvesting and processing). Taxes will increase the costs of these inputs to the entrepreneur while subsidies will reduce them. In both cases, the real cost to the economy of using these inputs may be distorted.

### *3.6 Economic performance criteria*

BEAM 4 uses a number of different criteria to evaluate (or predict) the economic performance of an unregulated fishery or of a fishery under a certain management regime. These include resource rent, profit, profitability, value added and net foreign exchange earnings.

Resource rent is calculated by adjusting private profit of the harvesting sector with the relevant opportunity costs, as discussed above, and by adjusting for taxes and subsidies. Private profit is defined as the difference between ex-vessel value of the catch and total harvesting costs. Resource rent is only considered for the harvesting sector.

In the short and medium-term, maximizing resource rent may result in socially undesirable effects including increased unemployment and undesirable income distribution. BEAM 4 allows to assess the income distribution and employment effects of alternative management regimes.

Income comprises of several components including (i) wages and salaries to crew, processing workers, shore staff and administrative personnel ; (ii) interest payments on capital ; (iii) profits to private investors ; (iv) taxes net of subsidies, and licence fees accruing to the government treasury. The summation over all these income elements is called the net value added. Adding depreciation of equipment gives the gross value added.

Not all income generated in a fishery may accrue to the national economy because some of it may be transferred abroad. Except for taxes and licence fees, all other elements of income may partially or entirely be transferred to other economies. In BEAM 4, the user can give the income shares (percentages) that are being transferred. The sum of the incomes that stay in the country are referred to as national net value added.

For many developing countries, foreign exchange earnings are of particular importance for economic growth because they allow the importation of essential production inputs. The BEAM 4 model allows the assessment of foreign exchange costs and earnings, so that the net contribution of the fishery can be assessed.

Employment is an important criterion for assessing the relative benefits of alternative management regimes. In BEAM 4, employment is measured in two ways : (i) numbers of people and (ii) numbers of person-years.

The integrated analysis of BEAM 4 simply consists of adding the various economic performance criteria for the harvesting and processing sectors (except for the resource rent). It is of great importance in the case of those fisheries where substantial onshore processing activities take place.

## REFERENCES

**Baranov F.I.** (1918). On the question of the biological basis of fisheries. *Nauchn. Issled. Ikhtiol. Inst. Izv.*, **1 :** 81-128 (in Russian).

**Beverton R.J.H. and S.J. Holt** (1957). On the dynamics of exploited fish populations.*Fish. Invest. Minist. Agric. Fish. Food G.B.* (2 Sea Fish.) **19 :** 533 p.

**Bertalanffy L. von** (1934). Untersuchungen uber die Gesetzlichkeiten des Wachstums I. *Roux'. Arch. Entwicklungsmech Org.***131 :** 613-52.

**Caddy J.F.** (1991). Death rates and time intervals : Is there an alternative to the constant natural mortality axiom ? *Reviews in Fish Biology and Fisheries.* (in press).

**Cochet Y and B. Gilly** (1990). Logiciels pour l'analyse bio-economique des pêcheries. BEAM 3 : Simulation bio-economique analytique des pêcheries de crevettes tropicales avec recrutement fixe ou aléatoire. *FAO. Document technique sur les pêches* . No. 310.2. Rome, FAO. 57 p.

**Coppola S.R, S.M. Garcia and R. Willmann** (1992). Software for bio-economic analysis of fisheries : BEAM1 and BEAM2 : Simple bio-economic simulation models for sequential fisheries on tropical shrimp using age groups or commercial categories. *FAO.Comp. Info. Series*, (401.1). 58 p. and micro-computer software.

**Flaaten O.** (1988). *The Economics of Multispecies Harvesting. Theory and Application to the Barents Sea Fisheries.* Springer-Verlag Berlin Heidelberg. 162 p.

**Fry F.E.J.** (1949). Statistics of lake trout fishery. *Biometrics*, **5 :** 27-67.

**Garcia S. and L. Le Reste** (1981). Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish. Tech. Pap.* (203) : 215 p. (Issued also in French).

**Gittinger J.P.** (1982). Economic Analysis of Agricultural Projects. Second Edition. The Economic Development Institute of the World Bank. The John Hopkins *University Press*. Baltimore and London 505p.

**Kimur D.K.** (1977). Logistic model for estimating selection ogives from catches of codends, whose ogives overlap. *Journ. Cons. Int. Explor. Mer.***38** (1) : 116-119.

**Quinn T.J.II, R.B. Deriso and P.R. Neal** (1990). Migratory Catch-Age Analysis. *Con.J.Fish.Aquat.Sci*, (47) : 2315-2327.

**Ricker W.E.** (1975). Computation and interpretation of biological statistics of fish population. *Bull. Fish. Res. Board Can.*, (191) : 382 p.

**Sparre P., E. Ursin and S.C. Venema** (1989). Introduction to tropical fish stock assessment. Part 1. Manual. *FAO. Fish. Tech .Pap.* No. 306/1. Rome, FAO. 337 p.

**Sparre P.** (1991). Introduction to Multispecies Virtual Population Analysis. *Rapp.- P.-v. Cons. int. Explor. Mer.* (in press).

**Sparre P. and R. Willmann** (1993). Software for bio-economic analysis of fisheries. BEAM 4 manual. Analytical bio-economic simulation of space-structured multi- species and multi-fleet fisheries. *FAO Comp. Info. Series* No. 403.

**Thompson W.F. and F.H. Bell** (1934). Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. *Rep. Int. Fish. (Pacific Halibut) Comm.* **8,** 49p.

**Willmann R. and S.M. Garcia** (1985). A Bioeconomic model for the analysis of sequential artisanal and industrial fisheries for tropical shrimp (with a case study of Suriname shrimp fisheries). *FAO Fish. Tech. Pap.*, (270) : 49 p.

# Gérez Vos Pêcheries *

**Claude de Verdelhan**

IFREMER, 7, place du Séminaire - BP 7 - L'houmeau - 17137 Nieul Sur Mer, France

RÉSUMÉ

*GEREZ VOS PECHERIES est un logiciel à vocation pédagogique permettant une compréhension rapide des mécanismes de base qui régissent la gestion des ressources halieutiques. Ce modèle basé sur les techniques d'analyses de cohortes sur compositions en âges des captures permet de voir sous une forme graphique claire :*

- *l'évolution des résultats globaux (production, chiffre d'affaires, bénéfices ou pertes) d'année en année ; les mêmes résultats par "métier" ;*
- *les évolutions dans le temps, par espèce, des compositions en nombre d'individus ou en poids par classe d'âge, des stocks et des captures ;*
- *les évolutions des biomasses totales et des biomasses fécondes.*

*A chaque instant, l'opérateur peut interrompre le processus de calcul afin d'imposer une modification des conditions d'exploitation (par métier : nombre de navires, nombre de jours de mer, maillage). Ceci permet donc d'expérimenter les conséquences à court terme et à long terme de ces changements. Une option permet d'avoir un recrutement aléatoire (loi log-normale).*

*Enfin un bilan systématique après 60 ans permet d'organiser des concours et de donner à ce logiciel un caractère ludique qui en facilite l'usage pédagogique. Un utilisateur connaissant bien une pêcherie particulière pourra créer un jeu de données spécifiques.*

## 1. LES RAISONS DU DÉVELOPPEMENT DE CE LOGICIEL PAR L'IFREMER

La lecture des journaux spécialisés du monde de la pêche montre que les mécanismes de base qui régissent l'évolution des ressources halieutiques soumises à une exploitation sont souvent mal compris. Il en résulte des difficultés

* Conditions de vente et d'utilisation

*"GÉREZ VOS PÊCHERIES"* est vendu ; il suffit de le commander à l'IFREMER, Laboratoire RH, place du Séminaire, BP n° 7, 17137 Nieul Sur Mer - France, en précisant le format de la disquette.

Son prix est de 500 FF. La licence d'utilisation donne droit d'installer le logiciel sur tous les ordinateurs du licencié (un seul site) afin de permettre son utilisation par des groupes disposant de plusieurs ordinateurs. Pour un bon fonctionnement, il faut un PC sous MSDOS, une carte graphique couleur EGA, ou VGA ou SVGA et une souris (non indispensable mais très utile).

Il existe une version en anglais mais la notice et l'aide en ligne ne sont pas traduites pour l'instant.

considérables dans l'élaboration des règles de gestion de ces ressources et plus encore dans leur mise en oeuvre. C'est pourquoi l'IFREMER a considéré qu'il était aussi de sa mission de mettre au point un logiciel pédagogique afin que toutes les personnes concernées par ce secteur d'activité puissent comprendre quels sont les facteurs principaux qui déterminent l'évolution économique d'une pêcherie.

## 2. ORIGINE DU LOGICIEL

Ce logiciel est déjà la troisième version d'une idée qui remonte à 1985.

La version 1, écrite en Basic par Claude de Verdelhan en 1988, ne permettait de simuler que l'exploitation d'une espèce par un engin. Cette version a été commercialisée par le CRDP de Poitiers (Centre Régional de Documentation Pédagogique).

La version 2 a été écrite par Olivier Le Pape dans le cadre de son diplôme d'Agronomie Approfondie en 1991 (Ecole Nationale Supérieure d'Agronomie de Rennes ENSAR). Elle permet des simulations plus complexes multi-métiers et multi-espèces pouvant utiliser des jeux de données très variés. Elle a été écrite en TURBO PASCAL (BORLAND) et bénéficie des avantages de la programmation orientée objet.

La version 3 reprend tous les acquis de la version 2 et l'enrichit d'une aide informatique, de graphiques supplémentaires, d'améliorations dans la présentation des graphiques (visionneuses graphiques et visionneuses graphiques animées), et dans les menus. Elle introduit aussi une option permettant de calculer le rendement actuariel brut d'une décision d'aménagement (réduction du nombre de jours de mer ou augmentation du maillage).

## 3. OBJECTIFS DU LOGICIEL

*"GÉREZ VOS PÊCHERIES"* est un logiciel qui permet de simuler une pêcherie composée d'un ou plusieurs métiers (type de navires et d'engins) exploitant une ressource composée d'une ou plusieurs espèces. Les résultats de cette simulation sont un graphique montrant, année par année, les résultats économiques de la pêcherie (chiffre d'affaires, bénéfices, coût).

A chaque instant le déroulement de la simulation peut être interrompu pour modifier les conditions d'exploitation en faisant varier :

(i) le nombre de navires,

(ii) le nombre de jours de mer par navire et par an,

(iii) le maillage utilisé,

par l'un ou l'autre des métiers.

Il est aussi possible de suspendre le déroulement de la simulation pour accéder très facilement à de très nombreux graphiques donnant des résultats détaillés pour chaque métier ou pour chaque espèce ainsi que de nombreux autres graphiques permettant de comprendre les raisons de ces évolutions. Parmi ceux-ci, on retiendra les graphiques donnant l'évolution des biomasses et biomasses fécondes par espèce et surtout les graphiques animés permettant de visualiser les structures en âge des populations et des captures (nombre d'individus par classe d'âge ou biomasse par classe d'âge) d'année en année, et de les comparer avec les structures des populations vierges. Ces graphiques sont animés car ils sont une succession d'images apparaissant automatiquement (une par année) et permettant de voir l'évolution des structures de la première année de la simulation à la dernière. De plus, l'usage des touches avec des flèches permet de revenir en arrière pour "rejouer" des périodes déterminantes (année de l'augmentation des maillages). Cette représentation permet de très bien voir la conséquence d'une augmentation du maillage ou d'une réduction d'effort de pêche.

*"GÉREZ VOS PÊCHERIES"* n'est pas un logiciel de plus pour les groupes de travail et les réunions d'experts. Ce n'est pas non plus un programme d'analyse de population ou de statistiques économiques. Son ambition est d'être un outil

pédagogique pour assurer une formation de base aux professionnels de la mer ou même à un public plus général (élèves des lycées..) et un moyen très agréable et efficace pour présenter des résultats d'une étude sur une pêcherie particulière, même complexe.

L'utilisation à des fins pédagogiques fait l'objet d'une publication dans le "EC Fischeries Cooperation - Bulletin - CE Coopération Pêche" de Septembre 1993.

## 4. LES BASES DU MODÈLE

Ayant été conçu par des biologistes et des halieutes, le modèle de *"GÉREZ VOS PÊCHERIES"* est très développé au niveau biologique et beaucoup plus simple au niveau économique.

### *4.1 Modèle biologique*

Les données de base du modèle sont lues dans un fichier. Pour chaque espèce elles consistent en :

- pour chaque âge la longueur, le poids et la mortalité naturelle,
- le recrutement moyen en nombre d'individus,
- le multiplicateur, diviseur maximum du recrutement moyen qui permet de limiter les valeurs maximales et minimales en cas de recrutement aléatoire (loi log-normale),
- le niveau de la biomasse (exprimé en pourcentage de la biomasse féconde moyenne du stock vierge) en dessous duquel il y a une relation stock-recrutement,
- l'écart-type de la loi log-normale de recrutement aléatoire,
- l'âge de maturité sexuelle,
- pour chaque métier et pour chaque âge, un coefficient de capturabilité,
- pour chaque métier, les coefficients de sélectivité $\alpha$ et $\beta$

$$\alpha = L50/D \qquad \text{et} \qquad \beta = \frac{L75 - L25}{L50}$$

ou D est le maillage exprimé en mm et L25, L50 et L75 sont les longueurs correspondant au taux de retenue de 25, 50 ou 75 %) qui permettent de calculer le taux de retenue pour chaque âge en fonction de la longueur correspondante du poisson.

Les équations de base sont tout-à-fait classiques :

– l'effectif $N_{i,\,j,\,k}$ de la cohorte d'âge j, de l'espèce i, au début de l'année k est calculé à partir de $N_{i,\,j-1,\,k-1}$ en fonction de l'équation de survie :

$$N_{i,j,k} = N_{i,j-1,k-1}\, e^{-\left(\sum_m F_{i,j-1,k-1,m} + M_{i,j-1}\right)}$$

avec $N_{i,1,k} = R_{i,k}$ (recrutement)

Le recrutement $R_{i,k}$ ne dépend pas du niveau de la biomasse féconde si celle-ci dépasse un niveau minimum (exprimé en % de la biomasse féconde d'un stock vierge). Il peut fluctuer par rapport au recrutement moyen en fonction d'une loi de distribution log-normale si l'option recrutement déterministe n'a pas été choisie.

$F_{i,j,k,m}$ est égal au coefficient de capturabilité multiplié par le taux de retenue (sélectivité), par le nombre de navires et par le nombre de jours de mer, pour chaque métier, âge, espèce, année.

Le changement des conditions d'exploitation modifie les valeurs de $F_{i,j,k,m}$ et par conséquent les taux de survie. Au contraire, $F_{i,j,k,m}$ ne dépend pas de l'abondance du stock. Ceci veut dire que ce modèle biologique est bien adapté à des espèces dont la capturabilité ne dépend pas de l'abondance. Cette condition est assez bien respectée pour les espèces démersales mais irréaliste pour les espèces pélagiques dont la capturabilité augmente souvent quand l'abondance diminue en raison de l'effet de bancs.

- Les captures en nombre réalisées par le métier m sur cette espèce au cours de l'année k se calculent :

$$C_{i,j,k,m} = \frac{F_{i,j,k,m}}{\left(\sum_m F_{i,j,k,m} + M_{i,j}\right)} N_{i,j,k}\left(1 - e^{-\left(\sum_m F_{i,j,k,m} + M_{i,j}\right)}\right)$$

(Laurec et Le Guen, 1981)
(Mesnil, 1988)

- On en déduit les captures en tonnage :

$Y_{i,j,k,m} = C_{i,j,k,m} P_{i,j}$ où $P_{i,j}$ est le poids moyen d'un individu de l'espèce i et d'âge j.

*4.2 Modèle économique*

Le modèle économique est alimenté par des données, pour chaque métier, lues dans le même fichier :

- coût fixe annuel d'un navire (amortissement, assurance, salaires minimums garantis),
- coûts d'opération par jour de mer (combustibles engins, suppléments de salaires),
- pour chaque espèce et par âge, prix au kilo du poisson pêché $PK_{i,j,m}$ (si le poisson est rejeté, son prix au kg est nul, si la moitié des poissons d'une classe d'âge est vendu en criée à 20 F au kg et que l'autre moitié est rejetée, le prix au kg du poisson pêché n'est que de 10 F).
- nombre de marins embarqués par navire et par an,
- taux de réduction annuel de la masse des chômeurs par transfert vers d'autres activités.

*4.3 Liaison des modèles biologiques et économiques*

La liaison entre le modèle biologique et le modèle économique est donc très simple. La valeur des captures $V_{i,j,k,m}$ est calculée de la manière suivante :

$$V_{i,j,k,m} = Y^*_{i,j,k,m} PK_{i,j,m}$$

Le coût annuel des opérations $D_{k,m}$ pour un métier est donc :

$$D_{k,m} = NbN_{k,m}(CF_m + NbJM_{k,m} \times CP_m) \quad \text{où}$$

$NbN_{k,m}$ est le nombre de navires du métier m pour l'année k

$NbJM_{k,m}$ le nombre de jours de mer par navire des métiers m pour l'année k.

$CF_m$ le coût annuel par navire pour le métier m

$CP_m$ le coût journalier par navire pour le métier m

Ainsi, ayant le coût des opérations et le chiffre d'affaires, il est possible de calculer les bénéfices et/ou pertes annuelles, globalement et par métier.

## 5. L'OPTION "ETUDES"

Tous ceux qui tentent d'expliquer qu'une augmentation de maillage ou une réduction d'effort de pêche présente un intérêt à long terme se trouvent confrontés au problème des pertes à court terme. Comment expliquer que le bénéfice attendu à long terme est à la hauteur des pertes à subir à court terme. C'est pour pouvoir chiffrer l'intérêt de ce type d'arbitrage qu'a été introduite l'option "Etudes". Elle permet de calculer le rendement actuariel brut d'une augmentation du maillage et/ou d'une réduction de l'effort de pêche et ainsi d'exprimer d'une façon synthétique l'intérêt d'une telle option. Deux types de résultats sont proposés :

(i) les résultats "Biologiques" ne prennent en compte que les réductions puis les augmentations à long terme du chiffre d'affaires. Ce qui revient à ne prendre en compte que les valeurs des captures perdues puis gagnées : ils correspondent donc au rendement de l'épargne biologique (réduction des captures) qui a été faite. La biomasse épargnée et les captures supplémentaires qui en résultent plus tard sont valorisées en tenant compte du prix de débarquement ;

(ii) les résultats "Economiques" prennent en compte l'évolution des bénéfices et/ou les pertes de la flottille. C'est-à-dire qu'ils ne s'intéressent pas seulement aux captures mais aussi aux coûts d'exploitation. Il faut cependant interpréter avec prudence ces résultats, en particulier dans le cas d'une réduction du nombre de navires de la flottille. Une diminution de 20 % du nombre de navires entraîne une réduction des coûts d'exploitation du même ordre pour la flottille, ce qui est pris en compte par le logiciel, mais en même temps, il y aura des charges exceptionnelles de restructuration (primes de licenciement pour les marins, pertes de valeur des navires, etc...) et des "recettes" correspondantes (ventes des navires à d'autres flottilles, primes et indemnités diverses) qui n'interviennent pas dans le modèle.

Il n'y a de différence entre les résultats biologiques et économiques que si les changements de conditions d'exploitation de la flottille ont amené des réductions des coûts d'exploitation (réduction du nombre de navires ou du nombre de jours de mer par navire et par an).

Dans les deux cas, les pertes (de chiffre d'affaires ou de bénéfice) à court terme sont considérées comme des investissements étalés dans le temps, qui donnent à long terme une rente qui est la différence entre le résultat (chiffre d'affaires ou bénéfice) qui sera réalisé et celui qui aurait été réalisé s'il n'y avait pas eu de changement des conditions d'exploitation. La somme de ces investissements est appelée "Investissement (sci)" (sci signifie sans capitalisation des intérêts). Le programme calcule par itérations l'"investissement (aci) " (aci signifie : avec capitalisation des intérêts) et le rendement de cet investissement

$$\left( \frac{Rente}{Investissement(aci)} - 1 \right) \times 100 .$$

Cette option n'est opérationnelle que dans le cas d'une pêcherie simple (une espèce exploitée par un seul métier).

## 6. SIMULATION DE L'ÉVOLUTION DE LA TAILLE DES ENGINS

Nous avons vu au cours des récentes années apparaître des nouveaux métiers qui ont évolué très rapidement. Ainsi par exemple est apparue la pêche de la sole au filet droit et les navires ont très vite (pour compenser une baisse du rendement) augmenté la longueur totale de leurs filets.

Actuellement, la dimension des engins n'est pas l'un des paramètres des conditions d'exploitation ; il semble donc impossible de simuler une évolution de ce type.

Il avait été envisagé pendant un moment d'ajouter cette option mais cette idée a été abandonnée afin de garder au logiciel un niveau de simplicité compatible avec un objectif pédagogique et de le rendre utilisable par des enseignants non spécialisés dans les problèmes de la pêche.

Comme *"GÉREZ VOS PÊCHERIES"* est un modèle multi-métiers, il est possible de contourner cette difficulté en créant par exemple 4 métiers de fileyeurs ayant respectivement des longueurs de filets de 5, 10, 15, 20 km. Cette manière de procéder permettra de changer les coûts fixes et proportionnels, mais aussi le prix du poisson (on a constaté que les navires ayant de grandes longueurs de filet débarquent plus de produits de qualité inférieure et vendent à un prix moyen inférieur). Pour simuler une augmentation de la taille des filets, il suffit donc de faire glisser la flottille d'un métier dans un autre.

## REFERENCES

**Chaussade J. et Corlay J.P.** (1990). *Atlas des pêches et des cultures marines.* Editions Ouest-France, **9-13** 186-190.

**Dardignac J. et de Verdelhan C.** (1978). Relation entre l'écart de sélection et la taille de retenue à 50 % dans la sélectivité du merlu. *Cons. int. Explor. Mer, CM 1978/B* : **21,** 14 p.

**Hoydal K., Rorvik C.J. et Sparre P.** (1982). Estimation of effective mesh sizes and their utilization in assessment. *Dana,* vol. 2, 69-95.

**Laurec A. et Le Guen J.C.** (1981). Dynamique des populations marines exploitées. Tome 1 : Concepts et modèles. *Rapports scientifiques et techniques n° 45,* CNEXO (Publication IFREMER), 118 p.

**Mesnil B.** (1988). Logiciels pour l'évaluation des stocks de poissons. ANACO : logiciel d'analyse des données de capture par groupe d'âge sur IBM PC et compatibles. *FAO Doc. Tech. Pêches,* (101) Suppl. **3 :** 78 p.

**Press W.H., Flannery B.P. et Vetterling W.T.** (1986). *Numerical Recipies - The art of scientific computing.* Cambridge University Press, 200-208.

**Ricker W.E.** (1954). Stock and recruitment. *J. Fish Res Board Can,* **11,** 84-94.

**de Verdelhan C.** (1993). "GEREZ VOS PECHERIES", Un logiciel pédagogique pour le secteur de la pêche. *Bulletin CE Coopération Pêche.* Septembre 1993.

# Aquaculture enterprise management by M. Antona and P. Paquotte

L'histoire de l'aquaculture et en particulier l'encadrement de son développement contribuent à l'hétérogénéité des structures des entreprises de ce secteur. Ainsi, dans les pays où la ressource en eau était déjà destinée à des usages agricoles (riziculture) complétés ou non par un usage aquacole extensif, plusieurs formes d'entreprises coexistent de la plus artisanale à la plus industrielle. L'aquaculture de crevettes en Asie et du catfish dans les états du sud des USA en sont une illustration.

A l'inverse, lorsqu'aucune tradition n'existe et que les entreprises du secteur sont issues de transferts de technologie assortis d'incitations publiques, leurs structures et leurs modes de fonctionnement sont industriels, comme on peut le constater en Amérique latine (crevettes, saumon). Entre ces deux extrêmes, les situations intermédiaires sont très diverses (saumon en Norvège, bar et daurade en Europe méditerranéenne) et dépendent de l'encadrement institutionnel du secteur.

Néanmoins, les entreprises de ce secteur ont en commun d'être confrontées à des marchés de plus en plus internationalisés et à de fortes disparités de coûts des facteurs. Elles sont aussi dépendantes de leur environnement naturel, dépendance renforcée par le cadre institutionnel qui définit les conditions d'accès, d'utilisation et de protection des espaces côtiers.

La gestion des entreprises d'aquaculture apparaît comme une gestion sous contraintes multiples. Parmi les contraintes les plus vives, on peut citer celles afférentes à la recherche de facteurs de compétitivité, à la réduction des externalités liées à l'usage intensif de la ressource naturelle, au financement du capital technique et de l'innovation ou encore propres aux espèces élevées. Les possibilités d'accroître la densité d'élevage ou la capacité de stockage des produits vivants sans une forte augmentation des coûts et des risques de l'activité, varient ainsi fortement selon les espèces.

Le thème de la gestion des entreprises aquacoles est relativement récent par comparaison au démarrage de

The history of aquaculture and, in particular, the management of its development has contributed to the heterogeneity of business structures in the sector. In countries where water resources were already used for agriculture (rice growing) whether or not complemented by extensive aquaculture, several kinds of businesses have co-existed from the most artisanal to the most industrial. Prawn aquaculture in Asia and catfish in the Southern States of the USA are such examples.

On the other hand, where there is no tradition and businesses in the sector have resulted from technology transfer accompanied by government incentives, their structures and their ways of operating are industrial, as can be seen in Latin America (prawns, salmon). Between these two extremes, there are many intermediate situations (salmon in Norway, bass and sea bream in Mediterranean Europe) which depend upon the sector's institutional management.

However, all businesses in the sector are confronted by increasingly globalised markets and by great variability in input cost. They also depend upon their natural environment, a dependence which is reinforced by the institutional framework defining the conditions of access, of use and protection of coastal zones.

The management of aquaculture businesses appears to operate under many constraints. Among the most important ones are those related to the search for competitive advantage, the reduction in externalities linked to the intensive use of the natural resource, the funding of technical capital and innovation as well as those constraints peculiar to the cultivated species. The possibilities of increasing the culture density or the stocking capacity of living products without drastically increasing costs and risks vary a lot according to the species considered.

The management of aquaculture businesses is a relatively recent theme when compared to the beginning of

recherches analogues en agriculture dès les années 60. Les analyses ont pour objectif de faciliter la prise de décision de l'entrepreneur ou de l'aménageur public en matière de système de production. La détermination de la taille optimale et la mesure des économies d'échelle ont été les premières questions soulevées en aquaculture. Ces interrogations correspondaient à la phase de démarrage de l'activité. Comme l'illustrent les communications présentées dans cette session, les problématiques s'orientent maintenant davantage vers l'identification des contraintes de fonctionnement et leur impact sur la gestion des entreprises, les outils d'analyse restant inchangés et les approches peu influencées par des caractères spécifiques à une espèce ou une zone.

Plusieurs questions sont abordées dans cette session, qui confortent cette évolution :

(i) le premier type concerne le choix de l'affectation des facteurs ou le mode de valorisation du produit sous contrainte de disponibilité de ressources (Pomeroy et Martin) ou sous contrainte biologique (Wright, Rizzo). La fonction objectif de l'entreprise est déterminée *a priori* : dans tous les cas il s'agit de maximiser le revenu. Les notions de revenu minimum et d'aversion au risque sont prises en compte par un seul auteur dans un modèle MOTAD (Pomeroy). Tous les modèles sont normatifs. A l'exception du modèle de Rizzo, ils font appel à la Programmation Linéaire (Pomeroy, Wright, Martin).

La contrainte d'affectation de l'espace introduite par Pomeroy renvoie à la question plus générale de diversification de l'agriculture et de choix entre plusieurs spéculations dont l'aquaculture. Dans ce cas, la programmation linéaire constitue un outil d'aide à la décision.

En ce qui concerne les choix techniques dans la conduite des élevages (fréquence des tris, durée d'élevage, taille à la vente), ce type d'approche a plus une vertu pédagogique. La confrontation des résultats de ces modèles à la réalité de l'entreprise révèle d'autres contraintes à prendre en compte (pénibilité des tâches, faisabilité des schémas d'élevage proposés, effets de seuil dans l'utilisation des facteurs).

(ii) le second type de question concerne les interdépendances entre facteurs pour évaluer l'impact sur le revenu d'une modification d'un des facteurs. Spratt présente un modèle descriptif qui retrace les liaisons entre variables physiques et financières et permet de simuler le fonctionnement d'une entreprise de bar en Méditerranée.

(iii) le troisième type de questions abordé dans cette session s'intéresse à la viabilité des entreprises

similar research in agriculture dating as far back as the sixties. The purpose of such studies is to help decision-making by the businessman or the public planner regarding productive systems. The first questions raised in aquaculture related to determining optimal size and measuring scale economies. These questions related to the start-up phase of the industry. As the papers presented in this session indicate, the main questions now concern identifying operational constraints and their effect on business management, although the analytical tools remain unchanged and approaches are not really influenced by the particular characteristics of a species or a zone.

Several issues are tackled in this session confirming this evolution:

(i) The first issue concerns the input choices or the mode of valorization of the product constrained by resource availability (Pomeroy and Martin) or by biological factors (Wright, Rizzo). The business objective is determined *a priori*: in every case, it is about maximizing revenue. The concepts of minimum revenue and risk aversion are taken into account by only one author in the MOTAD model (Pomeroy). All the models are normative and except for the Rizzo model, they are all based on linear programming (Pomeroy, Wright, Martin).

The constraint concerning spatial use introduced by Pomeroy is reminiscent of the more general question of agricultural diversification and the choice between several possibilities including aquaculture. In this case, linear programming is a tool helping decision-making. Such an approach is more educational when it concerns technical choices in culture management (sorting rate, culture time, marketable size). The results of such models when confronted to the business reality reveal other constraints that need to be taken into account (unpleasantness of the work, feasibility of the proposed culture plans, threshold effects in factor use).

(ii) the second issue concerns factor interdependence when evaluating the revenue impact of the change in any one factor. Spratt presents a descriptive model which shows the links between physical and financial variables and simulates the operation of a bass business in the Mediterranean.

(iii) the third issue dealt with in this session concerns the viability of businesses taking into account ecological, social and economic conditions. Mudiantonio illustrates this problem with monographs based on a sample of more than 200 businesses in three Indonesian regions. He identi-

compte-tenu des conditions écologiques, sociales et économiques. Mudiantonio illustre cette question au moyen de monographies basées sur un échantillon de plus de 200 entreprises dans trois régions d'Indonésie. Il identifie les contraintes à l'intensification en comparant les résultats comptables de différentes techniques -intensive, semi-intensive et extensive- et de divers modes de gestion -artisanal ou industriel. Cette recherche met en évidence les contraintes d'appropriation de l'espace, d'accès au crédit, de disponibilité en juvéniles d'écloserie et de capacité à maîtriser les techniques d'intensification. La rentabilité des entreprises n'apparaît pas directement liée à la taille ni à un système technique donné.

Plusieurs communications de cette session montrent que les réponses aux questions de gestion de l'entreprise ne se trouvent pas uniquement dans un modèle ou une simulation de paramètres propres à l'entreprise mais dans la prise en compte des variables externes saisies à un niveau méso-économique. Le cas de l'aquaculture en Europe illustre l'incidence des modes de financement et des conditions d'accès aux sites sur la viabilité des entreprises. Les conditions de financement alliées à la baisse actuelle des cours des produits d'aquaculture limitent l'entrée dans l'activité aux Industries agro-alimentaires qui disposent d'une surface financière leur permettant de couvrir les risques d'exploitation.

Cependant, des contraintes dont l'influence est croissante, sont encore peu traitées dans le cas de l'aquaculture. Issues du débat actuel protection des milieux naturels versus développement des activités économiques, les contraintes de préservation de l'environnement posent la question des modes de prise en compte des externalités et de leur impact sur la gestion des entreprises et les formes de compétitivité des activités.

fies the constraints to intensification by comparing the accounting results of different techniques - intensive, semi-intensive and extensive - and different managements schemes - artisanal or industrial. This research demonstrates the constraints related to space appropriation, credit opportunity, the availability of hatchery reared juveniles and the potential to master intensification techniques. Business profitability does not appear to be directly linked to a given size or technical system.

Several papers in this session show that the answers to business management questions cannot be found in a single model or in a simulation of the business's own parameters but by taking into account external variables at a meso-economic level. The aquaculture case in Europe illustrates the effects that funding procedures and accessibility to sites have on business viability. Funding conditions together with the present decrease in the prices of aquaculture products restrict entry into the activity to those agro-alimentary industries that have enough financial back-up to cover the operating risks.

However, some constraints of increasing importance are still not really dealt with in the case of aquaculture. Originating from the present debate on protection of the natural environment versus the development of economic activities, constraints imposed by environmental conservation raise the question of how to take into account externalities and their impact on business management in the competitive framework in which they operate.

# Profitability of Catfish on a Representative Multiple Enterprise Farm in the Southeastern United States Under Conditions of Risk

**Robert S. Pomeroy[a], Stephane M. Carlier[b] and Charles E. Curtis, Jr.[c]**

[a]International Center for Living Aquatic Resources Management, M.C. P.O. Box 1501 Makati, Metro Manila 1299, Philippines

[b]Ecole Nationale d'Ingenieurs Des Travaux Agricoles, Dijon, France

[c]Department of Agricultural and Applied Economics, Clemson University, Clemson, SC 29634-0355, USA

ABSTRACT

*Farmers in many parts of the world are looking toward agricultural enterprise diversification to provide an additional and stable revenue. Aquaculture has been presented as a viable alternative for farmers and as a profitable enterprise. However, aquaculture can be a high risk agricultural practice. Disease, predators, and poor water quality can be potential threats to the fish crop. The fluctuating price of feed and fish prices can significantly impact profit margins. The capital investment can be high and land use is committed to aquaculture for a long term.*

*The objective of this study is to investigate the potential of aquaculture as an alternative enterprise on a typical row crop farm in the Southeastern United States. Farmers may hesitate to include an aquaculture enterprise into their farming system because of the risk associated with this type of enterprise and the constraints inherent in the U.S. government farm bill. A comparison of traditional row crops with and without aquaculture will be conducted on a risk-return basis under the 1990 Farm Bill. A sensitivity analysis will also be conducted with different expected catfish yields. The Target MOTAD method is used for the analysis. Risk is defined as the absolute deviation from five target incomes.*

## 1. INTRODUCTION

The restructuring of United States agriculture in the 1980s was a difficult process for many farmers. The farm population decreased by 29 percent and the number of farms decreased by 11 percent during the decade. Both financial and climatic

conditions were causes of the problems. The elimination of some Federal government subsidy programs put additional pressure on farmers to adjust their farming practices. This restructuring was felt especially hard in the Southern United States, where, because of environmental constraints, much of the region is considered as marginal for producing major agronomic crops. During this period, and after, Southern farmers began to look toward enterprise diversification from traditional row crops (soybean, corn, wheat, cotton) to provide additional and stable income.

In the Southern United States, especially, aquaculture was developed as a viable alternative for farmers and as a potentially profitable investment. One fish species in particular, channel catfish, developed as a strong commercial alternative. However, catfish farming is a high risk agricultural practice. Disease, predators and poor water quality management can be potential threats to the fish crop. The price of feed, as well as fish prices, fluctuates and can significantly affect profits. The capital investment is high and land use is committed to aquaculture for a long term (Pomeroy and Rathwell, 1988).

In addition to aquaculture, vegetable production was also viewed as a potentially profitable alternative enterprise. This includes a variety of vegetable types such as bell pepper, cantaloupe, cucumber, snap bean and tomato. Risk is also an inherent part of vegetable production. Yields are susceptible to climate change, diseases and insects. Prices can vary during the growing season depending upon growing conditions in other production regions.

The economic viability of an alternative enterprise depends upon existing financial, marketing and managerial conditions. In addition, external parameters such as government programs can affect farmer decisions to diversify and their choice of crop. This is especially apparent under the 1990 U.S. Farm Bill which, due to restrictions on the number of acres eligible for deficiency payments, restricts the acreage and non-program crops which can be utilized (USDA, 1990).

The purpose of this paper is to compare opportunities for enterprise diversification on a representative multi-enterprise farm in the Southeastern United States under the 1990 U.S. Farm Bill. The specific objectives of the study are (1) to determine the best combination of agronomic crops on the base program acreage, and (2) to compare catfish, vegetable and row crop production on a risk return basis, including them in the total acreage of the farm. The Target MOTAD method is used to analyze the risk associated with enterprise diversification.

## 2. GOVERNMENT FARM POLICY

The Food, Agricultural, Conservation and Trade Act of 1990, commonly referred to as the "Farm Bill", provides a 5-year framework for agriculture and food programs in the United States. The primary goals of the Farm Bill are reducing the federal deficit, improving agricultural competitiveness, and enhancing the environment (USDA 1990, House 1991). The basic mechanisms brought into play are reducing deficiency and diversion payment acres, permitting crop planting flexibility, maintaining market-oriented loan rates, and implementing agricultural resources conservation program. Under the first mechanism, called the acreage reduction program (ARP), farmers are obliged to remove some acreage from crop production to qualify for program benefits and are restricted in the amount of acreage they can plant in any one crop and still collect subsidy payments. Each row crop has a different ARP value ; not less than 15 percent for wheat, 7.5 percent for corn and 5 percent for cotton.

Under the second mechanism, referred to as triple-base, farmers are given greater flexibility to produce non-program crops and still receive deficiency payments. In comparison to the 1985 Farm Bill, deficiency payments on 15 percent of base acreage are eliminated. However, these acres can be flexed (normal flex acreage, NFA). Under the new flexibility provision, farmers can plant the crop of their choice, except fruits and vegetables. Farmers are allowed to remove voluntarily an additional 10 percent of the base acreage program crop production under the same stipulation (optional flex acreage, OFA). If they choose to plant a crop other than their original program crop, they will be eligible for nonrecourse and marketing loans, but not for deficiency payments. The portion of the crop base left is the permitted planting acreage (PPA) on which the program crop can grow. Farmers have two options : planting the eligible crop (and receive subsidy payment) or participating in the 0/92 program (for feed grains) or 50/92 (for cotton). The -/92 program is an acreage diversion in which farmers devote all or a portion of their permitted planting acreage (in excess of 8 percent of required acreage) to conservation uses. Thus, under the 1990 Farm Bill, farmers have greater flexibility for using their land to produce alternative crops and still retain government payments than under the 1985 Farm Bill.

## 3. METHODOLOGY

### *3.1 Target MOTAD*

Risk is an inherent part of agriculture. The Target MOTAD methodology was chosen for this study because it includes risk in a linear programming framework that is easy to implement. Hazell (1971) developed the MOTAD model (Minimum Absolute Deviation from the Mean) as a linear substitute for quadratic programming in deriving an E-V frontier. Hazell's model can be formulated as the minimization of the total absolute deviation from the mean income for each activity, subject to technical constraints and to a parametric constraint on expected total net revenue. The decisionmaker can identify the combination of enterprises that maximize expected returns. Revenues above as well as below the mean are considered as elements of risk.

The concept of a target level which the decisionmaker wishes to exceed is similar in concept to the "focus loss" concept presented by Boussard and Petit (1967). They presented a linear optimization model in which they enforce the requirement that there is only a "negligible possibility of ruin". It is assumed that farmers will not select a production plan in which their income is below a minimum sufficient level to cover "unavoidable expenses", comprised of variable and fixed costs, a minimum amount for family consumption, and repayment of short-term loans.

Target MOTAD is a modification of MOTAD that can be used to optimize revenues subject to pursuit of a minimum target (Tauer 1983). Tauer assumed that decisionmakers are risk averse to only those revenues below their "target" (income level necessary for firm survival) and risk-neutral to revenues above. The utility function of income z is assumed as :

$$\begin{aligned} U(z) &= a + bz + c(z-t) && \text{if } z \leq T, \\ &= a + bz && \text{if } z \geq T, \end{aligned}$$

where T is the target income and a, b and c are constant.

The objective of the Target MOTAD model is to maximize expected revenues subject to technical constraints, and risk constraints defined as deviations below a fixed target (Hatch and Attwood 1988). The model is formulated as :

$$\text{Maximize } E(z) = \Sigma c_j \, x_j \text{ for } j = 1,..., n$$

$$\begin{aligned} \text{subject to } & \Sigma a_{ij} \, x_j \leq b_i \text{ for } i = 1,..., m \\ & \Sigma c_{rj} \, x_j - t_r + y_r \geq 0 \text{ for } r = 1,..., s \\ & \Sigma p_r \, y_r = \lambda \\ & x_j, \, y_r \geq 0 \end{aligned}$$

where

$n$ = number of activities,

$m$ = number of constraints,

$s$ = number of observations (usual years),

$a_{ij}$ = use of resource i by one unit of activity j,

$b_j$ = total availability of resource j

$c_j$ = expected revenue for activity j,

$c_{rj}$ = actual revenue for activity j in year r,

$x_j$ = level of activity j,

$T_r$ = the fixed target income for year r,

$y_r$ = absolute value of negative revenue deviation from the target income

$p_r$ = probability of year r,

$\lambda$ = maximum total negative deviations from the target.

For each specified target income, an "income target deviation" frontier is developed by varying $\lambda$ from 0 to unbounded. When $\lambda$ increases, the expected income increases and tends to approach the LP maximizing return solution.

In a comparative study, Watts et al. (1984) stated that Target MOTAD solutions will always yield higher income than MOTAD for a given level of risk. The authors state that "if only negative deviations from a correctly selected target are a source of risk, the Target MOTAD solutions are clearly superior."

For a large value of the risk parameter $\lambda$ (which is the allowable absolute deviation below the Target income), the model selects the mix of activities that maximize the income. In order to find the hypothetical risk efficient frontier of the programming model, the risk l is then minimized subject to an income change. By varying the risk level between these two extremes, several points of the risk frontier are determined.

### *3.2 The Representative Farm*

A typical commercial crop farm of the South Carolina Coastal Plain was selected for study (Boring, 1991). The representative farm used in the model consists of 1069 acres and produces 979 acres under the government program. The proportion of acreage in commercial production are assumed to be 117 acres of cotton, 604 acres of corn and 258 acres of wheat (including soybeans double cropped with wheat). The farm is considered to have in its possession all machinery and equipment for producing the row crops. One manager and two full-time persons work (600 hours/month) on the farm. The financial situation is assumed to be adequate to support diversification without interfering with the total farm financial conditions.

The addition of catfish farming as an enterprise requires significant investment, especially with the construction of the ponds and purchase of specialized equipment. Size of the operation affects yield, cost structure and profitability because of the managerial abilities and the economies of scale (Pomeroy and Rathwell 1988). Some producers, due to risk management, financial and/or marketing constraints, prefer to start small. For this reason, three sizes of catfish operations were considered in this study : 20 acres (two-ten acre ponds), 40 acres (four-ten acre ponds), and 80 acres (eight-ten acre ponds). It is assumed that the farmer has experience and knowledge of catfish farming.

Vegetable crops can be produced without special additional investment with the exception of irrigation machinery. The wells required by the catfish farming can be used for vegetable irrigation. The selected vegetables are fresh cabbage, fresh cucumber, turnip green, pickle cucumber, and watermelon. These vegetables were chosen because of their potential for high gross revenues and because the high labor requirement period is often in the slack time of the row crop enterprises. The production of vegetables is both labor intensive and requires high levels of managerial skills. It is assumed that the vegetable acreage cannot be more than 50 acres in spring and fall, because of the difficulties of management. It is assumed that the farmer has experience and knowledge of vegetable farming.

The farmer/farm manager is assumed to choose the best combination between these alternatives in order to obtain the highest return to land, labor, risk and management. Table 1 presents the Target MOTAD model. It includes the following activities : agronomic crop, aquaculture, spring vegetable crop, fall vegetable crop, monthly hired labor, risk deviation transfer, and target income transfer.

The objective function to be maximized is expressed as :

$$\text{Max } \Sigma c_j \, x_j - 4.25 \, h_m - 10sa \, ;$$

where

$x_j$ = level of activity (acres) ;

$h_m$ = monthly machinery labor hired (hours) ; its cost is \$4.25/hour ;

sa = set aside acres ; its cost is \$10/acre ;

$c_j$ = per acre average gross revenue return minus total variable costs for activity j ; representing the return to unpaid fixed resources including machinery, equipment and land debt, property taxes, insurance and labor available on the farm.

Yield and price data were obtained from records kept by members of the Central South Carolina Farm Management Association (FMA) (Boring, 1991). This data was supplemented by county yield and price data for agronomic crops in

two South Carolina counties, Sumter and Orangeburg, for the period 1983-1990 (S.C. Agricultural Statistics, 1991). Deficiency payments are added to receipts. Program yields for wheat, corn and cotton are set at the historic yields (based on the last five years) for the FMA. Annual deficiency payment rates were calculated by the difference between the 1990 target prices and the market prices of each year. Thus, these deficiency payment values deflated by the GNP price deflator, are thought to better capture risk under the new Farm Bill.

Costs and revenues for catfish farming were estimated based on the enterprise budgets developed by the Clemson University Cooperative Extension Service (Pomeroy, Schwedler and Luke 1988). The biological assumptions of production are reported in that report. As risk is minimized in the objective function, a variability of the catfish yield is required. Since no data currently exist in the United States on average commercial catfish yields, a random determination of yields for eight years was done. Three stocking rates of 3275, 3600 and 4500 fish per acre were used. The price of catfish were obtained from the U.S. Department of Agriculture monthly catfish report.

Costs and revenues for vegetables were estimated using 1983-1990 costs, yields and prices received by farmers in Sumter and Orangeburg counties and from enterprise budgets developed by the Clemson University Cooperative Extension Service (Rathwell, 1990).

### *3.3 Constraints : Technical, Risk and Policy*

Land and labor are the resources assumed to limit the maximization of the objective function. The labor is divided into two categories - labor for working with machinery and catfish management and labor for harvesting vegetable crops by hand. The labor on the farm is comprised of three full-time workers who provide 600 total hours of labor each month. Two workers can be hired during peak periods to provide 400 hours of additional labor per month. Other labor requirements for particular enterprises are reported in the respective enterprise budgets.

Capital is assumed not to be a limiting resource because of the availability of borrowed capital. The total 1069 land acreage of the representative farm is divided into two time periods because fresh cucumbers and pickle cucumbers can be produced during the spring and/or fall seasons. Soybeans and wheat and/or canola can also be double-cropped.

Prices, yields and costs for the years 1983-1990 are used to measure the variability of gross revenues over time. It is assumed that each of the eight annual observations of outcomes has the same probability of occurrence. The risk transfer rows contain the annual gross returns over the variable costs per acre for each activity. When the sum of the revenues is below the target income in a given year, the deviation is transferred into the risk constraints. By varying the risk-aversion parameter l, the model estimates farm plans corresponding to various degrees of risk aversion. The parameter l is defined as the average of the yearly deviations from the target income which is acceptable.

Farmers are assumed to be willing to participate in the government programs and, therefore, to agree to fulfill the requirements. Consequently, constraints are added to the model. Farmers cannot plant more than the permitted acreage in program crops to be eligible for program payments. Moreover, if they underplant their program crops, their future base acreage will be reduced.

Flexibility is the highlight of the 1990 Farm Bill. Crop acreage is henceforth divided into three categories : ARP (acreage reduction program), flexible acreage, and permitted acreage. The acreage constraints are shown in Figure 1.

Since the program crop of the farm is 979 acres, the producers have set aside 90 acres but it is allowed to flex at least 148 acres (up to 246 acres). The total planting of cotton, corn and wheat with deficiency payments can not exceed 743 acres. Catfish, vegetables and oilseeds are added to the model on the non-program acreage (90 acres).

The Target MOTAD model includes the suitable percentages of each Farm Bill constraint. Thus, the model can be adapted very quickly to another farm acreage (Tables 2 and 3).

The Target can be any goal that is important to the decisionmaker. In this study, the Target income represents the amount of money that can assure the long-run survival of the representative farm. Five Target incomes were selected as a function of different fixed costs between alternatives. The computation was conducted in two parts : (1) a base Target income, and (2) a specific additional cost for each scenario.

The base Target income included a minimum annual farm family income of $32,417 ; an annual full-time hired laborer income of $8,840 ; and the cash fixed costs for insurance, rent and property taxes. The base Target income is $124,390. It is applied to the representative farm without diversification.

Additional target incomes include :

Target 2 - $140,227 (20 acre catfish ponds)
Target 3 - $149,062 (40 acre catfish ponds)
Target 4 - $169,956 (80 acre catfish ponds)
Target 5 - $127,890 (no ponds, vegetables)

## 4. ANALYSIS AND RESULTS

The profitability of five combinations of row crops, aquaculture and vegetable enterprises are analyzed for the representative farm under the 1990 Farm Bill. For each Target, a comparison with three different catfish yields (5,000, 4,000 and 3,640 lbs. per acre, scenario 1,2 and 3, respectively) will be studied.

### *4.1 Target 1. ($124,390)*

The farm is first studied with the typical row crops (Target baseline) under the 1990 Farm Bill (Table 4). The program acreage is 979 acres and the non-program acreage is 90 acres. The most profitable plan ($116,806 Plan C) is approximately $8,000 smaller than the target income of $124,390. Interpreting the dual activity, it can be concluded that adding one acre of land in spring increases the income by $63 while adding one acre in the fall increases income by $12. The farmer chooses canola/soybean and corn on the NFA ; corn, cotton and wheat on the OFA ; corn, cotton and wheat on the PPA ; and canola/soybean on the 90 acres of non-program acreage.

The most profitable plan (C) is only $2,700 higher than the less risky plan (A). That means that South Carolina farmers do not have a lot of choices with their rotation. Even if farmers can make their decisions according to the market prices, they flex only the acreage that they are obliged to flex, and are not interested in the optimal flex acreage.

Thus, during a period of eight years, the expected income was below the Target for all three plans. Moreover, the risk deviation is high (near $30,000). Such a farmer is assumed to look for an alternative in order to increase his gross revenue and decrease the risk. Diversification seems to be the best way to obtain these goals in South Carolina.

### *4.2 Target 2. ($140,227)*

The farmer has the opportunity to raise catfish on a two ten-acre pond system and/or to plant vegetables on the 90 acres of non-program acreage. These 90 acres can also be planted in soybeans, canola, or canola/soybeans. Vegetable acreage is assumed to be less than or equal to 50 acres.

The most profitable plan (1C) produces a gross revenue of $205,229 (Table 5). Risk deviation is relatively low ($16,810).

Under plan 1C, the program acreage includes 147 acres of canola/soybean is planted on the N.F.A. acreage ; 60 acres of corn, 12 acres of canola/soybean and 26 acres of wheat are planted on the O.F.A. acreage ; 408 acres of corn, 82 acres of cotton and 155 acres of wheat are planted on the P.P.A. acreage. The remaining 90 acres of non-program acreage contains the 20 acres of catfish ponds, 17 acres of canola/soybean, 50 acres of spring cucumber and 50 acres of fall cucumber. Greens, spring cabbage and watermelon were not able to compete with spring cucumbers because the yield incomes were too low.

The comparison of the coefficients of variation (Table 6) shows that the production of fall pickles (C.V. = 74 percent) is less variable than the production of fall cucumbers (C.V. = 116 percent). This is due to the fact that pickles are sold under contract (where prices are less volatile), whereas fresh cucumbers are sold on the fresh market.

Under the remaining two catfish yield scenarios, plan 1C is the most profitable plan, although gross revenue decreases and risk increases. All other crops on both program and non-program acreage remain the same.

*4.3 Target 3. ($149,062)*

Catfish farming is conducted on four ten-acre ponds and the production of vegetables on 45 acres. The maximum gross revenue (plan 2C) obtainable in this scenario is equal to $219,944 (Table 7). It is higher than for Target 2 by $14,700 because the supplementary 20 acres of catfish ponds adds $23,700, although the reduction of the vegetable acreage by 5 acres decreases profits by $9,000. Catfish farming is still profitable. The risk associated with the expected incomes is lower than with the Target 2 because catfish provides additional revenue for the year 1990, resulting in a lower deviation from the target ($10,000 less).

On the program acreage, the evolution of the rotation is almost the same. On the NFA, soybean and canola/soybean share the acreage on the less risky plan (2A) ; canola/soybean is the only crop in the most profitable plan (2C). On the OFA, corn, canola/soybean and wheat share the 98 acres. The base corn, cotton and wheat share the PPA.

As with Target 2, fall pickles replace fall cucumbers when the risk parameter decreases. Spring cucumbers are included under all three plans. As fall cucumbers require more labor, corn is not flexed on the OFA.

Under the lower catfish yield scenarios, the profit maximizing plan stays the same (plan 2C). All program acreage crop mixes stay the same. Risk increases under each scenario and plan.

*4.4 Target 4. ($169,956)*

The farmer has the choice between eight, ten-acre ponds of catfish or non-program crops for the remaining 90 acres. With a catfish yield of 5,000 lbs per acre, both solutions are very close and the catfish ponds are selected in both cases (Table 8). The maximum gross revenue ($202,227, Plan 3B) is smaller than for the two previous Targets. This is because there is no production of vegetable, especially spring cucumbers, and 10 acres of land used for pond levees are not available for crops. The spring cucumbers are a highly profitable alternative.

The risk deviation is high since catfish farming on 80 acres is more risky than vegetable farming. The program acreage is almost the same as previous Targets. As catfish requires less management labor than vegetables, it is possible to plant canola/soybean on 45 acres of the OFA for the corn base in the most profitable solution (plan 3B).

With the other two yield scenarios, there is only one solution for the 4000 lb/acre and risk is high. No aquaculture enterprise enters the solution for the 3,640 lb/acre scenario.

*4.5 Target 5. ($127,890)*

In this case the vegetable enterprise is the only alternative analyzed. The maximum acreage of vegetable is 50 acres.

The most profitable plan (4C) produces $184,074 of gross revenue (about $56,000 above the Target). The risk deviation is $18,566.

Canola/soybean is planted on the NFA for each case. On the OFA, the program crops of corn,cotton and wheat replace soybeans in previous plans. Flexing optional acreage by soybean involves a low income but also a smaller risk (C.V. = 79 percent). The C.V. of cotton is relatively high (110 percent).

On the non-program acreage, canola/soybean is planted on 40 acres. As for previous plans, fall and spring cucumbers are planted.

*4.6 Return-Risk Target Comparison*

The return-risk target comparison evaluates the risk-efficient frontiers of the four Target levels for the three catfish yields (Figs. 1, 2, and 3). On each risk-efficient curve, the furthest point from the origin represents the most profitable but most risky farm plan. A risk-preferrer decisionmaker would maximize utility with such plans.

The efficient frontiers for the four Targets in scenario 1 are illustrated in Figure 1. With the exception of Target 4, the risk-efficient frontiers lie in descending order for the three other Target incomes, and indicate a lower level of utility. the

slope of the frontiers are the same. The marginal risk per additional dollar of revenue is similar for the three Targets. Higher Targets are associated with better return-risk trade-offs. Target 3 is clearly superior to Targets 2 and 5. The risk-efficient frontier for the Target 4 is reduced to a small segment with the highest risk deviation. With such a catfish yield, the more you diversify, the more you earn.

Under scenario 2 (Figure 2), strong changes appear. On the one hand, the risk level is higher. On the other hand, it is now lower Targets which are associated with better return-risk trade-offs. The slope of Target 2, 3 and 5 are still the same. Higher Target levels are associated with shifts of the efficient-frontiers to the right. The risk-efficient curve for Target 4 is reduced to one point. A combination of vegetable and catfish enterprises is not the most profitable solution anymore.

Figure 3 illustrates the scenario 3. The Target 4 has been retired. The risk-efficient frontiers are well separated. The higher the Target, the higher the risk deviation. The expected income for Target 3 is lower than for Target 2. The shift in the slope of the efficient-frontier for Target 2 and 3 corresponds to the substitution of catfish for canola/soybean.

## 5. SUMMARY AND CONCLUSIONS

A Target MOTAD model was used in this analysis to identify optimal farm plans under a strategy of enterprise diversification. When making production decisions, the farmer was assumed to be facing technical constraints (land and machinery were limited), risk constraints (deviations from the target incomes were parametrically decreased to reflect various risk-aversion degrees), and policy constraints (the farmer was assumed to be willing to benefit from farm programs and meet the required conditions for the 1990 Farm Bill).

The model was limited by the length of time used in the risk constraint data set ; capital was assumed to be borrowed without constraint ; no marketing constraints exist ; and the farmer was assumed to have knowledge and experience in producing the alternative enterprises.

## REFERENCES

**Boring T.M.** (1991). Unpublished Memograph Report, Central South Carolina Farm Management Association, pp. 1-13. Department of Agricultural and Applied Economics, Clemson University, Clemson, South Carolina, USA.

**Boussard J.M. and M. Petit** (1967). Representation of farmers' behavior under uncertainty with a focus-loss constraint. *American Journal of Agricultural Economics* (November) **49** (4) : 869-880.

**CUCES (Clemson University Cooperative Extension Service)** (1990). Cash crop budgets 1991 : estimated costs and returns for South Carolina. Extension Economics Report 126 (November). Department of Agricultural and Applied Economics, Clemson University, Clemson, South Carolina, USA.

**Hatch U. and J. Atwood** (1988). A risk programming model for farm-raised catfish. *Aquaculture* **70 :** 219-230.

**Hazel P.B.** (1971). A linear alternative to quadratic and semivariance programming for farm planning under uncertainty. *American Journal of Agricultural Economics* (February) **53** (1) : 53-62.

**House V.W.** (1991). U.S. Farm Policy : The 1990 Act. Working Paper (May), 16 p. Department of Agricultural and Applied Economics, Clemson University, Clemson, South Carolina, USA.

**Pomeroy R.S. and P.J. Rathwell** (1988). Economic evaluation of investment decisions for aquacultural enterprises. Extension Economics Report 105. Department of Agricultural Economics, Clemson University, Clemson, South Carolina, USA.

**Pomeroy R.S., D.B. Luke and T. Schwedler** (1989). Commercial catfish budgets and cashflow statements. Extension Economic Report 108 (April), 44 p. Clemson University Cooperative Extension Service, Clemson, South Carolina, USA.

**Rathwell P.J., W.P. Cook and D.B. Luke** (1990). South Carolina vegetable budgets for commercial producers. South Carolina Extension Service, Department of Agricultural and Applied Economics, Clemson University, Clemson, South Carolina, USA.

**SCASS (South Carolina Agricultural Statistics Service)** (1991). South Carolina crop, livestock and poultry statistics, 1988-1990. Columbia, South Carolina, USA.

**Tauer L.W.** (1984). Target MOTAD. *American Journal of Agricultural Economics* (August) **65 :** 606-610.

**US-DA (Department of Agriculture)** (1990). The 1990 Farm Act and the 1990 Budget Reconciliation Act. ERS, Miscellaneous Publication No. 1489, December. 34 p.

**Watts M.J., L.J. Held and G.A. Helmers** (1984). A comparison of Target MOTAD to MOTAD. *Canadian Journal of Agricultural Economics* (March) **32 :** 175-186.

TABLE 1.
CONDENSED TABLEAU OF THE TARGET MOTAD MODEL.

| | Row type | RHS | Row crop | Spri vege. | Fall vege. | | Hired labor mar .... nov | | Deviations 83 .... 90 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Unit | | | acre | acre | acre | | hour | hour | $ | $ |
| Objective function | max | $ | | $c_j$ | $c_j$ | $c_j$ | | -4.25 | -4.25 | |
| Land | | acres | | | | | | | | |
| Spring | | ≤ 1069 | 1 | 1 | 0 | | | | | |
| Fall | | ≤ 1069 | 1 | 0 | 1 | | | | | |
| Labor | | hours | | | | | | | | |
| mar. | | ≤ 600 | $a_{1j}$ | $a_{1j}$ | $a_{1j}$ | | -1 | 0 | | |
| . | | . | . | . | . | | . | . | | |
| nov. | | ≤ 600 | $a_{12j}$ | $a_{12j}$ | $a_{12j}$ | | 0 | 1 | | |
| Capital | | $ | | | | | | | | |
| | | ≥ 0 | $b_{1j}$ | $b_{1j}$ | $b_{1j}$ | | 4.25 | 4.25 | | |
| Risk Transfer | | $ | | | | | | | | |
| 1983 | | ≥ Target | $c_{83j}$ | $c_{83j}$ | $c_{83j}$ | | -4.25 | -4.25 | 1 | 0 |
| . | | . | . | . | . | | . | . | . | . |
| 1990 | | ≥ Target | $c_{90j}$ | $c_{90j}$ | $c_{90j}$ | | -4.25 | -4.25 | 0 | 1 |
| Risk parameter | | $ = \lambda$ | | | | | | | 1/8 | 1/8 |

$c_j$ = average return over variable cost per acre of activity j,
$a_{ij}$ = machinery labor required per acre for activity j per month i,
$b_{ij}$ = variable cost per acre for activity j,
$c_{rj}$ = return over variable cost per acre of activity j for year r (r = 1983 to 1990),
$\lambda$ = risk parameter to be varied from 0 to a large number.

TABLE 2.
ACREAGE CONSTRAINTS UNDER THE 1990 FARM BILL.

| | CORN 604 ac. | COTTON 117 ac. | WHEAT 258 ac. |
|---|---|---|---|
| ARP<br>90 acres | set aside<br>7.5%: 45 acres | set aside<br>5%: 6 acres | set aside<br>15%: 39 acres |
| | Any crop except fruit and vegetable. No deficiency income. | | |
| FLEX<br>148 acres | 15%: 91 acres | 15%: 18 acres | 15%: 39 acres |
| OPT. FLEX<br>98 acres | 10%: 60 acres | 10%: 12 acres | 10%: 26 acres |
| PERMITED PLANTED | Remaining land after ARP, NFA and OFA (if diverted) | | |
| 645 acres | 408≥ x ≥468 | 82≥ x ≥94 | 155≥ x ≥181 |

TABLE 3.
MATRIX WITH THE POLICY CONSTRAINTS.

| | | Cotbase | Corbase | Whtbase | RHS |
|---|---|---|---|---|---|
| Cotbase | E | 1 | | | 117 |
| Corbase | E | | 1 | | 604 |
| Whtbase | E | | | 1 | 258 |
| ARP | E | -0.05 | -0.075 | -0.15 | 0 |
| FLEX | E | -0.15 | -0.15 | -0.15 | 0 |
| OPcot | E | -0.10 | | | 0 |
| OPcor | E | | -0.10 | | 0 |
| OPwht | E | | | -0.10 | 0 |
| PPAcot | E | -0.70 | | | 0 |
| PPAcor | E | | -0.675 | | 0 |
| PPAwht | E | | | -0.60 | 0 |

TABLE 4.
PROFIT-MAXIMIZING FARM PLANS FOR THE TYPICAL ROW CROP FARM.

PLANS WITHOUT DIVERSIFICATION
TARGET INCOME: $ 124,390

| Plan | | A | B | C |
|---|---|---|---|---|
| Obj. function | | $ 114,100 | $ 116,787 | $ 116,806 |
| risk deviation | | $ 28,614 | $ 28,886 | $ 29,158 |
| N.F.A. (147) | | soybean (67)<br>can/soy (29)<br>wheat-ND (51) | can/soy (85)<br>wheat-ND (40)<br>corn-ND (22) | can/soy (122)<br>corn-ND (25) |
| | *Base* | | | |
| | *corn: 60* | corn (60) | corn (60) | corn (60) |
| O.F.A. | *cotton: 12* | cotton (12) | cotton (12) | cotton (12) |
| (98) | *wheat: 26* | wheat (26) | wheat (26) | wheat (26) |
| | *corn: 408* | corn (408) | corn (408) | corn (408) |
| P.P.A. | *cotton: 82* | cotton (82) | cotton (82) | cotton (82) |
| (645) | *wheat: 155* | wheat (155) | wheat (155) | wheat (155) |
| Non-program acreage: 90 acres | | | | |
| cano/soyb | | 90 | 90 | 90 |

TABLE 5.
PROFIT-MAXIMIZING FARM PLANS FOR THE TARGET 2, SCENARIO 1.

TWO-TEN ACRE PONDS AND VEGETABLES
TARGET INCOME: $ 140,227
Catfish yield: 5000 lb/acre

| Plan | | 1A | 1B | 1C |
|---|---|---|---|---|
| Obj. function | | $ 193,298 | $ 199,452 | $ 205,229 |
| risk deviation | | $ 15,696 | $ 16,253 | $ 16,810 |
| N.F.A. (147) | | soybean (63)<br>can/soy (84) | can/soy (147) | can/soy (147) |
| | *Base* | | | |
| | *corn: 60* | can/soy (60) | corn(38), ca/sy(12), sy(10) | corn (60) |
| O.F.A. | *cotton: 12* | can/soy (12) | can/soy (12) | can/soy (12) |
| (98) | *wheat: 26* | wheat (26) | wheat (26) | wheat (26) |
| | *corn: 408* | corn (408) | corn (408) | corn (408) |
| P.P.A. | *cotton: 82* | cotton (82) | cotton (82) | cotton (82) |
| (645) | *wheat: 155* | wheat (155) | wheat (155) | wheat (155) |
| Non-program acreage: 90 acres | | | | |
| pond: 20 acres | | 20 | 20 | 20 |
| levees: 3 acres | | 3 | 3 | 3 |
| soybean | | 17 | 17 | 0 |
| can/soy | | 0 | 0 | 17 |
| spr. cucumber | | 50 | 50 | 50 |
| fall cucumber | | 0 | 23 | 50 |
| fall pickle | | 50 | 27 | 0 |

TABLE 6.
PER ACRE GROSS REVENUES FOR SELECTED CROPS.

| Crop | 1983-90 Average | Standard Deviation | Coefficient of Variation |
|---|---|---|---|
| | $/acre | $/acre | |
| Cotton | 104 | 114 | 1.10 |
| Corn | 113 | 90 | 0.80 |
| Wheat/soybeans | 162 | 64 | 0.39 |
| Cotton No DP* | 28 | 116 | 4.14 |
| Corn No DP | 85 | 103 | 1.22 |
| Wheat/soyb No DP | 146 | 45 | 0.31 |
| Soybeans | 64 | 50 | 0.79 |
| Canola | 38 | 64 | 1.10 |
| Canola/soybeans | 124 | 95 | 0.81 |
| Spring Cucumber | 1093 | 1015 | 0.93 |
| Fall Cucumber | 382 | 445 | 1.16 |
| Spring Pickle | 456 | 181 | 0.40 |
| Fall Pickle | | | 0.74 |
| Spring Cabbage | 177 | 513 | 2.90 |
| Turnip Greens | 324 | 189 | 0.58 |
| Watermelon | 230 | 125 | 0.54 |

* "No DP" stands for "No Deficiency Payment".

TABLE 7.
PROFIT-MAXIMIZING FARM PLANS FOR TARGET 3, SCENARIO 1.

FOUR-TEN ACRE PONDS AND VEGETABLES
TARGET INCOME: $ 149,062
Catfish yield: 5000 lb/acre

| Plan | | 2A | 2B | 2G |
|---|---|---|---|---|
| Obj. function | | $ 209,644 | $ 215,718 | $ 219,944 |
| risk deviation | | $ 14,639 | $ 15,177 | $ 15,714 |
| N.F.A. (147) | | soybean (50) can/soy (97) | can/soy (147) | can/soy (147) |
| | *Base* | | | |
| | *corn: 60* | can/soy (60) | corn(45), can/soy(15) | corn(57),can/soy(3) |
| O.F.A. | *cotton: 12* | can/soy (12) | can/soy (12) | can/soy (12) |
| (98) | *wheat: 26* | wheat (26) | wheat (26) | wheat(26) |
| | *corn: 408* | corn (408) | corn (408) | corn (408) |
| P.P.A. | *cotton: 82* | cotton (82) | cotton (82) | cotton (82) |
| (645) | *wheat: 155* | wheat (155) | wheat (155) | wheat (155) |
| Non-program acreage: 90 acres | | | | |
| pond: 40 acres | | 40 | 40 | 40 |
| levees: 5 acres | | 5 | 5 | 5 |
| spr. cucumber | | 45 | 45 | 45 |
| fall cucumber | | 0 | 20 | 45 |
| fall pickle | | 45 | 25 | 0 |

TABLE 8.
PROFIT-MAXIMIZING FARM PLANS THE TARGET 4, SCENARIO 1–2.

EIGHT-TEN ACRE PONDS
TARGET INCOME: $ 169,956
Catfish yield: 5000 lb/acre

| Plan | | 3A | 3B |
|---|---|---|---|
| Obj. function | | $ 201,183 | $ 202,227 |
| risk deviation | | $ 20,054 | $ 20,138 |
| N.F.A. | | can/soy (126)<br>soybean (21) | can/soy (147) |
| | *Base* | | |
| | *corn: 60* | can/soy (60) | corn(15), can/soy(45) |
| O.F.A. | *cotton: 12* | can/soy (12) | can/soy (12) |
| | *wheat: 26* | wheat (26) | wheat (26) |
| | *corn: 408* | corn (408) | corn (408) |
| P.P.A. | *cotton: 82* | cotton (82) | cotton (82) |
| | *wheat: 155* | wheat (155) | wheat (155) |
| Non-program acreage: 90 acres | | | |
| pond: 80 acres | | 80 | 80 |
| levees: 10 acres | | 10 | 10 |

FIG. 1.
RISK-EFFICIENT FRONTIERS, SCENARIO 1.

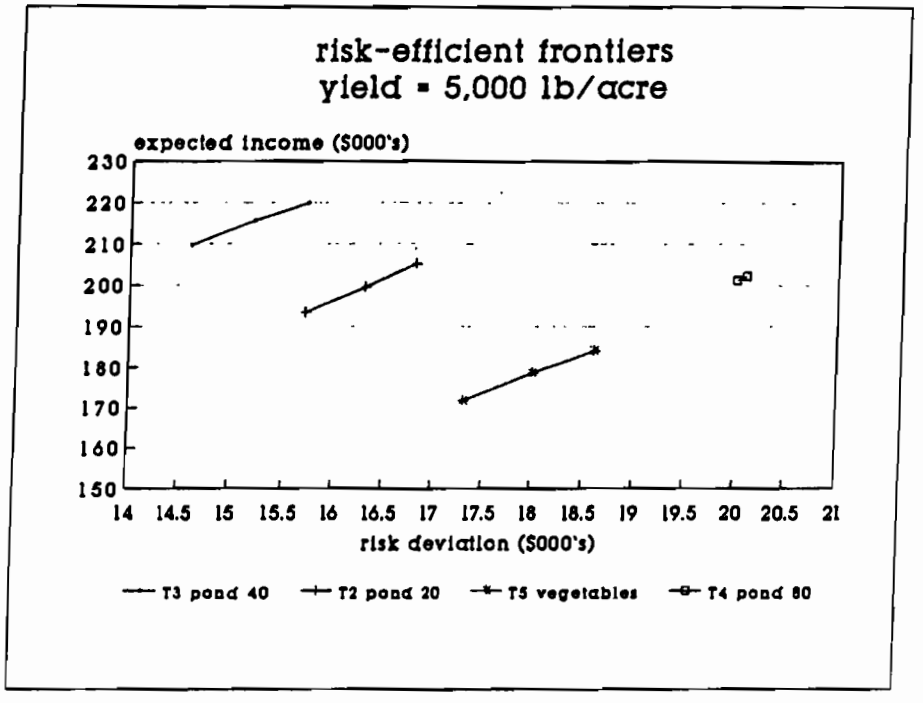



FIG. 2.
RISK-EFFICIENT FRONTIERS, SCENARIO 2.

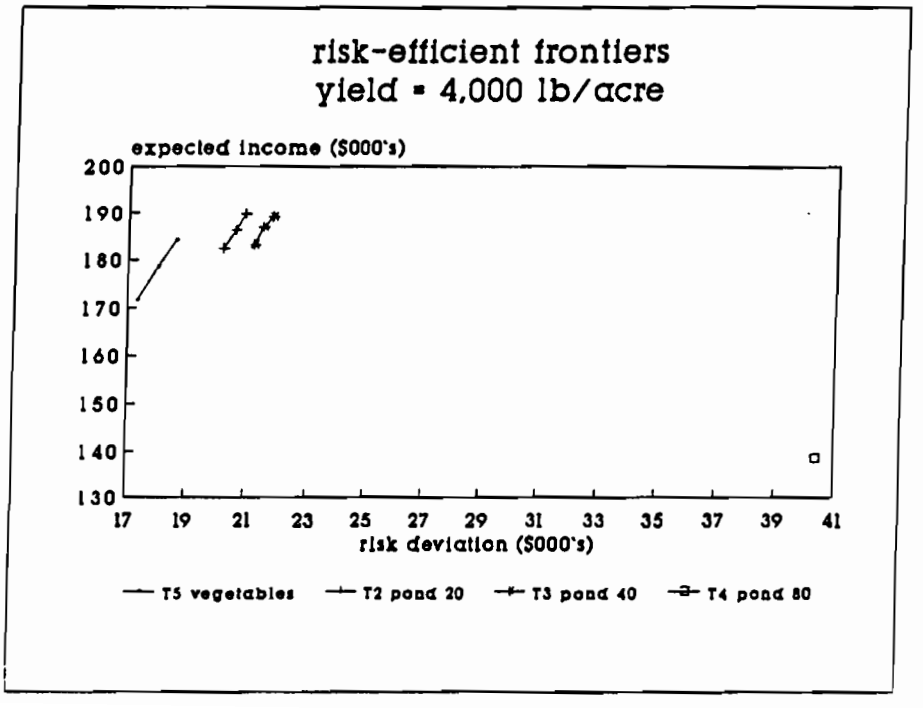
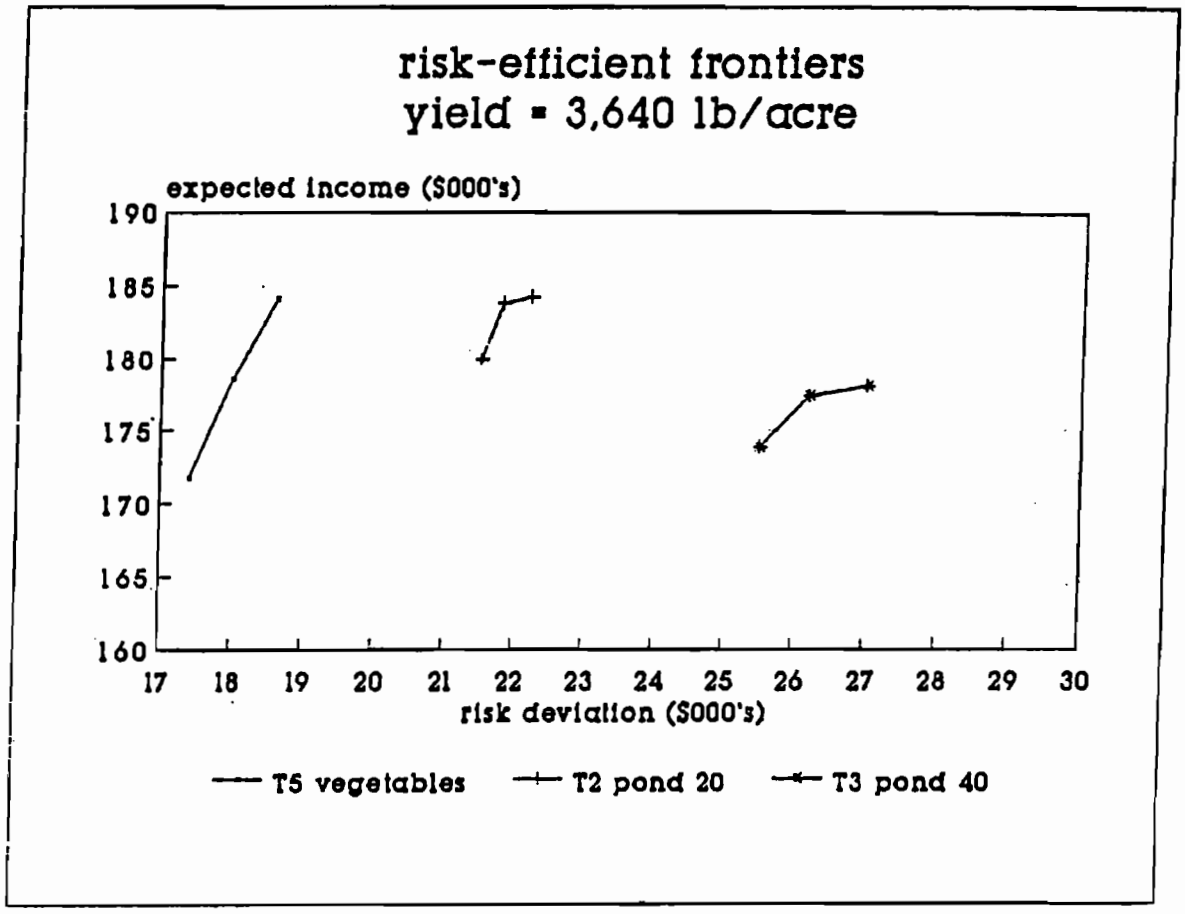


FIG. 3.
RISK-EFFICIENT FRONTIERS, SCENARIO 3.



# The Management Schemes for Brackishwater Pond Production

**Mudiantono**

Faculty of Economics, Diponegoro University, Jalan Erlangga Tengah 17, Semarang 50241, Indonesia

ABSTRACT

*Tambak production is a relatively new trend of business in Indonesia, since Indonesia has some experiences in the over exploitation of marine resources during 1970s. Many programs are set to develop the tambak in Indonesia. Most of those programs are in management system. This study has main objective to recommend alternative management schemes for tambak operation, basically for tambak operation in north coast of Java, and west coast of South Sulawesi as the leading areas for tambak production in Indonesia using 300 tambak operators as the samples.*

*The results of this study indicate that the tambak management in north coast of Java and west coast of South Sulawesi vary from region to another and levels of management. This variation may have generated differences in cultured species performance i.e. milkfish and shrimp. It seems that environmental variables such as temperature, salinity, soil texture and quality, and water control structure are to be significant roles in determining the cultured species performance. This is obviously, in turn, influencing the production level in each tambak culture systems.*

*The other husbandry parameters that also affecting the economic efficiency of tambak management are stocking density, and food and feeding practices. The study indicates that with increasing stocking density, the variable cost will also increase and in turn reduce the ratio of net profit to total costs.*

*In order to optimize tambak production and economic efficiency, it can be proposed that zonation of tambak areas according to ecological condition and supporting infrastructures in the sites is necessary to be done. It is especially important to tambak investors to determine the selected sites.*

## 1. BACKGROUND

The total shrimp production of the world has increased steadily since 1960s. It was recorded to increase in about 70 % during a decade of 1972 to 1982 amounted for 1.2 to 1.7 million tons. During the last five years, the world production

stayed at about 1.7 million tons. Out of these, according to the 1983 FAO yearbook of Fishery Statistics, the developing countries produced about 70 % with four leading producing countries from Asia i.e. India, China, Thailand and Indonesia.

The demand for shrimp in the world market is generally following an upward trend. This continous increase of the demand for shrimp has put an over increasing pressure to the producing countries to increase their supply. This has caused a sharp increase of the size and amount of trawler and small vessels which engage in shrimp capture fisheries. There is the danger of over exploitation of marine resources, because most of the major shrimp fisheries are at present being fully exploited to maximum sustainable yield.

Indonesia has some experiences in the over exploitation of marine resources during 1970s. In 1971, for example, the number of vessels harboured on Cilacap area alone was only 13 compared to 200 in 1976 with corresponding total catch was increased from 171.5 tons in 1971 to 3.055 tons in 1976. In 1980, there were 161 larger trawling vessels with 121 shrimp trawlers concentrating in the Maluku and Irian Jaya Areas. On the other hand, more than 13,000 vessels with inboard engines were concentrated in the Malacca Strait, East Sumatra and the northern of Java. This resulted the growth of Indonesia's fishery product exports from US$ 7 million in 1970 to US$ 253.6 million in 1982. Shrimp export constituted 71.5 % of the total revenue, 28.8 % of the volume and 28 % of the value of fishery products in that year. These activities placed the Indonesian shrimp industry in trouble especially of over exploitation of shrimp stocks (Palomares, 1985).

Although the over exploitation can be prevented through the better stock assessment and management, but there is no real hope for capture to give higher yields. To solve this problem, Indonesia has chosen to ban the trawler operation in Indonesian waters since 1980 and is looking primarily to its brackish water ponds (tambak) for further development of shrimp culture, in order to substitute shrimp cought from the sea.

North coast of Java is the leading tambak area in Indonesia. There is at present about 92,000 ha of tambak in Java. These tambak are generally cultivated for either shrimp or milkfish. The culture systems which are being practiced by the tambak operators are the traditional culture system for shrimp or milkfish as monoculture, and shrimp and milkfish in polyculture, the semi intensive culture system for shrimp in monoculture, and intensive culture system for shrimp in monoculture :

(i) the traditional culture system depends completely on natural food propagated in the pond with or without fertilization and on tidal water replenishment. In this system, the management practices depend mainly on the natural condition without any assistance from human. The stocking density ranges from 2,000 to 10,000 fry of shrimp and 500 to 3,000 fry of milkfish per ha.

(ii) the semi-intensive culture system is a higher level of the system than the traditional one. In this system requires the supplementary feed such as trashfish, mussel meat and artificial feed, and the use of water pumps in addition to tidal exchange. Stocking density is as higher as 10,000 to 40,000 fry/ha.

(iii) the intensive culture system is almost completely independent of the nature. This system usually stocks 40,000 to 200,000 fry/ha. Such high density can be supported only through major inputs of formulated feed mostly in the form of pellets and water exchange through the pumps and aeration facilities (e.g., paddle wheels). The size of ponds is smaller ranged between 3,000 and 6,000 m square. This system is usually characterized by capital intensive.

Some programs are set to develop tambak in Indonesia. One of the programs is tambak intensification. This program is aiming to improve and increase the production of tambak for exports and domestic consumption purposes, to increase the income of tambak operators by improving their business production and productivity, and to provide and to enlarge the employment opportunities. Meanwhile, to stimulate shrimp culture industry by private sectors, the government is also giving business fresh-atmospheres such as deregulations and debureaucratic policy in order to drive non-oil export commodities. To make this program successful, the government also provides a special facilities package such as special credit scheme with soft requirements, technical assistances, and input facilities. Up to now, the program has not been so successful in term of the target area. It was only about 9 % of the target come to the reality. It is generally due to the technical bank conditions which are still being employed by the executive banks, eventhough the bank requirements in this program have alternatively been reduced. The main problem faced by the most traditional tambak operators to join the program run by the government was to show their certificates of tambak ownership as a collateral to the bank. Most of them do not have it, so that the bank is not able to approve its credit scheme. It was one of the constraints in improving

the traditional tambak productivity. On the other hand, the self-financed shrimp culture industry run by private sectors have rapidly been growing. For the last four years, the number of intensive tambak financed by private sector has increased almost 200 %. It has mainly been operated by the investors who are often not necessarily come from the fisheries/aquaculture sector. The rapid growth of shrimp hatcheries in Java makes the shrimp fry be easily available. It has stimulated the investors to invest their money in tambak business (shrimp culture industry).

In most regions, there is a strong tendency that the traditional tambak are converted into the intensive cultured ones. For instance, in Tugu District Semarang Regency, Central Java nearly a half of the tambak area available has been used intensively by private investors. In the site selection, they are often ignoring the needs of other tambak operators. The conflicts among the tambak operators may arise from this situation. These investors occupied their tambak either by buying or renting from traditional tambak owners.

The texture of soils, water sources, accesebility and infrastructure facilities in surrounding tambak areas are usually used to be the considerations in the site selection. Pre-observations showed that the texture of soils and other facilities as mentioned above are not the same for the north coast of Java. Not all locations of existing tambak areas are suitable for intensive shrimp culture purposes. There are some investors that select the unsuitable locations for their intensive tambak sites. Since they are not able technically to select the suitable sites, they are mostly using trial and error method to find out the optimum use of inputs. Consequently, the maximum profit cannot be achieved by them. It is because they have to invest too much in tambak preparations and operating costs. It might be worthwhile to keep some certain locations of tambak area available to be operated by the extensive shrimp culture system in order to achieve the optimum production in certain level.

Eventhough shrimp culture has been becoming more popular, milkfish is still widely cultured. The market for milkfish is still large and the management operation of that culture is quite easy such that many tambak operators are interested to culture milkfish beside the lack of fund needed to convert their tambak for shrimp cultivation. However, the milkfish culture is still to be an important part of tambak culture system.

In this research, the identifications of tambak conditions based on the location, technological adaptation, species cultured and ownership should be conducted in order to get the initial descriptions of existing tambak operations. The various existing conditions as mentioned earlier on tambak could be used to analyze the conflicts which might be arise in the tambak resource allocations. So, the rational tambak utilization should be investigated. To achieve it, the economic and social considerations would be in the high priority in addition to the technical considerations.

## 2. OBJECTIVES

Generally, this study is aimed to recommend the alternative management schemes for tambak operation. This objective will be reached through some specific objectives such as :

(i) to describe the existing tambak operation based on the level of management and technology adaptation ;

(ii) to evaluate the performance of tambak enterprise management, and to find out the parameters affecting theeconomic efficiency of tambak management ;

(iii) to identify the critical externalities in intensive tambak development ;

(iv) to analyze the existing aquaculture systems in order to identify the appropriate (and economically sustainable) technological mix of enterprises in different environments.

## 3. METHODOLOGY

### *3.1 Data Collection*

The tambak location as study area is mainly on north coast of Java. The data collection activities are started by collecting the secondary data showing the locations of existing tambak with level of management adopted by tambak operators.

Some regions with strong tendencies of tambak traditional, semi-intensive or intensive are selected. The selection of culture systems of tambak uses the general description of existing tambak condition in those regions. To make the general description and to find out the major problems in the regions, the method of Rapid Rural Appraisal (RRA) is used. This method gives the researchers the simple and efficient ways to decide the sampling areas and the samples of tambak operators to be monitored in order to analyze the performance of tambak operations. The tambak operators who are to be the samples consist of operators operating traditional culture system for shrimp and milkfish in monoculture and polyculture of shrimp and milkfish, semi-intensive system for shrimp and intensive system for shrimp.

The sample area of this study consists of three provinces namely West Java, Central Java, and East Java. The total sample is 223 which can be divided into : 73 samples of West Java, 75 samples of Central Java and 75 samples of East Java.

The data were collected from those tambak for three seasons through one shot and monitoring data collections. One shot data collection was done for the first season in August 1989 (for the season which harvested around August 1989) by interviewing to the tambak operators. The monitoring was done for the two seasons after that season.

### *3.2 Data Analysis*

Some computer programs such as DBase III, ENFIN, and Lotus are used in this study to find out the optimum allocation of tambak resources. The data from the field are stored first in the computers using DBase III, so that they can be further processed easier through making the worksheet. ENFIN and Lotus programs are used to measure the returns and costs using certain level of management. The level of management employed by the tambak operators and natural conditions such as soil textures and the existing conditions of tambak infrastructures may be the constraints in developing the tambak. So, they will be analyzed first before the analysis of costs and return. The results of the analysis will recommend the alternative management schemes for tambak production.

### *3.3 Limitations of Study*

The monitoring could not be done smoothly because of the cropping season of each study sites was not started in the same time. When in one site has begun the season, in the other sites still waited the harvest time. This situation made the data collection from monitoring could not be done in the same time, while the researchers had the limit time. So, the data from monitoring came late to be analyzed. It made the research schedules could not be followed.

## 4. TAMBAK MANAGEMENT

### *4.1 Land and water supply*

Location of pond should be considered in the tambak system. Some factors which significantly influence the production process of tambak system are as below :

(i) water supply and water quality
The suitable water salinity ranges between 15 % and 25 % therefore in dry season, fresh-water should be available to maintain the optimal water salinity. Beside that, the water should be unpolluted by industrial, agriculture or water transportation activities.

(ii) tidal range
Tidal range related to the pond water management system would influence the pond construction as a whole. How strong the dykes, watergates, and canals should be built depend on the tidal movement.

(iii) Soil quality
Claysoil, sandy clay or loamy soil with pH around 7.5 and more or less 2 % organic materials contains are favourable conditions for pond.

Transport accessability, unflooded area, extended possibility and security aspect are other important factors of pond locations.

In this study, the distance of pond location to the fry sources varies among intensive, semi-intensive and traditional tambak systems. However there are two different patterns of West Java and Central Java in one side and East Java in other side. In West Java and Central Java, more than half of the pond are located in more than 50 Km from fry source. Meanwhile in East Java the distance of pond location to fry sources are more various.

Water supply, especially its quality, will stimulate sloughing and lead to high survival and growth rates in the pond. In contrary, poor water quality is one of the factors that caused mortality rate. In East Java the semi-intensive tambak system faces relatively higher problem of water quality than the other regions or other culture systems.

Related to the location of pond, this study found two problems which influence the tambak system, namely flood and physical-natural capacity conditions. Data indicate that the flood and physical-natural capacity conditions still become a problem in the tambak system not only for traditional and semi-intensive systems, but also for intensive culture system. It is also true that the problem is beyond the farmer control.

### *4.2 Fertilization and Pesticide Application*

Drying, cleaning, plowing and leveling of pond, application of lime and fertilizer are among the activities in pond preparation. These activities are done primarily to eradicate pests and predators, to reduce acidity and to enhance fertility of the soil. For old ponds, plowing to remove the surface soil comprising of accumulated unused feed during earlier rearing period is also an important activity in pond preparation. This is to prevent the soil and water pollution in the next rearing cycle.

This study found that all tambak operators practiced fertilizer and pesticide application into their ponds during pond preparation. However the frequency of fertilizer and pesticide applications are different and vary to the regions or culture systems.

In West Java and Central Java none of the tambak operators practicing fertilizer application three times during pond preparation. All traditional, semi-intensive and intensive tambak operators in East Java were practicing once, twice and three times fertilizer, respectively.

Eradicating pests and predators during pond preparation can be done by pesticide application. This study found that the frequency of pesticide application varies either to regions or to culture systems.

### *4.3 Acclimatization of Fry*

Water has many physical and chemical properties. There are some physical and chemical factors affecting water which are very important from the point of view of aquaculture, e.g. temperature, salinity, DO2, ammonia, nitrite, time and weather. Physical factors within and among the fish pond vary with space and time. No two ponds are exactly the same. Due to those factors, it is important to acclimatize the fry to the new condition when they are going to be stocked into rearing ponds.

To avoid high mortality of fry when they are stocked into the ponds, the tambak operators commonly do some treatments. Acclimatization of fry to the temperature and salinity of the water in ponds is done by the following manners :

(i) Replace water from the plastic bag as shrimp fry ( *benur*) container with that of the nursery pond water. This is usually done within an hour's time.

(ii) First stock the *benur* in the nursery pond before they are gradually released into the rearing pond.c.The stocking of fry are usually done early in the morning or late in the afternoon and night.

It is interesting to note that some traditional tambak operators in West Java stocked the fry into the pond at noon, although it is not theoritically suggested. This is, therefore, will be affecting to the mortality rate of shrimp during culture period.

### *4.4 Stocking of Fry*

Stocking the pond with shrimp fry involves two main activities, namely seed procurement and the practice of stocking. In the latter two factors are important, these are stocking rate and stocking time.

### 4.4.1 Seed Procurement

The main sources of shrimp fry for stocking are the hatchery and the nature. The first one is mostly applied for shrimp fry and the latter either for shrimp or milkfish fry. The shrimp hatchery supplies approximately 54 to 70 % of tambak in 3 provinces studied. The study revealed that the shrimp hatchery supplies approximately 63.01 %, 65.33 %, aand 70.76 % of tambak in West Java, Central Java and East Java, respectively. The rest of the tambak obtain the fry (shrimp or milkfish) from nature through the middlemen/suppliers. The fry is not always locally available, but some of them are supplied from other places at the a distance of more than 50 kilometers from the tambak location. Those are about 65 % for West Java, 58 % for Central Java and 38 % for East Java.

To some extent the distance affects the mortality rate or quality of fry. Without good transportation facilities, the more longer the distance the higher mortality rate will be. Therefore, the tambak operators usually prefer to buy the fry from the nearby shrimp hatchery or suppliers. But for some reasons, the shrimp fry supplied by those nearby hatchery or suppliers sometimes are inadequate. It forces the tambak operators to get fry from other places. The latter is also happened for other reasons, such as to get better quality and lower price. By experiences or local information sometimes they are able to get good quality of fry at low price. There is also a fact that even at the same location the tambak operators paid different prices for fry. So far the price of shrimp fry vary from one hatchery to the others and from one region to the others. The study indicated that the most intensive farmer have paid lower price than the traditional farmer (see Table 6).

### 4.4.2 Practice of Stocking

The level of technology adopted by the tambak operators can be classified into intensive, semi intensive and traditional systems. For each level of technology, the tambak operators tend to use different culture systems. The traditional tambak operators usually prefer to practicing polyculture and the intensive tambak operators tend to use monoculture systems. Meanwhile the semi-intensive tambak operators tend to do both culture systems, either monoculture or polyculture systems depending on their financial condition.

### 4.4.3 Stocking Rate

Stocking rate ranges from less than 50.000 to more than 100.000 shrimp fry per hectare. For the traditional systems, generally the stocking rate is less than 50.000 shrimp fry/ha, and the intensive systems stocked more than 100.000 shrimp fry/ha. According to the extension service officer the stocking rate adopted by most intensives tambak in Java is about 30 to 40 shrimp fry per square metre or 300,000 to 400,000 shrimp fry/ha. This is not for traditional tambak operators who are usually lack of capital.

### 4.4.4 Stocking Season

The stocking seasons are usually in October and April. These seasons are usually practiced by milkfish culture which has been done in Indonesia for a long time ago.

Compared to milkfish fry where their stocking depend on the fry season, shrimp fry can be obtained any time, especially from hatchery. Due to the field condition, however, the traditional operators still assume that October and April is also the stocking season for shrimp culture. This stocking season is not necessarily applied for the intensive operators since they can stock any time according to their own schedule of harvest. They do not fully depending on nature condition because they are able to manage the production process.

The frequency of stocking, however, is commonly practiced no more than twice a year per unit of pond. Most of tambak operators from different level of management stocked the shrimp fry only once throughout the year, even in the intensive systems (except in Central Java). It was happened for some reasons, such as : the availability of shrimp fry, current price (for shrimp and fry), capital availability, optimum production, etc.

### *4.5 Feeding Practice*

The extensive or traditional culture system of shrimp relies almost completely on natural foods in the pond. Occasionally, supplementary feeding e.g. trashfish, ricebran, and trashfish and ricebran mixed, may be needed when the availability of

*klekap* (natural food) is very limited. To generate the growth of natural food, the tambak operators applied fertilizer into the pond. They use different kinds of fertilizer and methods. In addition that, they are also using and buying fertilizer in different number and prices, even though they are in the same location.It is,therefore, affecting the operational cost of the tambak and its profitability. The field study indicated that the differences in using fertilizer to grow natural food is mainly due to the lack of technological information among them. There are several sources of technological information being used by the operators. There is no any single information acts as a dominant source.

As the stocking rate of biomass increases (more than 5,000 fry/ha) and the cultured species is, obviously the natural food will be limited. It is, therefore, the supplementary feeding needed. The supplementary feeds applied by traditional tambak operators are generally home made (e.g. trashfish, ricebran) rather than manufactured feed (pellet). In practice it is not necessarily like that since they used many kinds of supplementary feeding. In term of the feeding rate per ha, it can be identified that the traditional system is mostly applied it for less than the intensive one. In addition, the most traditional farmer tend to use the low price of supplementary feeding which is usually related to the low quality of feed.

The feeding frequency and the way of feeding practiced by tambak operators are varied from region to region. In general, the feeding frequency is given three times a day : in the morning, noon and evening. During morning and noon times, the feed is usually given at once, except in West Java. In the evening, however, the frequency of given ranged from one to three times. The feeding method adopted by the tambak operators are varied from one level of management to the others depending on their experience and background of technological information. The methods such as spreading or broadcasting the feed into the pond and 'tray' method.

### *4.6 Pest Control*

Saponin and Teodan are mostly applied by of intensive operators to eradicate wild fishes and other undesirable animals. In addition, there are still two other pesticides that mostly applied by traditional and semi-intensive operators (especially in West Java), namely Tridion and others. The intensive operators applied more pesticide in their ponds than the traditional systems except for those in Central Java, since the intensive operators in Central Java using the least pesticides. They only applied pesticide of less than 100 kg/ha. The most dominant pesticide users are tambak operators (i.e. intensive and semi intensive) in West Java, in which more than 47 % of them applied more than 100 kg/ha. Meanwhile, the majority of traditional operators can be considered as the low users of pesticide (less than 50 kg/ha). The price of pesticide varyto the regions. The traditional operators in East Java are mostly bought pesticide at price of more than Rp 700.00/kg.

In other places, meanwhile, the traditional operators have been paying the pesticide at low price (less than Rp 500.00/kg). The low price is normally related to the low quality of pesticide which in turn will affect its effectiveness as a means of controlling pest. This might due to different sources of information in practicing pest control or due to the low purchasing power. It seems that the role of experience and the extension service officer as source of information in South Sulawesi and East Java are more predominant than those in Central and West Java. In the latter provinces books and others seems to be more predominant as source of information in using pesticide. The different sources of information clearly will influencing the operators in determining : the kinds, number of pesticide, and the method of utilization. There is a variation frequency in using pesticide per season which is ranging from one to four times per season. They used pesticide either in dry or wet season without any preference.

## 5. HARVESTING

The cultured species in tambak system can reach marketable size within 4 to 5 months for shrimp and 5 to 6 months for milkfish after stocking. The frequency of harvesting varies either between regions or level of management. In East Java and South Sulawesi (especially for intensive culture systems) harvesting time is practiced twice a year by means of selective method using net, the small (non marketable) size is returned to the ponds for further rearing. While 70 % of traditional culture system in all regions (except East Java), are harvesting their products at once.

There are several reasons to harvest the tambak products. In West Java and Central Java, especially for intensive and semi intensive culture systems, more than 50 percent of the tambak harvest their products when the optimum production has been reached. The reason "Cash money need" has been answered by traditional operators in Central Java and East Java, with percentage of 3.5 and 3.7, respectively.

Draining the ponds or using net are two common methods of harvesting used by the tambak operators. However, there is no specific indication of harvesting method, it varies between regions or between culture systems.

## 6. COST AND RETURN ANALYSIS

### *6.1 Cost Structure*

In operating tambak, intensive culture system required the highest cost as compared to semi intensive and traditional ones. This is so since intensive system almost completely independent of the nature. By stocking relatively high density of fry, it uses not only artificial (formulated) feed, but also the pumps and aeration facilities. On the other hand, traditional system which are largely depended upon natural food propagated in the pond absorbed the lowest cost. However, tambak operators in Central Java who practiced this system still giving feed the shrimp by using artificial feed (such as trasfish, ricebran etc.).

In West Java, the traditional tambak system is completely depending on natural food, since the tambak operators do not applied supplementary feeding to the milkfish. As a consequence, variable costs as well as total costs of this culture system is the lowest as compared to intensive and semi intensive systems. Table IV.20. shows that the absolute amount of total costs for an average one ha tambak per season for intensive, semi intensive and traditional systems amounted to Rp 22,804,912, Rp 7,762,031 and Rp 639,093, respectively.

Variable costs dominated the cost structure in all management culture systems. As much as 96.43 %, 86.56 % and 53.91 % of total costs are absorbed by variable costs in intensive, semi intensive and traditional systems respectively. Unlike in intensive system, hired labour cost in semi intensive and traditional systems dominate variable costs comprising 48.76 % and 35.62 %, respectively. Feed cost in intensive system is the major cost accounting for 69.29 % of total costs.

Proportion of fixed costs and opportunity costs in cost structure for intensive as well as semi intensive systems are quite the same, i.e. about 3.25 % for intensive and less than 7 % for semi intensive. Whereas in traditional system, fixed costs and opportunity costs absorbed 31.24 % and 14.85 % of total costs respectively.

The total costs of tambak operation in Central Java on average one ha tambak per season for intensive, semi intensive and traditional systems amounted to Rp 11,252,683, Rp 4,258,745 and Rp 610,523, respectively. These figures indicate that the more intensive system or the less independency on nature practiced by taambak operators, the higher cost should be paid.

Proportion of variable costs in tambak operation in Central Java is the highest than fixed and opportunity costs. As percentage of total costs, variable costs absorb more than 90 % in intensive and traditional systems, and as much as 82.56 % in semi intensive system. Out of this, about 25 % is spent on purchasing fry. The major component of variable costs is cost of feed accounted for 62.06 %, 54.37 % and 48.04 % for intensive, semi intensive and traditional system respectively. It is interesting to note that proportion of fertilizer cost in cost structure of traditional system is relatively higher than the other two systems. As this culture system relied on natural feed produced in the ponds, it require more fertilizer to grow *klekap*. According to Slamet Suseno (1983), traditional or traditional culture system depends mainly on the natural condition without any assistance from human. In Central Java, however, the practice of tambak operation in this system employes labour as many as intensive and semi intensive systems. The proportion of hired labour cost accounting for 3.33 % is higher than intensive and semi intensive systems.

Fixed costs make up 8.72 %, 16.70 % and 2.75 % of total costs for intensive, semi intensive and traditional systems respectively. For all culture systems, proportion of opportunity costs is very low, accounting for less than 1.00 %.

Like West Java, the tambak operators in East Java who practice traditional system do not feed the milkfish using artificial feeding. The milkfish solely depends on natural food available in the ponds. The total costs on an average one ha tambak per season for intensive, semi intensive and traditional system amounted to Rp 11,584,090, Rp 2,733,785 and Rp 345,230, respectively.

In East Java, management intensity in operating tambak affected not only absolute amount of total costs, but also absolute amount of each cost component. In other words, the absolute amount of each component of cost structure increases as the more intensive management culture practiced.

More than three-fourth of total costs in all management systems is dominated by variable costs. As component of variable costs, purchased fry absorb the highest cost for intensive and traditional systems i.e. 57.80 % and 56.02 %, respectively, while only 27.79 % in semi intensive system. Thehighest proportion in semi intensive system is feed cost accounting for 47.48 %.

Fixed costs consisting of depreciation and land tax are higher for traditional system (16.69 % of total cots) than for semi intensive and intensive systems (16.56 % and 11.03 % of total costs respectively). Proportion of opportunity costs for traditional system is also higher as compared to semi intensive and intensive systems (5.50 % as compared to 3.87 % and 2.51 %, respectively).

### *6.2 Profitability*

The tambak farmers in three provinces observed are able to generate positive operating profit as well as net profit. It means that tambak operation is viable not only in the short-run, but also in the long-run. Furthermore, the tables above show that more intensive system applied, it can generate higher profit. Thus, culture system practiced for tambak operation affects total costs as well as profit earned by farmers.

By practicing intensive system, tambak operators in West Java earn the highest profitability. The calculation in terms of operating profit, net income and net profit, it amounts to Rp 21,000,267, Rp 20,259,589 and Rp 20,186,919 respectively. Although in absolute amount the net profit received by traditional tambak operators is the lowest, the ratio of net profit to gross revenues and to variable costs of this culture system is the highest i.e. 79.56 % and 722.10 %, respectively, as compared to intensive and semi intesive systems. The former indicated that for every Rp 100 received from the sale of the milkfish, tambak operators can obtain a net profit of Rp 79.56. And the latter indicates that for every Rp 100.00 spent on variable costs, the net profit is Rp 722.10. Then, its followed by intensive and semi intensive systems.

The tambak operators in Central Java earn net profits of Rp 26,739,446 (intensive system), Rp 12,374,876 (semi intensive system) and Rp 1,411,548 (traditional system). However, the highest ratio of net profit to gross revenues and to variable costs is generated by practicing semi intensive system, accounting for 74.40 % and 351.97 % respectively.

In East Java, net profit amounted to Rp 41,884,192, Rp 12,222,049 and Rp 422,275 are received by tambak operators who operate intensive, semi intensive and traditional systems, respectively. As like the tambak operators in Central Java, the practice of semi intensive system in East

Java generates the highest ratio of net profit to gross revenues and to variable costs accounting for 81.72 % and 561.85 % respectively. It indicates that farmers who practice this culture system is the most efficient in using inputs. It is followed by intensive and traditional systems.

The comparison among provinces under the culture systems is also carried out in this study. It shows that although tambak operators in East Java who practice intensive system uses the lowest inputs, which is represented by the lowest variable costs, they are superior in generating profit as compared to other provinces. Thus, rate of return of this province is also the highest. It indicates that productivity per unit input in this province is the highest.

By selling the shrimp and milkfish, tambak operators who practice semi intensive system in Central Java receive the highest profitability on an average one ha tambak per season. The rank is then East Java, West Java. However, the highest rate of return in terms of ratio of net profit to gross revenues, to variable costs, to fixed costs and to total costs, is received by tambak operators in East Java. It means that as compared to other provinces observed, tambak operators in East Java use inputs more efficiently.

In practicing traditional system, farmers in West Java and East Java do not feed the milkfish using artificial feed, as mentioned before. In calculating profit, however, there is an interesting information as farmers in West Java are able to generate the highest net profit of Rp 2,488,090 while tambak operators in East Java earn the lowest net profit amounting to Rp 422,275. Furthermore, tambak operators in West Java are also superior in generating the highest ratio of net profit to gross revenues and to variable costs accounting for 79.56 % and 722.10 %, respectively.

## 7. GENERAL DISCUSSIONS

### *7.1 Level of Management and Technology Adaptation*

During the past few years, there have been rapid development in tambak management in most tambak areas of Indonesia. One of the main reasons is the increase of international demand for shrimp production. Many tambak for milkfish are converted into tambak for shrimp, especially of *Penaeus monodon*. The government also persuades tambak operators to increase their productivity through some policies e.g. loan scheme for tambak operation (*TIR = Tambak Inti Rakyat*), training and information aids. Due to the promising price of shrimp in international market, many investors are interested in looking for tambak to be used for shrimp cultivation. This tendency in the short time rises new rich people from tambak operation. But this situation does not last for longer time. Some new comers in tambak operation fall in bankruptcy, since their experience is very limited besides there is sharp fluctuations in the price of shrimp. Shrimp hatcheries shortly became a new promising industry too. And due to the excess supply of benur (shrimp fry) the price of benur dropped. Due to the high demand for shrimp feed, the price of that feed increases sharply. This situation drives investors to set-up shrimp feed factories. Fortunately, these shrimp feed factories commonly are still survive.

The strong or big investors are usually more successful in operating shrimp tambak intensively. They may invest large money in tambak infrastructures and working capital as well. For newly built tambak, their productivity is increasing for the first two or three years, but decreasing again afterwards.

It seems that there is no serius problem in intensive tambak operaration, running hatcheries and shrimp feed factories as well, since in the beginning many of them employed foreign technicians such as from Taiwan and the Philippines. But for small tambak holders the absorption of this new technology does not rapidly happen. They could not afford employing technicians due to the lack of capital and the level of education. Up to now, the extensive or traditional tambak operation is still going on. Commonly, these traditional tambaks are used to cultivate milkfish ( *Bandeng*) as monoculture or as polyculture in combination with shrimp at low stocking density.

### *7.2 Externalities of Tambak Operation*

The rapid conversion of milkfish tambak to intensive shrimp tambak causes some main problems for local (former) tambak operators, social and ecological balances, as well as unexperienced new tambak investors. During the dry season, the water temperature may increase, especially in the shallower part of the pond. For instance, it can be seen in the conversion pond of intensive systems in Java (Brebes region). Providing a deeper pond bottom in this systems remedies the situation and serves as a hiding place for shrimp during a critical pond condition. When necessary, each pond compartment in intensive shrimp culture should have individual water supply and drainage outlets to make them independently from each other and therefore ecological balance in the systems can be sustained. Here, again, the strong aor big investors may much more easily make such adaptation than small tambak holders.

The raid of urban investors to buy or longterm rent for tambak may increase the proportion of landless people in the rural tambak areas. In the short period the former tambak owners become rich which drive their consumeristic consumption pattern. Many of the suddenly rich people could not used their money economically, such that they became poor again. On the other side, still many rural people did not get these windfall profit and were in poor condition. This social imbalance is not easily solved within the short time.

Some types of criminality tends to increase. The robbery of shrimp while in the ponds by force harvesting are more frequently happened. Most of intensive tambak operations have some guards to prevent the robbery or theft, but it may increase the cost of tmabak operation.

The burden of natural environment is becoming heavier. Some mangrove forests are spoilt to provide more land for tambak cultivations or other usages. The rest of shrimp feed and pesticides may deteriorate the quality of water in the surrounding areas. The low condition of the rural roads become worse due the heavier traffic in connection with activities in tambak operations.

### *7.3 Alternatives of Tambak Operation System*

The widely spread of intensive tambak in nearly all main tambak regions combined by the high stocking density of benur on the one hand is able to increase the profitability of tambak operation through the increase of production, but on the

others hand they have some diseconomies. The disturbance to the ecological balance of tambak systems is heavily predominated in some areas. Recent experience in the failure of shrimp cultivation due to the 'virus' epidemy can be exposed as a good example.

The growth of intensive tambak operation should be consistently controlled, especially for densely populated areas like in Java. However, there is natural power helping to do this job, i.e. through the decrease in benur stocking density because of the need to reduce the cost of feed and benur as well. Nowadays, many intensive tambak operation have reduced the high stocking density to the medium level in accordance with adopting most appropriate technology. Eventhough, there is a fall in their profit, many intensive tambak operators are forced to do so to avoid bigger losses by the high fixed cost.

By the reduction in stocking density, in terms of the number of shrimp fry (benur) planted, the management level tambak production would be regarded as semi-intensivesystems. The use of feed and pesticides are not so abundance such that the impact to the natural environment is not so heavy. It sounds that this level of technology adoption becoming the more appropriate technology for most shrimp tambaks in Java and South Sulawesi.

The profitability of semi-intensive tambak is not so high, but usually the risk of failure is also low. And, due to the lower working capital needed, this level of technology adoption is not beyond the reach of local people. These local people are badly needed for protection, otherwise the social turmulence or chaos may occur.

The intensive tambak operation with the main goal to reach high productivity of tambak per se, is still very needed in some selected tambak areas. It seems that the size or scale of intensive tambak operation do not have strong influence to the profitability of those tambak. The large scale tambak operation is rarely met. Most intensive tambak operation can be classified as small to medium scale of operation.

## 8. SUMMARY AND POLICY IMPLICATIONS

The results of this present study indicate that the husbandry management of tambak operation in north coast of Java vary from one region to another and levels of management (traditional, semi-intensive and intensive). This variation may have generated differences in cultured species performance i.e. milkfish and shrimp. It is, however, appreciated that a major limitation of the field study conducted is that the starting materials (inputs) to the systems e.g. stocking density, food and feeding practice, water quality management, pest control and harvesting method for the reaaring cycles recorded will have been very heterogenous from one region to another. These differences, therefore, make strict comparisons impossible and only generalizations can be made.

In general, environmental rearing conditions e.g. temperature, salinity, pH, DO in each level of tambak system (traditional, semi-intensive and intensive) varied. Among observed environmental variables, temperature, salinity, soil texture, and quality and water control structure seem to have a significant role in determining cultured species performance. This is obviously, in turn, influencing the production level in each tambak culture systems during field study.

In most tambak systems in Java no attempt has been made to maintain constant rearing temperatures and salinities. Tambak systems are allowed to remain at the temperature and salinity of the incoming sea water. The field study indicates that temperatures and salinities of tambak systems in Java vary considerably depending upon the season of the year. They can drop as low as 24 - 26 centigrades and 22 - 24 ppt during the peak rainy season and rise to 30 - 32 centigrades and 33 - 34 ppt in the peak dry season. This fluctuation is largely reflected by temperature and salinities in the traditional tambak system. It is, therefore, believed that these environmental variables, together with others such as the husbandry management adopted by tambak operators in each culture systems to have significant roles in determining economic efficiency in tambak enterprise management. These factors, however, are investigated in detail in an attempt to determine economic efficiency for tambak systems in Java.

A key variable suspected of affecting cultured species performance (shrimp) in semi-intensive and intensive tambak systems during the present study is water exchange rate, Most semi-intensive and intensive tambak in Java have adopted so-called "Taiwanese Technique" which is characterized by limited water exchange (10 % - 20 %/day) without disturbing the ecological balanced between larvae, algae, microorganism and organic materials in the systems. Such exchange rate are very low compared to those practiced in the Philippines or Taiwan (30 %/day). Waste products are allowed to

accumulate and decompose in a layer on the tambak bottom. This will obviously generate water quality problems such as increasing levels of ammonia-N and Nitrite-N in the systems as indeed seemed the case in Brebes and Pemalang Counties which is recently invaded by bacterial and viral diseases.

The tolerance of shrimp to ammonia-N-Nitrite-N in tambak systems has not been estimated in Indonesia. Such knowledge might contribute greatly to successful shrimpculture industry in Indonesia. Realizing the importance of this aspect, especially its role in economic efficiency of tambak operation further studies are needed to be done.

The other husbandry parameters that also affecting the economic efficiency of tambak management are stocking density and food and feeding practice. Stocking density is an important faactor that can influence survival aand growth performance of cultured species in tambak systems. The results of this study indicate that with increasing stocking density for intensive culture system, the variable cost will also increase and in turn reduce the ratio of net profit to total costs. It is particularly for the cases in West Java. There is a strong need to determine appropriate stocking density in each management level of tambak systems in Indonesia according to its carrying capacity and productivity level.

As indicated earlier, food and feeding strategies are also one of the parameters that affecting the economic efficiency of tambak management. Food and feeding strategies employed by tambak operators in Java are different. It can be noted that at any one feeding time, the cultured species received several different types of food and that quatity of food given vary from regions to regions. In each level of tambak management, it is often difficult to determine what kinds of food to give, how much to feed and the appropriate time to introduce new feeds (feeding time).

Introducing food at relatively low feeding rate results in cannibalism, while excessive food concentration lead to water quality deterioration and created high mortality. This is quite often the case in semi-intensive and intensive culture systems, as most tambak operators rely upon observation (visual judgement) and experience to determine food and feeding strategies resulting in variation of tambak production. Precise control and regulation of food and feeding strategies in the tambak systems (e.g. semi-intensive and intensive cultures), therefore are particularly important to be done, since they are the most critical husbandry variables in determining the economic efficiency of tambak management and tambak enterprise performance.

In order to optimalize tambak production and economic efficiency, it can be proposed that zonation of tambak areas in Java according to its level of ecological condition and supporting infrastructure in the sites is necessarily to be done. It is especially important to tambak operators e.g. potential investors to determine the selected sites and will significantly affected the tambak enterprise performance.

In conclusion, the optimal rearing conditions and husbandry management practices for tambak operation are still low not completely defined and current rearing practices are very much "rule of thumb". Sufficient scientific data and existing experiences in the field sholud be blended and applied both in apractical and economic way to tambak operation, it would undoubtedly benefit the tambak industry.

## REFERENCES

**Palomares Ma., D. Lourdes** (1985). Developing Countries Dominate the Shrimp Scene In *ICLARM Newsletter* vol. 8(3), July 1985. Metro Manila, Philippines

**Panayotou T.** (1985). Cost Structure And Profitability of Small-Scale Fishing Operations : A Conceptual Framework. In Panayotou, T. (ed.) *Small-Scale Fisheries in Asia : Socio Economic Analysis And Policy.*

**Sadono S.** (1981). Ekonomi Pembangunan (Development Economics) Borta-Gorat, Medan (In Indonesian).

**Sudiyon R.** (1979). Ekonomi Makro : Pengantar Analisa Pendapatan Nasional (Macroeconomics :Introduction toNational Income Analysis) Liberty, Yogyakarta (In Indonesian).

**Sutrisno P.H.** (1981). Dasar-dasar Evaluasi Proyek (Basic Project Evaluation) Faculty of Economics, GadjahmadaUniversity, Yogyakarta (In Indonesian).

# Dynamic Cash Flow Models in Aquaculture: Amplifying the Scope of Managers

**Christopher S. Wright**

Institute of Fisheries Analysis, Simon Fraser University, Burnaby, B.C., USA

ABSTRACT

*Cash flow modeling is a crucial element of successful investment analysis and management. The cash flow models currently available for salmon farms tend to portray fish farm managers as being powerless to manage except in the choice of when to harvest their crop. The limitations of these myopic tools were not important when salmon prices were high and salmon farms could sell all that they could produce. However, as salmon farm profit margins narrow, the need for more powerful and flexible salmon farm management tools grows. Aquaculture, unlike many industries, is not limited to fixed input proportions. The complication of variable input proportions is either a curse or a benefit, depending on a manager's ability. The method of cash flow modeling developed in this paper is more representative of the broad choice of control elements that aquaculture managers have at their disposal. This is accomplished via concepts such as a standard growth function, factor shift functions (for feed ration, water temperature, density, etc.) and the use of bio-age (to free the analysis from the tyranny of the calendar). A well designed cash flow model can be used to simulate a single grow-out cycle of a fish farm. This paper examines various ways that cash flow simulation models can be manipulated and analyzed to provide insights into fish farm management. Selecting and simultaneously solving a few key decision variables over the entire cycle was found to provide a good solution. The information requirements of the cash flow model used in this paper precluded the use of Dynamic Programming.*

## 1. INTRODUCTION

Cash flow modeling is a vital element of successful investment analysis and management. The cash flow models currently available to salmon farms (e.g. Bjørndal, 1990, pp.64-79; Fisheries and Oceans, 1989 and 1990) tend to portray fish farm managers as being powerless to manage, except in choosing when to harvest their crop. However, aquaculture, unlike many industries, is not limited to fixed input proportions.

The variable input proportions that are potentially available in aquaculture can either be ignored (via simplifying assumptions) or managers can accept the more difficult challenge of optimizing over the host of margins that are made possible by varying input proportions.

However, managers can only use the opportunities presented by variable input proportions if they have a means to grasp what happens if specific input proportions are varied by specific amounts. Cash budgets can be adapted to provide that means.

## 2. WHAT IS A CASH FLOW BUDGET

The cash flow budget is a statement of the cash flows due to operations, capital acquisitions and other commitments (paying down of loans, A/P, etc.). Managing cash flows is a vital part of managing an enterprise - a firm that does not meet its cash obligations as they come due goes TECHNICAL BANKRUPT and dies.

A cash budget is (ideally) based on forecast information from all aspects of the enterprise. As a result, if the budgeting process is carefully designed, the cash budget can be a powerful information and evaluation tool for managers.

### *The focus (cost object) of cash budgeting*

A common problem with cash flow budgets in aquaculture is that they define their cost object too broadly[1]. Specifically, cash flow analysis often:

- Encompasses an entire farm or site or (multi-site) company. This melds information from several cohorts and obscures the causal link between outcomes and management choices[2].
- Mixes the effects of investment decisions with the effects of operating decisions. This mix may be of value to potential investors, but it tends to obfuscate the planning and control information needed to operate a farm.
- Hides causal relations in assumptions or formulas and shows only the end cash results of a host of management actions, decisions and/or environmental events.

If managers want to identify and manage the crucial margins in an aquaculture farm, each cash budget should:

i) focus on the progress of a cohort or even a single pen

ii) report only the effects of current operating decisions,

iii) show physical and financial flows, in separate statements (i.e. this provides better management information and provides a means to cross check results), and

iv) distinguish between exogenous factors, decision variables and endogenous variables.

This cash flow approach increases the costs of gathering and rendering operating information. However, it provides a potent source of planning and control information. It should also be noted that, while information gathered at a lower scale (e.g. data on a cohort in a pen) can be combined to provide meaningful information at a higher scale (e.g. the operating results of a farm as a whole or the return on the capital invested in a farm) the reverse process is difficult, if not impossible.

## 3. DEVELOPING A CASH BUDGET TO ANSWER WHAT IF?

The first step in creating a cash flow budget that can answer "what if questions" is to identify the key decision (control) variables. These variables must be optimized simultaneously, rather than iteratively. One way to solve this problem is to;

1. In accouting a *cost object* is a thing or a process for which we want to gather cost information.
2. In biology, a cohort is a group of individuals (within a distinct population), all born during the same time interval.

i) select a single value to be optimized (a proxy),

ii) grid the N-space represented by the feasible set of values for the decision variables,

iii) find the value of the proxy for each grid node, and

iv) identify the maximum or the minimum proxy value in the grid (depending on the nature of the proxy) and use the grid coordinates of that value as the optimum solution.

The number of grid nodes varies exponentially with the number of decision variables and with the tightness of the grid mesh. In this study, there are four key decision variables[3].

If the mesh = 4 ..... nodes = 256 = $4^4$
= 5 ..... nodes = 625 = $5^4$
= 10 ..... nodes = 10,000 = $10^4$
= 100 ..... nodes = 1E8 = $100^4$

As the grid mesh is tightened, the calculation time increases exponentially, but it becomes more likely that the estimated optimum coincides with the global maximum/minimum. However, an optimum is not always the global maximum/minimum. Specifically, in an uncertain world, managers need solutions that are relatively insensitive to minor deviations between the planned and actual values of the decision variables. This desire for well behaved solutions makes an iterative search approach a reasonable way to search for the optimum.

One way of making an iterative-heuristic search for an approximation of the optimum is to;

i) select limits (minimum and maximum values) for each of the decision variables,

ii) use a grid mesh of four, identify the proxy value at each node, select the best proxy value and note the associated coordinates (e.g. the values of the decision variables).

iii) if the improvement in the proxy value is less than two percent of the previous iteration's best proxy value, stop the program and list the coordinates of the current best-proxy-value node, otherwise

iv) reset the upper/lower limit, for each decision variable, one mesh unit above/below that variable's value at the best-proxy-value node and go back to step (b).

This process can be made more elegant if a computer program uses nested loops to:

i) flow from node to node,

ii) compare each node's proxy value with the best previous proxy value examined, and

iii) if the current node's proxy value is better, update the best proxy value and the associated node coordinates.

## 4. WHAT VALUE SHOULD BE OPTIMIZED?

A true optimum involves a multitude of attributes. Managers often express this multitude in the form of a single proxy value. Examples of commonly used proxy values are: NPV (net present value), IRR (internal rate of return), market share, total revenues and average production costs[4].

It is important for decision makers to recognize that, while some proxies are better than others, no proxy is ever perfect. Thus, blindly optimizing a proxy is almost always an inferior substitute for good managerial judgment.

3. Piece Weight at First Thinning, Thinning Rate, Ration (e.g. the conversion rate) and Number of Smolts,
4. Only out-of-pocket costs during the current growth cycle are considered in this analysis - other costs are not relevant because they normally cannot be changed during one growth cycle.

This analysis looks at two proxy values: NPV and PV (present value) average cost. The second proxy provides a minimum risk stance, but fails to maximize wealth. NPV includes the output prices and thus maximizes the expected wealth. However, this strength is also a weakness - a dramatic shift in output prices can make an earlier NPV based strategy a path to calamity.

## 5. THE CASH FLOW MODEL

Details on the mechanics of the cash flow model are available, from the author. The model is designed to meet the criteria in listed in subsection 2.0, and has the following features:

i) Growth is a nonlinear function of the feed ration, water temperature, mean piece starting weight and density. The model is stabilized by first expressing the growth rate as a function of standardized conditions and then using nonlinear indexes to adjust the growth to the nonstandard conditions actually experienced.

ii) The fish are feed a ration based on the ration rate times the expected net growth in kilograms. The expected growth is estimated by converting the period starting weight to bio-age (the age the fish would have achieved that weight under standard conditions and a feed ration of 1).

iii) At low densities, the mortality rate looks constant, but as density increases the mortality rate increases exponentially. Mortality in the first month after smolting is assumed to be five percent.

iv) The piece weight is distributed around the mean weight, the market price ($/kg) varies with piece weight and thinning takes the larger fish, first[5].

v) Only out-of-pocket operating costs during the cycle are considered. Some costs (e.g. wages) have a component that is incurred during a period, even if there are no fish.

vi) The turn-around time for the pens is assumed to be one month and any costs during that month are non-incremental and are excluded from the analysis. Thus, the effective operating cycle is 11, 23 or 35 months. The example model uses a 23 months in a two year production cycle.

vii) Variables are held constant for discrete periods of one month. This simplifies the analysis in this illustrative example. However, in an actual operating situation it may be more appropriate to use discrete periods of one week.

The cash flow model and the driving program (described in subsection 3.0) were programed using Framework IV (1991) - one of the few spreadsheet packages with a programming capability.

A baseline for evaluating results was established by setting the decision variable values at those used by Bjørndal (1990, p.96). Using those values the result is:

Proxy Values: NPV = $603,000 and PV Cost/Kg = $3.331
Decision Variables: Piece Weight at First Thinning = 3.06,
Thinning Rate = 100%,
Ration (conversion rate) = 1.7,
Number of Smolts = 180,000.

## 6. THE RESULTS OF CONSTANT RATE DECISION VARIABLES

One approach to the decision variables is to fix their values over the entire growth cycle. When the decision variables are set so as to maximize the NPV, the result is:

5. The model assumes that more agressive fish grow faster bacause they get mode feed, get bigger, get more feed, etc. The removal of large fish enables smaller fish to get more feed and grow faster - increasing the cycle NPV.
An alternative view is that some fish grow faster because of genetics. If this view is correct, thinning the larger fish may reduce the cycle NPV. Research is needed to determine which effect is dominant.

Proxy Values: NPV = $1,257,000 and PV Cost/Kg = $3.009
Decision Variables: Piece Weight at First Thinning = .71,
Thinning Rate = 6.28%,
Ration (conversion rate) = 1.46,
Number of Smolts = 547,000.

When the decision variables are set so as to minimize the PV of the average cost, the result is:

Proxy Values: NPV = $658,000 and PV Cost/Kg = $2.551
Decision Variables:
Piece Weight at First Thinning = .76,
Thinning Rate = 1.00%,
Ration (conversion rate) = 1.03,
Number of Smolts = 237,000.

*Constant rate decision variables - constrained optimization*

There is a trade-off between the proxies; maximizing for NPV causes costs to rise 18.0 percent over the minimum PV average cost; minimizing the PV average cost reduces the NPV TO 52.3 percent of the maximum NPV. As output price rises, these trade -offs are likely to become greater.

One way of resolving this trade-off problem is to optimize one proxy subject to an inequality constraint on the associated changes in the other proxy.

In Table 1, the first five columns of values represent the efficient frontier of the possible trade-offs between NPV and PV average cost (i.e. return vs risk). Figure 1 illustrates this trade off as an efficient frontier.

This analysis can also be adapted to review a large range of possible strategies. Specifically, a program can be written to record the coordinates of all nodes where the NPV and PC average cost are within prespecified limits. This approach would be particularly useful for *contrarians* (i.e. those who pursue a strategy of not doing what most others are doing)

## 7. PERIOD BY PERIOD OPTIMIZATION

Ideally, decision variable values should be optimized for each period in the growth cycle. However, there are 23 months in a two year growth cycle. Based on the cash flow model associated with best NPV results reported in Subsection 6.1, 15 of the 23 production months have thinning. The thinning rates in those 15 months are all decision variables, as are the ration rate and the number of smolts. A mesh of four lines applied to the 17 decision variables creates 1.7E10 (417) nodes - an unmanageably high number of calculations[6].

Separating the optimization process into period by period segments is difficult - *the opportunity cost* of *harvesting* or *not harvesting* a fish is only fully defined in the last period.

*Period by period optimization - dynamic programming*

A variant of dynamic programming is one way of resolving such problems[7]. However, per feature (d) in subsection 5.0, for any period, the starting mean piece weight depends on the starting population structure. This means that the harvest decision in the prior period must be known in the period under consideration - which precludes the use of dynamic programing.

6. The example model (on an i486, 33MHZ PC using Framework IV, 1991) examines 8.2 nodes per minute and would take just under 4,000 years to do one pass through the nodes.
7. Dynamic programing is a maximization theory that enables one to maximize over a whole series of states (time or other) where the results in each state are dependent to some degree on decisions that have been made in earlier states.
Rather than starting which a known present and planning to an unknown future, *Dynamic Programing* works from a known future point (a budgeted output) toward a malleable present and defines what is needed to acieve the future goal.

Dynamic programming can be used as a planning tool if:

i) The size distribution is assumed away. However, that simplification may eliminate useful information.

ii) The farm does not thin the stock in the months before harvest. However, that simplification may greatly reduce the cycle NPV.

iii) The thinning takes a representative sample of the size distribution of the population. However, that simplification may remove a potentially lucrative effect (feature c, Subsection 5).

Thus, dynamic programming appears to be an inappropriate planning process for the type of cash flow statement used in this study. However, the use of dynamic programming may be appropriate for other types of cash flow statements or conditions.

## 8. PERIOD-SPECIFIC THINNING

Thinning acts as a stabilizing influence (Section 5, feature c). Therefore, it is reasonable to start with the Section 6 optimal result and to optimize the thinning rate for each of the months where thinning takes place. When that optimization process is applied twice, the result is:

Proxy Values: Cycle NPV = $1,276,000 and PV Cost/Kg = $2.951
Decision Variables: Thinning Percent by Month:

| | |
|---|---|
| MONTH 5 Apr. | Cycle Start |
| MONTH 12 Dec. | 3.3% |
| MONTH 13 Jan. | 5.9% |
| MONTH 14 Feb. | 4.1% |
| MONTH 15 Mar. | 4.0% |
| MONTH 16 Apr. | 5.3% |
| MONTH 17 May | 5.9% |
| MONTH 18 Jun. | 7.3% |
| MONTH 19 Jul. | 8.7% |
| MONTH 20 Aug. | 9.6% |
| MONTH 21 Sep. | 9.4% |
| MONTH 22 Oct. | 6.1% |
| MONTH 23 Nov. | 5.8% |
| MONTH 24 Dec. | 5.7% |
| MONTH 25 Jan. | 10.0% |
| MONTH 26 Feb. | 6.1% |
| MONTH 27 Mar. | 100.0% |
| Ration ..... | 1.420 |
| Number of Smolts ..... | 532,000 |

In the example model, this iterative process involved a lot of effort/time and generated a meager 1.5% gain (1276/1257 - 1).

## 9. CONCLUSIONS

Aquaculture managers should seek ways to tap the potential of the cash budget as an information and evaluation tool.

Cash budgets have an immense potential to simulate the complex multiphase situations often found in aquaculture, can use several criteria when seeking budget solutions and can be adapted to show their solutions in a cash flow and/or physical flow form. The use of a cash flow simulation decision tool is also cost effective in that it generates the cash flow budget that would be needed not matter what decision tool is used.

The development and use of a cash flow simulation decision tool helps managers to visualize, in advance:

i) What decision variables are important.

ii) What cash flow and physical flow effects will arise from various decisions.

iii) The timing of when decision need to be made and/or prediction verified.

Actual period by period results can be fed into the cash flow simulation decision tool to rapidly update forecasts and to enable managers to make the best of a bad situation or to make a good situation better.

In the example analysis, the cash flow simulation generated an array of high NPV and low PV average cost solutions (Table 1) where the NPVs were all much higher than the baseline NPV and the PV average costs were all significantly below the baseline PV average cost. It should be noted that the thinning effects that give rise to these solutions would not be apparent in a poorly designed cash flow simulation tool.

Cash flow simulation, ideally, should be used as an aid to explore new ways to manage - it is a tracing board rather than a blue print. This approach of tracing out possible future will be of particular use to Contrarians (i.e. those who pursue a strategy of not doing what most others are doing).

## REFERENCES

**Austreng E., T. Storebakken and T. Åsgård** (1987). Growth Rate Estimates for Cultured Atlantic Salmon and Rainbow Trout. *Aquaculture.* Vol. **60**: 157-160.

**Bjørndal T.** (1990). *The Economics of Salmon Aquaculture.* Blackwell Scientific Publications. London.

**Fisheries and Oceans** (1989). *Financial Analysis of Salmon Farming in Coastal British Columbia.* Economic & Commercial Analysis, Report No. 54. Prepared by: B.D. Egan, H.M. Egan and B.F. Wright. Dec.

**Fisheries and Oceans** (1990). *Financial Analysis of Atlantic Salmon Farming in Coastal British Columbia.* Economic & Commercial Analysis, Report No. 95. Prepared by: B.D. Egan and B.F. Wright. Sep.

**Framework III** (1988). An Integrated Software Package - Spreadsheet, Graphics, Word Processor, Data Base and Programming Language. Ashton-Tate. Torrance, California.

**Framework IV** (1991). An Integrated Software Package. Borland/AshtonTate. Torrance, California.

**Gulland J.** (1983). *Fish Stock Assessment: A Manual of Basic Methods.* FAO/Wiley series on food and agriculture. John Wiley & Sons. Toronto, Ont.

**Papoutsoglou S., E. Papaparaskeva-Papoutsoglou and M. Alexis.** (1987). Effect if Density on Growth Rate and Production of Rainbow Trout Over a Full Rearing Period. *Aquaculture.* Vol. **66**: 9-17.

**Ricker W.** (1975). Computation and Interpretation of Biological Statistics of Fish Populations. *Bull. Fish. Res. Board Can.* Vol. **191.**

**Storebakken T. and E. Austreng** (1987a). Ration Level for Salmonids I. Growth, Survival, Body Composition, and Feed Conversion in Atlantic Fry and Fingerlings. *Aquaculture.* Vol. **60**: 189-206.

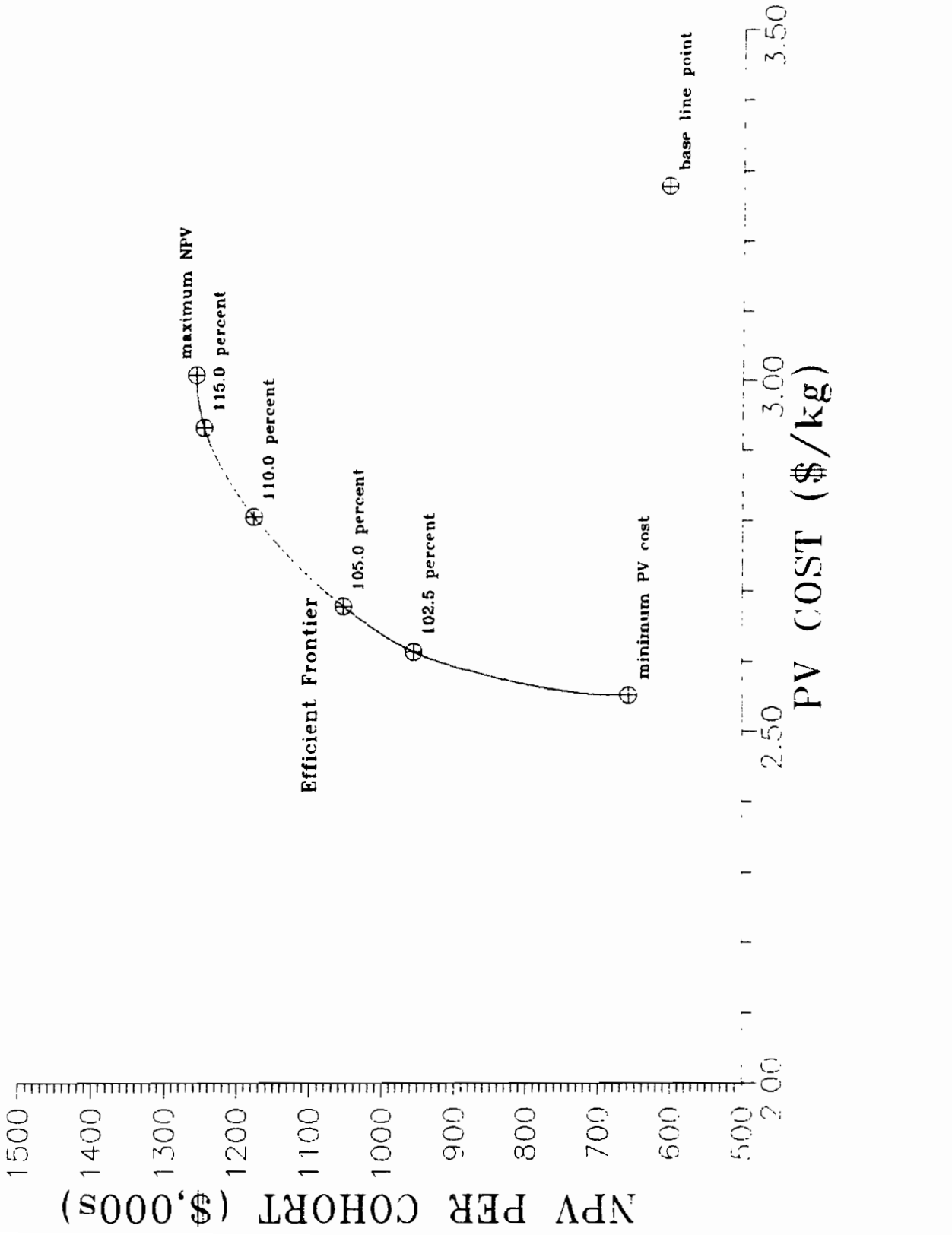
**Storebakken T. and E. Austreng** (1987b). Ration Level for Salmonids II. Growth, Feed Intake, Protein Digestibility, Body Composition, and Feed Conversion in Rainbow Trout Weighing 0.5-1.0 Kg. *Aquaculture.* Vol. **60**: 207- 221.

**Thomson R.E.** (1981). *Oceanography of the British Columbia Coast.* Department of Fisheries and Oceans, Canadian Special Publication of Fisheries and Aquatic Sciences 56. Sidney, B.C.

**TABLE 1.**
**MAXIMIZING NPV, SUBJECT TO VARIOUS CONSTRAINTS ON THE CHANGE IN THE PV OF THE AVERAGE COST.**

| | PV AVERAGE COST THE FOLLOWING PERCENT OF MINIMUM PV AVERAGE COST | | | | | | BASELINE RESULTS |
|---|---|---|---|---|---|---|---|
| PV AVG COST -- INDEX | 100.0% | 102.5% | 105.0% | 110.0% | 115.0% | 118.0% | 130.6% |
| -- $/kg | $2.551 | $2.614 | $2.678 | $2.806 | $2.933 | $3.009 | $3.331 |
| NPV -- ACTUAL ($ ,000s) | $658 | $955 | $1,054 | $1,177 | $1,246 | $1,257 | $603 |
| -- INDEX | 52.3% | 76.0% | 83.9% | 93.6% | 99.2% | 100.0% | 48.0% |
| Piece Wt @ 1st Thinning | .76 | .76 | .76 | .68 | .71 | .71 | 3.06 |
| Thinning Rate | 1.00% | 4.20% | 5.25% | 5.99% | 6.03% | 6.28% | 100.00% |
| Ration (Conversion Rate) | 1.03 | 1.10 | 1.11 | 1.23 | 1.39 | 1.46 | 1.70 |
| Number Of Smolts (,000s) | 237 | 384 | 480 | 565 | 545 | 547 | 180 |

**FIGURE 1.**
**MAXIMIZING NPV VS MINIMIZING PV UNIT COST.**



## APPENDIX A: CASH FLOW MODEL - PHYSICAL FLOWS, FIRST 10 MONTHS

| DATE - Month & Year | May 1992 | Jun 1992 | Jul 1992 | Aug 1992 | Sep 1992 | Oct 1992 | Nov 1992 | Dec 1992 | Jan 1993 | Feb 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| - Month | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| I EXOGENOUS FACTORS: | | | | | | | | | | |
| - Months Since Start | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| - Water Temperature (°C) | 6.9 | 8.3 | 11.7 | 13.8 | 12.4 | 8.7 | 6.9 | 6.1 | 5.8 | 5.2 |
| - Mortality Rate | 5.0% | 1.50% | 1.50% | 1.50% | 1.50% | 1.54% | 1.76% | 2.44% | 2.51% | 2.47% |
| - Start Piece Weight (Kg) | .007 | .027 | .069 | .153 | .286 | .444 | .582 | .706 | .780 | .849 |
| II CONTROL VARIABLES: | | | | | | | | | | |
| - Pen Volume ($m^3$) | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 |
| - Starting # of Pieces | 547,000 | 519,650 | 511,855 | 504,177 | 496,614 | 489,155 | 481,620 | 473,127 | 432,598 | 395,238 |
| - Starting Biomass (Kg) | 3,829 | 14,066 | 35,399 | 77,109 | 142,003 | 216,945 | 280,471 | 333,826 | 337,351 | 335,530 |
| - Starting Density ($Kg/m^3$) | .142 | .521 | 1.311 | 2.856 | 5.259 | 8.035 | 10.388 | 12.364 | 12.494 | 12.427 |
| - Ration (Piece Conv. Rate) | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 |
| III ENDOGENOUS VARIABLES: | | | | | | | | | | |
| - Start Bioage (Months) | 8.6 | 9.4 | 10.2 | 11.2 | 12.2 | 13.2 | 14.0 | 14.6 | 14.9 | 15.2 |
| - Piece Growth Rate | | | | | | | | | | |
| -- Standard | 436.50% | 204.06% | 122.97% | 79.94% | 56.20% | 43.30% | 36.50% | 32.19% | 30.08% | 28.36% |
| -- Temp. Index | 46.33% | 53.98% | 70.43% | 79.19% | 73.46% | 56.07% | 46.33% | 41.71% | 39.93% | 35.98% |
| -- Density Index | 99.84% | 99.40% | 98.50% | 96.73% | 93.98% | 90.81% | 88.11% | 85.85% | 85.70% | 85.78% |
| -- Ration Index | 142.01% | 142.01% | 142.01% | 142.01% | 142.01% | 142.01% | 142.01% | 142.01% | 142.01% | 142.01% |
| -- Index Achieved | 286.70% | 155.49% | 121.14% | 86.96% | 55.10% | 31.30% | 21.16% | 16.37% | 14.62% | 12.43% |
| - Achieved Growth (Kg) | .020 | .042 | .084 | .133 | .158 | .139 | .123 | .115 | .114 | .106 |
| - Preharvest: | | | | | | | | | | |
| -- Mortality (Pieces) | 27,350 | 7,795 | 7,678 | 7,563 | 7,458 | 7,535 | 8,493 | 11,540 | 10,876 | 9,781 |
| -- End # of Pieces | 519,650 | 511,855 | 504,177 | 496,614 | 489,156 | 481,620 | 473,127 | 461,587 | 421,722 | 385,457 |
| -- Feed Use (Kg) | 15,627 | 31,694 | 62,141 | 97,168 | 113,387 | 98,391 | 85,883 | 78,801 | 71,094 | 60,149 |
| -- End Piece Weight (Kg) | | | | | | | | | | |
| • Mean Average | .027 | .069 | .153 | .286 | .444 | .582 | .706 | .821 | .894 | .954 |
| • Smallest .5 % | .006 | .015 | .034 | .063 | .097 | .128 | .155 | .180 | .196 | .209 |
| • Next 35.0 % | .018 | .045 | .101 | .188 | .292 | .383 | .464 | .540 | .588 | .628 |
| • Next 54.5 % | .030 | .076 | .168 | .314 | .486 | .639 | .774 | .900 | .980 | 1.047 |
| • Next 9.0 % | .045 | .114 | .252 | .470 | .729 | .958 | 1.160 | 1.350 | 1.470 | 1.570 |
| • Largest 1.0 % | .062 | .159 | .352 | .658 | 1.021 | 1.341 | 1.625 | 1.891 | 2.058 | 2.198 |
| -- End Biomass (Kg) | 14,066 | 35,399 | 77,109 | 142,003 | 216,945 | 280,471 | 333,826 | 378,991 | 376,944 | 367,909 |
| - Harvest: | | | | | | | | | | |
| -- Percent of End Pieces | .00% | .00% | .00% | .00% | .00% | .00% | .00% | 6.28% | 6.28% | 6.28% |
| -- Total Pieces | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28,988 | 26,484 | 24,207 |
| -- Distribution (Pieces) | | | | | | | | | | |
| • Smallest .5 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • Next 35.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • Next 54.5 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • Next 9.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24,372 | 22,267 | 20,352 |
| • Largest 1.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,616 | 4,217 | 3,855 |
| -- Total Kilograms | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41,640 | 41,414 | 40,422 |
| - Post Harvest -- Pieces | 519,650 | 511,855 | 504,177 | 496,614 | 489,155 | 481,620 | 473,127 | 432,598 | 395,238 | 361,249 |
| -- Kilograms | 14,066 | 35,399 | 77,109 | 142,003 | 216,945 | 280,471 | 333,826 | 337,351 | 335,530 | 327,487 |
| -- Mean Wt | .027 | .069 | .153 | .286 | .444 | .582 | .706 | .780 | .849 | .907 |
| -- Actual Conv. Rate | 1.526 | 1.486 | 1.490 | 1.497 | 1.513 | 1.549 | 1.610 | 1.745 | 1.796 | 1.858 |

## APPENDIX B: CASH FLOW MODEL - CASH FLOWS, FIRST 10 MONTHS

| DATE - Month & Year<br>- Month | May 1992<br>5 | Jun 1992<br>6 | Jul 1992<br>7 | Aug 1992<br>8 | Sep 1992<br>9 | Oct 1992<br>10 | Nov 1992<br>11 | Dec 1992<br>12 | Jan 1993<br>13 | Feb 1993<br>14 |
|---|---|---|---|---|---|---|---|---|---|---|
| I BIOLOGICAL FACTORS: | | | | | | | | | | |
| - Months Since Start | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| - Start Mean Weight (Kg) | .007 | | | | | | | | | |
| - Preharvest: | | | | | | | | | | |
| -- # of Pieces | 519,650 | 511,855 | 504,177 | 496,614 | 489,156 | 481,620 | 473,127 | 461,587 | 421,722 | 385,457 |
| -- End Piece Weight (Kg) | .027 | .069 | .153 | .286 | .444 | .582 | .706 | .821 | .894 | .954 |
| -- Stock Value per Kg: | | | | | | | | | | |
| • Smallest .5 % | 1.738 | 1.762 | 1.807 | 1.878 | 1.961 | 2.032 | 2.095 | 2.153 | 2.188 | 2.218 |
| • Next 35.0 % | 1.768 | 1.836 | 1.969 | 2.171 | 2.397 | 2.585 | 2.744 | 2.886 | 2.972 | 3.042 |
| • Next 54.5 % | 1.797 | 1.910 | 2.124 | 2.442 | 2.786 | 3.060 | 3.284 | 3.479 | 3.594 | 3.686 |
| • Next 9.0 % | 1.834 | 2.000 | 2.311 | 2.755 | 3.213 | 3.563 | 3.836 | 4.064 | 4.196 | 4.298 |
| • Largest 1.0 % | 1.877 | 2.105 | 2.522 | 3.094 | 3.652 | 4.053 | 4.352 | 4.590 | 4.722 | 4.823 |
| -- Stock Value: | | | | | | | | | | |
| • Smallest .5 % | 27 | 68 | 153 | 292 | 466 | 625 | 767 | 895 | 904 | 895 |
| • Next 35.0 % | 5727 | 14968 | 34958 | 70976 | 119725 | 166931 | 210886 | 251812 | 257942 | 257698 |
| • Next 54.5 % | 15109 | 40400 | 97895 | 207262 | 361122 | 512920 | 655207 | 787907 | 809633 | 810475 |
| • Next 9.0 % | 3819 | 10479 | 26374 | 57914 | 103182 | 147910 | 189556 | 228010 | 234105 | 234082 |
| • Largest 1.0 % | 608 | 1716 | 4478 | 10118 | 18242 | 26178 | 33454 | 40058 | 40988 | 40857 |
| • Total | 25290 | 67632 | 163857 | 346563 | 602738 | 854565 | 1089870 | 1308682 | 1343572 | 1344006 |
| II HARVEST: | | | | | | | | | | |
| - Pieces | | | | | | | | | | |
| • Smallest .5 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • Next 35.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • Next 54.5 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • Next 9.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24,372 | 22,267 | 20,352 |
| • Largest 1.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,616 | 4,217 | 3,855 |
| • Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28,988 | 26,484 | 24,207 |
| III CASH FLOW | | | | | | | | | | |
| Harvest Revenues | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 173826 | 178328 | 178188 |
| Operating Costs: | | | | | | | | | | |
| - Smolts | 382900 | | | | | | | | | |
| - Feed | 17971 | 36448 | 71462 | 111743 | 130395 | 113150 | 98766 | 90622 | 81758 | 69172 |
| - Salaries & Wages | 5563 | 7169 | 10214 | 13717 | 15339 | 13839 | 12588 | 11880 | 11109 | 10015 |
| - Maintenance & Misc. | 356 | 517 | 821 | 1172 | 1334 | 1184 | 1059 | 988 | 911 | 801 |
| - Harvest & Processing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28028 | 25607 | 23405 |
| TOTAL COSTS | 406790 | 44134 | 82497 | 126632 | 147067 | 128173 | 112413 | 131518 | 119385 | 103394 |
| Net Income/(Loss) | -406790 | -44134 | -82497 | -126632 | -147067 | -128173 | -112413 | 42308 | 58943 | 74794 |
| NPV ($000s; @.5% per month) | 1,257.387 | | | | | | | | | |
| IIR -- regular | | | | | | | | | | |
| -- Modified (safe i = 6%) | | | | | | | | | | |
| PV of Production Cost/kg | $3.01 | | | | | | | | | |

# Elaboration d'un modèle bio-économique dynamique relatif à l'élevage de la palourde de l'Atlantique *(Spisula solidissima)*

**Michel Martin, James R. Wilson, Louise Dufresne, Lucien Adambounou and Roxanne Bouchard ***

Université du Québec à Rimouski 300, allée des Ursulines Rimouski, (Québec), Canada, G5L 3A1

RÉSUMÉ

*Dans la plupart des pêcheries, la sélectivité, à partir de la taille des espèces pêchées, est difficilement applicable. Par contre, en aquiculture, la détermination de la taille pour un marché déterminé constitue un avantage majeur. Toutefois, cet avantage comparatif peut comporter des coûts considérables en terme d'intrants, comme par exemple, l'énergie.*

*La contrainte énergétique est particulièrement évidente dans les pays froids. Afin de minimiser les impacts négatifs de cette contrainte, il serait tout à fait opportun de développer des marchés pour les jeunes individus. En effet, la croissance est beaucoup plus rapide dans les premiers stades de la vie des individus et l'apport énergétique s'en trouve, de ce fait, réduite (toute proportion gardée). De plus, il est envisagé de produire ces individus durant la saison "chaude". (de mars à octobre). Tel que déjà démontré dans la littérature bio-économique des pêches, un propriétaire seul peut choisir de surexploiter une population donnée, et ainsi satisfaire les conditions d'optimalité relatives au taux de croissance du stock et au taux d'intérêt. Le même comportement est observé dans le secteur de l'aquiculture, et pour les mêmes raisons. En aquiculture, les taux d'intérêt élevés aussi bien que les coûts de l'énergie nous incitent à modifier la fonction de croissance d'une espèce et à développer des marchés pour des produits se situant dans la structure d'âge juvénile.*

*Cette analyse explore, notamment, les relations fondamentales entre les coûts de l'énergie, les taux d'intérêt et les stratégies de marketing relatives à la taille, en utilisant les données de croissance en milieu contrôlé de la palourde de l'Atlantique (Spisula solidissima). Pour ce faire, nous utilisons les méthodes dynamiques de programmation linéaire.*

*De façon plus spécifique, l'analyse porte sur les cycles de production optimaux dans un horizon de temps à l'infini, lorsque les marchés existent pour les juvéniles et lorsque les taux d'intérêt et les coûts de l'énergie changent.*

* Nous tenons à souligner la précieuse collaboration de messieurs Louis Bernier et Réal Fournier de l'Institut National de la Recherche Scientifique (Océanologie), Rimouski, ainsi que la participation des étudiants de micro-économie des ressources maritimes, automne 1991.

*D'un point de vue plus pratique et en supposant que les hypothèses soient vérifiées, les stratégies de marketing adoptées par les pays affectés par des coûts d'énergie et des taux d'intérêt élevés, tendront vers la production de juvéniles ; les pays ayant des taux d'intérêt et/ou des coûts d'énergie moins élevés ne seront pas dans l'obligation d'adopter ces stratégies.*

## 1. INTRODUCTION

Actuellement, les stocks de palourdes de l'Atlantique (dans les eaux québécoises) sont à un niveau tel qu'il serait non-rentable et dangereux pour la survie de l'espèce de les exploiter. Quelques auteurs (dont Bernier et Poirier, 1979) ont démontré que l'espèce n'est pas suffisamment dense pour justifier une exploitation commerciale intensive. L'alternative la plus logique serait d'en faire l'élevage soit en milieu naturel, soit en milieu contrôlé, ou les deux. Il a d'ailleurs été démontré (Malouf et Bricelj, 1989) que *Spisula solidissima* est celui qui a le plus fort taux de croissance parmi les bivalves. Bien entendu, la rentabilité d'une telle activité n'est pas démontrée et passe nécessairement par plusieurs variables : prix du produit brut ou transformé, coût de l'énergie, fonction de croissance de la palourde, etc. Ce document consiste donc à dégager ces variables et à analyser la rentabilité d'un élevage de palourde au Québec, en évaluant le comportement dynamique du modèle que nous aurons construit au préalable.

Pour ce faire, il s'agit de mettre en place tous les outils nécessaires afin de réaliser une étude économique portant sur le taux de croissance de la palourde en milieu contrôlé, sur les coûts de production et sur les marchés existants et/ou potentiels. Nous avons, au préalable, développé une technologie d'élevage de la palourde que nous croyons réaliste, et sur laquelle sera basée notre étude. Par la suite, nous utiliserons la programmation linéaire pour déterminer les cycles de production optimaux qui maximiseront la valeur actuelle des profits. Il est aussi prévu d'effectuer une analyse de sensibilité sur certaines variables telles que les taux d'intérêt, les prix du produit brut et les coûts de l'énergie hydro-électrique.

## 2. MÉTHODOLOGIE

Afin de mieux cerner tous les éléments qui composent notre modèle bio-économique, il est opportun de faire une revue théorique des hypothèses qui sont à la base de notre étude. D'abord, nous avons simulé les dynamiques de production d'une entreprise qui fait l'élevage de palourdes dans un horizon de temps à l'infini, c'est-à-dire que cette entreprise existe depuis toujours et qu'elle existera toujours. Nous prenons en quelque sorte une photographie (qui couvre 19 mois, commençant en janvier) de cette entreprise et nous analysons son comportement dans un contexte dynamique (c'est-à-dire que nous débutons une nouvelle cohorte à chacun des 19 mois). Nous pouvons donc, de cette façon, éliminer les biais causés par les investissements de départ et les frais de fermeture au début et à la fin de la vie de cette entreprise.

Ces dynamiques de production se réflètent dans le choix des variables et leur coefficient qui composent la fonction objective et les contraintes de notre programme linéaire. De façon plus pratique, il s'agit de construire sur le logiciel Quattro-pro, un programme linéaire dont les coefficients des différentes variables peuvent être rapidement modifiés. La nécessité d'utiliser l'informatique s'explique par le fait que notre modèle est composé de 646 variables de décision (dans la fonction objective) et de 396 contraintes. Par exemple, il fallait recalculer rapidement tous les coefficients des variables concernées en modifiant le taux d'intérêt de 8 % à 30 % et par la suite, "exporter" le nouveau programme linéaire de Quattro-pro vers Lindo. Ce dernier logiciel permet de traiter les programmes linéaires en maximisant la fonction de profit (dans notre cas) et en déterminant les cycles de production optimaux. De façon générale, l'utilisation de la programmation linéaire dans un contexte dynamique est conceptuellement simple mais implique un grand nombre de calculs mathématiques qui nécessitent le support de certains logiciels.

### *2.1 Le modèle*

Le problème est décrit comme étant :

$$Max \sum_{i=0}^{18} \sum_{j=1}^{17} \sum_{k=3}^{18} - \delta_i(B_i) - C_i(M_i H_j) + R_{i,k}(M_i S_k) \quad \forall i, j, k . \tag{1}$$

Sous contraintes de :

$$\sum_{j=1}^{17} M_i H_j - \sum_{k=3}^{18} M_i S_k \leq 200 \qquad \forall i, j, k \qquad i = 0, 1, \ldots, 18 \tag{2}$$

$$-B_i + M_{i+1} H_j = 0 \qquad i = 0, 1, \ldots, 17 \; ; \quad j = 1 \tag{3}$$

$$-M_i H_1 + M_{i-1} H_2 = 0 \qquad \forall i \; ; \qquad i = 0, 1, \ldots, 17 \tag{4}$$

$$-M_i H_j + \alpha M_{i-1} H_{j+1} + \alpha M_{i+1} S_k = 0$$
$$i = 0, \ldots, 17 \quad j = 2, \ldots, 16 \quad k = 3, \ldots, 17 \quad \alpha = 0.5, 1 \quad k = j + 1 \tag{5}$$

$$-M_i H_{17} + M_{i+1} S_{18} = 0 \qquad i = 0, 1, \ldots, 17 \tag{6}$$

$$M_0 H_j - M_{18} H_j = 0 \qquad j = 1, 2, \ldots, 17 \tag{7}$$

$$M_0 S_k - M_{18} S_k = 0 \qquad k = 3, 4, \ldots, 18 \tag{8}$$

$$\sum_{j=1}^{17} M_i H_j + \sum_{k=3}^{18} M_i S_k \leq 200 \qquad i = 0, 1, \ldots, 18 \tag{9}$$

### 2.1.1 La fonction objective (Équation # 1)

i représente chacun des mois de la période concernée

j représente l'âge (en mois) des individus gardés

k représente l'âge (en mois) des individus vendus

$\delta_i$ représente le prix d'achat actualisé des larves

$B_i$ est la variable qui représente le choix d'acheter ou de produire des larves de palourdes ($2 \times 10^6$) au début de chacune des périodes.

$C_i$ représente les coûts de production mensuels par raceway, pour chacune des périodes, et cela afin garder un inventaire de palourdes ($M_i H_j$). Un raceway est un contenant qui sert à faire l'élevage de mollusques. Ses dimensions sont de 2440 mm de longeur, 920 mm de largeur et 200 mm de hauteur. Les coûts sont fonction de la période (i).

$M_i H_j$ est la variable qui représente le choix de garder un inventaire plutôt que de le vendre. Par exemple, $M_1 H_{16}$ signifie qu'au mois de février, l'on peut garder les individus âgés de 16 mois.

$R_{i,k}$ correspond aux revenus actualisés tirés de la vente de palourdes pour chacun des âges par raceway. Il faudra tenir compte ici de la taille des individus (cf. fonction de croissance).

$M_i S_k$ est la variable qui représente le choix de vendre un inventaire

Dans tous les cas, les choix d'acheter, de garder ou de vendre se font au début de chacune des périodes. La valeur de la fonction objective représente les profits nets actualisés maximaux que peut tirer un entrepreneur faisant l'élevage de la palourde. Ces profits sont tirés des opérations courantes de l'entreprise et ne tiennent pas compte des impôts et de l'amortissement d'un immeuble principal. Ils peuvent être représentés par l'équation suivante :

$$Max\ \Pi_a = R_a - C_a - B_a \tag{10}$$

Afin de bien saisir les dynamiques de production ainsi que le sens de chacune des variables, nous avons diminué la taille du problème de 19 à 4 mois (cette nouvelle situation est purement hypothétique et n'a pour but qu'une meilleure compréhension). La période considérée couvre donc les mois de janvier, février, mars et avril. Tel qu'illustré au tableau 1, cela nous permet d'effectuer les analyses dans une période d'activité normale (où toutes les cellules sont remplies) et ceci afin d'éviter les biais du début et de la fin de la vie de l'entreprise.

On établit la règle suivante : on garde nécessairement les post-larves, les premier et deuxième mois de vie des individus (parce que trop petit pour la vente). Le troisième mois, on peut soit vendre, soit garder les individus qui sont âgés de 3

mois. Le quatrième mois, on vend nécessairement les individus. On remarque que les variables qui sont situées dans les cellules grisées proviennent de cohortes qui ont été débutées avant la période d'analyse. Cela est le résultat de la planification dans un horizon de temps à l'infini ; c'est plus précisément la partie-$\infty$. Dans l'exemple du TABLEAU 1, la fonction objective deviendrait :

$$\text{Max} - \delta_0(B0) - C_0(M0H1) - C_0(M0H2) - C_0(M0H3) + R_{0,3}(M0S3) + R_{0,4}(M0S4) - \delta_1(B1) - C_1(M1H1) - C_1(M1H2) - C_1(M1H3) + R_{1,3}(M1S3) + R_{1,4}(M1S4) - \delta_2(B2) - C_2(M2H1) - C_2(M2H2) - C_2(M2H3) + R_{2,3}(M2S3) + R_{2,4}(M2S4) - \delta_3(B3) - C_3(M3H1) - C_3(M3H2) - C_3(M3H3) + R_{3,3}(M3S3) + R_{3,4}(M3S4)$$

ainsi $\delta_i = 500/(1+t)^i$ et $\delta_i$ = Prix d'achat des larves, actualisé.
$C_i = C_i/(1+t)^i$ $C_i$ = Coût selon le mois i, actualisé.
$R_{i,k} = R_k/(1+t)^i$ $R_{i,k}$ = Revenu à l'âge k, actualisé.

De cette façon, les coefficients des variables de la fonction objective sont facilement modifiables. En changeant, par exemple, le taux d'actualisation de 8 % à 7 %, tous les coefficients des variables de la fonction objective sont presque aussitôt modifiés, puisque les cellules sur Quattro correspondent à des formules mathématiques et sont reliées entre elles.

### 2.1.2 Les contraintes

Les contraintes sont divisées en 4 principaux groupes .

- Tout d'abord l'**équation # 2** fait référence à la disponibilité des ressources matérielles. On considère ici que l'on ne peut opérer que 200 raceways (ce qui est plausible, compte tenu de la technologie retenue. Le fait de garder le contenu d'un raceway en inventaire pour un mois additionnel, implique que le nombre de raceways disponibles est réduit d'une unité. Par contre, l'action de vendre le contenu d'un raceway libèrera ce raceway pour être utilisé ultérieurement.

- Le deuxième groupe de contraintes (**les équations #3, #4, #5 et #6**) sont les équations de transfert entre les périodes. Elles expliquent le rôle de la fonction de croissance et l'impact qu'a cette fonction sur la planification du calendrier en ce qui concerne le partage des individus d'un raceway vers d'autres raceways. Dans cette optique, on doit interpréter $\alpha$ comme la règle suivante : A partir de 1 mm, à chaque fois que la taille des individus double, nous dédoublons les raceways où $\alpha = 0.5$ (L. Bernier). Dans tous les autres cas, $\alpha = 1$. Les objectifs visés par ce groupe de contraintes sont de "suivre" les individus entre les périodes et de maximiser l'espace disponible de chacun des raceways.

- Le troisième groupe de contraintes (**l'équation #7 et #8**) concerne les conditions initiales et terminales (i.e. inventaire et vente au début et à la fin de la période de référence). Dans le contexte de la programmation linéaire, le choix des conditions initiales et terminales de notre problème pose un difficulté théorique. Il a été démontré (cf Wagner, 1977) que des spécifications arbitraires des conditions initiales et terminales impliquent également une valeur arbitraire de la fonction objective (en valeur actuelle nette des profits), ainsi que du cycle de production optimal. Ainsi, un modèle dont les conditions initiales seraient différentes des conditions terminales, n'aurait pas d'utilité pour la gestion. Les recommandations de McCarl et Spreen (1989) semblent appropriées dans ce contexte. Ils suggèrent d'égaler les conditions initiales et terminales de façon à les rendre moins contraignantes ; dans notre cas, l'inventaire et les ventes du début sont égaux à ceux de la fin et cela pour chaque cohorte.

- Le quatrième groupe de contraintes (**l'équation #9**) est aussi relatif à la disponibilité des ressources. Sans ces contraintes, nous aurions obtenu un très grand nombre de raceways dû au dédoublement de ces derniers. Cette équation limite à 200 raceways les opérations de garde, de vente et de dédoublement de raceways.

## 3. LES RÉSULTATS

### *3.1 La fonction de croissance*

Pour répondre plus adéquatement à notre question de rentabilité, il fallait développer une fonction de croissance de la palourde, à partir de données limitées. L'unité de mesure des transactions étant le $U.S. par boisseau (le boisseau est une

mesure de volume et est égal à 36,36 l.), il nous faut connaître la taille (longeur), la largeur et la hauteur des individus en fonction de leur âge. Il est donc essentiel d'estimer une fonction de croissance en milieu contrôlé et pour ce faire, nous avons utilisé les données brutes de la Station aquicole de Pointe-au-Père (les 55 premiers jours après fécondation) ainsi que celles de Goldberg (1980) pour compléter la série de données jusqu'à un an. La régression non-linéaire (à partir du logiciel NCSS) a été utilisée pour estimer le modèle de Richards (figure 1) et la forme générale est :

$$L_t = A * [\, 1 + (B - 1) * e^{-c * (t - D)} \,]^{\frac{1}{1 - B}} \qquad (11)$$

où
$A = 106.5 \quad 6.1$
$B = -0.57 \quad -1.6$
$C = 0.0019 \quad 1.8$
$D = -121.6 \quad -0.5$

$L_t$ est la taille à l'âge t, A est la longeur asymptotique et C est le taux de croissance.

*3.2 Les revenus*

Les revenus tirés de la vente des palourdes sont fonction de la taille des individus (selon le modèle de Richards) ainsi que de la mortalité et des manipulations lors des tamisages. L'estimation de la mortalité est d'au moins 75 % durant la période larvaire (de 0 à 21 jours). Les données prélevées (L. Bernier, 1992) à la Station aquicole nous indiquent que l'écart-type de la taille des palourdes est très prononcé. Cela justifierait un taux de perte élevé (25 % jusqu'à 11 mois et 5 % de 12 à 18 mois) lors des tamisages. Ces taux incluent aussi les individus morts qui ont été rejetés aux tamisages. Les cylindres de 275 mm. ont été utilisés pour l'élevage en monocouche des palourdes. 24 cylindres peuvent être placés dans chacun des raceways pour une superficie totale disponible de 1,425,500 mm.ca. Il est aussi suggéré que l'espace occupé par les palourdes ne doit pas dépasser cette dernière mesure. L'on doit toutefois s'en rapprocher le plus possible afin de maximiser l'espace disponible. Le Tableau 2 illustre les opérations nécessaires à l'évaluation de la valeur d'un raceway en fonction de la taille des palourdes. Le prix obtenu pour un boisseau de palourdes (peu importe la taille) est d'approximativement $85.00 US. On ne tient pas compte ici de la saisonnalité des prix.

*3.3 Les coûts de production*

Outre l'achat des lots de larves (à $500.00 du lot), nous pouvons classifier les coûts de production en 4 catégories. Les coûts de l'énergie hydro-électrique, les coûts de la main d'oeuvre, les coûts de production de phytoplancton et nourriture lyophilisée ainsi que les coûts du matériel et entretien général. Il est à noter que nous avons estimé tous les coûts afférents à un système de production performant. Les coûts mensuels suivants ont été estimés pour l'ensemble des 200 raceways :

i) Énergie hydro-électrique : entre $777. (juillet) et $2,590 (janvier)

ii) Main-d'oeuvre : $6,000.

iii) Phytoplancton et algues lyophilisées : $1,252.

iv) Matériel et entretien général : $1,762.

Le Tableau 3 est relatif aux coûts de production par raceway et pour chacun des mois de la période de référence.

*3.4 Sommaire des résultats*

La valeur de la fonction objective (ou profits actualisés maximaux) est de **$2,519.** pour un taux d'actualisation de 8 %. Ce dernier montant est insuffisant pour "rencontrer" les amortissements sur l'immeuble principal, payer les impôts et effectuer un réinvestissement éventuel des profits dans l'amélioration du système de production. Par ailleurs, selon le cycle de production illustré à la figure 3, il serait illogique d'initier un élevage de palourde. En effet, acheter un lot de larves au mois 12, et vendre des individus âgés de 6 mois aux mois 0 et 18 ne constitue pas un cycle de production

intéressant. Nous remarquons aussi que les palourdes ne sont vendus qu'à l'âge de 6 mois. Cela est principalement dû au fait qu'il y a un dédoublement de raceways au $7^{ième}$ mois et que, par conséquent, la valeur ($45.64) d'un raceway au $6^{ième}$ mois est plus grande que la valeur ($33.11) au $7^{ième}$ mois. L'effet du taux d'actualisation ainsi que les coûts de production plus élevés durant les mois "froids" influencent aussi la décision de vendre des juvéniles âgés de 6 mois. Dans les conditions actuelles, le projet est **non-rentable**.

## 4. ANALYSE DE SENSIBILITÉ

Dans le but d'éprouver la validité du modèle et de connaître la sensibilité de certaines variables, nous ferons varier certains paramètres. Par exemple, en diminuant les coûts de l'énergie hydro-électrique de 50 % (on peut imaginer l'utilisation de capteurs solaires), les profits passent de $2,519 à $3,074. Cela représente un coefficient d'élasticité de -0.44, et le cycle de production demeure le même que précédemment. Cette variable est très peu sensible et le projet n'est toujours pas rentable. En augmentant le prix de vente de 50 % (de $85 à $127.50), les profits augmentent à $11,271., et le cycle de production est le même. Le coefficient d'élasticité est de 6.95. Cette variable est donc beaucoup plus sensible que les coûts d'électricité et les profits commencent à être intéressants. Le cycle de production est toujours inintéressant.

Dans un autre ordre d'idée, il peut être opportun de simuler les conditions qui prévalent dans certains pays en développement. Les coûts d'énergie et de main-d'oeuvre y sont souvent plus bas et les taux d'intérêt plus élevés (ou très variables). Nous considérons ici une espèce différente de *Spisula solidissima*, mais ayant des caractéristiques semblables. En diminuant les coûts de production de 50 % (par rapport aux données du Québec) et en conservant un taux d'actualisation de 8 %, nous enregistrons des profits de $26,807. et le cycle optimal est illustré à la figure 4 (les chiffres au-dessus des histogrammes correspondent au nombre de raceways vendus). Nous sommes déjà dans la voie de la rentabilité et la production se fait de façon plus continue. En conservant des coûts de production diminués de 50 % et en augmentant le taux d'actualisation à 50 % (taux souvent rencontré en Amérique du Sud), notre profit est de $19,512. et le cycle de production est illustré à la figure 5. Il est intéressant de constater que la production a tendance à se "contracter" sur une plus courte période.

## 5. CONCLUSION

On ne peut que constater la non-rentabilité d'un élevage de palourdes dans un pays où les coûts de production sont élevés et surtout où la valeur marchande de ce produit est faible. Quelques alternatives sont à considérer. Par exemple, il serait possible de débuter les opérations en milieu contrôlé et de les terminer en milieu naturel. Les coûts de production seraient alors diminués ; par contre, la croissance des individus diminuerait (voir le modèle de Von Bertalanffy de la figure 2). Il serait aussi avantageux de développer des marchés de consommation où la valeur serait augmentée. Du seul point de vue de la programmation linéaire, il est optimal de vendre des juvéniles âgés de 3 cm (ou 6 mois) mais cela peut ne pas correspondre aux besoins du marché. Par exemple, le marché de "frais" est plutôt orienté vers les juvéniles de 5 cm (ou 11 mois). En "forçant" la vente d'individus plus âgés, nous réduirions alors la valeur de la fonction objective, ce qui est non souhaitable.

Dans les pays "chauds", l'élevage d'une espèce apparentée à *Spisula solidissima*, peut toutefois être rentable. La programmation linéaire nous suggère alors de produire des juvéniles dans un court laps de temps, lorsque les taux d'intérêt sont élevés. Dans les deux cas, il semble que le prix de vente des palourdes soit le facteur déterminant dans la recherche d'une plus grande rentabilité. Dans le secteur de l'aquiculture, il apparaît que l'utilisation d'une technologie avancée et coûteuse trouve sa justification dans la mise en marché d'un produit de haute valeur.

## REFERENCES

**Bernier L. et L. Poirier** (1979). Évaluation sommaire du stock des mactres de l'Atlantique, *Spisula solidissima,* des Iles-de-la-Madeleine. M.I.C., Dir. Gén. des Pêches marit., Dir. Rech., *Cah. inf.* **92,** 42 p.

**Brêthes J.-C. et R.N. O'Boyle** (1990). Méthodes d'évaluation des stocks halieutiques. Vol. 1. pp. 279-313

**Caddy J.F. et A.R. Billard** (1976). A first estimate of production from an unexploited of the bar clam, *Spisula solidissima. Fish Mar. Serv. Res. Dev. Tech. Rep.* **648,** 13 p.

**Gendron L.** (1988). Exploitation et état du stock de mactres *(Spisula solidissima)* des Iles-de-la- Madeleine en 1986. Rapport manuscrit canadien des sciences halieutiques et aquatiques. no 1993, 17 p.

**Goldberg R.** (1980). Biological and technological studies on the aquaculture of yearling surf clams. Part 1 : Aquaculture production. *Proceedings of the National shellfisheries association,* **70 :** pp. 55-60.

**Manzi J.J. et M. Castagna** (1989). *Clam mariculture in North America.* Elsevier Science publishers B.V. 261 p.

**McCarl B.A. et T.H. Spreen** (1989). *Applied mathematical programming.* Texas A.M. University Press.

**Stamatopoulos C. and J.F. Caddy** (1989). Estimation of von Bertalanffy growth parameters : A versatile linear regression approach. -J. *Cons. int. Explor. Mer,* pp. 200-208

**Wagner H.M.** (1977). *Principles of operation research.* Prentice Hall, Englewood Cliffs, N.J., 1032 p.

TABLEAU 1.
MODÉLISATION DYNAMIQUE DANS UN HORIZON DANS UN HORIZON DE TEMPS À L'INFINI.
MATRICE DES VARIABLES.

| | 0<br>Janvier | 1<br>Février | 2<br>Mars | 3<br>Avril | 4<br>Mai | 5<br>Juin | 6<br>Juillet |
|---|---|---|---|---|---|---|---|
| Achat<br>Vente<br>Garder | B0<br><br>M0H1 | <br><br>M1H2 | <br>M2S3<br>M2H3 | <br>M3S4 | | | |
| Achat<br>Vente<br>Garder | <br>M0S4 | B1<br><br>M1H1 | <br><br>M2H2 | <br>M3S3<br>M3H3 | <br>M4S4 | | |
| Achat<br>Vente<br>Garder | <br>M0S3<br>M0H3 | <br>M1S4 | B2<br><br>M2H1 | <br><br>M3H2 | <br>M4S3<br>M4H3 | <br>M5S4 | |
| Achat<br>Vente<br>Garder | <br><br>M0H2 | <br>M1S3<br>M1H3 | <br>M2S4 | B3<br><br>M3H1 | <br><br>M4H2 | <br>M5S3<br>M5H3 | <br>M6S4 |

**TABLEAU 2.**
**ÉVALUATION DE LA VALEUR D'UN RACEWAY DE PALOURDES EN FONCTION DE LA TAILLE DES INDIVIDUS.**

| Age (jours) | Taille (mm) | Nombre individus après mortalité | Nombre d'individus après tamisage | Nombre d'individus après dédoublement | Volume total (mm.cu.) (Note 1) | Nombre de boisseaux | Valeur par raceway ($ US) |
|---|---|---|---|---|---|---|---|
| 0 | | 2,000,000 | | | | | |
| 30 | | 500,000 | 375,000 | | | | |
| 60 | | | 281,250 | 140,625 | | | |
| 90 | | | 105,469 | 52,734 | | | |
| 120 | 6.44 | | 39,551 | 19,775 | 9.05E+05 | 0.02 | 2.12 |
| 150 | 18.99 | | 14,832 | 7,416 | 8.71E+06 | 0.24 | 20.36 |
| 180 | 27.35 | | 5,562 | 5,562 | 1.95E+07 | 0.54 | 45.64 |
| 210 | 34.09 | | 4,171 | 2,086 | 1.42E+07 | 0.39 | 33.11 |
| 240 | 39.81 | | 1,564 | 1,564 | 1.69E+07 | 0.47 | 39.57 |
| 270 | 44.82 | | 1,173 | 1,173 | 1.81E+07 | 0.50 | 42.34 |
| 300 | 49.27 | | 880 | 880 | 1.81E+07 | 0.50 | 42.20 |
| 330 | 53.28 | | 660 | 660 | 1.71E+07 | 0.47 | 40.01 |
| 360 | 56.91 | | 627 | 627 | 1.98E+07 | 0.55 | 46.33 |
| 390 | 60.23 | | 596 | 596 | 2.23E+07 | 0.61 | 52.16 |
| 420 | 63.26 | | 566 | 566 | 2.46E+07 | 0.68 | 57.44 |
| 450 | 66.06 | | 538 | 538 | 2.66E+07 | 0.73 | 62.12 |
| 480 | 68.64 | | 511 | 511 | 2.83E+07 | 0.78 | 66.20 |
| 510 | 71.03 | | 485 | 485 | 2.98E+07 | 0.82 | 69.69 |
| 540 | 73.24 | | 461 | 461 | 3.10E+07 | 0.85 | 72.59 |

Note 1 : Le volume d'une palourde est V = 4/3*π*a*b*c où a, b, c sont les semi-axes

**TABLEAU 3.**
**COÛTS DE PRODUCTION PAR RACEWAY PAR MOIS.**

| Mois | Coûts ($ US) | Mois | Coûts ($ US) |
|---|---|---|---|
| Janvier | 58.02 | Novembre | 58.02 |
| Février | 58.02 | Décembre | 58.02 |
| Mars | 58.02 | Janvier | 58.02 |
| Avril | 55.43 | Février | 58.02 |
| Mai | 50.25 | Mars | 58.02 |
| Juin | 48.95 | Avril | 55.43 |
| Juillet | 48.95 | Mai | 50.25 |
| Août | 48.95 | Juin | 48.95 |
| Septembre | 48.95 | Juillet | 48.95 |
| Octobre | 50.25 | | |

FIG. 1.
CROISSANCE DE SPISULA SOLIDISSIMA EN MILIEU CONTROLE

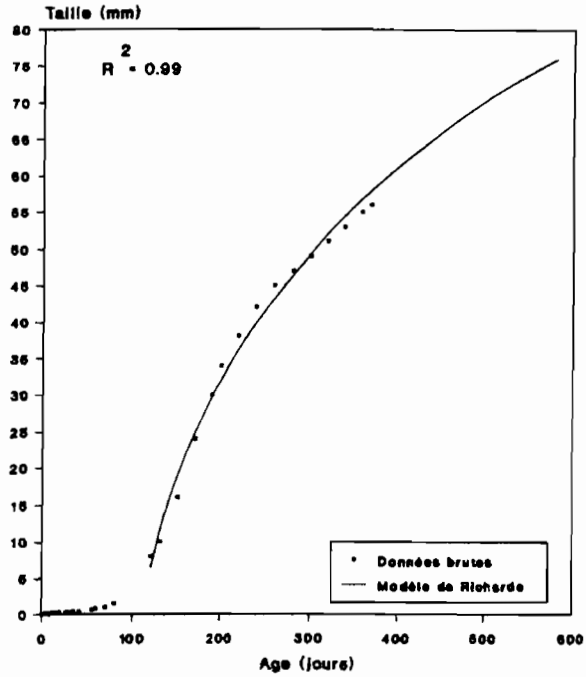



FIG. 2.
CROISSANCE DE SPISULA SOLIDISSIMA EN MILIEU NATUREL

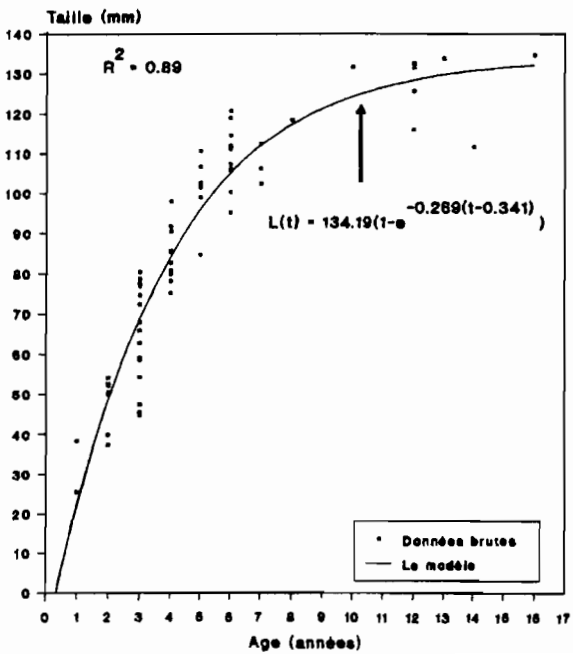


FIG. 3.
CYCLE DE PRODUCTION - TAUX D'ACTUALISATION = 8% - SELON LA TECHNOLOGIE RETENUE

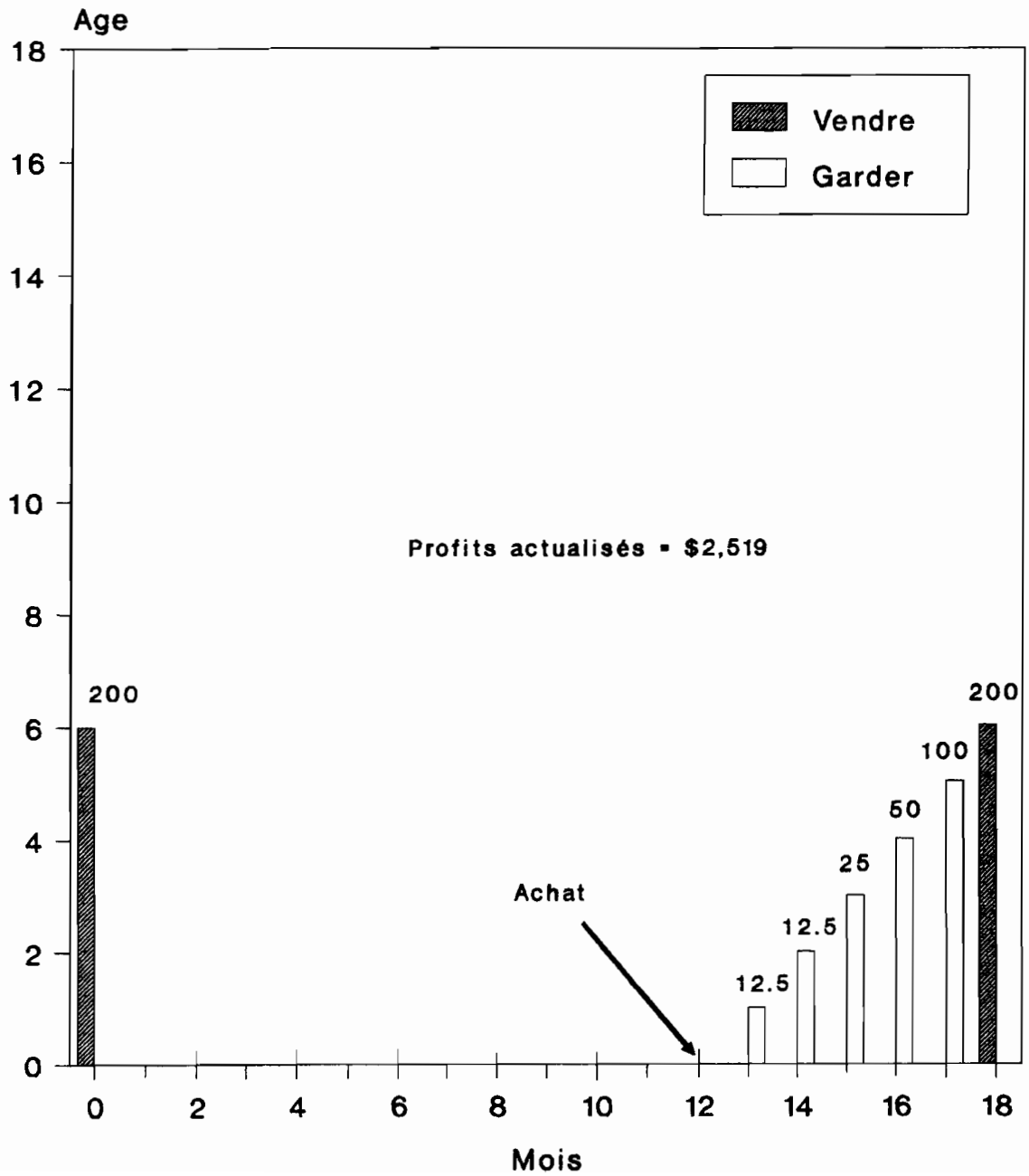


FIG. 4.
CYCLE DE PRODUCTION - TAUX D'ACTUALISATION = 8% - COUTS DE PRODUCTION REDUITS DE 50%

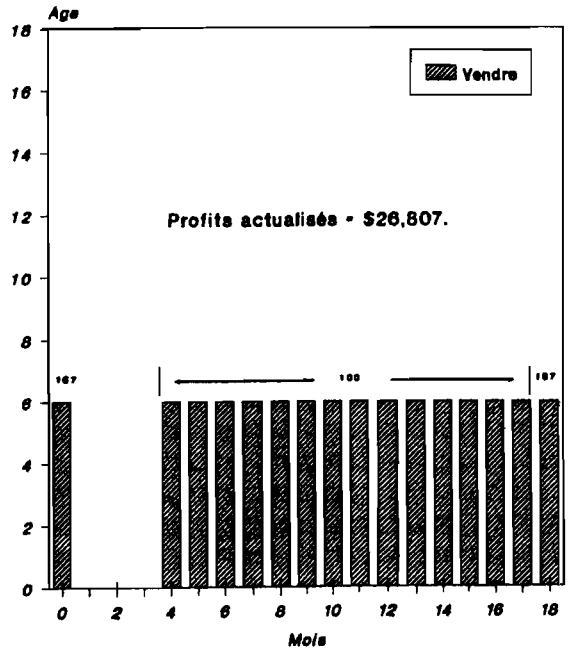
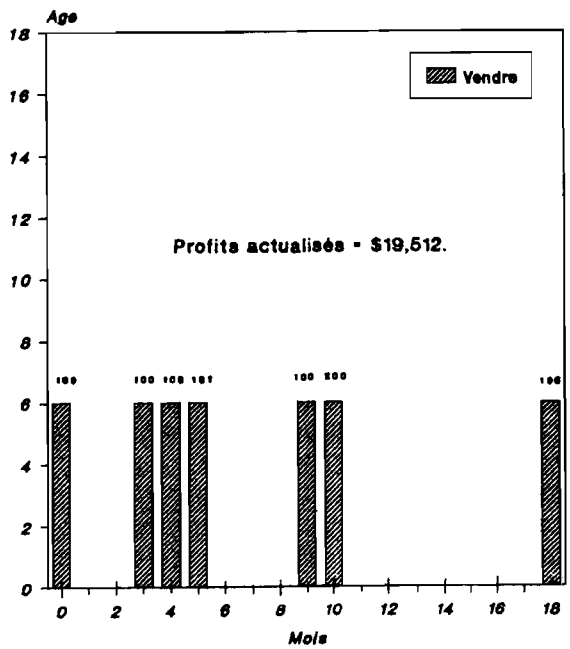



FIG. 5.
CYCLE DE PRODUCTION - TAUX D'ACTUALISATION = 50% - COUTS DE PRODUCTION REDUITS DE 50%



# A Model for the Optimal Management of Sea-Bass Aquaculture

**Gian Franco Rizzo and Massimo Spagnolo ***

IREPA Via Benedetto Croce, Italy

ABSTRACT

*A bio-economic model for the simulation and the optimal management of a plant for Sea-Bass aquaculture is presented. Growth and mortality, considered as a Markovian process, are described by a biological sub-model, taking into account the effects of water temperature, feeding level, oxygen content and water supply. Stochastic effects in growth and mortality, relating to the effects of genetic differences, can be also considered in the model. An economic sub-model evaluates costs and revenues relating to plant management.*

*The model exhibits satisfactory capabilities in predicting the effects of operating variables on fish growth and in determining the optimal strategies for plant management in different scenarios.*

## 1. GENERAL

In recent years, many applications of mathematical models to aquaculture management have been described in literature. General overviews are reported by Leung [1986] and Piedrahita [1988]. A model for simulation and optimal management of salmon aquaculture is described by Bjorndal [1990]. A prawn production management system has been modeled by Leung and Shang [1989], within a dynamic Markov decision approach. Similar methods have been adopted for the optimization of production planning in trout farm [Sparre]. Other models have been applied to social and economic aspects of aquaculture activity [IRPAI, 1990].

An important contribution to the study of sea-bass aquaculture has been given by Querellou [1984], which has proposed simple relationships among growth, mortality and water temperature, for sea-bass populations. This model, not even

* the authors wish to express their gratitude to G. Bonfiglio and F.Massa (AGEI, Rome) for their cooperation in this research.

considering all the physiological and biological aspects involved, can predict with acceptable precision growth and mortality in typical plants. Nevertheless, it does not represent a tool directly usable to define optimal management strategies, since it does not consider all biological, operating and economic aspects involved in sea-bass aquaculture.

The models described in literature, applied to different species, exhibit significant differences in structure and complexity. It emerges the unavailability of a model directly usable for the optimal management of aquaculture plants for species like sea-bass and sparus aurata and, moreover, of any comprehensive model able to represent all aquaculture systems.

A model for the simulation and optimization of sea-bass aquaculture plants has been then proposed, composed of a stochastic Markovian biological sub-model and an economic sub-model. The biological part is based on the model proposed by Querellou [1984], integrated by further relationships to consider feeding levels, oxygen consumption and additional mortality due to harvesting and fish-pond transfer. This base model has been then included in a stochastic model, in order to describe growth and mortality variability due to genetic and environmental conditions through a Markovian transition matrix. An economic sub-model expresses revenues due to harvesting and costs for stocking, food, water supply, auxiliary oxygenation, water heating and fixed costs.

## 2. A MODEL FOR SEA-BASS AQUACULTURE

The model is based on a biological sub-model, obtained starting from the relationships validated by Querellou [1984], which essentially describes the effects of water temperature on growth and the physiological mortality. This model has been integrated by further relationships in order to consider feeding levels, oxygen consumption and additional mortality relating to pond transfer. The model takes also into account stochastic effects on growth due to genetic and environmental factors according to a Markovian process [Leung and Shang, 1989, Sparre]. An economic sub-model describes revenues and the most relevant costs relating to aquaculture management, i.e. recruits, feeding, water and oxygen supply, water heating, fixed costs. The model, which can be used for both simulation and optimization analysis, is formulated according to the following assumptions :

(i) A population of sea-basses is considered, distributed in different ponds according to weight classes. The entire process is described, starting from recruitment of fries. Multiple production cycles can be also considered.

(ii) Time horizon is divided in periods in which both external variables (temperatures, prices, costs) and decision variables can be considered constant. The presented results refer to a time horizon of 2 years, divided in 24 periods of one month.

(iii) It is assumed that a whatever fraction of the biomass contained in the last $N_c$ weight classes can be harvested, and that it can be sold at a variable price independent on the supplied biomass. An additional mortality, proportional to the harvested biomass, is considered for the fish left in the ponds.

(iv) The recruits exhibit homogeneous genetic behavior and weight distribution, and their price is independent from demand.

(v) Each fish pond is defined by a minimum and a maximum weight class; biomass which exceeds maximum weight can be transferred to the next pond with continuity, in each period. An additional mortality affects the transferred biomass.

Fish farming process can be depicted as a multi-stage dynamic system (fig.1) where each stage represents a period of the process. For the K-th stage, output variables $L_k$ and state variables $x_{k+1}$, input for the next stage, are determined as a function of external variables $v_k$, decision variables $u_k$ and state variables $x_k$.

Fig 2 shows the detailed structure of an elementary stage with the relationships among external decision and state variables on the biological, technical and economic aspects.

### *2.1 The biological sub-model*

The following relationships hold for the average weight of a sea-bass population [Querellou, 1984] :

$$P = k\,(S_{01})^x \tag{1}$$

where :

$$S_{01} = \sum_{i=t0}^{tl} T'_t$$

with $t_0 = 0$, $t_1$ = fish age

$k = 0.9\ 10^{-8}$, $x = 2.81$, $T' = (T - 10)/\omega$,

with $\omega = 1$ if $T > 10$ and $\omega = 5$ if $T < 10$

The term $S_{01}$ represents the sum of the daily temperatures T' in the period $t_0$-$t_1$. The equation (1) can be rearranged in order to evaluate the weight $P_2$ at the time $t_2$, starting from the weight $P_1$ at $t_1$ and from the term $S_{12}$ referring to the daily temperatures T' between $t_1$ and $t_2$ :

$$P_2 = k(S_{02})^x = k(S_{01} + S_{12})^x$$

Where $S_{01}$ can be evaluated as

$$S_{01} = (P_1/k)^{1/x}$$

In order to take into account the effects on growth of the feeding level $F_m$ (see par.2.6.), a further term ($F_m$) has been considered, not present in the original relation proposed by Querellou :

$$P_2 = k(S_{01} + S_{12})^x\ \phi(F_m) \tag{2}$$

A simple linear relation with feeding level has been assumed :

$$\phi(F_m) = F_m \tag{3}$$

The followed approach is consistent with the assumption of Markovian process. That is, the growth, in a given period, depends only on the environmental variables (temperatures, feeding) in that period and on the initial fish weight (state variable), irrespective of how long each fish used to reach the initial weight $P_1$. The Markovian assumption is enough realistic in typical and well-kept fish farms and has been commonly adopted by other modelers [Sparre, Leung and Shang, 1989].

With regard to mortality, one should distinguish between a mortality due to particular pathologies and a physiological one. The former is not considered in the present model, since it substantially influences growth mechanism and requires ad hoc remedies. The monthly amount of physiological mortality is estimated by the following relationship :

$$TM_1 = a/N^b/100 \tag{4}$$

Where N is the fish age (months), a is the mortality rate for the first month and b is an exponent relating to fish farming conditions. The following values have been suggested for sea-bass aquaculture [Querellou, 1984] :

$a = 4$, $b = 1.17$ (optimal conditions)
$a = 7$, $b = 0.7$ (poor conditions)

Fish age can be computed from its weight $P_1$ by the relationship :

$$30\ N\ (\overline{T} - 10) = S_{01} = (P1/k)^{1/x} \tag{5}$$

Where T represents the average temperature in the period $t_0$ $t_1$. Physiological mortality coefficient $TM_2$ and $TM_3$ express mortality due to harvesting and to fish transfer between ponds ; they are proportional respectively to the fractions of harvested and transferred biomass in the previous period :

$$TM_2 = B_c / B_k \chi_2 \tag{6}$$

$$TM_3 = B_{tr} / B_k \chi_3 \tag{7}$$

The total mortality coefficient $TM_T$ can be then evaluated, for each weight class :

$$TM_T = TM_1 + TM_2 + TM_3 \tag{8}$$

The mortality probability in the given period is :

$$P_m = TM_T N_g / 30 \tag{9}$$

*2.2 The Markovian matrix*

Mortality and transition from a weight class to others are described by a two dimension Markovian matrix M, where $M_{i,j}$ indicates the probability that fish belonging to i-th weight class will grow to the j-th class during a given period and $M_i$, $N_{cl}$ represents probability of death. It is assumed that in each period, fish can either stay in the same class, grow to a larger class or die. Therefore, only the terms $M_{i,j}(i \leq j \leq N_{cl+1})$ are greater than zero and their sum is 1.

Matrix M has been evaluated considering normal distribution of weight P around its average value provided by (2). For a given standard deviation SD and for the weight classes $j \geq i$, the area $A_j$ subtended by probability curve which lies in the j-th class can be evaluated.

Probability $p_j$ is proportional to area $A_j$. In order to avoid that unrealistic growth velocities can be considered for an even small part of the biomass, the probability $p_j$ corresponding to areas less than a threshold values $c_3$ are considered zero. Therefore :

$$\begin{aligned} p_j &= 0 \quad \text{if } j < i \\ p_j &= A_j \quad \text{if } j \leq i \text{ and } A_j \geq C_3 \\ p_j &= 0 \quad \text{if } j \leq i \text{ and } A_j < C_3 \end{aligned} \tag{10}$$

Standard deviation SD is computed as :

$$SD = c_1 \Delta P_i + C_2 (P - P_i) \tag{11}$$

where $P_i$ and $\Delta P_i$ are average weight and width of the i-th class and P is the weight at the end of the i-th period. SD is then composed of two terms : the former is proportional to weight class width and reduces the effect of discretization, due to the fact that the average weight $P_i$ is associated to all the biomass in the i-th class ; the latter term is proportional to the predicted growth, and then represents the scattering due to environmental and genetic differences.

The terms of Markovian matrix for the given i-th weight class are then computed by the following relationships :

$$M_{i,j} = 0 \qquad j < i \tag{12}$$

$$M_{iJ} = (1 - p_m)\, p_j / \sum_{k=1}^{N_{cl}} pk \qquad j = i, \quad N_{cl} \tag{13}$$

$$M_{i,\, Ncl+1} = p_m \tag{14}$$

*2.3 Biomass evaluation*

The following data are considered known :

- the number of the weight classes $N_{ci}$ and their upper limit ; the average value is :

$$P_i = (P_i^* - P_{i-1}^*) / 2 \qquad (P_0 = 0) \tag{15}$$

- the number of fish ponds $N_v$, their volume $V_{v,j}$ and the minimum and maximum weight class referring to each fish pond ;

- the maximum allowable density per pond $\delta_{max}$ ;

- the weight distribution $F_{st,i}$ for the recruits among the first $i_{st}$ classes :

$$\sum_{i=1}^{i_{st}} F_{st,i} = 1 \tag{16}$$

$$F_{st,i} = 0 \qquad i = i_{st} + 1, N_{cl} \tag{17}$$

- the minimum class for harvesting $i_c$ ;

- the length of a period $D_p$ and the number of periods $N_p$ considered in the time horizon ;

- the distribution of temperature $T_k$ and fish prices $Pr_k$ in the $N_p$ periods ;

- the distribution of the decision variables in the $N_p$ periods (harvesting levels $\alpha_k$, stocking level $\beta_k$, feeding level $I_K$, pond temperature increase) ; in case of optimization analysis, these values are assumed as initial values for the iterative process leading to the optimal values ;

- biomass $B_1$ at the beginning of the process and the vector $x_{i,1}$ describing the initial fish distribution among the $N_{cl}$ weight classes ; it holds :

$$\sum_{i=1}^{N_{cl}} x_{i,1} = 1 \tag{18}$$

- the daily amount of food to furnish, as a function of fish weight and water temperature ;

- unit costs for feed $C_m$ and recruits $C_{st}$ .

The initial number of fishes $S_1$ can be evaluated as :

$$S_1 = \frac{B_1}{\sum_{i=1}^{N_{cl}} x_{i,1} P_i} \tag{19}$$

While the number of fishes $S_{i,1}$ in the i-th class at the start of first period is :

$$S_{i,1} = S_1 x_{i,1} \qquad i = 1, N_{cl} \tag{20}$$

For the k-th period, fish distribution in weight classes is represented by $x_{i,k}$, which is the ratio between the number of fishes in the i-th class at the k-th period and the total number $S_1$, at the beginning of the first period :

$$x_{i,k} = S_{i,k}/S_1 \tag{21}$$

The total number of fishes $S_k$ at the beginning of the k-th period is :

$$S_k = S_1 \sum_{i=1}^{N_{cl}} x_{i,k} \tag{22}$$

where the sum of $x_{i,k}$ can differ from unit, due to the presence of stocking, harvesting and death. Stocking can occur at the beginning of each period ; fish distribution after stocking is expressed as a function of stocking level $\beta_{i,k}$ :

$$x_{1,k,1} = x_{1,k}(1 + \beta_{i,k}) \tag{23}$$

and the stocked biomass is :

$$B_{st} = \sum_{i=1}^{I_{st}} x_{1,k}\,\beta_{i,k} \tag{24}$$

Fish distribution at the end of the period is computed according to the Markovian matrix M, which accounts for growth mechanism and mortality :

$$x_{1,k,2} = \sum_{j=1}^{I} x_{1,k,1}\,M_{j,1} \tag{25}$$

The final fish distribution is then computed considering harvesting, concentrated at the end of each period :

$$x_{1,k+1} = x_{i,k,2}\,(1 - \alpha_{i,k}) \tag{26}$$

Where the harvesting level is zero for the classes with index lower the minimum harvested class $I_c$. The number of fishes harvested in the k-th period $S_{c,k}$ is :

$$S_{c,k} = S_1 \sum_{i=1}^{N_{cl}} x_{i,k,2}\,\alpha_{1,k} \tag{27}$$

and the corresponding biomass $B_{c,k}$ is :

$$B_{c,k} = S_1 \sum_{i=1}^{N_{cl}} x_{i,k,2}\,\alpha_{1,k} P_1 \tag{28}$$

Accordingly, for the stocked fish is :

$$S_{st,k} = S_1 \sum_{i=1}^{N_{cl}} x_{i,k}\,\beta_{i,k} \tag{29}$$

and

$$B_{st,k} = S_1 \sum_{1=1}^{N_{cl}} x_{1,k}\,\beta_{1,k} P_i \tag{30}$$

All the computation relating to food, water and oxygen consumption refers to the average biomass in the period $B_k$ :

$$B_k = \sum_{i=1}^{N_{cl}} B_{i,k} = \sum_{i=1}^{N_{cl}} S_1 (x_{i,k,1} + x_{1,k,2})\,P_i / 2 \tag{31}$$

*2.4 Water and oxygen consumption*

The density of the v-th fish pond is computed as :

$$\delta_v = \frac{\sum B_{1,k}}{V_v} 10^3 \qquad [kg/m^3] \tag{32}$$

Where the sum is extended only to weight classes included in the given pond. The water flow rate theoretically needed to satisfy the oxygen requirement R can be computed as a function of the oxygen concentration in the pond $O_{2,v}$, in the input water $O_{2,i}$ and in output $O_{2,o}$ :

$$Q = \frac{R}{O_{2,i} - O_{2,0}} \quad [m^3/h] \tag{33}$$

Oxygen consumption is computed from the unit consumption per mass r :

$$R = r\ B_v\ 10^6\ [mg/h] \tag{34}$$

It has been assumed :

$$r = 0.177\ mg/g/h\ [Barnabé, 1986]$$

$$\begin{aligned} O_{2,v} &= 4.5\ mg/l \\ O_{2,i} &= 6\ mg/l \\ O_{2,0} &= O_{2,v} \end{aligned} \tag{35}$$

Mass flow rate in the pond $Q_v$ is equal to Q, if $Q \leq Q_{max}$, where this latter is the maximum mass flow rate that pumps can provide. Otherwise, is it assumed $Q_v = Q_{max}$. In this case, further oxygen will be provided by auxiliary devices ; their oxygen supply $R_a$ is :

$$R_a = R\ \frac{Q - Q_{max}}{Q} \tag{36}$$

and the corresponding energy consumption can be evaluated, given a performance index I, in KW per kg/h of oxygen :

$$E_{o2} = 24\ N_g\ R_a\ 10^{-6}\ I\ [kwh] \tag{37}$$

It has been assumed I=4.99 kg $O_2$/HP (mechanical oxygenator Nan-Rong, power=1 HP).

Water supply in terms of volume per day can be finally evaluated :

$$R_v = 24\ Q_v\ /V_v \tag{38}$$

*2.5 Pumping energy consumption*

The power $P_p$ for the pumps is computed from flow rate Q, from total head H and of pump efficiency $\eta_p$ :

$$P_p = 9.81\ \frac{Q}{3600\ \eta_p}\ H \tag{39}$$

The total head H is the sum of the geodetic term $H_u$ , equal to the difference in height from the water reservoir and the fish ponds, and of head losses $H_p$ in pipes :

$$H = H_u + H_p \tag{40}$$

for the latter term, the following formula has been used [Colombo, 1971] :

$$H_p = 2\,L((1.64\ 10^{-3} + 4.2\ 10^{-5}/D)\ Q/3600)^2 / D^5 \quad (41)$$

Where D is pipe diameter and L is its length. The energy consumption $E_k$ in the k-th period is :

$$E_k = P_p\ 24\ N_g\ [kwh] \quad (42)$$

*2.6 Feeding*

For each weight class, the theoretical amount of food to supply is computed as a function of water temperature, fish size and weight, from suitable data provided by food producers [Feeding Chart for Sea-Bass with Trouvit Branzini]. The actual amount $B_{m,k}$ is obtained considering the feeding level $F_{m,k}$ :

$$B_{m,k} = N_g \sum_{i=1}^{N_{cl}} B_{i,k}\ v_i F_{m,k} \quad (43)$$

with

$$0.5 \leq F_{m,k} \leq 1 \quad (44)$$

In default of more precise information about the influence of feeding on growth, a linear relationship (3) between $F_{m,k}$ and the growth has been assumed. The following relationship between fish length and weight has been used [Barnabé, 1986] :

$$l_i = (Pi / 9.10^{-2})^{1/3}\ [cm] \quad (45)$$

*2.7 Energy for water heating*

Given water flow rate Qv, it is possible to compute the thermal energy consumption $E_R$ needed for heating water from external temperature T to the desired value T*, in $N_g$ days :

$$E_R = 24\ N_g\ Q_v\ 10^{-3}\ (T^* - T)\ [kcal] \quad (46)$$

It is assumed that temperature in ponds is equal to T*, neglecting possible heat losses, due to the small temperature differences between pond temperature and the surrouding and to the relevant water flow rate. No heat recovery from output water is considered.

*2.8 Biological constraints*

In each period, density in each pond $\delta_{i,k}$ have to be lower than an upper limit $\delta_{max}$. A suitable constraint is so defined :

$$c_{i,k} = \delta_{max} - \delta_{i,k} \quad (47)$$

The solutions provided by the optimization method correspond to densities not greater than the maximum value $\delta_{max}$. This result is obtained by selecting suitable strategies for stocking and harvesting.

*2.9 Final period. Residual biomass*

At the end of the selected time horizon, a residual biomass could remain in the ponds. Therefore, in order to homogeneously compare different management stragegies, its value has to be considered. Given residual biomass distribution and price $Pr_{f,i}$ for each weight class, the residual value VR is so computed :

$$VR = \sum_{i=1}^{N_{cl}} VR_i = \sum_{i=1}^{N_{cl}} B_{i,\,Np+1} Pr_{f,i} \tag{48}$$

## 3. ECONOMIC SUB-MODEL. COSTS AND REVENUES

For each period, it is assumed that all the harvested biomass can be sold to a price $Pr_k$, variable in time but independent on the supplied biomass.

Therefore, revenue $R_k$ can be obtained :

$$R_k = B_{c,k}\, Pr_k \tag{49}$$

The following costs are considered :

- cost for pumping $C_{p,k}$ and for auxiliary oxygen $C_{o2,k}$ proportional to the required energy and to the unit cost for electrical power :

$$C_{p,k} = E_{p,k}\, K_p \tag{50}$$

$$C_{o2,k} = E_{o2,k}\, K_p \tag{51}$$

- cost for stocked fish $C_{st,k}$ proportional to the number of recruits supplied :

$$C_{st,k} = S_{st,k}\, K_{st} \tag{52}$$

- cost for feeding $C_{m,k}$, proportional to the amount of food provided :

$$C_{m,k} = B_{m,k}\, K_m \tag{53}$$

- cost for water heating, proportional to the required energy and to the unit cost of thermal energy :

$$C_{r,k} = E_{r,k}\, K_r \tag{54}$$

- In order to consider the incidence of all fixed costs, not depending on operative variables, a cost $C_{a,k}$ is introduced. Such cost is equally distributed over the periods.

Total cost per period $C_k$ is then given by :

$$C_k = C_{c,k} + C_{st,k} + C_{m,k} + C_{p,k} + C_{r,k} + C_{o2,k} + C_{a,k} \tag{55}$$

Profit $U_k$ is computed by :

$$U_k = R_k - C_k \tag{56}$$

In order to compare costs and revenues referring to different periods, all economic terms are multiplied by a discount coefficient $f_{at}$ :

$$f_{at} = 1/(1 + T_{at})^t \tag{57}$$

Where $T_{at}$ is the yearly discount rate, t is the time, in years,when the given term occurs.

## 4. SIMULATION ANALYSIS

In order to assess the predicting capability of the model, a simulation analysis has been performed, for the plant described in table 1. A maximum weight of 400 g has been considered, divided in 20 classes with increasing width, in order to take into account the exponential nature of the growth process. Minimum and maximum weights for each classes are shown in table 2.

Table 3 displays the parameters used by the biological model, relating to growth, mortality and stochastic effects. Values for k, x, a and b comply with indications provided by Querellou [1984]. The parameters $c_1$, $c_2$ and $c_3$ have been assigned according to growth curve spread observed in typical cases of sea-bass aquaculture by Iandoli and Saroglia [1989].

### *4.1 The base case*

The simulation analysis has been performed starting from a base-plant, described in tab.4, also analyzing the influence of the most significant parameters on the results.

For this base case, the distribution of temperatures and variables describing harvesting, stocking, feeding level and water heating are assumed constant over the periods. However, the model can also consider time varying distribution. Harvesting strategy consists in extracting in each period the 80 % of the biomass present in the last 5 classes. The 20 % remaining biomass will be affected in the subsequent period by a 1 % mortality, due to harvesting stress. A further mortality relating to fish transfer between ponds has been estimated to 2 % of the transferred biomass. The stocking of recruits, with an average weight of 1.5 g, is concentrated in the first month. The maximum water flow rate is computed to assure that the total pond volume can be changed 20 times a day. Auxiliary oxygenation occurs only when the required water flow is greater than this limit.

### *4.2. Results of the base case.*

The results of the base case are described in tabs. 5a-b and in figs. 3A-3F. For each period, table 5a reports :

- water temperature (deg) ;
- harvesting level (for the classes 5 classes) ( %) ;
- stocking level ( % of the initial biomass) ;
- feeding level ( % of the theoretical value) ;
- auxiliary water heating (deg) ;
- average fish weight AW (g) ;
- total biomass, evaluated at the middle of the period (tons) ;
- harvested biomass, evaluated at the end of the period (tons) ;
- stocked biomass, evaluated at the start of the period (tons) ;
- the amount of food supplied (tons) ;
- the number of fishes with respect to the initial value ( %) ;
- the weight limits for the central 90 % of the biomass : 5 % has a weight less than P05, while another 5 % has a weight greater than P95. weight spread is computed according to the stochastic model.

The terms of the economic sub-model are reported in the table 5b [1]. The last column displays the cumulated profit, which usually reaches its maximum value before the end of the period. The value of the residual biomass is also reported.

For the base case, sea-bass harvesting is concentrated between the 8th and the 19th period, with a maximum value in the 13th month. The maximum amount of food, pumping and oxygen costs occurs in the 11th month where the maximum biomass is present in the plant. Auxiliary oxygen is supplied only from the 9th to the 13th month, when water flow is inadequate to satisfy the whole oxygen requirement ; cost for oxygen (852) is almost equal to pumping cost for the entire period (885) : in this case, it should be more convenient to adopt higher water pumping rates, so reducing auxiliary oxygenation.

1. Economic terms are expressed in million LIT (1.000.000 LIT = 630 US $, June 12, 1992).

In the 7th month, before the start of harvesting, about 95 % of the initial fishes survive while the remaining 5 % is affected by physiological mortality. After the 16th month, only 1 % remains in ponds, with an average weight of 280 g. Maximum profit per month (about 901) occurs in the 13th month, while maximum cumulated profit is reached in the 16th month. In the subsequent period, revenues are lower than costs, which is mainly due to the incidence of fixed costs. At the end of the 24th month, however, a positive profit of about 434 million LIT can be collected.

A total production of 241 tons of sea-bass is achieved, with a conversion ratio of 3.04, maximum density of about 20 $kg/m^3$ and a maximum water flow rate corresponding to 32 volumes per day.

The incidence of the single costs on the total cost is enough well-balanced, with a light prevalence of stocking costs.

Biomass, harvest and average weight are displayed in fig.3A, while costs, revenues and profit are shown in figs.3B and 3C. It can be observed (fig.3D) that the spread of the biomass around its average weight increases with time, and that weight distribution becomes asymmetric when harvest occurs. Maximum pond density is reached in the second pond, around the 11th month (fig.3E). It can be observed that water flow remains constant in the period between the 9th and the 13th month (fig.3F), when auxiliary oxygen is provided (fig.3C).

### *4.3 Effects of the operating variables. Parametric analysis*

The model can be utilized to study the effects of the different variables. In tabs.6a, 6b and 6c, the results of a parametric analysis obtained varying each time one of the most relevant operating variables with respect to the base case are presented. The first column of the table indicates the value assumed by the corresponding independent variable. The most significant effects are briefly summarized.

#### 4.3.1 Water temperature effects

As it is known, water temperature plays a major role in growth mechanism and in locating aquaculture plant. Although the model can also consider also variable temperatures in order to stress their effects, constant temperature values between 18 and 24 degrees have been considered. It can be observed that production and revenues increase with temperature, while the opposite occurs for costs. Between 18 and 24 degrees, profit increases of about 1 600 million Lit and conversion ratio changes from 3.93 to 2.31.

#### 4.3.2 Harvesting strategy effects

The minimum weight of the harvested fish has varied from 81 g (10th weight class) to 361 (20th class). Production, maximum density, revenues, costs and process length increase with minimum harvesting weight, while maximum profit is realized for the 16th class, corresponding to the base case. However, it must be observed that the model does not consider further weight increments after the 20th weight class (400 g) and therefore, the revenues obtained by harvesting only the last weight classes may be underestimated.

#### 4.3.3 Stocking strategy effects

Stocking strategy can be varied acting on both the total amount of stocked biomass and on its time distribution. In the first series of results, stocking is concentrated on the first period. When stocked biomass changes from 0.3 to 0.9 tons, an increase in production, revenues, density and costs is observed. Profit is maximized when stocked biomass is 0.6 tons : for lower values, plant is not enough utilized, and high incidence of fixed costs results, while for values greater than 0.6 excessive costs for oxygen are required.

In the second test, a given biomass (0.5 tons) has been stocked in periods varying from 1 to 16 months. Maximum profit is reached for a period of 10 months, which allows a reduction in maximum density (from 20 to 10 kg/m3) and lower oxygen costs. In case of more diluted distributions, a residual biomass is present after the last period and lower revenues and profit result.

In order to test the sensitivity of these results with respect to other parameters, the same analysis has been repeated with a higher value of the maximum flow rate (40 volumes per day). The corresponding results are described in tab.6c.

Maximum profit is achieved when 1 ton of fish is stocked, with higher density (about 40 kg/m3). With respect to stocked biomass distribution, in this case it seems more convenient to stock all the biomass in the first month. The difference between the 2 cases is mainly due to the costs for the auxiliary oxygen, which in the first case penalize the solutions corresponding to high density.

#### 4.3.4 Water heating effects

The results show that, starting from temperatures of 22 degrees, the increase of fish production and revenues do not compensate the higher cost due to water heating for the first pond ; in this case, however, heat recovery has not been considered.

#### 4.3.5 Water supply effects

When the maximum water flow rate changes from 10 to 40 volumes per day, profit increases of about 1 300 million Lit, since the higher pumping cost is largely compensated by the lower cost for auxiliary oxygen. Pumping costs and profit depend also on the difference in height : its variation from 10 to 40 meters causes a profit decrease of about 1 300 million Lit.

This kind of analysis is particularly useful in order to clarify the influence of the single variables, but it may not provide exhaustive information on system behavior, since the effect of a variable may depend on the values assumed by other variables, due to the presence of interactions and non linearities in the model. In this case, optimization analysis represents the best tool to select the best management strategies, considering the interactions among thc variables.

## 5. OPTIMIZATION ANALYSIS

Management strategies can be optimized determining the distribution of the decision variables which maximizes profit in the given time horizon and respects the constraints on maximum density in ponds. A classical non linear constrained optimization problem [Gill et al., 1984] is then defined :

$$\min_{u} F(u) \tag{58}$$

$$C_i(u) \geq 0 \qquad i = 1, M \tag{59}$$

where the decision variables u represent stocking and harvesting strategies, and F is the sum of the profit $U_k$ in the periods and of the possible residual value, at the end of the time horizon :

$$F(u) = -VR - \sum_{k=1}^{N_p} U_k \tag{60}$$

The inequality constraints express the condition that pond density must be lower than a given maximum value :

$$ci = \delta_{max} - \delta \tag{61}$$

Using the Augmented Lagrangian approach, an equivalent unconstrained optimization problem can be defined [Gill et al., 1984] :

$$\min L_u(u,\lambda) \tag{62}$$

where :

$$L = F(u) + \sum_{i=1}^{M} \begin{cases} -\lambda_i c_i(u) = \rho/2 c_i(u)^2 & \text{if} \quad c_i(u) \leq \lambda_i/\rho \\ -\lambda_i^2/2\rho & \text{if} \quad c_i(u) > \lambda_i/\rho \end{cases}$$

The Lagrange multiplier $\lambda_i$ is a non negative number associated to the i-th constraint $c_i$ ; $\rho$ is a positive penalty factor.

The unconstrained minimization (62) is performed by an iterative Quasi-Newton technique, with the following features :

- linear search based on safeguard inverse interpolation ;
- numerical gradient evaluation ;
- iterative estimate of the Hessian matrix (second derivatives) using the Davidon-Flechter-Powell algorithm.

After each minimization, Lagrange multipliers are updated according to the following relationship :

$$\bar{\lambda}_i = \lambda_i - \min(\rho c_i, \lambda_i) \tag{64}$$

A new unconstrained minimization is then performed, until convergence is achieved.

*5.1 Results of the optimization analysis*

Some results obtained with optimization analysis are presented in the following. The decision variables are : harvesting strategy (percent of the harvested biomass, for the weight classes from 16 to 20) and stocking strategy. Tab. 7 shows the four cases considered.

For each case, the optimal results have been compared with the ones obtained with the initial distribution of harvesting and stocking levels :

80 % harvesting level for the weight classes upper to 15th, biomass of 0.5 tons stocked in the first month. Global results are presented in tab. 8, for all the cases described in tab.7 ; detailed results are shown for the case BOP2 in tab. 9a-b and in figs. 4a-f, and for the cases BOP4, BOP6 and BOP8 in tabs. 10a-b ; 11a-b and 12a-b, respectively.

In the case A, by the comparison of the initial and the optimal solutions it emerges :

- a profit increase of about 1 300 million Lit, due to a relevant increase in revenues and also to a reduction in costs, chiefly for food, pumping and stocking ;
- an increase in the stocked biomass and in production, which allows a better plant utilization and then a lower incidence of fixed costs (after the 24th month, a residual biomass is present in the plant) ;
- stocked biomass has been subdivided in different periods, spaced of about 5 months, in order to limit maximum pond density and to reduce auxiliary oxygenation ;
- harvesting level increases up to 100 % in last periods (to reduce residual biomass) and when auxiliary oxygen should be needed ; harvesting level decreases when density is lower (e.g. months 21-23), in order to allow further growth and then greater revenues in the following periods.

Economic terms, biomasses and density for the optimal case are shown in fig. 4a-f. It can be remarked that average weight, harvested biomass and density exhibit more complex trends, with respect to the traditional solution (base case, fig.3a-f). Density is usually higher, but within the imposed upper limit of 25 kg/m3, so allowing a more complete productive utilization. The second case (B) is characterized by a non uniform price distribution (tabs 10a-b). The optimal solutions are similar to case A, but with higher harvesting levels in periods where price growths. Profit increase (1480 million Lit) is higher than the previous case.

Case C (tabs 11a-b) is characterized by higher pumping height with respect to case B. It exhibits unprofitable result (440 million Lit) with standard solution, while optimal strategy gives rise to a positive result of about 300 million Lit, obtained by increasing fish production from 240 to 350 tons ; both revenues and costs increase with respect to initial solution.

In the last case (tabs 12a-b), finally, variable temperatures are considered,with lower values respect to previous cases. The initial solution gives rise to a loss of 1 370 million Lit, which is reduced to about 800 million Lit with optimized solution. This result is obtained by reducing fish production (from 0.5 to about 0.3 tons) and so eliminating costs for oxygen ; stocking is concentrated in the first period, unlike previous cases. Harvesting is maximized in the periods with higher prices, and reduced in the previous ones.

These examples, even if extended only to harvesting and stocking strategies and not representative of all possible conditions occuring in aquaculture management, show the considerable benefits obtainable with optimal management strategies, which can account for the influence of structural, environmental and economic variables and for their complex interactions.

## 6. CONCLUSIONS

A model for the simulation and the optimal management of sea-bass aquaculture plants has been presented. The model accounts for the effects on growth and mortality of water temperature, harvesting and stocking strategies, feeding level and oxygen consumption and can evaluate costs and revenues. Cost-benefit analysis can be easily obtained examining the effects of each operating variable on the management outputs.

The results of the optimization analysis prove that, for given environmental and economic conditions, optimal harvesting and stocking strategies can be determined which allow relevant benefits in profit, with respect to traditional management strategies. Further work is needed in order to include other management options, to impose the detail and the precision of the sub-models and to validate the model estimates and the optimal strategies by direct comparison on aquaculture plants.

## REFERENCES

**Anon.** Feeding Chart for Sea-Bass with Trouvit Branzini.

**Barnabé G.** (1986). *Aquaculture*, TEC & DOC Lavoisier, Paris.

**Bjorndal T.** (1990). *The Economics of Salmon Aquaculture* , Blackwell Scientific Publications, Oxford.

**Brison A.E., Y.C. Ho** (1975). *Applied Optimal Control* , Hemisphere Publishing Co.

**Colombo G.** (1971). *Il manuale dell' ingegnere*, Hoepli.

**Engle C.R.** (1989). An Economic Comparison of Aeration Devices for Aquaculture Ponds, *Aquaculture Engineering* **8,** 193-207.

**Gill P.H., W. Murray. and M.H. Wright** (1984). *Practical Optimization*, Academic Press, London.

**Leung P.S.** (1986). Application of System Modeling in Aquaculture, *Aquacultural Engineering* **5** 171-182.

**Iandoli C., Saroglia M.** (1989). Allevamento di specie Eurialine in Italia, *Quaderni ICRAP Aquacoltura* 1, Roma

**IREPA** (1992). Definizione di un modello informatizzato di pianificazione finalizzato alla gestione ottimale di allevamenti ittici intensivi in acque marine e salmastre, Salerno.

**IRPAI** (1990). Elaborazione di modelli di ottimizzazione gestionale in funzione dell' intensita di capitale investito in acquacoltura, Ministeriale n622/2327 del 23 giugno 1990, Ministero Marina Mercantile.

**Leung P.S., Y.C. Shang** (1989) Modeling Prawn Production Management System : a Dynamic Markov Decision Approach, *Agricultural Systems* **29,** 5-20.

**Piedrahita R.H.** (1988). Introduction to Computer Modeling of Aquaculture Pond Ecosystems, *Aquaculture and Fisheries Management* **19,** 1-12.

**Querellou J.** (1984). *Modèles de production en pisciculture intensive : application à l'élevage du Loup, L'Aquaculture du Bar et des Sparides*, INRA Publ, Paris, 483-494.

**Sparre P.** A Markovian Decision Process Applied to Optimization of Production Planning in Fish farming, *Meddr Danm. Fisk - og Havunders*, **7,** 111-197.

TABLE 1.
DESCRIPTION OF THE TESTED PLANT.

| Sector | N. of ponds | Area [$m^2$] | Volume [$m^3$] | Weight [g] |
|---|---|---|---|---|
| I | 27 | 4050 | 4050 | 0.5 to 81 |
| II | 24 | 6720 | 6720 | 81 to 400 |

TABLE 2.
WEIGHT CLASSES.

| Classes | — weight [g] — | | | Classes | — weight [g] — | | |
|---|---|---|---|---|---|---|---|
| | Min. | Av. | Max. | | Min. | Av. | Max. |
| 1 | 0.0 | 0.5 | 1.0 | 11 | 100.0 | 110.5 | 121.0 |
| 2 | 1.0 | 2.5 | 4.0 | 12 | 121.0 | 132.5 | 144.0 |
| 3 | 4.0 | 6.5 | 9.0 | 13 | 144.0 | 156.5 | 169.0 |
| 4 | 9.0 | 12.5 | 16.0 | 14 | 169.0 | 182.5 | 196.0 |
| 5 | 16.0 | 20.5 | 25.0 | 15 | 196.0 | 210.5 | 225.0 |
| 6 | 25.0 | 30.5 | 36.0 | 16 | 225.0 | 240.5 | 256.0 |
| 7 | 36.0 | 42.5 | 49.0 | 17 | 256.0 | 272.5 | 289.0 |
| 8 | 49.0 | 56.5 | 64.0 | 18 | 289.0 | 306.5 | 324.0 |
| 9 | 64.0 | 72.5 | 81.0 | 19 | 324.0 | 342.5 | 361.0 |
| 10 | 81.0 | 90.5 | 100.0 | 20 | 361.0 | 380.5 | 400.0 |

TABLE 3.
PARAMETERS OF THE BIOLOGICAL MODEL.

| | |
|---|---|
| $k=0.9\ 10^{-9}$ , $x=2.81$ | growth (1) |
| $a=4$ , $b=1.17$ | mortality (4) |
| $c_1=0.20$ , $c_2=0.20$ , $c_3=0.10$ | stochastic model (10, 11) |

TABLE 4.
DESCRIPTION OF THE BASE CASE.

| | | |
|---|---|---|
| Stocked biomass | 0.5 T | |
| Stocking period | first month | |
| Average weight of recruits | 0.5 g | |
| Water temperature | 22° C | (constant) |
| Harvesting percentage | 80 % | " " |
| Feeding level | 100 % | " " |
| First pond heating | not | " " |
| Price for sale | 22 000 L/Kg | " " |
| Weight classes harvested | 16 to 20 | |
| Mortality for harvesting | 1% of harvested biomass | |
| Mortality for pond transfer | 2 % of transferred biomass | |
| Max water supply | 20 volumes per day | |
| Cost of recruits | 1 000 Lit/each | |
| Cost of food | 1 200 Lit/kg | |
| Cost of electrical power | 240 Lit/kwh | |
| Cost of thermal power | 0.049 Lit/Kcal | |
| Other costs | 400 Lit x 1E6 / year | |
| Yearly discount rate | 0.10 | |

TABLE 5A.
SIMULATION OF THE BASE CASE - BIOMASS.

| Per. | Temp. | Harv. | Stock. | Feed | DT | AW | -- | Biomasses(ton) | | | -- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | deg | % | % | % | deg | g | Tot. | Harv. | Stock. | Feed | % fish | P05 | P95 |
| 1 | 22.0 | 80.0 | 100.0 | 100.0 | 0.0 | 1.5 | 1.45 | 0.00 | 0.50 | 2.12 | 100.00 | 0.1 | 2.4 |
| 2 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 4.3 | 4.17 | 0.00 | 0.00 | 5.69 | 98.21 | 0.8 | 6.3 |
| 3 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 9.0 | 8.68 | 0.00 | 0.00 | 10.76 | 97.20 | 2.9 | 12.5 |
| 4 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 16.0 | 15.30 | 0.00 | 0.00 | 17.35 | 96.48 | 6.8 | 27.0 |
| 5 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 25.7 | 24.40 | 0.00 | 0.00 | 26.07 | 95.93 | 12.5 | 41.5 |
| 6 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 38.5 | 36.33 | 0.00 | 0.00 | 36.83 | 95.48 | 19.0 | 63.5 |
| 7 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 54.8 | 51.47 | 0.00 | 0.00 | 49.18 | 95.09 | 28.2 | 88.0 |
| 8 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 75.0 | 70.16 | 0.21 | 0.00 | 63.14 | 94.69 | 40.4 | 120.4 |
| 9 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 99.8 | 92.84 | 2.91 | 0.00 | 78.90 | 94.09 | 56.1 | 160.8 |
| 10 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 129.7 | 118.36 | 13.74 | 0.00 | 95.46 | 92.35 | 73.7 | 221.9 |
| 11 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 161.5 | 137.79 | 35.59 | 0.00 | 106.57 | 86.32 | 93.7 | 239.2 |
| 12 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 190.3 | 134.85 | 59.43 | 0.00 | 101.19 | 71.70 | 115.0 | 266.2 |
| 13 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 213.1 | 101.29 | 61.26 | 0.00 | 74.43 | 48.09 | 136.1 | 291.5 |
| 14 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 231.9 | 56.09 | 40.16 | 0.00 | 40.57 | 24.47 | 156.5 | 324.2 |
| 15 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 250.1 | 23.58 | 18.40 | 0.00 | 16.82 | 9.54 | 167.1 | 352.6 |
| 16 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 269.6 | 7.98 | 6.49 | 0.00 | 5.62 | 2.99 | 182.4 | 367.8 |
| 17 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 290.5 | 2.30 | 1.90 | 0.00 | 1.60 | 0.80 | 188.6 | 373.5 |
| 18 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 311.4 | 0.59 | 0.48 | 0.00 | 0.40 | 0.19 | 197.5 | 375.9 |
| 19 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 330.7 | 0.14 | 0.11 | 0.00 | 0.09 | 0.04 | 211.8 | 377.1 |
| 20 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 346.8 | 0.03 | 0.02 | 0.00 | 0.02 | 0.01 | 230.9 | 377.8 |
| 21 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 359.1 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 253.9 | 378.1 |
| 22 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 367.7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 283.1 | 378.3 |
| 23 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 373.3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 318.3 | 378.5 |
| 24 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 376.7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 342.9 | 378.5 |
| Total | | | | | | | | 240.71 | 0.50 | 732.82 | | | |

| Conversion r. | Max.density | Max. volumes per day |
|---|---|---|
| 3.04 | 20.42 | 32.08 |

TABLE 5B.
SIMULATION OF THE BASE CASE - COSTS AND REVENUES (IN MILLION IT. LIRE).

| | | | Costs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Per. | Price | Revenue | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Cumulated |
| 1 | 22.0 | 0.0 | 2.5 | 2.0 | 1000.0 | 0.0 | 0.0 | 33.3 | 1037.9 | -1037.9 | -1037.9 |
| 2 | 22.0 | 0.0 | 6.7 | 5.7 | 0.0 | 0.0 | 0.0 | 33.3 | 45.8 | -45.8 | -1083.7 |
| 3 | 22.0 | 0.0 | 12.7 | 11.8 | 0.0 | 0.0 | 0.0 | 33.3 | 57.8 | -57.8 | -1141.5 |
| 4 | 22.0 | 0.0 | 20.3 | 20.7 | 0.0 | 0.0 | 0.0 | 33.3 | 74.3 | -74.3 | -1215.8 |
| 5 | 22.0 | 0.0 | 30.2 | 32.7 | 0.0 | 0.0 | 0.0 | 33.3 | 96.2 | -96.2 | -1312.0 |
| 6 | 22.0 | 0.0 | 42.3 | 48.4 | 0.0 | 0.0 | 0.0 | 33.3 | 124.1 | -124.1 | -1436.1 |
| 7 | 22.0 | 0.0 | 56.0 | 68.2 | 0.0 | 0.0 | 0.0 | 33.3 | 157.9 | -157.8 | -1593.9 |
| 8 | 22.0 | 4.3 | 71.4 | 92.6 | 0.0 | 0.0 | 0.0 | 33.3 | 198.0 | -193.7 | -1787.6 |
| 9 | 22.0 | 59.6 | 88.5 | 99.5 | 0.0 | 0.0 | 71.4 | 33.3 | 293.2 | -233.6 | -2021.3 |
| 10 | 22.0 | 279.2 | 106.2 | 98.7 | 0.0 | 0.0 | 177.6 | 33.3 | 416.0 | -136.8 | -2158.1 |
| 11 | 22.0 | 717.4 | 117.6 | 97.9 | 0.0 | 0.0 | 256.8 | 33.3 | 505.7 | 211.7 | -1946.5 |
| 12 | 22.0 | 1188.6 | 110.8 | 97.2 | 0.0 | 0.0 | 242.7 | 33.3 | 484.0 | 704.6 | -1241.8 |
| 13 | 22.0 | 1215.5 | 80.9 | 96.4 | 0.0 | 0.0 | 103.6 | 33.3 | 314.2 | 901.2 | -340.6 |
| 14 | 22.0 | 790.6 | 43.7 | 70.4 | 0.0 | 0.0 | 0.0 | 33.3 | 147.4 | 643.2 | 302.6 |
| 15 | 22.0 | 359.3 | 18.0 | 29.2 | 0.0 | 0.0 | 0.0 | 33.3 | 80.5 | 278.8 | 581.4 |
| 16 | 22.0 | 125.7 | 6.0 | 9.8 | 0.0 | 0.0 | 0.0 | 33.3 | 49.1 | 76.6 | 658.1 |
| 17 | 22.0 | 36.5 | 1.7 | 2.8 | 0.0 | 0.0 | 0.0 | 33.3 | 37.8 | -1.4 | 656.7 |
| 18 | 22.0 | 9.2 | 0.4 | 0.7 | 0.0 | 0.0 | 0.0 | 33.3 | 34.5 | -25.2 | 631.5 |
| 19 | 22.0 | 2.1 | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 33.3 | 33.6 | -31.5 | 600.0 |
| 20 | 22.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 33.4 | -32.9 | 567.1 |
| 21 | 22.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 33.3 | -33.3 | 533.8 |
| 22 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 33.3 | -33.3 | 500.5 |
| 23 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 33.3 | -33.3 | 467.2 |
| 24 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 33.3 | -33.3 | 433.8 |
| Res.value | | 0.0 | | | | | | | | | |
| Total | | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | |

## TABLE 6A.
## PARAMETRIC ANALYSIS.

Variations with respect to the base-case (indicated by *).

Base case. Water supply: Maximum volumes per day = 20.

Water temperature variations (18-24 degrees)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t18 | 4439.3 | 989.2 | 1255.7 | 1000.0 | 0.0 | 1256.6 | 800.0 | 5301.8 | -862.5 | 232.37 | 3.93 | 8.0 | 94.84 | 21.3 | 32.0 |
| t20 | 4653.8 | 928.5 | 1054.6 | 1000.0 | 0.0 | 1157.2 | 800.0 | 4942.3 | -288.5 | 238.33 | 3.54 | 19.8 | 93.40 | 22.3 | 32.7 |
| t22 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| t24 | 4937.2 | 636.4 | 800.9 | 1000.0 | 0.0 | 923.6 | 800.0 | 4162.5 | 774.7 | 245.81 | 2.31 | 15.2 | 40.29 | 22.5 | 32.1 |

Feeding level variations (100%-60 %)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| rm10 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| rm09 | 4698.3 | 837.1 | 982.5 | 1000.0 | 0.0 | 1067.3 | 800.0 | 4688.7 | 9.6 | 238.73 | 3.17 | 18.4 | 90.06 | 22.1 | 32.1 |
| rm08 | 4560.6 | 798.0 | 1067.9 | 1000.0 | 0.0 | 1097.7 | 800.0 | 4765.6 | -205.0 | 233.54 | 3.11 | 19.9 | 91.35 | 21.3 | 32.1 |
| rm07 | 4407.8 | 756.4 | 1163.6 | 1000.0 | 0.0 | 1154.1 | 800.0 | 4876.0 | -468.2 | 228.37 | 3.04 | 22.0 | 92.42 | 21.1 | 32.1 |
| rm06 | 4176.5 | 708.4 | 1296.9 | 1000.0 | 0.0 | 1158.6 | 800.0 | 4966.1 | -789.6 | 219.77 | 2.99 | 0.0 | 92.20 | 20.6 | 32.0 |

Stocked biomass variations (0.3-1.0 tons)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b03 | 2873.2 | 489.7 | 673.5 | 600.0 | 0.0 | 48.6 | 800.0 | 2612.8 | 260.4 | 144.42 | 3.04 | 16.9 | 71.70 | 12.3 | 32.1 |
| b04 | 3830.9 | 652.9 | 803.2 | 800.0 | 0.0 | 373.4 | 800.0 | 3430.9 | 399.9 | 192.57 | 3.04 | 16.9 | 71.70 | 16.3 | 32.1 |
| b05 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| b06 | 5746.3 | 979.3 | 953.6 | 1200.0 | 0.0 | 1372.7 | 800.0 | 5307.7 | 438.6 | 288.85 | 3.04 | 16.9 | 71.70 | 24.5 | 37.2 |
| b07 | 6704.0 | 1142.5 | 1011.5 | 1400.0 | 0.0 | 1928.4 | 800.0 | 6284.9 | 419.2 | 336.99 | 3.04 | 16.9 | 71.70 | 28.6 | 43.4 |
| b08 | 7661.8 | 1305.8 | 1049.7 | 1600.0 | 0.0 | 2546.6 | 800.0 | 7304.9 | 356.9 | 385.13 | 3.04 | 16.9 | 71.70 | 32.7 | 45.7 |
| b09 | 8619.5 | 1469.0 | 1082.8 | 1800.0 | 0.0 | 3181.3 | 800.0 | 8336.2 | 283.2 | 433.27 | 3.04 | 16.9 | 71.70 | 36.8 | 45.7 |
| b10 | 9577.2 | 1632.2 | 1116.0 | 2000.0 | 0.0 | 3816.0 | 800.0 | 9367.7 | 209.5 | 481.41 | 3.04 | 16.9 | 71.70 | 40.8 | 50.1 |

Minimum harvesting class variazions (10th-20th)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cat10 | 1974.4 | 297.2 | 354.6 | 1000.0 | 0.0 | 0.0 | 800.0 | 2453.5 | -479.2 | 96.25 | 2.71 | 12.4 | 1.47 | 10.9 | 31.0 |
| cat11 | 2378.3 | 370.5 | 457.5 | 1000.0 | 0.0 | 0.0 | 800.0 | 2629.8 | -251.5 | 116.64 | 2.80 | 13.2 | 4.76 | 10.9 | 31.0 |
| cat12 | 2831.3 | 452.4 | 567.1 | 1000.0 | 0.0 | 32.2 | 800.0 | 2853.4 | -22.1 | 139.66 | 2.87 | 14.8 | 12.70 | 10.9 | 31.0 |
| cat13 | 3484.3 | 546.4 | 664.4 | 1000.0 | 0.0 | 181.2 | 800.0 | 3193.8 | 290.5 | 172.83 | 2.81 | 14.8 | 27.18 | 14.2 | 31.7 |
| cat14 | 3909.7 | 631.7 | 740.0 | 1000.0 | 0.0 | 362.4 | 800.0 | 3535.8 | 373.9 | 194.79 | 2.89 | 15.6 | 43.83 | 16.1 | 31.8 |
| cat15 | 4333.7 | 719.2 | 809.9 | 1000.0 | 0.0 | 584.6 | 800.0 | 3915.4 | 418.4 | 216.86 | 2.97 | 16.2 | 59.64 | 18.9 | 32.0 |
| cat16 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| cat17 | 5408.0 | 954.2 | 963.5 | 1000.0 | 0.0 | 1341.5 | 800.0 | 5061.0 | 347.0 | 273.33 | 3.15 | 17.7 | 83.81 | 24.9 | 32.1 |
| cat18 | 5934.8 | 1082.2 | 1039.1 | 1000.0 | 0.0 | 1798.8 | 800.0 | 5721.9 | 213.0 | 301.39 | 3.25 | 18.4 | 88.48 | 27.3 | 32.1 |
| cat19 | 6443.2 | 1229.7 | 1115.0 | 1000.0 | 0.0 | 2370.9 | 800.0 | 6517.4 | -74.2 | 328.82 | 3.40 | 19.0 | 91.74 | 31.5 | 32.1 |
| cat20 | 6712.3 | 1380.8 | 1178.3 | 1000.0 | 0.0 | 3007.8 | 800.0 | 7368.7 | -656.4 | 344.22 | 3.66 | 19.8 | 92.58 | 34.5 | 32.1 |

Stocking distribution variations (1-16 months)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| st1 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| st2 | 4770.0 | 812.9 | 897.8 | 996.0 | 0.0 | 796.5 | 800.0 | 4304.9 | 465.1 | 240.73 | 3.04 | 18.0 | | 20.3 | 32.1 |
| st3 | 4751.5 | 809.7 | 906.7 | 992.1 | 0.0 | 752.9 | 800.0 | 4263.2 | 488.3 | 240.74 | 3.04 | 19.8 | | 19.1 | 32.1 |
| st4 | 4733.1 | 806.6 | 928.3 | 988.2 | 0.0 | 669.1 | 800.0 | 4193.8 | 539.2 | 240.76 | 3.04 | 20.1 | | 18.1 | 32.1 |
| st5 | 4714.6 | 803.4 | 950.2 | 984.3 | 0.0 | 583.9 | 800.0 | 4123.5 | 591.1 | 240.77 | 3.04 | 21.1 | | 16.7 | 32.0 |
| st6 | 4696.0 | 800.3 | 977.1 | 980.4 | 0.0 | 482.7 | 800.0 | 4042.1 | 653.8 | 240.77 | 3.04 | 22.1 | | 15.3 | 32.0 |
| st8 | 4657.7 | 793.9 | 1032.2 | 972.7 | 0.0 | 275.6 | 800.0 | 3876.2 | 781.6 | 240.68 | 3.05 | 0.0 | | 12.6 | 30.9 |
| st10 | 4601.0 | 786.8 | 1083.5 | 965.1 | 0.0 | 75.7 | 800.0 | 3712.8 | 888.2 | 239.55 | 3.06 | 0.0 | | 10.3 | 28.9 |
| st12 | 4424.7 | 773.2 | 1085.3 | 957.2 | 0.0 | 0.0 | 800.0 | 3617.3 | 807.4 | 231.75 | 3.13 | 0.0 | | 8.6 | 24.3 |
| st16 | 3530.3 | 692.0 | 959.1 | 942.8 | 0.0 | 0.0 | 800.0 | 3395.5 | 134.8 | 185.41 | 3.52 | 0.0 | | 6.5 | 18.3 |

## TABLE 6B–6C.
## PARAMETRIC ANALYSIS.

Variations with respect to the base-case (indicated by *).

Base case. Water supply: Maximum volumes per day = 20.

External heating of first pond. Temperature increase variations (0-3 degrees)

| Case | Revenues | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | %12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dt0 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| dt1 | 4824.6 | 800.8 | 867.8 | 1000.0 | 699.3 | 854.1 | 800.0 | 5023.7 | -199.0 | 241.52 | 2.97 | 16.3 | 60.73 | 21.2 | 32.1 |
| dt2 | 4850.0 | 786.8 | 838.3 | 1000.0 | 1295.1 | 900.8 | 800.0 | 5622.6 | -764.5 | 242.25 | 2.90 | 15.8 | 48.31 | 21.0 | 32.1 |
| dt3 | 4906.1 | 762.1 | 817.8 | 1000.0 | 1682.8 | 876.4 | 800.0 | 5940.4 | -1034.3 | 243.35 | 2.79 | 15.0 | 31.71 | 21.2 | 32.1 |

Maximum water flow variations (10-40 volumes per day)

| Case | Revenues | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | %12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ric10 | 4788.6 | 816.1 | 554.7 | 1000.0 | 0.0 | 1908.0 | 800.0 | 5080.6 | -292.0 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 25.0 |
| ric20 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| ric30 | 4788.6 | 816.1 | 1092.8 | 1000.0 | 0.0 | 204.4 | 800.0 | 3915.1 | 873.5 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 48.1 |
| ric40 | 4788.6 | 816.1 | 1160.5 | 1000.0 | 0.0 | 0.0 | 800.0 | 3778.4 | 1010.2 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 57.8 |

Pumping height variations (10-40 meters)

| Case | Revenues | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | %12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dh10 | 4788.6 | 816.1 | 445.5 | 1000.0 | 0.0 | 852.0 | 800.0 | 3915.4 | 873.2 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| dh20 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| dh30 | 4788.6 | 816.1 | 1324.3 | 1000.0 | 0.0 | 852.0 | 800.0 | 4794.2 | -5.6 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| dh40 | 4788.6 | 816.1 | 1763.7 | 1000.0 | 0.0 | 852.0 | 800.0 | 5233.6 | -445.0 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |

Table 6c -

Variations with respect to the base-case (indicated by *).

Base case. Water supply: Maximum volumes per day = 40.

Stocked biomass variations (0.3-1.0 tons)

| Case | Revenues | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | %12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bx03 | 2873.2 | 489.7 | 688.9 | 600.0 | 0.0 | 0.0 | 800.0 | 2579.6 | 293.6 | 144.42 | 3.04 | 16.9 | 71.70 | 12.3 | 34.7 |
| bx04 | 3830.9 | 652.9 | 922.8 | 800.0 | 0.0 | 0.0 | 800.0 | 3177.1 | 653.8 | 192.57 | 3.04 | 16.9 | 71.70 | 16.3 | 46.3 |
| bx05 * | 4788.6 | 816.1 | 1160.5 | 1000.0 | 0.0 | 0.0 | 800.0 | 3778.4 | 1010.2 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 57.8 |
| bx06 | 5746.3 | 979.3 | 1369.3 | 1200.0 | 0.0 | 97.2 | 800.0 | 4447.9 | 1298.4 | 288.85 | 3.04 | 16.9 | 71.70 | 24.5 | 64.1 |
| bx07 | 6704.0 | 1142.5 | 1517.0 | 1400.0 | 0.0 | 380.7 | 800.0 | 5242.7 | 1461.3 | 336.99 | 3.04 | 16.9 | 71.70 | 28.6 | 64.1 |
| bx08 | 7661.8 | 1305.8 | 1638.2 | 1600.0 | 0.0 | 746.9 | 800.0 | 6093.7 | 1568.1 | 385.13 | 3.04 | 16.9 | 71.70 | 32.7 | 64.2 |
| bx09 | 8619.5 | 1469.0 | 1724.4 | 1800.0 | 0.0 | 1218.5 | 800.0 | 7015.1 | 1604.4 | 433.27 | 3.04 | 16.9 | 71.70 | 36.8 | 64.2 |
| bx10 | 9577.2 | 1632.2 | 1806.5 | 2000.0 | 0.0 | 1704.0 | 800.0 | 7946.3 | 1630.9 | 481.41 | 3.04 | 16.9 | 71.70 | 40.8 | 64.2 |

Stocking distribution variations (1-16 month)

| Case | Revenues | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | %12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| stx1 * | 4788.6 | 816.1 | 1160.5 | 1000.0 | 0.0 | 0.0 | 800.0 | 3778.4 | 1010.2 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 57.8 |
| stx2 | 4770.8 | 812.9 | 1155.2 | 996.0 | 0.0 | 0.0 | 800.0 | 3765.9 | 1004.1 | 240.73 | 3.04 | 18.0 | | 20.3 | 57.4 |
| stx3 | 4751.5 | 809.7 | 1149.4 | 992.1 | 0.0 | 0.0 | 800.0 | 3753.0 | 998.5 | 240.74 | 3.04 | 19.0 | | 19.1 | 54.2 |
| stx4 | 4733.1 | 806.6 | 1143.5 | 988.2 | 0.0 | 0.0 | 800.0 | 3740.0 | 993.1 | 240.76 | 3.04 | 20.1 | | 18.1 | 51.4 |
| stx5 | 4714.6 | 803.4 | 1137.5 | 984.3 | 0.0 | 0.0 | 800.0 | 3727.0 | 987.6 | 240.77 | 3.04 | 21.1 | | 16.7 | 47.4 |
| stx6 | 4696.8 | 800.3 | 1131.5 | 988.4 | 0.0 | 0.0 | 800.0 | 3713.9 | 982.1 | 240.77 | 3.04 | 22.1 | | 15.3 | 43.5 |
| stx8 | 4657.7 | 793.9 | 1119.9 | 972.7 | 0.0 | 0.0 | 800.0 | 3688.3 | 969.4 | 240.68 | 3.05 | 0.0 | | 12.6 | 35.6 |
| stx10 | 4601.0 | 786.8 | 1107.5 | 965.1 | 0.0 | 0.0 | 800.0 | 3641.1 | 939.9 | 239.55 | 3.06 | 0.0 | | 10.3 | 29.1 |
| stx12 | 4424.7 | 773.2 | 1085.3 | 957.2 | 0.0 | 0.0 | 800.0 | 3617.3 | 807.4 | 231.75 | 3.13 | 0.0 | | 8.6 | 24.3 |
| stx16 | 3530.3 | 692.0 | 959.1 | 942.8 | 0.0 | 0.0 | 800.0 | 3395.5 | 134.8 | 185.41 | 3.52 | 0.0 | | 6.5 | 18.3 |

## TABLE 7.
## CASES FOR OPTIMIZATION ANALYSIS.

Variations with respect to the base-case (indicated by *).

Base case. Water supply: Maximum volumes per day = 20.

Water temperature variations (18-24 degrees)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t18 | 4439.3 | 989.2 | 1255.7 | 1000.0 | 0.0 | 1254.6 | 800.0 | 5301.8 | -862.5 | 232.37 | 3.93 | 8.0 | 94.84 | 21.3 | 32.0 |
| t20 | 4653.8 | 928.5 | 1054.6 | 1000.0 | 0.0 | 1157.2 | 800.0 | 4942.3 | -288.5 | 238.33 | 3.54 | 19.8 | 93.40 | 22.3 | 32.7 |
| t22 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| t24 | 4937.2 | 636.4 | 800.9 | 1000.0 | 0.0 | 923.6 | 800.0 | 4162.5 | 774.7 | 245.81 | 2.31 | 15.2 | 40.29 | 22.5 | 32.1 |

Feeding level variations (100%-60 %)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| rm10 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| rm09 | 4698.3 | 837.1 | 982.5 | 1000.0 | 0.0 | 1067.3 | 800.0 | 4688.7 | 9.6 | 238.73 | 3.17 | 18.4 | 90.06 | 22.1 | 32.1 |
| rm08 | 4560.6 | 798.0 | 1067.9 | 1000.0 | 0.0 | 1097.7 | 800.0 | 4765.6 | -205.0 | 233.54 | 3.11 | 19.9 | 91.35 | 21.3 | 32.1 |
| rm07 | 4407.8 | 756.4 | 1163.6 | 1000.0 | 0.0 | 1154.1 | 800.0 | 4876.0 | -468.2 | 228.37 | 3.04 | 22.0 | 92.42 | 21.1 | 32.1 |
| rm06 | 4176.5 | 708.4 | 1296.9 | 1000.0 | 0.0 | 1158.6 | 800.0 | 4966.1 | -789.6 | 219.77 | 2.99 | 0.0 | 92.20 | 20.6 | 32.0 |

Stocked biomass variations (0.3-1.0 tons)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b03 | 2873.2 | 489.7 | 673.5 | 600.0 | 0.0 | 48.6 | 800.0 | 2612.8 | 260.4 | 144.42 | 3.04 | 16.9 | 71.70 | 12.3 | 32.1 |
| b04 | 3830.9 | 652.9 | 803.2 | 800.0 | 0.0 | 373.4 | 800.0 | 3430.9 | 399.9 | 192.57 | 3.04 | 16.9 | 71.70 | 16.3 | 32.1 |
| b05 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| b06 | 5746.3 | 979.3 | 953.6 | 1200.0 | 0.0 | 1372.7 | 800.0 | 5307.7 | 438.6 | 288.85 | 3.04 | 16.9 | 71.70 | 24.5 | 37.2 |
| b07 | 6704.0 | 1142.5 | 1011.5 | 1400.0 | 0.0 | 1928.4 | 800.0 | 6284.9 | 419.2 | 336.99 | 3.04 | 16.9 | 71.70 | 28.6 | 43.4 |
| b08 | 7661.8 | 1305.8 | 1049.7 | 1600.0 | 0.0 | 2546.6 | 800.0 | 7304.9 | 356.9 | 385.13 | 3.04 | 16.9 | 71.70 | 32.7 | 45.7 |
| b09 | 8619.5 | 1469.0 | 1082.8 | 1800.0 | 0.0 | 3181.3 | 800.0 | 8336.2 | 283.2 | 433.27 | 3.04 | 16.9 | 71.70 | 36.8 | 45.7 |
| b10 | 9577.2 | 1632.2 | 1116.0 | 2000.0 | 0.0 | 3816.0 | 800.0 | 9367.7 | 209.5 | 481.41 | 3.04 | 16.9 | 71.70 | 40.8 | 50.1 |

Minimum harvesting class variazions (10th-20th)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cat10 | 1974.4 | 297.2 | 354.6 | 1000.0 | 0.0 | 0.0 | 800.0 | 2453.5 | -479.2 | 96.25 | 2.71 | 12.4 | 1.47 | 18.9 | 31.0 |
| cat11 | 2378.3 | 370.5 | 457.5 | 1000.0 | 0.0 | 0.0 | 800.0 | 2629.8 | -251.5 | 116.64 | 2.80 | 13.2 | 4.76 | 18.9 | 31.0 |
| cat12 | 2831.3 | 452.4 | 567.1 | 1000.0 | 0.0 | 32.2 | 800.0 | 2853.4 | -22.1 | 139.66 | 2.87 | 14.8 | 12.70 | 18.9 | 31.0 |
| cat13 | 3484.3 | 546.4 | 664.4 | 1000.0 | 0.0 | 181.2 | 800.0 | 3193.8 | 290.5 | 172.83 | 2.81 | 14.8 | 27.18 | 14.2 | 31.7 |
| cat14 | 3909.7 | 631.7 | 740.0 | 1000.0 | 0.0 | 362.4 | 800.0 | 3535.8 | 373.9 | 194.79 | 2.89 | 15.6 | 43.83 | 16.1 | 31.8 |
| cat15 | 4333.7 | 719.2 | 809.9 | 1000.0 | 0.0 | 584.6 | 800.0 | 3915.4 | 418.4 | 216.86 | 2.97 | 16.2 | 59.64 | 18.9 | 32.0 |
| cat16 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| cat17 | 5408.0 | 954.2 | 963.5 | 1000.0 | 0.0 | 1341.5 | 800.0 | 5061.0 | 347.0 | 273.33 | 3.15 | 17.7 | 83.81 | 24.9 | 32.1 |
| cat18 | 5934.8 | 1082.2 | 1039.1 | 1000.0 | 0.0 | 1798.8 | 800.0 | 5721.9 | 213.0 | 301.39 | 3.25 | 18.4 | 88.48 | 27.3 | 32.1 |
| cat19 | 6443.2 | 1229.7 | 1115.0 | 1000.0 | 0.0 | 2370.9 | 800.0 | 6517.4 | -74.2 | 328.82 | 3.40 | 19.0 | 91.74 | 31.5 | 32.1 |
| cat20 | 6712.3 | 1380.8 | 1178.3 | 1000.0 | 0.0 | 3007.8 | 800.0 | 7368.7 | -656.4 | 344.22 | 3.66 | 19.8 | 92.58 | 34.5 | 32.1 |

Stocking distribution variations (1-16 months)

| Case | Revenues | Food | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | X12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| st1 * | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| st2 | 4770.0 | 812.9 | 897.8 | 996.0 | 0.0 | 796.5 | 800.0 | 4304.9 | 465.1 | 240.73 | 3.04 | 18.0 | | 20.3 | 32.1 |
| st3 | 4751.5 | 809.7 | 906.7 | 992.1 | 0.0 | 752.9 | 800.0 | 4263.2 | 488.3 | 240.74 | 3.04 | 19.0 | | 19.1 | 32.1 |
| st4 | 4733.1 | 806.6 | 928.3 | 988.2 | 0.0 | 669.1 | 800.0 | 4193.8 | 539.2 | 240.76 | 3.04 | 20.1 | | 18.1 | 32.1 |
| st5 | 4714.6 | 803.4 | 950.2 | 984.3 | 0.0 | 583.9 | 800.0 | 4123.5 | 591.1 | 240.77 | 3.04 | 21.1 | | 16.7 | 32.0 |
| st6 | 4696.0 | 800.3 | 977.1 | 980.4 | 0.0 | 482.7 | 800.0 | 4042.1 | 653.8 | 240.77 | 3.04 | 22.1 | | 15.3 | 32.0 |
| st8 | 4657.7 | 793.9 | 1032.2 | 972.7 | 0.0 | 275.6 | 800.0 | 3876.2 | 781.6 | 240.68 | 3.05 | 0.0 | | 12.6 | 30.9 |
| st10 | 4601.0 | 786.8 | 1083.5 | 965.1 | 0.0 | 75.7 | 800.0 | 3712.8 | 888.2 | 239.55 | 3.06 | 0.0 | | 10.3 | 28.9 |
| st12 | 4424.7 | 773.2 | 1085.3 | 957.2 | 0.0 | 0.0 | 800.0 | 3617.3 | 807.4 | 231.75 | 3.13 | 0.0 | | 8.6 | 24.3 |
| st16 | 3530.3 | 692.0 | 959.1 | 942.8 | 0.0 | 0.0 | 800.0 | 3395.5 | 134.8 | 185.41 | 3.52 | 0.0 | | 6.5 | 18.3 |

TABLE 8.
OPTIMIZATION ANALYSIS - GLOBAL RESULTS

| Case | Revenues | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Prod. | Conv.f | 1% | %12M | Dens. | Ric. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bep1 | 4788.6 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.0 | 800.0 | 4354.8 | 433.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| bep2 | 9012.8 | 1543.8 | 1795.9 | 1922.4 | 0.0 | 1209.0 | 800.0 | 7274.5 | 1738.3 | 466.94 | 3.06 | 0.0 | 158.33 | 20.5 | 32.9 |
| bep3 | 4792.8 | 816.1 | 884.9 | 1000.0 | 0.0 | 852.8 | 800.0 | 4354.8 | 438.0 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| bep4 | 8985.3 | 1487.3 | 1717.8 | 1880.2 | 0.0 | 1181.9 | 800.0 | 7070.5 | 1914.8 | 452.35 | 3.04 | 0.0 | 158.56 | 19.9 | 32.1 |
| bep5 | 4792.8 | 816.1 | 1763.7 | 1000.0 | 0.0 | 852.0 | 800.0 | 5233.6 | -440.8 | 240.71 | 3.04 | 16.9 | 71.70 | 20.4 | 32.1 |
| bep6 | 7075.8 | 1153.6 | 2977.9 | 1445.2 | 0.0 | 399.5 | 800.0 | 6778.7 | 297.2 | 354.30 | 3.03 | 0.0 | 234.40 | 13.3 | 32.1 |
| bep7 | 4792.9 | 935.2 | 2272.9 | 1000.0 | 0.0 | 1151.3 | 800.0 | 6161.6 | -1368.6 | 240.29 | 3.55 | 20.6 | 93.10 | 19.5 | 32.1 |
| bep8 | 2893.0 | 555.1 | 1774.0 | 571.6 | 0.0 | 0.0 | 800.0 | 3701.9 | -808.9 | 143.03 | 3.55 | 20.6 | 93.09 | 11.2 | 31.6 |

TABLE 9A.
OPTIMIZATION RESULTS - CASE BOP2 - BIOMASS.

| Per. | Temp. deg | Harv. % | Stock. % | Feed % | DT deg | AW g | -- Tot. | Biomasses(ton) Harv. | Stock. | Feed | -- X fish | P0S | P9S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22.0 | 80.0 | 103.0 | 100.0 | 0.0 | 1.5 | 1.49 | 0.00 | 0.52 | 2.18 | 100.00 | 0.1 | 2.4 |
| 2 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 4.3 | 4.30 | 0.00 | 0.00 | 5.86 | 98.21 | 0.8 | 6.3 |
| 3 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 9.0 | 8.94 | 0.00 | 0.00 | 11.09 | 97.20 | 2.9 | 12.5 |
| 4 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 16.0 | 15.76 | 0.00 | 0.00 | 17.88 | 96.48 | 6.8 | 27.0 |
| 5 | 22.0 | 80.0 | 2.4 | 100.0 | 0.0 | 25.2 | 25.17 | 0.00 | 0.01 | 26.90 | 98.29 | 12.3 | 41.5 |
| 6 | 22.0 | 80.0 | 29.6 | 100.0 | 0.0 | 29.5 | 37.95 | 0.00 | 0.15 | 38.70 | 126.55 | 17.1 | 63.3 |
| 7 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 42.6 | 54.47 | 0.00 | 0.00 | 52.61 | 125.63 | 23.6 | 87.8 |
| 8 | 22.0 | 80.8 | 0.0 | 100.0 | 0.0 | 59.1 | 75.21 | 0.22 | 0.00 | 68.65 | 124.92 | 31.4 | 119.6 |
| 9 | 22.0 | 91.5 | 0.0 | 100.0 | 0.0 | 79.8 | 100.76 | 3.42 | 0.00 | 87.04 | 124.09 | 30.8 | 158.2 |
| 10 | 22.0 | 100.3 | 22.8 | 100.0 | 0.0 | 88.5 | 129.89 | 17.17 | 0.11 | 107.10 | 144.18 | 30.7 | 218.9 |
| 11 | 22.0 | 95.6 | 40.2 | 100.0 | 0.0 | 84.9 | 151.59 | 39.75 | 0.20 | 121.29 | 175.42 | 36.5 | 234.1 |
| 12 | 22.0 | 100.4 | 0.0 | 100.0 | 0.0 | 94.0 | 151.48 | 67.77 | 0.00 | 119.45 | 158.33 | 39.8 | 253.1 |
| 13 | 22.0 | 100.2 | 0.0 | 100.0 | 0.0 | 88.1 | 117.60 | 60.81 | 0.00 | 93.89 | 131.06 | 17.4 | 257.6 |
| 14 | 22.0 | 82.7 | 0.0 | 100.0 | 0.0 | 76.0 | 82.63 | 28.53 | 0.00 | 68.42 | 106.80 | 14.6 | 255.3 |
| 15 | 22.0 | 86.2 | 0.0 | 100.0 | 0.0 | 78.2 | 75.80 | 21.14 | 0.00 | 63.66 | 95.24 | 19.2 | 266.4 |
| 16 | 22.0 | 98.2 | 0.0 | 100.0 | 0.0 | 85.7 | 75.93 | 20.06 | 0.00 | 63.97 | 87.02 | 26.2 | 253.7 |
| 17 | 22.0 | 98.8 | 0.0 | 100.0 | 0.0 | 95.4 | 76.84 | 21.10 | 0.00 | 64.39 | 79.11 | 35.5 | 240.1 |
| 18 | 22.0 | 100.2 | 0.0 | 100.0 | 0.0 | 105.7 | 75.92 | 19.53 | 0.00 | 63.06 | 70.56 | 46.9 | 241.4 |
| 19 | 22.0 | 100.1 | 0.0 | 100.0 | 0.0 | 119.4 | 76.16 | 14.95 | 0.00 | 62.20 | 62.64 | 60.7 | 231.9 |
| 20 | 22.0 | 100.2 | 0.0 | 100.0 | 0.0 | 142.1 | 81.73 | 19.18 | 0.00 | 64.71 | 56.48 | 77.8 | 232.0 |
| 21 | 22.0 | 88.1 | 0.0 | 100.0 | 0.0 | 168.3 | 83.39 | 27.87 | 0.00 | 64.02 | 48.66 | 97.4 | 240.4 |
| 22 | 22.0 | 31.9 | 0.0 | 100.0 | 0.0 | 193.8 | 74.03 | 13.92 | 0.00 | 55.38 | 37.53 | 117.8 | 264.6 |
| 23 | 22.0 | 21.3 | 0.0 | 100.0 | 0.0 | 232.6 | 75.97 | 14.21 | 0.00 | 54.86 | 32.08 | 146.4 | 320.5 |
| 24 | 22.0 | 100.1 | 0.0 | 100.0 | 0.0 | 276.3 | 75.92 | 77.30 | 0.00 | 53.20 | 26.98 | 179.8 | 366.3 |
| Total | | | | | | | | 466.94 | 0.99 | 1430.52 | | | |

| Conversion r. | Max.density | Max. volumes per day |
|---|---|---|
| 3.06 | 20.50 | 32.92 |

TABLE 9B.
OPTIMIZATION RESULTS - CASE BOP2 - COSTS AND REVENUES (IN MILLION IT. LIRE).

| | | | Costs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Per. | Price | Revenue | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Cumulated |
| 1 | 22.0 | 0.0 | 2.6 | 2.1 | 1030.1 | 0.0 | 0.0 | 33.3 | 1068.1 | -1068.1 | -1068.1 |
| 2 | 22.0 | 0.0 | 7.0 | 5.9 | 0.0 | 0.0 | 0.0 | 33.3 | 46.2 | -46.2 | -1114.3 |
| 3 | 22.0 | 0.0 | 13.0 | 12.2 | 0.0 | 0.0 | 0.0 | 33.3 | 58.6 | -58.6 | -1172.8 |
| 4 | 22.0 | 0.0 | 20.9 | 21.3 | 0.0 | 0.0 | 0.0 | 33.3 | 75.5 | -75.5 | -1248.3 |
| 5 | 22.0 | 0.0 | 31.1 | 33.8 | 23.6 | 0.0 | 0.0 | 33.3 | 121.8 | -121.8 | -1370.1 |
| 6 | 22.0 | 0.0 | 44.5 | 50.6 | 284.6 | 0.0 | 0.0 | 33.3 | 413.0 | -413.0 | -1783.2 |
| 7 | 22.0 | 0.0 | 60.0 | 72.2 | 0.0 | 0.0 | 0.0 | 33.3 | 165.8 | -165.7 | -1948.9 |
| 8 | 22.0 | 4.4 | 77.6 | 99.3 | 0.0 | 0.0 | 0.0 | 33.3 | 211.0 | -206.6 | -2155.5 |
| 9 | 22.0 | 70.1 | 97.6 | 99.5 | 0.0 | 0.0 | 104.7 | 33.3 | 335.8 | -265.6 | -2421.1 |
| 10 | 22.0 | 349.0 | 119.2 | 98.7 | 212.6 | 0.0 | 225.8 | 33.3 | 689.7 | -340.8 | -2761.9 |
| 11 | 22.0 | 801.3 | 133.9 | 97.9 | 371.5 | 0.0 | 314.1 | 33.3 | 950.8 | -149.5 | -2911.4 |
| 12 | 22.0 | 1355.4 | 130.8 | 97.2 | 0.0 | 0.0 | 311.1 | 33.3 | 572.5 | 782.9 | -2128.5 |
| 13 | 22.0 | 1206.7 | 102.0 | 96.4 | 0.0 | 0.0 | 170.3 | 33.3 | 402.2 | 804.4 | -1324.1 |
| 14 | 22.0 | 561.7 | 73.8 | 95.6 | 0.0 | 0.0 | 27.2 | 33.3 | 230.1 | 331.6 | -992.5 |
| 15 | 22.0 | 412.8 | 68.1 | 94.7 | 0.0 | 0.0 | 0.0 | 33.3 | 196.2 | 216.6 | -775.8 |
| 16 | 22.0 | 388.7 | 67.9 | 94.1 | 0.0 | 0.0 | 0.1 | 33.3 | 195.5 | 193.3 | -582.6 |
| 17 | 22.0 | 405.5 | 67.8 | 93.4 | 0.0 | 0.0 | 3.6 | 33.3 | 198.4 | 207.1 | -375.5 |
| 18 | 22.0 | 372.5 | 65.8 | 92.6 | 0.0 | 0.0 | 0.0 | 33.3 | 192.2 | 180.3 | -195.2 |
| 19 | 22.0 | 282.8 | 64.4 | 91.9 | 0.0 | 0.0 | 0.9 | 33.3 | 190.8 | 92.0 | -103.2 |
| 20 | 22.0 | 360.0 | 66.5 | 91.2 | 0.0 | 0.0 | 22.5 | 33.3 | 213.5 | 146.4 | 43.2 |
| 21 | 22.0 | 518.9 | 65.3 | 90.5 | 0.0 | 0.0 | 28.6 | 33.3 | 217.7 | 301.2 | 344.4 |
| 22 | 22.0 | 257.2 | 56.0 | 87.5 | 0.0 | 0.0 | 0.0 | 33.3 | 176.8 | 80.4 | 424.8 |
| 23 | 22.0 | 260.4 | 55.1 | 89.0 | 0.0 | 0.0 | 0.2 | 33.3 | 177.6 | 82.8 | 507.6 |
| 24 | 22.0 | 1405.4 | 53.0 | 88.3 | 0.0 | 0.0 | 0.0 | 33.3 | 174.6 | 1230.8 | 1738.3 |
| Res.value | | 0.0 | | | | | | | | | |
| Total | | 9012.8 | 1543.8 | 1795.9 | 1922.4 | 0.0 | 1209.0 | 800.0 | 7274.5 | 1738.3 | |

TABLE 10A.
OPTIMIZATION RESULTS - CASE BOP4 - BIOMASS.

| Per. | Temp. | Harv. | Stock. | Feed | DT | AW | -- | Biomasses(ton) | | | -- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | deg | % | % | % | deg | g | Tot. | Harv. | Stock. | Feed | % fish | P05 | P95 |
| 1 | 22.0 | 80.0 | 100.1 | 100.0 | 0.0 | 1.5 | 1.45 | 0.00 | 0.50 | 2.12 | 100.00 | 0.1 | 2.4 |
| 2 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 4.3 | 4.18 | 0.00 | 0.00 | 5.70 | 98.21 | 0.8 | 6.3 |
| 3 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 9.0 | 8.69 | 0.00 | 0.00 | 10.77 | 97.20 | 2.9 | 12.5 |
| 4 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 16.0 | 15.31 | 0.00 | 0.00 | 17.37 | 96.48 | 6.8 | 27.0 |
| 5 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 25.7 | 24.41 | 0.00 | 0.00 | 26.08 | 95.93 | 12.5 | 41.5 |
| 6 | 22.0 | 80.0 | 33.0 | 100.0 | 0.0 | 29.0 | 36.83 | 0.00 | 0.17 | 37.55 | 128.46 | 17.2 | 63.3 |
| 7 | 22.0 | 80.0 | 2.7 | 100.0 | 0.0 | 41.1 | 52.92 | 0.00 | 0.01 | 51.15 | 130.15 | 23.6 | 87.8 |
| 8 | 22.0 | 80.7 | 0.0 | 100.0 | 0.0 | 57.2 | 73.18 | 0.21 | 0.00 | 66.89 | 129.37 | 31.0 | 119.6 |
| 9 | 22.0 | 87.6 | 0.0 | 100.0 | 0.0 | 77.3 | 98.18 | 3.19 | 0.00 | 84.96 | 128.50 | 24.1 | 158.0 |
| 10 | 22.0 | 100.6 | 30.5 | 100.0 | 0.0 | 81.8 | 127.03 | 16.85 | 0.15 | 105.02 | 156.96 | 27.6 | 219.3 |
| 11 | 22.0 | 99.9 | 27.4 | 100.0 | 0.0 | 85.1 | 148.41 | 40.35 | 0.14 | 119.14 | 176.26 | 33.0 | 234.0 |
| 12 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 93.7 | 146.96 | 63.74 | 0.00 | 116.50 | 158.56 | 36.2 | 249.9 |
| 13 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 89.3 | 116.65 | 58.98 | 0.00 | 93.51 | 132.05 | 18.1 | 257.3 |
| 14 | 22.0 | 89.7 | 0.0 | 100.0 | 0.0 | 78.3 | 83.55 | 29.87 | 0.00 | 69.41 | 107.84 | 16.1 | 254.5 |
| 15 | 22.0 | 99.8 | 0.0 | 100.0 | 0.0 | 80.0 | 75.51 | 20.80 | 0.00 | 63.72 | 95.44 | 21.2 | 255.6 |
| 16 | 22.0 | 73.8 | 0.0 | 100.0 | 0.0 | 88.5 | 76.10 | 12.27 | 0.00 | 64.17 | 86.97 | 28.6 | 232.1 |
| 17 | 22.0 | 99.9 | 0.0 | 100.0 | 0.0 | 106.2 | 85.74 | 27.91 | 0.00 | 70.43 | 81.66 | 39.1 | 256.7 |
| 18 | 22.0 | 99.9 | 0.0 | 100.0 | 0.0 | 113.5 | 79.06 | 22.41 | 0.00 | 64.79 | 70.41 | 49.9 | 242.7 |
| 19 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 126.8 | 76.58 | 18.15 | 0.00 | 61.82 | 61.09 | 63.7 | 235.9 |
| 20 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 148.0 | 78.33 | 21.36 | 0.00 | 61.53 | 53.50 | 80.9 | 235.1 |
| 21 | 22.0 | 41.7 | 0.0 | 100.0 | 0.0 | 172.7 | 76.20 | 13.21 | 0.00 | 58.22 | 44.62 | 100.3 | 245.5 |
| 22 | 22.0 | 36.1 | 0.0 | 100.0 | 0.0 | 208.8 | 80.82 | 20.90 | 0.00 | 59.54 | 39.14 | 124.8 | 295.4 |
| 23 | 22.0 | 99.8 | 0.0 | 100.0 | 0.0 | 246.0 | 75.79 | 69.75 | 0.00 | 54.18 | 31.15 | 154.6 | 347.7 |
| 24 | 22.0 | 100.1 | 0.0 | 100.0 | 0.0 | 216.0 | 14.81 | 12.39 | 0.00 | 10.87 | 6.93 | 149.9 | 266.3 |
| Total | | | | | | | | 452.35 | 0.97 | 1375.41 | | | |

| Conversion r. | Max.density | Max. volumes per day |
|---|---|---|
| 3.04 | 19.90 | 32.07 |

**TABLE 10B.**
**OPTIMIZATION RESULTS - CASE BOP4 - COSTS AND REVENUES (IN MILLION IT. LIRE).**

| | | | Costs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Per. | Price | Revenue | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Cumulated |
| 1 | 22.0 | 0.0 | 2.5 | 2.0 | 1000.6 | 0.0 | 0.0 | 33.3 | 1038.5 | -1038.5 | -1038.5 |
| 2 | 22.0 | 0.0 | 6.8 | 5.7 | 0.0 | 0.0 | 0.0 | 33.3 | 45.8 | -45.8 | -1084.3 |
| 3 | 22.0 | 0.0 | 12.7 | 11.8 | 0.0 | 0.0 | 0.0 | 33.3 | 57.8 | -57.8 | -1142.1 |
| 4 | 22.0 | 0.0 | 20.3 | 20.7 | 0.0 | 0.0 | 0.0 | 33.3 | 74.3 | -74.3 | -1216.4 |
| 5 | 22.0 | 0.0 | 30.2 | 32.8 | 0.0 | 0.0 | 0.0 | 33.3 | 96.3 | -96.3 | -1312.7 |
| 6 | 22.0 | 0.0 | 43.1 | 49.1 | 317.2 | 0.0 | 0.0 | 33.3 | 442.7 | -442.7 | -1755.4 |
| 7 | 22.0 | 0.0 | 58.3 | 70.1 | 25.5 | 0.0 | 0.0 | 33.3 | 187.5 | -187.5 | -1942.9 |
| 8 | 22.0 | 4.3 | 75.6 | 96.6 | 0.0 | 0.0 | 0.0 | 33.3 | 206.3 | -202.0 | -2144.9 |
| 9 | 22.0 | 65.3 | 95.3 | 99.5 | 0.0 | 0.0 | 93.9 | 33.3 | 322.5 | -257.3 | -2402.2 |
| 10 | 22.0 | 342.4 | 116.9 | 98.7 | 284.2 | 0.0 | 213.8 | 33.3 | 747.1 | -404.7 | -2806.9 |
| 11 | 22.0 | 813.5 | 131.5 | 97.9 | 252.7 | 0.0 | 300.8 | 33.3 | 816.4 | -2.9 | -2809.7 |
| 12 | 22.0 | 1274.8 | 127.6 | 97.2 | 0.0 | 0.0 | 292.5 | 33.3 | 550.7 | 724.1 | -2085.6 |
| 13 | 22.0 | 1170.3 | 101.6 | 96.4 | 0.0 | 0.0 | 166.4 | 33.3 | 397.9 | 772.3 | -1313.3 |
| 14 | 22.0 | 588.1 | 74.8 | 95.6 | 0.0 | 0.0 | 30.9 | 33.3 | 234.9 | 353.1 | -960.1 |
| 15 | 22.0 | 406.2 | 68.1 | 94.3 | 0.0 | 0.0 | 0.0 | 33.3 | 195.9 | 210.3 | -749.8 |
| 16 | 22.0 | 237.7 | 68.1 | 94.1 | 0.0 | 0.0 | 0.7 | 33.3 | 196.4 | 41.3 | -708.4 |
| 17 | 24.0 | 585.1 | 74.1 | 93.4 | 0.0 | 0.0 | 38.9 | 33.3 | 240.0 | 345.2 | -363.3 |
| 18 | 24.0 | 466.3 | 67.7 | 92.6 | 0.0 | 0.0 | 12.3 | 33.3 | 206.3 | 260.0 | -103.3 |
| 19 | 22.0 | 343.4 | 64.0 | 91.9 | 0.0 | 0.0 | 2.6 | 33.3 | 192.1 | 151.3 | 48.0 |
| 20 | 22.0 | 400.9 | 63.2 | 91.2 | 0.0 | 0.0 | 9.3 | 33.3 | 197.1 | 203.8 | 251.8 |
| 21 | 22.0 | 246.0 | 59.4 | 90.5 | 0.0 | 0.0 | 1.1 | 33.3 | 184.3 | 61.8 | 313.6 |
| 22 | 24.0 | 421.3 | 60.2 | 89.7 | 0.0 | 0.0 | 18.6 | 33.3 | 201.9 | 219.3 | 532.9 |
| 23 | 24.0 | 1394.5 | 54.4 | 88.9 | 0.0 | 0.0 | 0.0 | 33.3 | 176.6 | 1217.9 | 1750.8 |
| 24 | 22.0 | 225.2 | 10.8 | 17.1 | 0.0 | 0.0 | 0.0 | 33.3 | 61.2 | 164.0 | 1914.8 |
| Res.value | | 0.0 | | | | | | | | | |
| Total | | 8985.3 | 1487.3 | 1717.8 | 1880.2 | 0.0 | 1181.9 | 800.0 | 7070.5 | 1914.8 | |

TABLE 11A.
OPTIMIZATION RESULTS - CASE BOP6 - BIOMASS.

| Per. | Temp. | Harv. | Stock. | Feed | DT | AW | -- | Biomasses(ton) | | | -- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | deg | % | % | % | deg | g | Tot. | Harv. | Stock. | Feed | % fish | P05 | P95 |
| 1 | 22.0 | 80.0 | 54.9 | 100.0 | 0.0 | 1.5 | 0.79 | 0.00 | 0.27 | 1.16 | 100.00 | 0.1 | 2.4 |
| 2 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 4.3 | 2.29 | 0.00 | 0.00 | 3.13 | 98.21 | 0.8 | 6.3 |
| 3 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 9.0 | 4.77 | 0.00 | 0.00 | 5.91 | 97.20 | 2.9 | 12.5 |
| 4 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 16.0 | 8.41 | 0.00 | 0.00 | 9.53 | 96.48 | 6.8 | 27.0 |
| 5 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 25.7 | 13.40 | 0.00 | 0.00 | 14.32 | 95.93 | 12.5 | 41.5 |
| 6 | 22.0 | 80.0 | 42.2 | 100.0 | 0.0 | 22.0 | 20.56 | 0.00 | 0.21 | 21.12 | 172.22 | 14.9 | 63.1 |
| 7 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 32.5 | 30.03 | 0.00 | 0.00 | 29.41 | 170.47 | 5.7 | 87.5 |
| 8 | 22.0 | 80.3 | 0.0 | 100.0 | 0.0 | 45.9 | 42.20 | 0.11 | 0.00 | 39.22 | 169.29 | 8.5 | 118.6 |
| 9 | 22.0 | 87.1 | 0.0 | 100.0 | 0.0 | 62.9 | 57.44 | 1.74 | 0.00 | 50.65 | 168.13 | 13.0 | 156.0 |
| 10 | 22.0 | 100.2 | 52.7 | 100.0 | 0.0 | 53.4 | 75.90 | 9.26 | 0.26 | 64.43 | 261.85 | 18.1 | 217.2 |
| 11 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 66.5 | 91.12 | 22.17 | 0.00 | 75.60 | 252.45 | 23.6 | 232.4 |
| 12 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 74.6 | 94.98 | 34.95 | 0.00 | 78.23 | 234.40 | 20.8 | 245.6 |
| 13 | 22.0 | 99.5 | 0.0 | 100.0 | 0.0 | 74.9 | 84.35 | 32.31 | 0.00 | 70.42 | 207.56 | 14.3 | 252.2 |
| 14 | 22.0 | 99.3 | 0.0 | 100.0 | 0.0 | 74.3 | 73.78 | 19.18 | 0.00 | 63.01 | 183.02 | 17.9 | 243.8 |
| 15 | 22.0 | 100.6 | 0.0 | 100.0 | 0.0 | 83.0 | 75.83 | 13.21 | 0.00 | 64.62 | 168.23 | 25.1 | 228.3 |
| 16 | 22.0 | 57.7 | 0.0 | 100.0 | 0.0 | 99.6 | 85.30 | 10.72 | 0.00 | 70.95 | 157.82 | 35.2 | 231.3 |
| 17 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 121.8 | 98.68 | 36.69 | 0.00 | 79.36 | 149.27 | 47.9 | 264.7 |
| 18 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 127.3 | 84.81 | 26.76 | 0.00 | 68.21 | 122.78 | 60.4 | 245.6 |
| 19 | 22.0 | 100.4 | 0.0 | 100.0 | 0.0 | 141.0 | 78.60 | 22.13 | 0.00 | 62.25 | 102.67 | 75.8 | 238.1 |
| 20 | 22.0 | 83.1 | 0.0 | 100.0 | 0.0 | 162.8 | 76.01 | 21.62 | 0.00 | 58.71 | 85.99 | 94.2 | 238.7 |
| 21 | 22.0 | 0.0 | 0.0 | 100.0 | 0.0 | 190.5 | 72.08 | 0.00 | 0.00 | 54.08 | 69.71 | 115.2 | 265.0 |
| 22 | 22.0 | 91.0 | 0.0 | 100.0 | 0.0 | 236.1 | 89.14 | 72.27 | 0.00 | 64.18 | 69.55 | 146.8 | 326.1 |
| 23 | 22.0 | 100.0 | 0.0 | 100.0 | 0.0 | 233.2 | 28.50 | 25.24 | 0.00 | 20.59 | 22.51 | 155.4 | 345.9 |
| 24 | 22.0 | 100.1 | 0.0 | 100.0 | 0.0 | 219.5 | 6.69 | 5.93 | 0.00 | 4.89 | 5.61 | 158.2 | 265.8 |
| Total | | | | | | | | 354.30 | 0.75 | 1073.98 | | | |

| Conversion r. | Max.density | Max. volumes per day |
|---|---|---|
| 3.03 | 13.30 | 32.09 |

TABLE 11B.
OPTIMIZATION RESULTS - CASE BOP6 - COSTS AND REVENUES (IN MILLION IT. LIRE).

| | | | Costs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Per. | Price | Revenue | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Cumulated |
| 1 | 22.0 | 0.0 | 1.4 | 2.2 | 549.3 | 0.0 | 0.0 | 33.3 | 586.2 | -586.2 | -586.2 |
| 2 | 22.0 | 0.0 | 3.7 | 6.3 | 0.0 | 0.0 | 0.0 | 33.3 | 43.3 | -43.3 | -629.5 |
| 3 | 22.0 | 0.0 | 7.0 | 13.0 | 0.0 | 0.0 | 0.0 | 33.3 | 53.3 | -53.3 | -682.8 |
| 4 | 22.0 | 0.0 | 11.1 | 22.7 | 0.0 | 0.0 | 0.0 | 33.3 | 67.2 | -67.2 | -750.0 |
| 5 | 22.0 | 0.0 | 16.6 | 35.9 | 0.0 | 0.0 | 0.0 | 33.3 | 85.8 | -85.8 | -835.8 |
| 6 | 22.0 | 0.0 | 24.3 | 54.7 | 405.1 | 0.0 | 0.0 | 33.3 | 517.4 | -517.4 | -1353.2 |
| 7 | 22.0 | 0.0 | 33.5 | 79.3 | 0.0 | 0.0 | 0.0 | 33.3 | 146.3 | -146.3 | -1499.5 |
| 8 | 22.0 | 2.3 | 44.3 | 110.6 | 0.0 | 0.0 | 0.0 | 33.3 | 188.7 | -186.3 | -1685.8 |
| 9 | 22.0 | 35.6 | 56.8 | 149.6 | 0.0 | 0.0 | 0.0 | 33.3 | 240.0 | -204.4 | -1890.2 |
| 10 | 22.0 | 188.2 | 71.7 | 196.5 | 490.8 | 0.0 | 0.0 | 33.3 | 792.4 | -604.2 | -2494.4 |
| 11 | 22.0 | 447.0 | 83.5 | 195.0 | 0.0 | 0.0 | 63.1 | 33.3 | 374.9 | 72.1 | -2422.3 |
| 12 | 22.0 | 699.0 | 85.7 | 193.4 | 0.0 | 0.0 | 78.5 | 33.3 | 391.0 | 308.0 | -2114,3 |
| 13 | 22.0 | 641.1 | 76.5 | 191.9 | 0.0 | 0.0 | 34.5 | 33.3 | 336.5 | 304.6 | -1809.8 |
| 14 | 22.0 | 377.5 | 67.9 | 184.9 | 0.0 | 0.0 | 0.0 | 33.3 | 286.4 | 91.1 | -1718.6 |
| 15 | 22.0 | 258.0 | 69.1 | 188.6 | 0.0 | 0.0 | 0.0 | 33.3 | 291.1 | -33.1 | -1751.8 |
| 16 | 22.0 | 207.8 | 75.3 | 187.4 | 0.0 | 0.0 | 37.4 | 33.3 | 333.5 | -125.8 | -1877.6 |
| 17 | 24.0 | 769.4 | 83.5 | 185.9 | 0.0 | 0.0 | 90.1 | 33.3 | 393.1 | 376.3 | -1501.3 |
| 18 | 24.0 | 556.6 | 71.2 | 184.4 | 0.0 | 0.0 | 34.9 | 33.3 | 324.2 | 232.4 | -1268.9 |
| 19 | 22.0 | 418.6 | 64.5 | 182.9 | 0.0 | 0.0 | 10.4 | 33.3 | 291.3 | 127.3 | -1141.5 |
| 20 | 22.0 | 405.9 | 60.3 | 181.5 | 0.0 | 0.0 | 0.4 | 33.3 | 275.5 | 130.3 | -1011.2 |
| 21 | 22.0 | 0.0 | 55.1 | 170.9 | 0.0 | 0.0 | 0.0 | 33.3 | 259.3 | -259.3 | -1270.6 |
| 22 | 24.0 | 1456.4 | 64.9 | 178.6 | 0.0 | 0.0 | 50.3 | 33.3 | 327.2 | 1129.2 | -141.4 |
| 23 | 24.0 | 504.5 | 20.7 | 66.3 | 0.0 | 0.0 | 0.0 | 33.3 | 120.3 | 384.3 | 242.9 |
| 24 | 22.0 | 107.9 | 4.9 | 15.4 | 0.0 | 0.0 | 0.0 | 33.3 | 53.6 | 54.3 | 297.2 |
| Res.value | | 0.0 | | | | | | | | | |
| Total | | 7075.8 | 1153.6 | 2977.9 | 1445.2 | 0.0 | 399.5 | 800.0 | 6778.7 | 297.2 | |

TABLE 12A.
OPTIMIZATION RESULTS - CASE BOP8 - BIOMASS.

| Per. | Temp. | Harv. | Stock. | Feed | DT | AW | -- | Biomasses(ton) | | | -- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | deg | % | % | % | deg | g | Tot. | Harv. | Stock. | Feed | % fish | P05 | P95 | |
| 1 | 17.0 | 80.0 | 57.2 | 100.0 | 0.0 | 1.2 | 0.69 | 0.00 | 0.29 | 0.68 | 100.00 | 0.1 | 2.4 | |
| 2 | 18.0 | 80.0 | 0.0 | 100.0 | 0.0 | 3.2 | 1.79 | 0.00 | 0.00 | 1.87 | 98.54 | 0.6 | 6.1 | |
| 3 | 19.0 | 80.0 | 0.0 | 100.0 | 0.0 | 6.4 | 3.56 | 0.00 | 0.00 | 3.85 | 97.58 | 1.4 | 11.8 | |
| 4 | 20.0 | 80.0 | 0.0 | 100.0 | 0.0 | 11.4 | 6.23 | 0.00 | 0.00 | 6.83 | 96.90 | 3.2 | 19.6 | |
| 5 | 21.0 | 80.0 | 0.0 | 100.0 | 0.0 | 18.4 | 10.06 | 0.00 | 0.00 | 10.82 | 96.38 | 6.8 | 30.3 | |
| 6 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 28.4 | 15.47 | 0.00 | 0.00 | 16.28 | 95.97 | 11.8 | 51.0 | |
| 7 | 22.0 | 80.0 | 0.0 | 100.0 | 0.0 | 41.9 | 22.72 | 0.00 | 0.00 | 22.61 | 95.64 | 18.5 | 71.5 | |
| 8 | 21.0 | 80.0 | 0.0 | 100.0 | 0.0 | 58.1 | 31.37 | 0.00 | 0.00 | 28.61 | 95.33 | 27.5 | 98.2 | |
| 9 | 20.0 | 80.0 | 0.0 | 100.0 | 0.0 | 75.9 | 40.85 | 0.00 | 0.00 | 34.15 | 94.97 | 37.8 | 125.2 | |
| 10 | 19.0 | 80.2 | 0.0 | 100.0 | 0.0 | 94.9 | 50.82 | 0.10 | 0.00 | 38.98 | 94.52 | 49.4 | 152.0 | |
| 11 | 18.0 | 81.8 | 0.0 | 100.0 | 0.0 | 114.5 | 60.97 | 0.80 | 0.00 | 43.06 | 94.01 | 61.9 | 178.7 | |
| 12 | 17.0 | 80.4 | 0.0 | 100.0 | 0.0 | 134.6 | 70.97 | 6.66 | 0.00 | 44.22 | 93.09 | 75.3 | 215.5 | |
| 13 | 17.0 | 97.7 | 0.0 | 100.0 | 0.0 | 152.3 | 75.91 | 15.63 | 0.00 | 46.25 | 87.97 | 87.8 | 229.8 | |
| 14 | 18.0 | 100.1 | 0.0 | 100.0 | 0.0 | 165.1 | 71.56 | 14.57 | 0.00 | 46.63 | 76.50 | 98.4 | 228.5 | |
| 15 | 19.0 | 71.2 | 0.0 | 100.0 | 0.0 | 181.7 | 67.77 | 16.72 | 0.00 | 45.29 | 65.85 | 113.8 | 236.5 | |
| 16 | 20.0 | 0.0 | 0.0 | 100.0 | 0.0 | 203.0 | 61.79 | 0.00 | 0.00 | 42.14 | 53.72 | 132.1 | 266.4 | |
| 17 | 21.0 | 100.0 | 0.0 | 100.0 | 0.0 | 245.3 | 74.52 | 69.52 | 0.00 | 51.06 | 53.62 | 158.4 | 331.6 | |
| 18 | 22.0 | 4.0 | 0.0 | 100.0 | 0.0 | 215.0 | 13.88 | 0.46 | 0.00 | 10.20 | 11.40 | 148.9 | 265.0 | |
| 19 | 22.0 | 90.5 | 0.0 | 100.0 | 0.0 | 262.2 | 16.43 | 15.49 | 0.00 | 11.61 | 11.06 | 184.7 | 329.1 | |
| 20 | 21.0 | 85.3 | 0.0 | 100.0 | 0.0 | 277.6 | 2.75 | 2.39 | 0.00 | 1.85 | 1.75 | 181.9 | 367.0 | |
| 21 | 20.0 | 81.0 | 0.0 | 100.0 | 0.0 | 281.5 | 0.65 | 0.51 | 0.00 | 0.41 | 0.41 | 181.1 | 373.9 | |
| 22 | 19.0 | 81.0 | 0.0 | 100.0 | 0.0 | 278.4 | 0.18 | 0.14 | 0.00 | 0.11 | 0.12 | 182.3 | 374.5 | |
| 23 | 18.0 | 80.5 | 0.0 | 100.0 | 0.0 | 272.3 | 0.05 | 0.04 | 0.00 | 0.03 | 0.03 | 182.6 | 373.2 | |
| 24 | 17.0 | 80.4 | 0.0 | 100.0 | 0.0 | 265.8 | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 | 182.6 | 371.5 | |
| Total | | | | | | | | 143.03 | 0.29 | 507.56 | | | | |

| Conversion r. | Max.density | Max. volumes per day |
|---|---|---|
| 3.55 | 11.16 | 31.61 |

TABLE 12B.
OPTIMIZATION RESULTS - CASE BOP8 - COSTS AND REVENUES (IN MILLION IT. LIRE).

| | | | Costs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Per. | Price | Revenue | Feed | Pump. | Stock. | Heat. | Oxyg. | Other | Total | Profit | Cumulated |
| 1 | 22.0 | 0.0 | 0.8 | 1.9 | 571.6 | 0.0 | 0.0 | 33.3 | 607.7 | -607.7 | -607.7 |
| 2 | 22.0 | 0.0 | 2.2 | 4.9 | 0.0 | 0.0 | 0.0 | 33.3 | 40.5 | -40.5 | -648.2 |
| 3 | 22.0 | 0.0 | 4.5 | 9.7 | 0.0 | 0.0 | 0.0 | 33.3 | 47.6 | -47.6 | -695.7 |
| 4 | 22.0 | 0.0 | 8.0 | 16.8 | 0.0 | 0.0 | 0.0 | 33.3 | 58.2 | -58.2 | -753.9 |
| 5 | 22.0 | 0.0 | 12.5 | 27.0 | 0.0 | 0.0 | 0.0 | 33.3 | 72.8 | -72.8 | -826.7 |
| 6 | 22.0 | 0.0 | 18.7 | 41.1 | 0.0 | 0.0 | 0.0 | 33.3 | 93.2 | -93.2 | -919.9 |
| 7 | 22.0 | 0.0 | 25.8 | 60.0 | 0.0 | 0.0 | 0.0 | 33.3 | 119.1 | -119.1 | -1039.0 |
| 8 | 22.0 | 0.0 | 32.3 | 82.2 | 0.0 | 0.0 | 0.0 | 33.3 | 148.1 | -148.1 | -1187.1 |
| 9 | 22.0 | 0.0 | 38.3 | 106.2 | 0.0 | 0.0 | 0.0 | 33.3 | 178.2 | -178.2 | -1365.2 |
| 10 | 22.0 | 1.9 | 43.4 | 131.2 | 0.0 | 0.0 | 0.0 | 33.3 | 208.2 | -206.3 | -1571.5 |
| 11 | 22.0 | 16.2 | 47.5 | 156.3 | 0.0 | 0.0 | 0.0 | 33.3 | 237.3 | -221.1 | -1792.7 |
| 12 | 22.0 | 133.2 | 48.4 | 180.7 | 0.0 | 0.0 | 0.0 | 33.3 | 262.5 | -129.4 | -1922.0 |
| 13 | 22.0 | 310.1 | 50.3 | 191.9 | 0.0 | 0.0 | 0.0 | 33.3 | 275.5 | 34.6 | -1887.4 |
| 14 | 22.0 | 286.7 | 50.3 | 179.3 | 0.0 | 0.0 | 0.0 | 33.3 | 263.0 | 23.8 | -1863.6 |
| 15 | 22.0 | 326.5 | 48.4 | 168.4 | 0.0 | 0.0 | 0.0 | 33.3 | 250.2 | 76.3 | -1787.3 |
| 16 | 22.0 | 0.0 | 44.7 | 152.2 | 0.0 | 0.0 | 0.0 | 33.3 | 230.3 | -230.3 | -2017.6 |
| 17 | 24.0 | 1457.7 | 53.7 | 182.4 | 0.0 | 0.0 | 0.0 | 33.3 | 269.5 | 1188.2 | -829.4 |
| 18 | 24.0 | 9.6 | 10.7 | 33.6 | 0.0 | 0.0 | 0.0 | 33.3 | 77.6 | -68.0 | -897.3 |
| 19 | 22.0 | 293.0 | 12.0 | 39.4 | 0.0 | 0.0 | 0.0 | 33.3 | 84.8 | 208.3 | -689.1 |
| 20 | 22.0 | 44.8 | 1.9 | 6.5 | 0.0 | 0.0 | 0.0 | 33.3 | 41.8 | 3.0 | -686.1 |
| 21 | 22.0 | 9.5 | 0.4 | 1.5 | 0.0 | 0.0 | 0.0 | 33.3 | 35.3 | -25.8 | -711.9 |
| 22 | 24.0 | 2.8 | 0.1 | 0.4 | 0.0 | 0.0 | 0.0 | 33.3 | 33.9 | -31.1 | -743.0 |
| 23 | 24.0 | 0.8 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 33.3 | 33.5 | -32.7 | -775.7 |
| 24 | 22.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 33.4 | -33.2 | -808.9 |
| Res.value | | 0.0 | | | | | | | | | |
| Total | | 2893.0 | 555.1 | 1774.0 | 571.6 | 0.0 | 0.0 | 800.0 | 3701.9 | -808.9 | |

FIG. 1.
SCHEME OF A MULTI-STAGE DYNAMICAL SYSTEM.

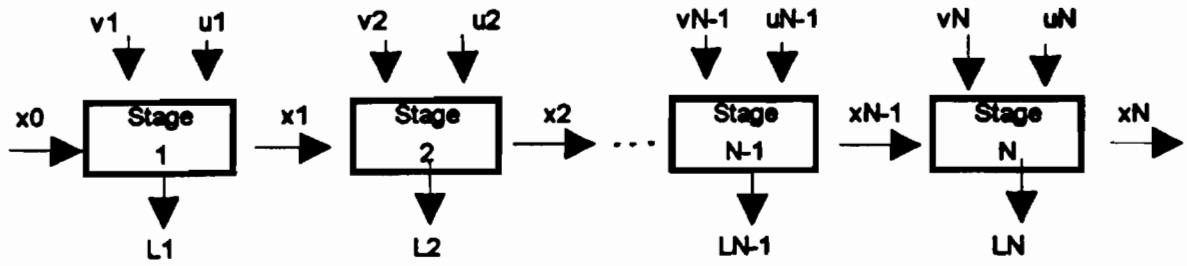



FIG. 2.
SCHEME OF A SINGLE STAGE OF FISH FARMING PROCESS.

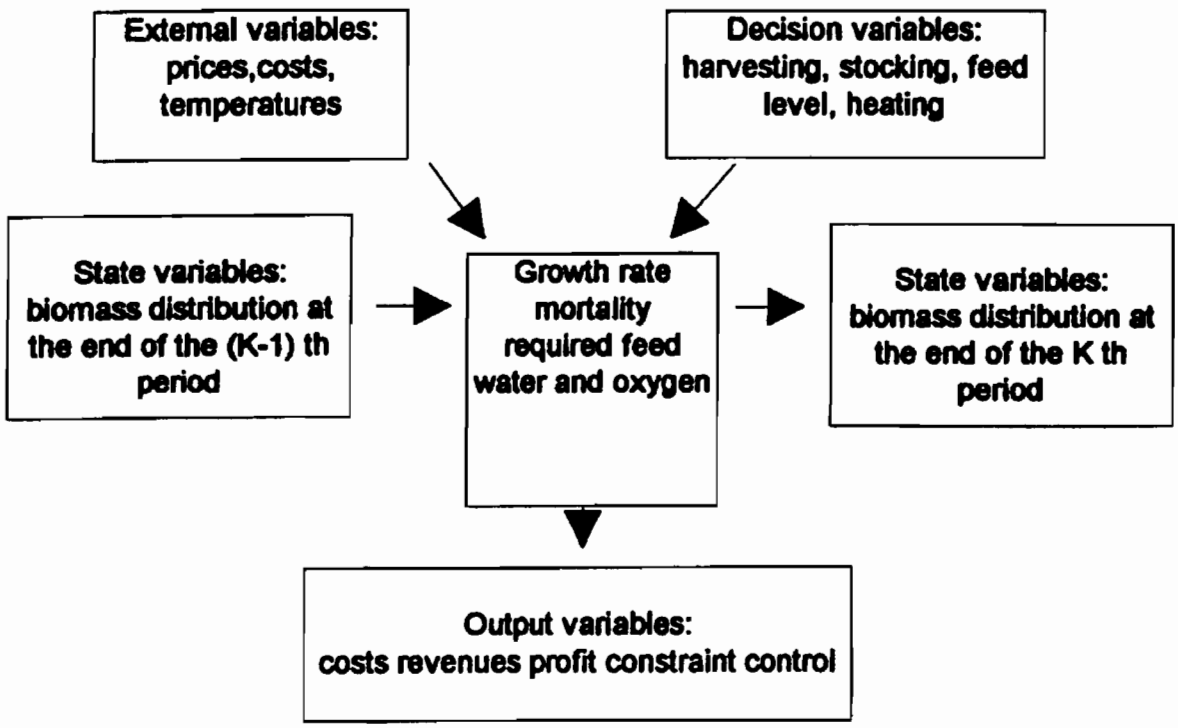


**FIG. 3A-3F.**
**BASE CASE.**

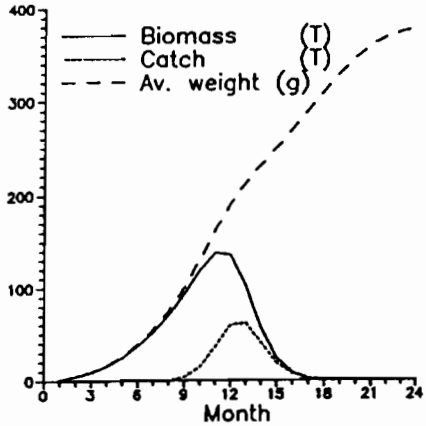


Fig. 3A – Base case

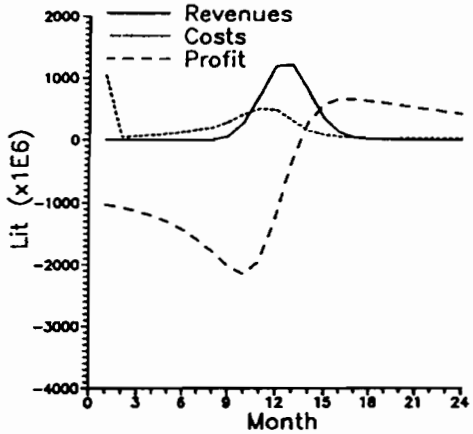


Fig. 3B – Base case

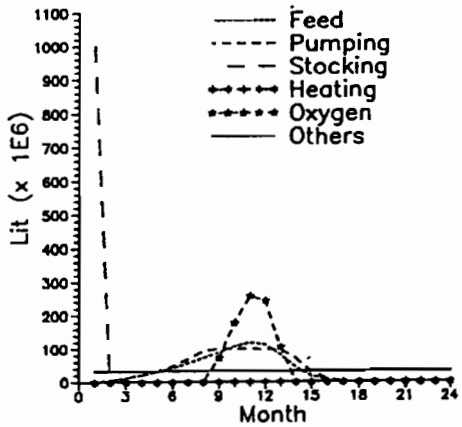


Fig. 3C – Base case

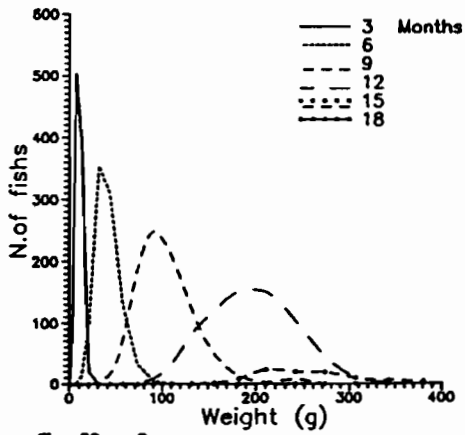


Fig. 3D – Base case

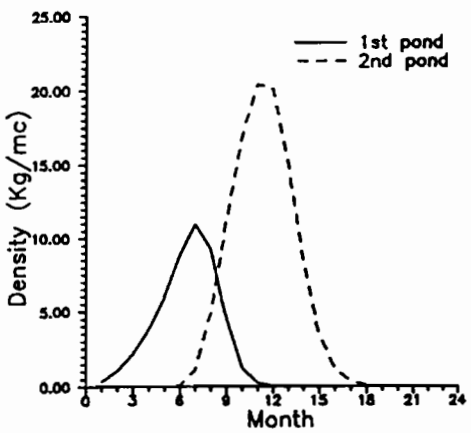


Fig. 3E – Base case

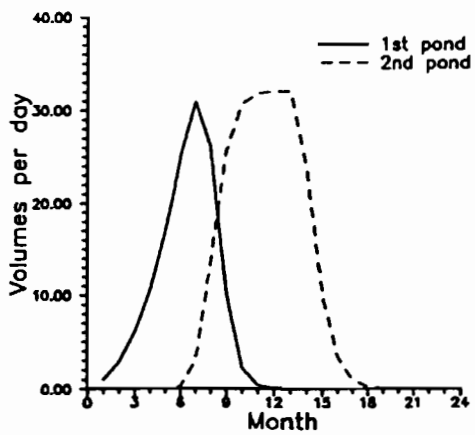


Fig. 3F – Base case

**FIG. 4A-4F.**
**CASE BOP2.**

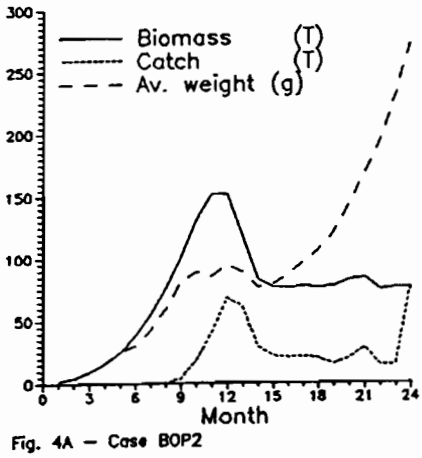


Fig. 4A – Case BOP2

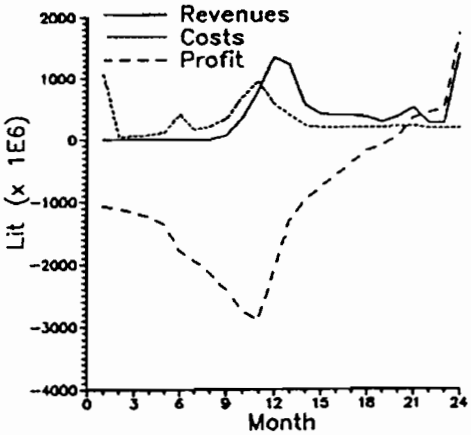


Fig. 4B – Case BOP2

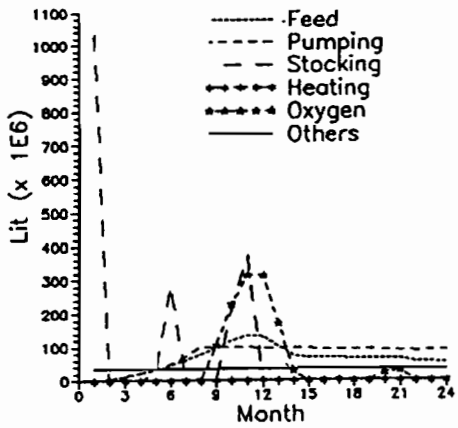


Fig. 4C – Case BOP2

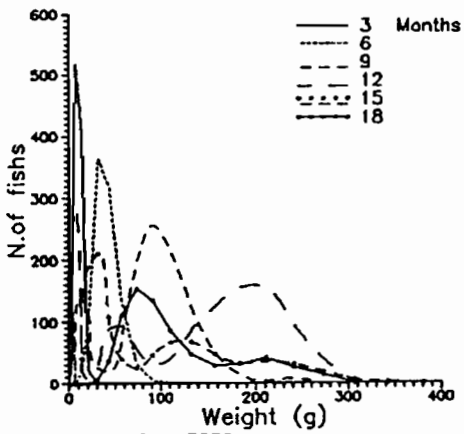


Fig. 4D – Case BOP2

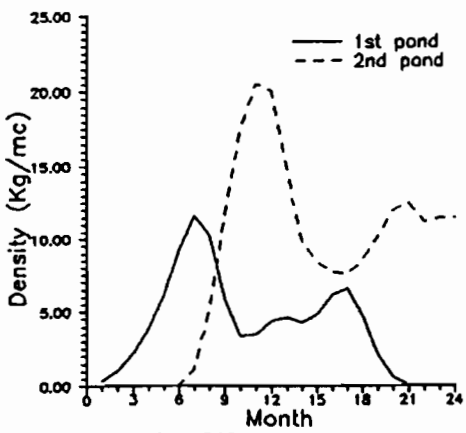


Fig. 4E – Case BOP2

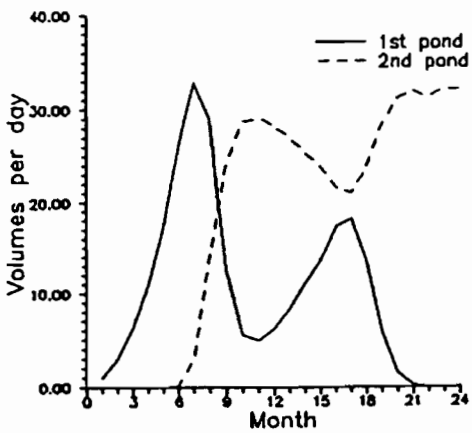


Fig. 4F – Case BOP2

# Simulation of Aquaculture Production for Economical and Environmental Impact

**Michael Spratt**

APPLYING EVOLVING TECHNOLOGIES, 13 rue du Nord, 34000 Montpellier, France

ABSTRACT

*Simulations of aquaculture production requires standard information often with unique technical and economical considerations, depending upon the user's current and projected requirements, budget and personnel constraints. Simple simulation tools can aid (re-)define these constraints while providing deeper insight into their relations. Using LOTUS 123, we defined and developed small functional modules which were incorporated in order to simulate production of Sea Bass (D. labrax) in cages in the open sea for five years.*

## 1. INTRODUCTION

Today, simulation of aquaculture production must include a minimum of information and features. Economical, financial, biological, geo-physical and zoo-technical data are as important as features like simple, easy to use, understand, adapt and enhance. Database management, reports and graphics are key elements, as well as the simulation execution time.

It is now possible to avoid problems associated with other models and simulation systems. Limitations include application specific, inflexible, closed, dependent upon the author(s) for enhancements and adaptations, and also reflect the author's era and methods, and become outdated quickly.

Finally, development of a simulator depends upon a need, multi-disciplinary experts, time and financing. For the project "PRIMO/MOSART", we developed a system in order to simulate the viability of different production configurations. This project was for IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) and concerned the production of Sea Bass (*D. labrax* ) in cages in the open sea (see figure 1).

## 2. PROBLEM SUB-DIVISIONS

Our main development tool was the spread sheet LOTUS 123, subdivided into several sub-tables, similar to our problem. The decomposition and grouping of the problem into manageable units was essential in order to satisfy the original

criteria. Each sub-division or area performs unique functions and operations. The figure 2 illustrates the six major sub-divisions and their relative location within the spread sheet. We will further describe the functioning of each sub-division.

### *2.1 Business control*

The simulation of production is based upon a "what-if" strategy. The cascade features of spread sheets are used to explore, develop and balance financial and production critera. The principle criteria for simulation are **Economical** and **Production** (see figure 3).

**Economics** include Financing, (starting date, tax rates, social charges and parameters used to evaluate the value of fish stock, etc.) **Credit** (type, amount, length, interest rate and number of years of repayment) and **Subventions** (ie. source, amount and number of payments) are used to vary economical constraints.

**Production** elements such as the Lots, Food Costs and Variable Charges control the biological aspects :

(i) **Lots** controls the grouping and growth of fish (starting date, number, mean weight and value per individual and projected mortality, plus a predetermined ending date, mean weight or biomass and a sale price per kilo). **Lots** also contains information needed for environmental appreciations (cage volume and length).

(ii) **Food Costs** contains the granulometery, or pellet size and purchase date with the price payed per kilo at their intersection. Based upon user estimations the computer will calculate the cost of food, using the weight of fish and the daily feeding table.

(iii) **Variable Charges** (vitamins, anaestheticss, disinfectants and medicines) are calculated using a ratio of cost per kilo of production.

### *2.2 Fixed costs*

Fixed costs contains **Investments, Salaries** and **Fixed Costs** (see figure 4).

The French accountining system, **Investments** are classified into 8 groups : (Ocean) structures, (Ocean) Equipment, Construction, Material for Functioning, Production Control, Security and Sanitary, Processing and Commercializing Equipment and General Equipment.

We established 20 lines for each of the 8 classes of investment, with each investment being defined by a name (and/or code), the quarter in which it is purchased, the number and price per unit and the duration of amortization.

This information permits the calculation of the purchase/payment date, the amount and taxes. The investment is amortized quarterly and presented annually in the Resume Of Investments and Amortization which summarizes investments by class and by year.

**Salaries** include the title, number of employees, monthly or yearly salary, plus social charges. In France, the total number of months per year is also important as a $13^{th}$ month may be added, as an employee bonus.

**Fixed Costs** can vary but usually include energy, transportation, veterinary charges, required insurances, (specific) insurances ie. for the fish stock, repair and maintenance, travel expenses, etc.

### *2.3 Geo-physical and zoo-technical areas*

The grouping of site and species parameters combines basic scientific information concerning the bio-physical charateristics. This area contains the **Geo-physical** and **Zoo-technical** sub-tables (see figure 5).

The **Geo-physical** information concerns the Thermal Profile of the Site (mean weekly water temperature by year), Daily Growth Rate - DGR (general model obtained from Leclercq & Tanguy), Daily Feeding Table - DFT (usally the

manufacture's suggested daily percentage of food in relation to the biomass), Daily O2 Consumption Rate (mean hourly rate expressed in mg per liter), Food to Nitrate Production (ammonium and organic nitrogen rate, based upon grams produced per Kg of food provided), Food to Particulate Matter Production (the conversion rate minus a constant).

The **Zoo-technical** table calculates a variety of values based upon daily activities, which are summarized by week and then by quarter. Calculations include the date, week number, mean weekly temperature, number of individuals, mean weight, mortality, biomass, daily feeding rate, daily growth rate, food costs, density, etc.

### *2.4 Details of production and environment*

Production results of the simulation are summarized in the Details of Production. For each of the ten lots, the closest simulation date to the end of the quarter is stored with the lot's status, number of individuals, mean weight, sales price (if sold) food costs with the biomass and value of the lots.

Details of Environment contains summary information concerning the mean and maximum O2 consumption in mg/h/kg and mg/h/l, the required minimum percent of hourly exchange, the minimum mean daily current speed (m/h), the quarterly and annual production of ammonia (Kg/week), organic nitrogen and organic matter (Kg).

All these values are calculated in the Zoo-Technical area and moved to their respective area via the macro command (see figure 7).

### *2.5 Results*

The financial results are calculated in the Production Resume, summarizing livestock purchases, sales, biomass produced, food costs, variable and fixed charges and annual stock variations.

The Variable Charges (ie. vitamins, anaesthesties, etc.), are calculated with the V.A.T. and stored in this table.

LIABILITIES, ASSETS and RESULTS describe the yearly economic realities of expenditures, resources and global production results (see figure 7).

### *2.6 Macro commands*

A macro command was developed in order to reduce the size and execution time of the simulator by limiting execution to specified lots and quarters and also controls the processing and storage of data.

Without the macro command, the time to load and backup the file after each modification would require minutes in addition to the recalculation time. The zoo-technical area is the best example. The simulation of ten lots, for 200 to 300 weeks (4 to 5 years) with the macro command, only requires 16 lines of calculations as opposed to 2000 to 3000 lines for the same calculations without the macro command. Ten lots is an arbitrary choice, the system is not limited by this factor.

The execution macro command relies on a control area, which contains key values, such as days per zoo-technical calculation (7 : days), division per year (4 : quarters), maximum number of lots (10) and quarters (20) etc. It also contains the location and size of the two three-dimensional tables *(Details of Production and Environment).* This makes it easier to modify the spread sheet and/or the macro command.

We also established other macro commands in order to jump from one area to another and to transfer tables spread sheets.

## 3. CONCLUSIONS

The aquaculture profession is facing increasing competition, higher costs, stricter regulations and reporting requirements for environmental and political reasons. Certain technologies like data bases, spread sheets and expert systems, hold great promises for this sector.

Simulations are just one of the many applications for spread sheets which are precious planning support and decision making tools. Every exploitation needs them as well as informed, interdisciplinary personnel, able to understand biological factors, face economical constraints and support growing technical complexity. The application of technology and its use are becoming manditory requirements for aquaculture businesses.

## REFERENCES

**Ali C.Q., L.G. Ross and M.C.M. Beveridge**. "Microcomputer spreadsheets for the implementation of Geographic Information Systems in Aquaculture : A case Study on Carp in Pakistan", *Aquaculture*, vol **92** : 199-205.

**Belaud A., R. Labat, and P. Lim** (1985). "Amelioration de la gestion technique des salmonicultures par programmation sur microordinateur", Lab. Ichtyol. Appl., Ec. Natl. Agron., 145 Ave. Muret, 31076 Toulouse Cedex, France, *Bull. Fr. Peche Piscic. ;* no. **297,** 55-67 ; ISSN 0373-0514.

**FAO/UNDP Aquaculture Development and Coord**. Programme, (1983), "Aquaculture information system users' manual.", FAO/UNDP ; Rome (Italy) ; *Fao/Undp Adcp/Rep/83/19*, 63pp.

**Griffin W.L., C.M. Adams, L.A. Jensen, G. Kinra, and M.A. Johns** (1983). "A generalized budget simulation model for aquaculture.", Raj Texas A&M Univ., College Station (USA). Sea Grant Coll. Program, 144 pp ; Rep. Tex. A&M Univ. Sea Grant Program., TAMU-SG-83-202. NT : NOTE NTIS Order No. : PB83-144626 ; Grant NA81AA-D-00092.

**Griffin W.L., W.E. Grant, R.W. Brick and J.S. Hanson** (1984). "A bioeconomic model of shrimp maricultural systems in the U.S.A.", ep. Agric. Econ., Texas A & Univ., College Station, TX 77843, USA, *ecological modelling ;* vol. **25**, no. 1-3 : 47-68 ; ISSN 0304-3800.

**Kapetsky J.M., J.M. Hill, J.M. and L.D. Worthy** (1988). "A geographical information system for catfish farming development.", FAO Inland Water Res. and Aquacult. Serv., Via delle Terme di Caracalla, 00100 Rome, Italy, *Aquaculture* ; vol. **68,** no. 4 : 311-320.

**Killcreas W.E.** (1982). "Microcomputer helps fish farmers make production management decisions.", Mississippi State Univ., Agric. Economics Dep., MS, USA, *Aquacult. Mag. ;* vol. **8**, no. 3, p. 14.

**McElroy J.K. (ed.)** (1983). "Provisional world list of computer programmes for fish production (including aquaculture) and fisheries management.", Stirling Univ. (UK). Technol. Econ. Res. Unit, S ; *Discuss. Pap. Stirling Univ.*, no. 37, 23 pp.

**McNown W. and A. Seireg** (1983). "Computer aided optimum design and control of staged aquaculture systems.", Dep. Mech. Eng., Univ. Wisconsin-Madison, 1513 University Ave., Madison, WI 53706, USA, *J. World Maricult. Soc.* ; vol. **14** : 417-433.

**Muller-Feuga A.S** (1984). "The developmental conditions of intensive pisciculture to the open sea. (Original title "Les conditions d'extension de la pisciculture intensive à la mer ouverte"), Aix-Marseille Univ. (France), Thesis. Doct. Sci., 192 pp.

**Piedrahita R.H.** (1988). "Introduction to computer modelling of aquaculture pond ecosystems.", Dep. Agric. Eng., Univ. California, Davis, CA 95616, USA, *Aquacult. Fish. Manage* ; vol. **19**, no. 1 : 1-12.

**Piedrahita R.H., D.E. Brune, G. Tchobanoglous and G.T. Orlob** (1984). "A general model of the aquaculture pond ecosystem.", Dep. Agric. Eng., Univ. California, Davis, CA 95616, USA, *J. World Maricult. Soc.* ; vol. **14** : 355-366.

**Plaia W.C.** (1987). "A computerized environmental monitoring and control system for use in aquaculture.", Florida Dep. Nat. Resour., Bur. Mar. Res., St. Petersburg, FL 33701, USA, vol. **6**, no. 1 : 27-37 ; ISSN 0144-8609.

**Skurla J.A. and M.E. McDonald** (1988). "Predicting the economics of a walleye aquaculture operation using bioenergetics models.", Nat. Resour. Res. Inst., Univ. Minnesota, Duluth, MN 55812, USA, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, British Columbia, Canada, September 6-9 ; Proc. Aquac. Int. Congr., NT : NOTE Summary only, p. 68.

**Whitehead C., N. Bromage and G. Lindfield** (1980). "Table fish moves into the computer age." Forster, J.,ep. Biol. Sci., Univ. Aston, Birmingham, UK, Fish Farmer. ; vol. **3**, no. 2 : 14-16.

**Zeigler T.R.** (1988). "Aquaculture technology in the future.", Zeigler Bros., Inc., Gardners, Proc. Aquacult. Int. Congr. NT : NOTE, p. 24.

FIGURE 1.
SCHEMATIC DIAGRAM

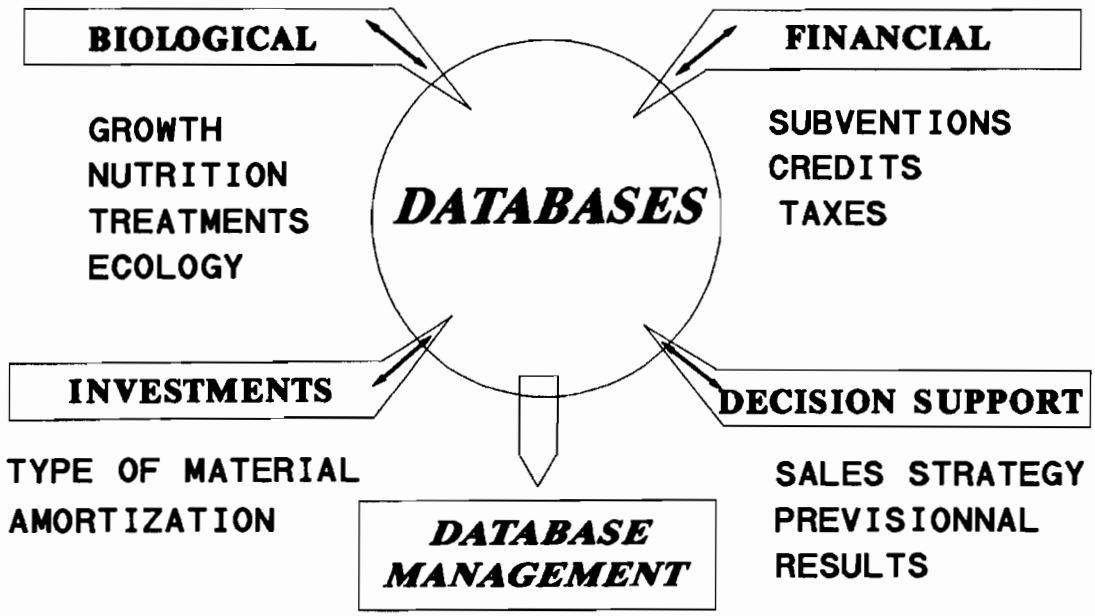


FIGURE 2.
PRINCIPE COMPONENTS

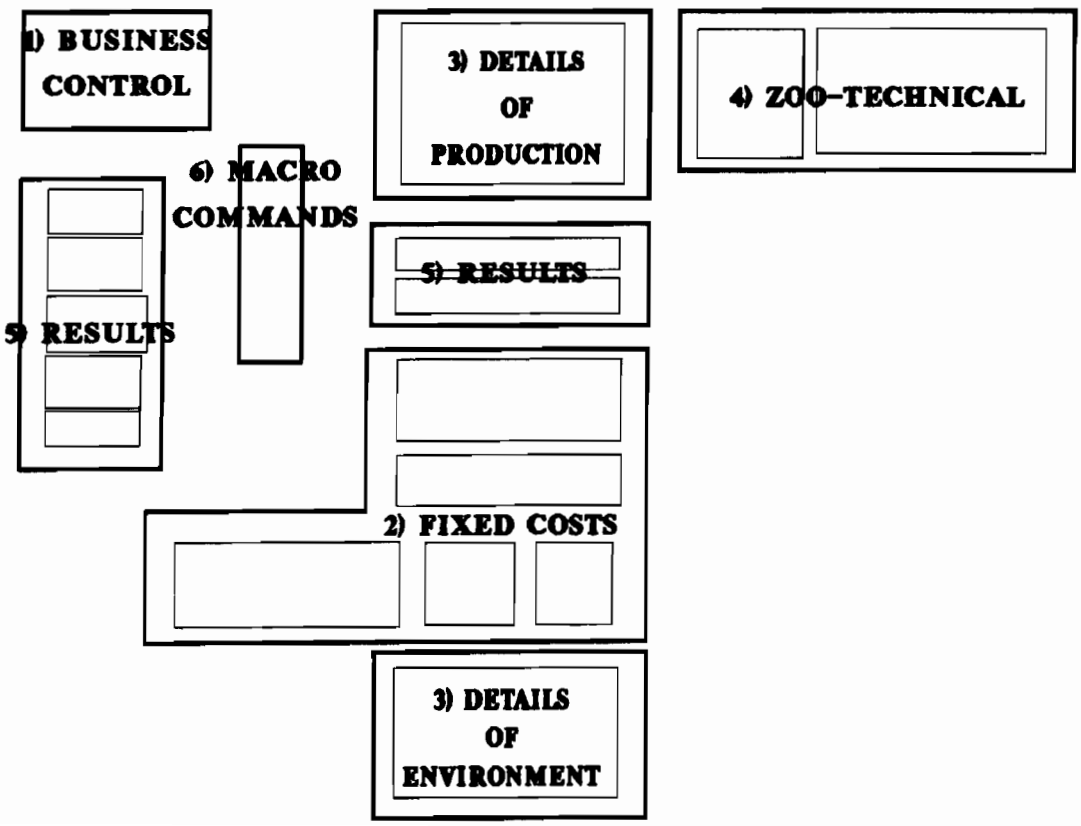


FIGURE 3.
PRINCIPLE BUSINESS SIMULATION CONTROL ELEMENTS

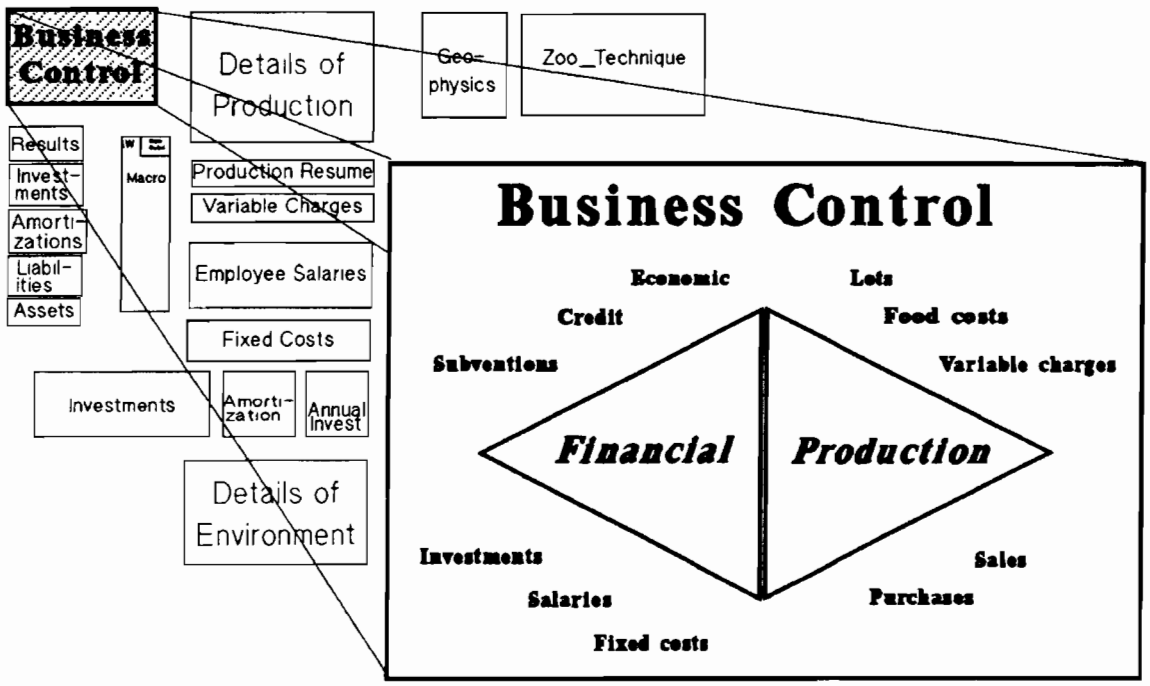



FIGURE 4.
FIXED COSTS

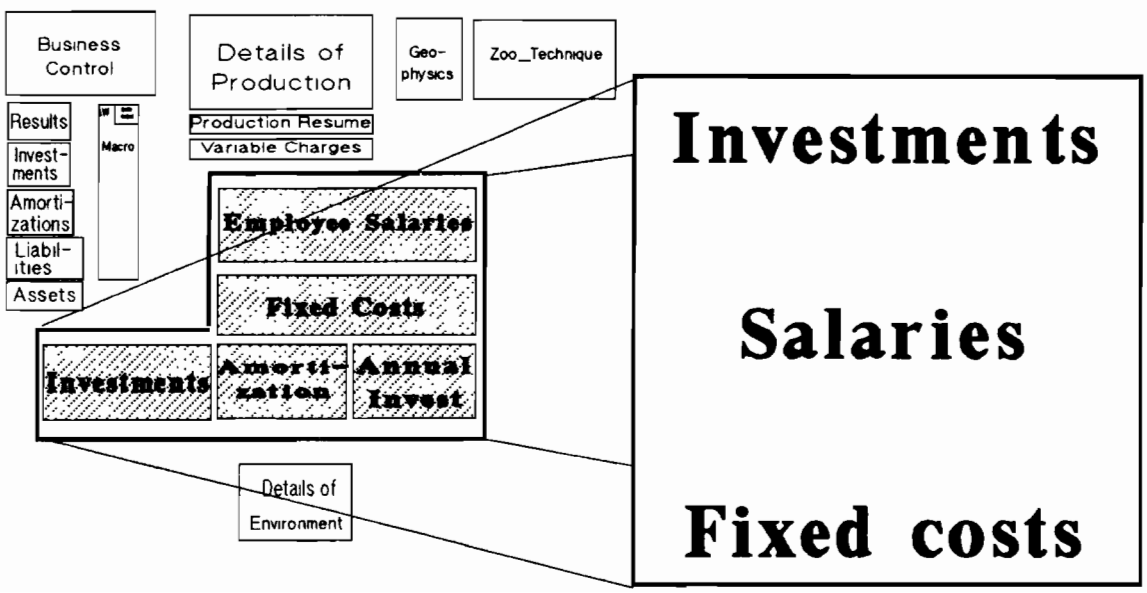


**FIGURE 5.**
**GEO-PHYSICAL AND ZOO-TECHNICAL AREAS**

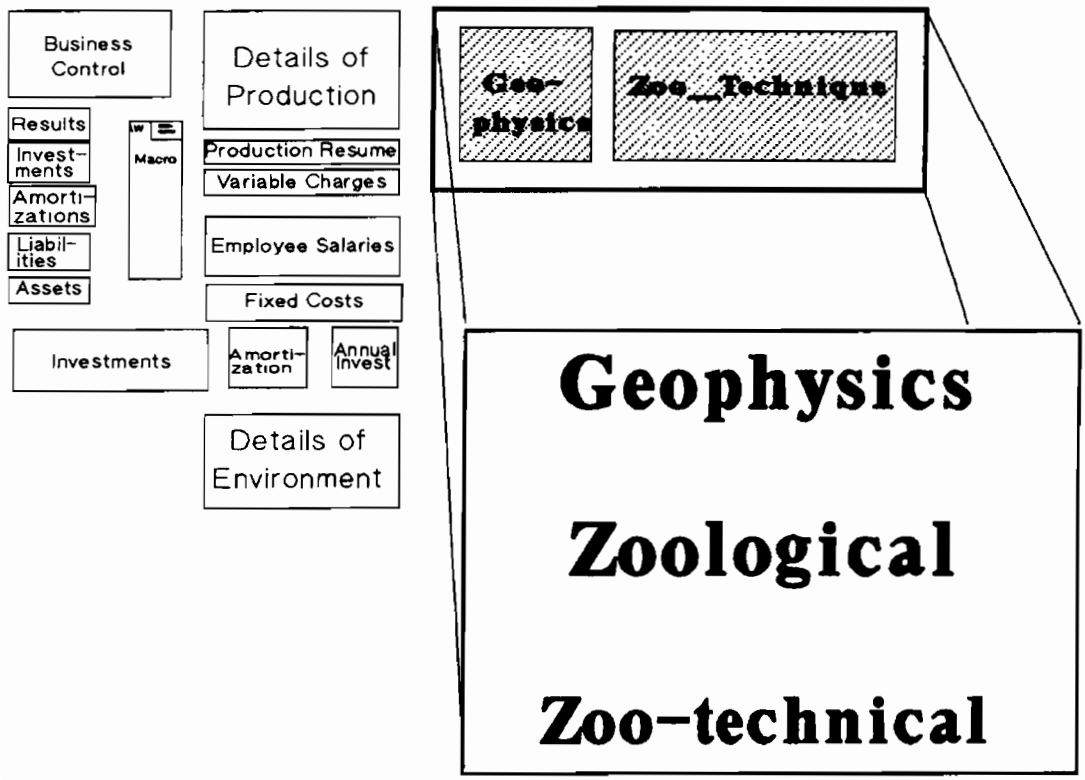


**FIGURE 6.**
**DETAILS OF PRODUCTION AND ENVIRONMENT**

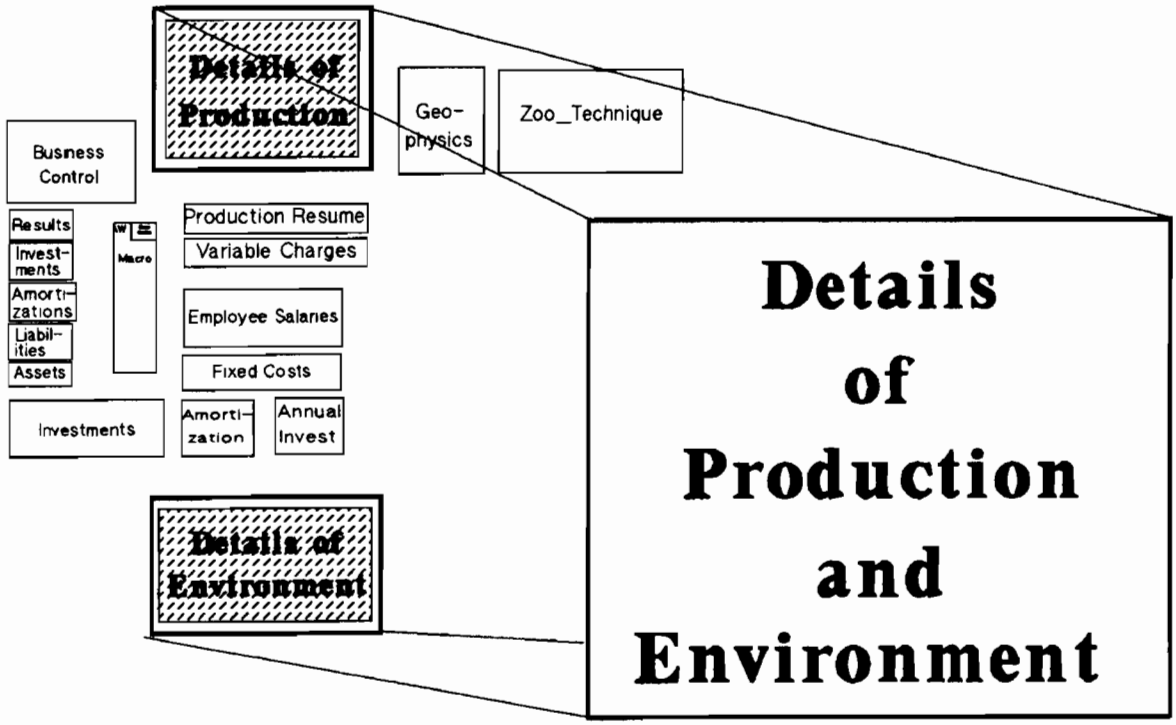
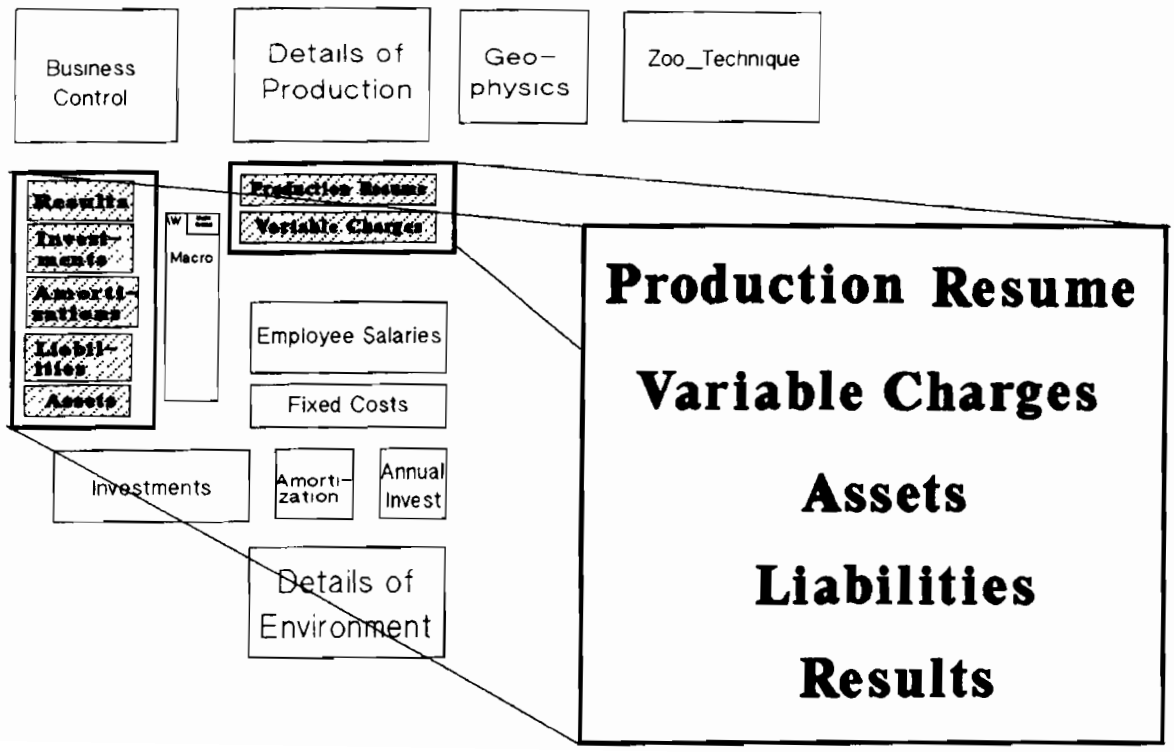


**FIGURE 7.**
**RESULTS**



# Consumption and Demand
# by
# C. R. Wessels

Jusqu'à récemment, la recherche halieutique concernant le marché de la pêche a été en grande partie négligée. Cependant, on réalise maintenant dans l'industrie de la pêche et dans la recherche que les marchés jouent un rôle crucial dans l'utilisation optimale et efficace des ressources halieutiques et en particulier que les décisions de gestion ont un impact important sur les marchés des produits de la pêche lesquels, à leur tour influencent l'efficacité des programmes de gestion. Les pêcheurs, eux aussi, demandent souvent qu'une plus grande régulation soit appliquée quand les forces du marché entraînent une exploitation excessive des ressources.

Pour mieux comprendre les relations étroites entre la gestion de la pêche et le marché, nous devons d'abord mieux comprendre la complexité du marché. Cela peut se faire soit en examinant le marché en général dans le cadre d'un produit ou d'un groupe de produits, soit en se concentrant sur un aspect particulier du marché. Une meilleure compréhension du secteur est obtenue dans les deux cas.

Pendant les dernières années, et ceci afin de répondre au manque d'informations concernant la demande et les marchés des produits de la mer, un nombre croissant de chercheurs nous a apporté des éléments sur les facteurs agissant sur le marché du poisson. En général, les études se divisent en deux grandes catégories :

(i) les analyses du marché global - certaines sont présentées dans d'autres sessions.

(ii) les analyses de la demande de produits ou d'attributs de ces produits par des groupes particuliers de consommateurs. Dans les deux cas, déterminer l'élasticité de la demande est crucial dans le calcul des gains et des pertes de bien-être liés à des modifications dans la gestion des pêches ou la commercialisation des produits.

Les contributions présentées dans cette section traduisent les progrès faits dans ce domaine. Elles constituent

Fisheries market research has, until recently, been largely neglected component of fisheries related research. However, many in the fishing industry and fisheries research have begun to realize that markets play a crucial role in the optimal and efficient use of fisheries resources. In particular, management decisions often impact the markets for fisheries products which, in turn, often transmit themselves back to impact the effectiveness of management programs. Furthermore, fishermen have often requested, on their own initiative, more regulation in cases where market forces are driving excessive harvest of the resource.

To better understand the interrelationships between fisheries management and the market sector, we must first gain a better appreciation for the intricacies of the market sector. In some cases this is done by taking a global view of the market for a particular product or group of products; in other cases, researchers focus on a particular aspect of the market. In both instances, the understanding of the marketing sector is increased.

In response to a lack of information on the general area of seafood demand and markets, a growing number of researchers in the past few years have greatly increased our knowledge of what drives the market for fish. In general, the studies have fallen into two broad categories:

(i) analysis of the aggregate market - some of which are found in others sections of these proceedings;

(ii) analysis of demand for specific products or attributes of products by specific user groupes. In both cases, determination of demand elasticities are a crucial component in the calculation of welfare gains and losses associated with changes in marketing and management schemes.

The papers presented in this section reflect advances made in the latter area. The group of papers in this

un superbe exemple des efforts réalisés par la profession dans l'état-de-l'art de l'analyse de la demande de produits de la mer. Dans leur communication, Burton et Young par exemple s'intéressent à la demande domestique de poisson en Grande-Bretagne. En appliquant l'analyse économétrique de la demande aux données disponibles, les auteurs constatent plusieurs résultats en désaccord avec la théorie micro-économique de la demande du consommateur. Ils utilisent alors une analyse non paramétrique afin de déterminer si les données satisfont les axiomes de préférence révélée, au lieu d'imposer une forme standard de la fonction de demande aux mêmes données. Les résultats indiquent que la forme fonctionnelle retenue pour la demande n'est pas neutre ; le choix de la fonction peut ainsi avoir des conséquences significatives sur la détermination des élasticités de la demande.

Johnston et Larson cherchent à expliquer pourquoi une élasticité du prix positive se retrouve quelquefois dans les études de marché des produits de la mer aux U.S.A., où la consommation augmente avec la hausse des prix. Ils conçoivent leur explication sous forme d'"effet Giffen" et démontrent théoriquement comment il est possible que l'élasticité des prix soit positive. Il est clair que cela aurait alors un effet considérable sur toute analyse des effets en terme de bien-être d'un changement des régimes de gestion.

Les quatre contributions restantes dans cette section s'intéressent plus spécialement à la demande d'attributs des produits de la mer, qui reflètent pour la plupart la qualité du produit. Ces études sont identiques dans la mesure où elles utilisent les données rassemblées directement par les chercheurs à partir des groupes d'individus. Les chercheurs peuvent ainsi utiliser les données obtenues sur des aspects particuliers du marché des produits de la mer. La contribution de Brook et Anderson est une étape importante dans l'étude du marché des coquillages et des conséquences sur la demande de la perception de la qualité sanitaire du produit par le consommateur. Les auteurs s'intéressent plus particulièrement au marché de la moule dans le nord-est des E.U. Avant l'étude, le marché de la moule aux E.U. était mal compris et plus particulièrement le marché potentiel. Ces perceptions influencent aussi la demande domestique et la demande de produits importés, comme le montrent Kusakabe et Anderson dans le cas du marché Japon du saumon. Les perceptions du consommateur y sont très différenciées selon les espèces, la forme du produit et sa technique de production (pêche ou aquaculture). Kusakabe et Anderson estiment directement la demande de ces attributs, afin de déterminer quelles en sont les combinaisons préférées constituant le saumon « optimal » selon les commerçants japonais. Ces deux contri-

session is a superb exemple of the strides the profession has made in the state-of-the-art in seafood demand analysis. The paper by Burton and Young for example looks at household demand for fish in the United Kingdom by presenting an alternative method of evaluating the data. After having attempted to apply econometric demand analysis to the data, the authors found several anormalous results which conflicted with microeconomic theory of the consumer demand. Rather than continue to impose a particular functional form for demand on the data, the authors decided instead to let the data tell them directly wether or not the data were consistent with consumer theory. Specifically the authors utilized non-parametric analysis to determine if the data satisfy the axioms of revealed preference. Results indicate that functional form imposed on a demand system may have important implications. In turn, the choice of functional form may have significant consequences in the determination of demand elasticities.

Johnston et Larson seek to explain why positive own-price elasticities are sometimes found in studies of the U.S. seafood market, where consumption has grown simultaneously with a rise in price. They frame the explanation in the form of Giffen good behavior and demonstrate theoritically how it is possible that the price elasticities could be positive. Clearly, if price elasticities are positive this would have a considerable effect on any analysis of welfare effects from changing management regimes.

The remaining four papers in this section focus specifically on demand for attributes of seafood products, where in many cases those attributes reflect quality of the product. These studies are similar in that they use data gathered directly by the researchers from groups of individuals. Thus, these researchers were able to direct the focus of the data obtained to particular aspects of the seafood market. In a paper that sets a standard in the study of shellfish markets and seafood safety perceptions on consumer demand, Brook and Anderson look specifically at the mussel market in the Northeastern United States. Prior to the study, the U.S. Mussel market was poorly understood; in particular the potential market for mussels was obscure. Similarly, Kusakabe and Anderson found the complex japanese seafood market which is characterized by large differences in perceptions by japanese consumers on the various salmon species, product form and harvest method (wild or aquacultured), in turn effting domestic and import demand. Thus Kusakabe and Anderson directly estimate the demand for these attributes based on market research techniques to determine the most prefered combination of attributes to make-up the composite 'optimal' salmon from the point of view of japanese salmon traders. Both of these papers

butions sont très intéressantes aussi bien pour les chercheurs que pour les individus directement impliqués dans le marketing des produits de la mer.

La contribution d'Anderson et Wessels reflète l'intérêt accru de l'industrie à déterminer si les consommateurs sont capables de discerner la qualité des produits de la mer dans le commerce. Le contrôle de la qualité est de plus en plus réclamé par les consommateurs mais aussi de plus en plus régulé par les gouvernements. Cependant, les fournisseurs de produits de qualité doivent être sûrs que leurs sur-coûts seront compensés par le fait que les clients reconnaissent et sont prêts à payer pour cette qualité. La contribution de Wessels et Anderson envisage ce dernier point. Dans ces deux contributions, l'approche utilisée pour recueillir les données a consisté à amener les consommateurs à un marché expérimental artificiel. Cela a permis de rassembler de très nombreux renseignements quant à l'impact sur la demande attribué aux perceptions de la qualité et de la sécurité par le consommateur.

Pour résumer, les contributions de cette section reflètent une nouvelle façon de penser et un désir de s'éloigner des approches usuelles de la recherche sur les marchés de la pêche. Elles reflètent plutôt l'état-de-l'art dans l'analyse de la demande des produits de la pêche. Continuer dans une telle voie devrait permettre d'enrichir l'étude du secteur et favoriser une gestion plus proche d'un usage efficient de vastes ressources halieutiques mondiales qui maximise le bien-être du consommateur et du producteur.

are interesting to fisheries markets researchers as well as individuals directly involved in marketing seafood.

The paper by Anderson and Wessels reflects an increased interest on the part of industry to determine if consumers are able to discern quality in seafood available at retail outlets. Quality control is both increasingly regulated by governments and demanded by consumers. However, suppliers of quality must be assured that their increased costs associated with providing higher quality products will be rewarded by consumer awareness of and willingness to pay for better quality. The latter point is adressed in the paper by Wessels and Anderson. In both of these papers, the approach used in collecting data was to bring consumers to an experimental market-like setting. This allowed for a rich set of information to be gathered, focused specifically on impacts of seafood quality and safety perceptions on consumer demand.

To summarize, the papers in this section reflect innovative thinking and an unwillingness to be bound to previous approaches to fisheries market research. Instead these papers reflect the state-of-the-art of seafood demand analysis. A continued pursuit of such progress will enhance the study of fisheries and bring fisheries management closer to establishing the efficient use of the world's vast fisheries resources which maximizes producer and consumer welfare.

# Consumer Ability to Discern Seafood Quality : Results of Experimental Studies

**Joan Gray Anderson[a], Cathy Roheim Wessells[b]**

[a]Consumer Affairs Program, University of Rhode Island, Kingston, Rhode Island, 02881 USA

[b]Department of Resource Economics, University of Rhode Island, Kingston, Rhode Island, 02881 USA

ABSTRACT

*Much has been written about the absence of and need for high quality product in the seafood market. Yet, little research exists to demonstrate whether consumers will be able to distinguish high quality product at the market and consequently, compensate quality-oriented sellers for their added effort and expense.*

*The purpose of this paper is to present the results of an experimental study which was conducted at the University of Rhode Island. In a simulated supermarket setting, survey respondents were asked to evaluate the quality of seafood. Researchers sought to relate quality judgements to other consumer characteristics such as seafood consumption patterns, knowledgeability of seafood, and demographic characteristics.*

*The respondents were presented with fillets of salmon, cod and flounder. Quality differences were simulated by a controlled aging process. All portions, once purchased, were held in refrigerated conditions identical to that of seafood retailers. First, consumers were presented with fillets of differing quality and asked to choose the highest quality fillet. Results indicate that consumers' ability to discern quality differences varies by species as well as age of the fillet. Second, consumers were presented with fillets of identical quality but bearing varying prices, and were asked to choose the highest quality fillet. Results indicate that consumers do not use prices as proxies for quality, although this also varies by species. Statistical analysis indicates that frequency of consumption and education level impact one's ability to discern quality.*

*This research provides valuable information on consumers' seafood quality perceptions. The circumstances under which rewards from the provision of high quality seafood to the marketplace will be explored, as will the cases where further consumer education regarding seafood quality is required.*

## 1. INTRODUCTION

Much of the literature on consumer demand for seafood finds that the price of seafood as well as income, prices of various substitutes (such as particular species of fish, or beef, pork, and chicken), and advertising are determinants of consumer demand (e.g., Cheng and Capps, 1991 ; Hayes, Wahl, and Williams, 1990 ; Brooks and Anderson, 1991 ; Capps and Lambregts, 1991 ; Kinnucan and Venkateswaran, 1990). However, a determinant of consumer demand that is often overlooked in traditional economic demand studies is the consumer's perception of the quality of seafood products. Quality variables have been left out of demand studies despite the fact that much has been written about the absence of and need for high quality product in the seafood market. With ever increasing publicity regarding seafood quality, this factor may become the dominant factor in the seafood purchasing decision and is an issue which the seafood industry must address.

Before the effect of consumer perceptions of quality on seafood demand can be determined, a question which must first be answered is whether or not consumers are able to discern seafood quality. Little research exists to demonstrate whether consumers are able to distinguish high quality product, and consequently compensate sellers who consistently provide high quality products for the added effort and expense.

According to a leading expert in the field of seafood technology, quality is one of the most critical issues facing the seafood industry today (Kinsella, 1988). Despite the numerous nutritional benefits associated with seafood, a number of problems exist which must be resolved before consumption parallels that of other protein sources. These obstacles include : supply, cost, quality (especially flavor and odor), safety, convenience, and aesthetics. Variable and unreliable quality of seafood often discourages potential buyers. "A major problem in retail fish is the lack of consistent quality in terms of odor, taste, and texture" (Kinsella, p. 148).

Before it can improve quality, the industry must understand how the consumer perceives seafood. This is not a simple task. As noted by Anderson and Anderson (1991) :

> Seafood quality is a multidimensional attribute - nutritional value ; incidence of parasites ; presence of micro-organisms and bacteria ; shelf life ; taste ; level of additives, irradiation, pesticides or preservatives ; amount of discoloration ; size ; number of bones ; number of scars or cuts ; uniformity ; odor ; and a host of other factors may be used to define quality. In addition, as seafood ages, its quality deteriorates more rapidly than other protein sources such as chicken and red meat (pp. 148-149).

The purpose of this paper is to present the results of two experimental studies which were conducted in the Food Science Laboratory at the University of Rhode Island in which consumers were asked to evaluate the quality of seafood which had been purchased at a local market. Three species were used : flounder, cod, and salmon. Each was purchased at intervals to create an "aging" proxy for freshness/quality.

The objectives of this experiment were to determine if :

i) consumers were able to identify the highest quality (as defined by age) sample from three quality/age levels ;

ii) consumers' ability to discern quality varies by species ; and

iii) price effects on quality perceptions.

Researchers also sought to relate quality judgments to other consumer characteristics such as species consumption, seafood knowledge, and demographic characteristics.

## 2. BACKGROUND AND LITERATURE REVIEW

Seafood quality is defined differently by different groups. Siang and Tsukuda (1989) state that the methods for assessing quality can be broadly categorized into three areas : sensory (odor, color, texture, and such), microbiological, and chemical. Consumers can assess the former while laboratory analysis must be used to measure the latter two.

Several studies (Sawyer, Cardello, and Prell, 1988 ; Bisogni, Ryan, and Regenstein, 1987 ; and Hadlett and Raab, 1990) have been conducted to assess consumers' perceptions of seafood quality.

These studies indicate that :

i) consumers place a very high value on quality but use different terminology to describe it than food scientists do ;

ii) consumers would eat more seafood if they could be assured of high quality ;

iii) consumers feel quality in seafood is less certain than in other food groups, and the need exists for more assurance from retailers and the government ;

iv) consumers lack nomenclature and scientific know-how to verbalize seafood quality needs.

However, none of these studies presented actual samples of seafood to consumers for their quality assessment. It may be that consumers are able to select the best quality seafood in actual practice even though they are unable to articulate the scientific reasons behind their selection. For example, it is not necessary to understand microbial deterioration, lipid oxidation, autolysis, or hydrolytic enzyme activity to be able to determine, by odor, that fish is not fresh or notice that the color and texture make the fish look old. Thus, experimental studies were undertaken to simulate as closely as possible the conditions under which consumers actually choose seafood in a retail market.

## 3. METHODS

### *3.1 The Telephone Survey*

In the summer of 1990, a telephone survey of Rhode Island households was conducted. A sample of 256 was obtained, which is believed to be representative of the Rhode Island population. The survey was six pages long. Depending on how much seafood a respondent consumed, between fifteen minutes and two hours were needed to complete one interview. The survey included detailed questions regarding seafood consumption. Hypothetical questions were posed to elicit consumer response to changes in seafood consumption which might result from a variety of factors. Questions were also asked regarding how consumers defined and assessed quality and safety. Demographic data were also gathered.

### *3.2 Four Experimental Studies*

Respondents who answered the telephone survey were invited to participate in a set of four experimental studies which were conducted on a Saturday afternoon in the Food Science Laboratory at the University of Rhode Island. Due to scheduling conflicts and transportation difficulties, most respondents from the telephone survey were not able to participate, however, other consumers were invited at random from the telephone book. Additional self-selected respondents were included to obtain a broader distribution of income, education, and occupational groups. However, because the sample was self-selected, it was not random. Therefore, results cannot be generalized to the population at large. In all, 55 consumers participated in this phase of the study.

The four experiments conducted were :

i) a market simulation in which the consumer was asked to select the highest quality sample both with and without price data ;

ii) a three-way comparison of seafood quality assessment : in two separate groups, consumers and food scientists rated quality characteristics of three species in three age groups. Samples of the fish were also analyzed in the laboratory ;

iii) a conjoint study of the factors consumers use to select seafood ;

iv) a willingness-to-pay for alternative seafood safety assurances.

The focus of this paper is to combine the results of the first experiment with the consumer portion and laboratory results from the second. Relevant results from other sections of the study are also cited.

For the first two experiments, actual samples of seafood were used. For each experiment, fillets of flounder, cod, and salmon were purchased from a retail market with a high quality reputation at three intervals : ten days before the study was conducted ; five days before ; and the same day. Samples were stored in a manner designed to replicate those of the retailer. Care was taken to obtain the freshest fillets possible from the retailer.

In the first experiment, a market setting was simulated. Several pieces of each sample were placed on ice in three containers. The containers held three samples each of a given species--one for each age category. Initially, each sample was randomly labeled with a letter. Respondents were asked which letter corresponded to the best quality. Next, three samples of each species were again presented. However, this time, all three samples had been purchased that day and were the freshest samples. Each sample had a price : actual market price, two dollars lower than actual market price, and two dollars higher than actual market price. Respondents were asked to identify which sample they would purchase to obtain the highest quality.

In the second experiment, consumers were asked to rate (from 0 to 4) the same three species for each of the three times--zero-day, five-day, and ten-day--on each of four characteristics : appearance, color, odor, and texture. Each of the nine samples (three species each at three ages) was displayed separately on ice in a plastic container. No two samples of the same species were displayed next to each other, so comparisons between samples of the same species could not be made.

Four different laboratory tests were performed on the seafood fillets. The thiobarbituric acid (TBA) test, which measures the oxidative deterioration of lipids, was conducted only for salmon, as it is a test for fish with a high fat content and measures chemicals associated with rancidity (Tarladgis, Watts, and Younathan, 1960).

The total volatile base (TVB) test measures the level of protein deterioration. This is an excellent quality indicator as fish is comprised mainly of protein. The emergence of these bases correlates well with ammonia content, a main contributor to "fishy" odor and flavor. As quality declines, TVB scores increase.

The trimethyl amine (TMA) test assesses the deterioration of TMA-oxide to TMA, a compound which contributes to off odors (Dyer, 1945). It is considered an excellent quality indicator for spoilage of white-fleshed fish, especially cod. If levels of TMA are over 10-20 mg per 100 g fish, the fish is regarded as undesirable.

The aerobic plate count is a good overall indicator of the degree of spoilage and approximates the numbers of live bacterial cells per gram of fish. Upon storage, the microbial numbers increase exponentially. Generally, up to 10,000,000 colony forming units (CFUs) per gram are acceptable for consumption. Above this level, the flesh is considered spoiled. Details of this study are available in Reilly and Morrissey (1991).

## 4. RESULTS

### *4.1 Laboratory Tests*

Laboratory analyses (trimethyl amine, total volatile base, and aerobic plate count) indicated that the samples of cod and flounder were representative of fish kept zero, five, and ten days in storage. Results for these two species indicated that the level of spoilage increased almost linearly with days in storage.

However, results were not as expected for the salmon samples. There were no differences in the chemical or microbial tests for the zero and five-day salmon. Analysis indicated that the five-day sample was slightly fresher than the zero-day sample obtained on the day of the evaluation.

A thiobarbituric acid test was performed on the salmon samples which indicated that the zero-day sample had a slightly higher level of fat decomposition than the five-day sample. This may be the result of poor handling prior to purchase for the experiment (temperature/time abuse, physical mishandling) of the zero-day salmon at either the wholesale or retail level.

*4.2 Market Simulation*

### 4.2.1 Consumer Ability to Select Freshest Specimen

• Flounder

The majority of respondents (74.5%, n=41) selected the ten-day-old flounder as the highest quality, indicating an inability of consumers to correctly assess flounder quality. However, about one-quarter (23.6%, n=13) of those questioned thought the zero-day-old specimen to be the freshest (refer to Table 1).

• Cod

In contrast, as shown in Table 1, most respondents (87.3%, n=48) were able to correctly identify the zero-day or freshest cod fillets. Only five thought the five-day sample was the freshest, while none thought the ten-day sample was the freshest. Two respondents thought all samples were the same.

• Salmon

Results of the salmon section are somewhat more ambiguous. As discussed in the previous section, laboratory testing of specimens from each of the three age groups indicates the existence of some quality problems with the zero-day batch. As shown in Table 1, many (38.2%, n=21) of the respondents identified the five-day-old sample as the freshest. Almost one-third (30.9%, n=7) of the respondents found the zero-day salmon, which laboratory tests indicated was only slightly less fresh than the five-day sample, to be the highest quality ; 21.8% (n=12) chose the ten-day-old sample as the freshest ; while 9.1% (n=5) thought all samples were equally fresh.

To summarize, consumers were able to successfully discern real quality differences, as identified in objective laboratory tests, for cod and salmon, but were far less accurate in their judgments of flounder.

### 4.2.2 Effect of Price on Consumers' Seafood Quality Perceptions

Table 2 lists the results obtained when consumers were presented with three identical samples of each of the three species. All three samples were purchased on the day that the survey was conducted. Respondents were asked to identify which sample they believed to be the highest quality and would consequently purchase. It was assumed that consumers who were able to correctly identify no differences between the three samples, would select the lowest priced sample. It was also assumed that consumers who were unable to make quality judgments might select the highest priced sample following the "high price buys high quality" axiom.

• Flounder

Only one-quarter of the sample (29.1 %, n=16) correctly identified the lowest priced flounder as the one they would purchase, while more than one-third (36.4 %, n=20) chose the highest priced piece. The middle priced piece (actual market price) was chosen as frequently as the low priced sample.

• Cod

Respondents demonstrated better ability in their cod selection. More than two-thirds of the sample (69%, n=38) selected the least expensive sample. Less than one-third (29.1%, n=16), selected the sample with the actual market (middle) price. Only one respondent selected the most expensive sample.

• Salmon

Relative to the other two species, respondents were most successful in selecting salmon. Almost three-quarters of the sample (74.5%, n=41) selected the lowest priced salmon. However, quite a few selected the highest priced piece (18.2%, n=10).

To summarize this section, one can note that respondents selected the correct choice--the lowest priced sample--most frequently for cod and salmon. Yet for the samples of flounder, the highest priced sample was most frequently selected (36.4%, n=20). Salmon was correctly identified most often, while flounder was correctly identified least often.

### *4.3 Quality Selection and Related Factors :*

Whether a consumer's ability to correctly assess the highest quality seafood sample is related to certain attitudes, behaviors, or demographic characteristics, was analyzed using Chi-Square tests. Several factors were considered

i) how well the respondent likes seafood in general ;

ii) respondent's self-assessment of seafood knowledge ;

iii) frequency of consumption of the specific species being evaluated ;

iv) frequency of finfish consumption ;

v) frequency of finfish consumption at home ;

vi) respondent's perception of seafood safety ;

vii) education level ; and

viii) income level.

How well a respondent likes seafood was related to the ability to correctly identify the highest quality seafood in only one case, the flounder price trial. In that trial, respondents who were able to correctly identify the lowest priced flounder as the best buy were significantly more likely (more than 2 to 1) to rate seafood as their favorite food ($X^2$=5.52, d.f.=2).

No significant differences were found for any of the six trials for either knowledge self-assessment, or safety perceptions. Income was also not related to consumers' ability to assess quality in any of the trials.

The amount of seafood consumed was significantly related to ability to discern quality in only one case. Consumers who had above average consumption of flounder were significantly more likely to pick the zero-day sample than those with below average flounder consumption ($X^2$=3.06, d.f.=1). Neither quantity of fish eaten in general or at home was significantly related to the results of any of the six trials.

Finally, highest level of education attained was significantly related to obtaining the correct answer in the cod price trial. Specifically, persons with a college or professional degree were more likely to correctly identify the lowest priced cod as the best value ($X^2$=6.37, d.f.=2).

### *4.4 Sensory Evaluations*

Results of the consumers' evaluations of the nine seafood samples can be seen in Table 3.

- Flounder

Consumers correctly rated the zero-day flounder highest ($\overline{X}$=12.73). However, the ten-day sample was rated higher overall ($\overline{X}$=9.56) than the five-day sample ($\overline{X}$=8.96). Although the lab results indicated that the samples were consistent with the length of time they had been aged, the tests performed in the laboratory did not incorporate appearance into their results. The five-day sample had a different color than the other two flounder samples. There were grey flecks throughout the flesh giving it an overall "grey" appearance. This quality flaw was not detected by the laboratory tests but was clearly detected by the sample respondents in this experiment and the market simulation.

- Cod

Respondents rated the zero-day cod highest on all four characteristics. Out of a maximum of 16 points, the zero-day cod received an average of 12.76. However, they rated the five and ten-day samples almost equally, giving the ten-day sample

a slightly higher evaluation ($\overline{X}$=9.93) as compared to 9.13 for the five-day sample. In comparing these results to the market section results, it appears that for cod, consumers are more successful in quality evaluation in a market setting than in the laboratory setting.

• Salmon

Consumers rated the five-day salmon slightly higher ($\overline{X}$=12.51) than the zero-day salmon ($\overline{X}$=11.95). The ten-day sample was rated the lowest ($\overline{X}$=11.13). Their ratings very are consistent with the results of the laboratory tests. These results are also consistent with those obtained in the market experiment.

## 5. SUMMARY AND CONCLUSIONS

The results of the market simulation and the sensory evaluations in conjunction with the laboratory tests indicate that, in general, consumers are quite capable in their ability to detect quality seafood, whether it is displayed in a market-like setting or in an objective sensory test. This conclusion holds even in the cases such as the zero-day salmon, and the five-day flounder, in which quality is not consistent with expectations based on aging factors alone. Quality indicators such as color and handling were detected by respondents and incorporated into their quality evaluations. While the limited sample size makes it difficult to find factors which are significantly related to consumer ability to discern seafood quality, it is clear from the results of this study that this sample of consumers is able to discern quality. Further research is needed to determine what factors are related to this ability.

## REFERENCES

**Anderson J.G. and J.L. Anderson** (1991). Seafood quality : Issues for consumer researchers. *Journal of Consumer Affairs*, **25** (1), 144-163.

**Bisogni C.A., G.J. Ryan and J.M. Regenstein** (1987). What is fish quality ? Can we incorporate consumer perceptions ? *Proceedings of the International Symposium on Seafood Quality Determination.* University of Alaska Sea Grant College Program, Anchorage, Alaska, USA, 10-14 November 1986.

**Brooks P.M. and J.L. Anderson** (1991). Effects of retail pricing, seasonality, and advertising on fresh seafood sales. *Journal of Business and Economic Studies,***1:** 55-68

**Capps O. and J. Lambregts** (1991). Assessing effects of prices and advertising on purchases of finfish and shellfish in a local market in Texas. *Southern Journal of Agricultural Economics*, **23:** 181-194.

**Cheng H. and O. Capps** (1988). Demand analysis of fresh and frozen finfish and shellfish in the United States. *American Journal of Agricultural Economics,***70:** 533.

**Dyer W.J.** (1945). Amines in fish muscle-development of TMA and other amines. *J. Fish. Res. Bd., Canada,***6** (5).

**Hadlett H.M. and C.A. Raab** (1990). Consumer perceptions of fresh fish quality. *Journal of the American Dietetic Association,***90** (8), 1109-1110.

**Hayes D.T., T. Wahl and G. Williams** (1990). Testing restrictions on a model of Japanese meat demand. *American Journal of Agricultural Economics,***72:** 556-566.

**Kinnucan H. and M.Venkateswaran** (1990). Effects of generic advertising on perceptions and behavior : The case of catfish. *Southern Journal of Agricultural Economics,***22:** 137-151.

**Kinsella J.E.** (1988). Fish and seafoods : nutritional implications and quality issues. *Food Technology,* May, 146-150.

**Reilly T.I. and M.T. Morrissey** (1991). Consumer perceptions of finfish quality. In V. Haldeman (ed.), *The Proceedings of the American Council on Consumer Interests 37th Annual Conference.*

**Sawyer F.M., A. V. Cardello and P.A. Prell** (1988). Consumer evaluation of the sensory properties of fish. *Journal of Food Science,* **53** (1), 12-18 and 24.

**Siang N.C. and N. Tsukda** (1989). Laboratory tests and equipment for quality assessment of chilled and frozen fish. *Infofish International*, June 24-27.

**Tarladgis B., B. Watts and M. Younathan** (1960). *J. Amer. Oil Chemists' Soc.,* **37** (44).

**TABLE 1.**
**CONSUMER SELECTION OF SEAFOOD SAMPLES FOR THREE SPECIES WITH THREE QUALITY LEVELS (n=55).**

| | Percentage of Sample that Selected: (actual number in parentheses) | | | | |
|---|---|---|---|---|---|
| Species | Zero-Day Sample | Five-Day Sample | Ten-day Sample | Said All Same | Don't Know |
| Flounder | 23.6 (13) | 1.8 (1) | 74.5 (41) | 0 | 0 |
| Cod | 87.3 (48) | 9.1 (5) | 0 | 3.6 (2) | 0 |
| Salmon | 30.9 (17) | 38.2 (21) | 21.8 (12) | 9.1 (5) | 0 |

**TABLE 2.**
**CONSUMER SELECTION AMONG IDENTICAL SEAFOOD SAMPLES WITH VARYING PRICES (n=55).**

| | Percentage of Consumers Who Selected (actual number in parentheses) | | | |
|---|---|---|---|---|
| Species | Lowest Price | Middle Price | Highest Price | Don't Know |
| Flounder | 29.1 (16) | 29.1 (16) | 36.4 (20) | 5.5 (3) |
| Cod | 69.0 (38) | 29.1 (16) | 1.8 (1) | 0 |
| Salmon | 74.5 (41) | 5.5 (3) | 18.2 (10) | 1.8 (1) |

**TABLE 3.**
**CONSUMER RATINGS OF THREE SPECIES OF THREE AGES FOR FOUR QUALITY CHARACTERISTICS (n=55).**

| | Sample Means[1] | | | | |
|---|---|---|---|---|---|
| Species | Appearance | Color | Odor | Texture | Overall Score |
| Flounder | | | | | |
| Zero-Day | 3.11 | 2.91 | 3.40 | 3.31 | 12.73 |
| Five-Day | 2.18 | 2.07 | 2.43 | 2.24 | 8.96 |
| Ten-Day | 2.47 | 2.49 | 2.36 | 2.25 | 9.56 |
| Cod | | | | | |
| Zero-Day | 3.31 | 3.20 | 3.15 | 3.11 | 12.76 |
| Five-Day | 2.18 | 2.25 | 2.49 | 2.18 | 9.13 |
| Ten-Day | 2.35 | 2.58 | 2.67 | 2.32 | 9.93 |
| Salmon | | | | | |
| Zero-Day | 3.00 | 2.91 | 3.24 | 2.80 | 11.95 |
| Five-Day | 3.11 | 3.05 | 3.38 | 2.95 | 12.51 |
| Ten-Day | 2.91 | 3.05 | 2.53 | 2.71 | 11.12 |

[1]On a scale of 0-4 for each characteristic.

# Conjoint Analysis of the Japanese Salmon Market

**Yuko Kusakabe and James L. Anderson**

Department of Resource Economics, University of Rhode Island, Kingston, RI 02881, USA

ABSTRACT

*In 1990, cultured salmon constituted approximately 16 percent of Japan's total salmon imports. Salmon is consumed in increasingly diversified fashion in terms of product types and market outlets. Conjoint analysis was applied to elicit the structure of a salmon buyer's preferences. Relative contribution of individual attributes to the product's overall preference was estimated through two-limit tobit and rank-order logit models. The models estimated the buyer's preference function reasonably well despite the survey results from different salmon buyers at different points in time.*

## 1. INTRODUCTION

In the face of increasing aquaculture production, declining high-seas operations, and changing in consumer behavior, the salmon market in Japan is going through some major changes. Japan's salmon market has become highly differentiated and dynamic. A conventional demand approach which treats salmon as a homogeneous product does not completely explain why the Japanese salmon market is evolving the way it is. Questions such as whether cultured salmon is a perfect substitute for wild-caught salmon can only be answered by understanding what buyers perceive in these products.

Salmon is a heterogeneous product differentiated with respect to attributes such as species, country of origin, method of catch, flesh color, fat content, and price. Each attribute has several subclasses of characteristics (levels) such as the flesh color attribute has several grades of color; deep red, pink red, pale pink. Salmon can therefore be described as a composite of attributes at different levels. A buyer's overall preference for the product in question is the totality of the utility he/she derives from individual attributes of the product.

Available market data never fully identify the attributes of the product. Market data generally quantify product price and quantity as if products were homogeneous. Therefore, despite the fact that salmon is widely traded in the market, the buyer's valuation of individual attributes can not be estimated using available market data.

## 2. CONJOINT ANALYSIS

An experimental technique called conjoint analysis was applied to elicit the structure of a salmon buyer's preferences through survey measures. By obtaining buyers' evaluation for product profiles pre-specified in terms of levels of different attributes, conjoint analysis allows the researcher to estimate the relative contribution of the individual levels of attributes to the respondent's overall evaluation of the product.

The conjoint method used in this paper was originally proposed by Luce and Tukey in psychometrics literature and now widely used for market research. The first consumer-oriented application of conjoint analysis was brought out by Green and Rao in 1971. Since then, numerous theoretical and empirical contributions have been made to the advancement of this technique (Green and Rao, 1971; Green and Wind, 1975; Johnson, 1974; Green and Srinavasan 1978 and 1990). Anderson and Brooks first applied this approach for the analysis of the salmon market in New England in 1986.

One conceptual difference between conjoint measures and other non-market valuation techniques such as contingent valuation, is that the price of the good is treated as simply another component of the product and thus minimizes many of the biases that can arise in contingent-valuation studies when respondents are presented with the unrealistic task of putting prices on non-market goods.

## 3. EXPERIMENTAL DESIGN

Attributes and attribute levels for our experiment were chosen based on *a priori* knowledge of the Japanese market, a similar study done by Anderson and Brooks of the New England salmon market (1986), a survey of Japanese traders in Seattle and Vancouver, and discussions with several Japanese traders in Boston. Wholesale price information from the Tokyo Central Wholesale Market was used to select price levels. The selected attributes and the levels of each attribute are listed in Table 1. There are 12 attributes with the number of levels ranging from 2 to 8 per attribute.

If all combinations of attributes and attribute levels were considered (full factorial design), this would result in $7 * 6^2 * 4^3 * 3^5 * 2 = 7{,}838{,}208$ possible products. With the assumption of minimal interaction among attributes, a minimum design necessary for the estimation of main-effect was obtained using orthogonal main-effect plans for asymmetrical factorial experiments devised by Addelman. (Addelman, 1962)

Since occurrence of the levels of attributes is balanced regardless of whether a certain combination exists in the real world, product profiles generated by orthogonal design include unrealistic products. Pre-testing of the survey instrument with Japanese traders in Boston strongly indicated that the inclusion of these unrealistic products undermines a respondent's confidence and cooperation with the survey.

In order to circumvent this problem, a larger matrix was designed using orthogonal arrays (81 profiles), and then 27 unrealistic profiles were deleted from the original design, resulting in 54 profiles to be tested. Although the deletion of any profile from a fractional factorial design may make some attributes somewhat correlated, the presence of inter-attribute correlations per se does not violate any assumptions of conjoint analysis (Green and Srinavasan 1990).

A full-profile procedure was used for data collection where respondents were presented with product profiles which consist of a complete set of attributes. An example of the profile card can be found in Table 2. In order to avoid possible information overload on the part of the respondent, product profile cards were divided into subgroups and only 6 product profiles were presented to each respondent. With only 6 profiles evaluated by each respondent, a minimum of nine interviews with salmon buyers was necessary in order to complete all 54 cards. This segmentation of the full design across individual respondents is commonly used in conjoint experiments (Green and Srinavasan 1990).

## 4. SURVEY PROCEDURES

The survey was conducted in Japan on two different occasions; March and April, 1988 and November 1989. Respondents were chosen from the member list of the Japan Marine Products Importers Association. Out of 79 firms included in the list, 56 firms imported salmon as one of their primary products. Because of travel logistics and time constraints, those headquartered in Tokyo were targeted (51 firms out of 56).

The salmon import division of each firm was contacted. In 1988, out of 24 traders contacted, 15 traders completed the survey. Imports of salmon are handled by a relatively small number of large firms in Japan. The 15 firms surveyed in 1988 handled approximately 60% of Japan's salmon imports in 1988.[1] In 1989, out of 46 traders contacted, 29 traders completed the survey. The 29 firms surveyed in 1989 handled about 65-70% of Japanese salmon imports in 1989.

The survey was conducted using in-person interviews. The questionnaire was 4 pages long and took about 20-30 minutes to administer. It consisted of three parts :

i) description of the respondent's firm,

ii) a self-explicated utility measure, and

iii) a conjoint measure.

In the self-explicated utility part, the respondents evaluated attributes and levels of attributes directly. Respondents rated the relative importance of salmon attributes for their purchase decision on the scale of 0 to 100. The most important attribute was assigned 100 points and the remaining attributes were scored relative to that attribute. The same score could be placed on more than one attribute. The respondent then rated the levels of each attribute such as coho, king, sockeye, chum, pink, and Atlantic salmon on the scale of 0 to 10 respectively. While evaluating levels of an attribute, the rest of the attributes were assumed to be held constant.

A total of 54 salmon profile cards were divided into 9 groups of 6 profiles. In the conjoint part, the respondent evaluated these 6 hypothetical salmon product profiles and ordered them from the most to least preferred. When the ranking of 6 products was completed, a respondent placed preference scores on each product profile on the scale of 0 to 100. Prior to rating, the ideal product was composed of the combination of attributes the respondent described as most preferred in the self-explicated part. The ideal product varied among respondents. The respondent placed scores on each hypothetical salmon profile relative to the ideal product. This was done in order to establish the ceiling of the preference scoring.

## 5. MODEL ESTIMATION

Through the in-person interviews of the Japanese salmon buyers, the preference rankings and scores of the hypothetical salmon products were obtained. The rankings and scores reflect the respondent's relative preference of the products and are used as dependent variables and regressed against product attribute levels in our model.

A ranking is ordinal-scaled where it represents a simple ordering such as product A is preferred to product B. Ranking as a function of various attribute levels, therefore, was developed in a discrete choice model. Rank-order logit, a variation of a multinomial logit model which incorporates all ranking information was used for the estimation. LIMDEP's regression procedure for observed rank-order data was used, which is based on the model developed by Beggs, Cardell, and Hausman. (Beggs, et al., 1981)

Scores, on the other hand, are interval scaled, wherein the distance between any two numbers on the scale represents not only preference ordering but also the intensity of the respondent's preference for the products. Given a larger amount of information, preference scores as the dependent variable regressed against attribute levels is expected to outperform ranking in terms of specifying a respondent preference function. The preference scores obtained from our survey are limited between 0 and 100. When the value of the dependent variable is limited in a certain range, the sample data become the mixture of discrete limit observations and continuous non-limit observations and thus ordinary least squares estimator will be biased and inconsistent (Maddala, 1990).

The two-limit censored regression model, an extension of the basic Tobit model, was used for the estimation. The two-limit specification was developed by Rosett and Nelson (1975). Nakamura and Nakamura (1983) applied two-limit censored regression in the analysis of work behavior of married women.

1. The percentage was calculated from total Japanese imports of salmon in 1987 (published by the Ministry of Finance) and the aggregate of the each company's salmon import quantity.

A two-limit censored regression model is formulated as follows. Define a latent non-observable variable $y_i^*$, such that;
$y_i^* = \beta' x + l \qquad l \sim N(0, \sigma^2)$

where $\beta$ is a $k \times 1$ vector of unknown parameters, x is a $k \times i$ vector of explanatory variables and residuals. If we denote by $y_i$ the observed dependent variable,

$$\begin{aligned} y_i &= L_{1i} && \text{if } y^* \geq L_{1i}, \\ y_i &= y^* && \text{if } L_{1i} \leq y^* \leq L_{2i} \\ y_i &= L_{2i} && \text{if } y_i^* \geq L_{2i} \end{aligned}$$

where L1i and L2i are respectively lower and upper limit which are 0 and 100 in our model.

The likelihood function for this model is given by :

$$L(\beta, \sigma / y_i, x_i, L_{1i}, L_{2i}) = \prod_{y_i = L_{1i}} \Phi\left(\frac{L_{1i} - \beta' x}{\sigma}\right) \prod_{y_i = y_i^*} \frac{1}{\sigma} \varphi\left(\frac{y_i - \beta_x}{\sigma}\right) \prod_{y_i = L_{2i}} \left(1 - \Phi\left(\frac{L_{2i} - \beta' x}{\sigma}\right)\right)$$

where $\phi$ represents the cumulative distribution function and the density function of the standard normal distribution (Maddala, 1990). Maximization is obtained by equating the partial derivatives of the log-likelihood function with respect to $\beta$ and $\varsigma^2$ to zero. The two-limit tobit procedure in LIMDEP was used for estimation of our model, which utilizes OLS estimators as initial values and Newton-Raphson method as an iterative procedure.

Except for price, all the other explanatory variables included in the model are dummy variables. Price is the only continuous variable. Since there are relatively large price differentials among species of salmon, using one continuous price across all salmon species introduces inconsistency as to how the respondent perceives price. In order to circumvent this problem, base prices were calculated for each salmon species by product type from the average wholesale prices at the Tokyo Central Wholesale Market, adjusted for estimated CIF price. Price is then expressed as the difference between listed price in the product profile and the base price, converting, for example, 790 yen/kg for both sockeye and pink frozen salmon to -545 yen/kg for sockeye and +112 yen/kg for pink salmon respectively.

More detail in experimental design, survey procedure, and model estimation is available in "Conjoint Analysis of the Japanese Salmon Buyer's Preference : Market Analysis of Norweigian Farmed Salmon", published by the Center for Research in Economics and Business Administration.

## 6. RESULTS OF CONJOINT ANALYSIS

Out of the 44 traders who agreed to respond to the survey, four did not complete the self-explicated measure task, one did not complete ratings of hypothetical product, and one only partially completed the ratings. The rest of the respondents provided ratings of 6 hypothetical products. The ideal product the respondent described prior to rating hypothetical products was incorporated into the data. When the respondents voluntarily provided new product ratings by changing one of the attribute levels of the hypothetical product, they were also incorporated into the data. This has resulted in a total of 298 rating observations.

The preliminary results of the self-explicated measure and conjoint analysis are compiled in this paper where survey data of 1988 and 1989 is pooled together. Separate analysis of the data in different years is not included here.

Table 3 summarizes the weighted average of the direct evaluation of attributes and attribute levels in the self-explicated measure. It indicates that traders consider price and quality as the most important attributes in the product. The ideal product is described as; sockeye salmon from Canada, troll caught, frozen, high quality, with bright silver skin, deep red flesh color, high fat, in head-off/2-3kg size, available year-round, at the price of 580 yen/kg.

Table 4 shows the results of the estimation of the discrete rank-order logit model and the two-limit tobit models. Despite the intertemporal difference among responses by traders, the model estimated the buyer's preference function reasonably well. Higher performance was expected for the two-limit tobit model given that the score was used for the dependent

variable (rather than rankings). At least in this model specification, however, discrete rank-order logit outperformed the two-limit tobit model in terms of overall lower standard errors. The signs and relative magnitude of the coefficients, although they are not directly comparable due to different regression procedures, are in general accordance between two-limit tobit and rank-order logit models. These results are also generally comparable to the self-explicated result, which indicates the robustness of the model specification.

The sign of the coefficient for the price variable, which was the difference between listed price and estimated CIF price, conform to prior expectations for both models, though the degree of significance was low for tobit model. Quality variables also show expected signs and the difference in quality is highly significant in both tobit and rank-order logit models.

The rank-order logit model indicates that coho, king, sockeye, and Atlantic salmon are all significantly preferred to chum, which is the omitted dummy variable from species category. Pink salmon is significantly less preferred to chum salmon. The tobit model, however, indicates that coho and pink are not significantly different from chum salmon.

In the rank-order logit model, Canada is significantly preferred to Alaska as the country of origin, while all the other places of origin for salmon are not significantly different from Alaska. Two-limit tobit, on the other hand, show insignificant preference difference among all salmon origins.

The tobit model indicates that troll-caught is significantly preferred to farmed among different methods of catch. The result is consistent with the indication of the respondent's direct ratings in the self-explicated measure. The rank-order logit model, on the other hand, showed no significant differences among all methods of catch in terms of contribution to the buyer's overall preference for the product.

Fresh and salted product is not significantly different from frozen form in both models. This result does not concur with the respondent's direct ratings of product type where frozen is strongly preferred. When comparing just product type attributes holding other characteristics constant, traders may prefer frozen, since the vast majority of the product handled by traders is frozen. However, traders move different products through many market channels. In evaluating individual hypothetical products, fresh/frozen/salted attributes may not hinder buyers' overall preference for the product.

No significant differences were detected among all skin color/appearance attributes in both tobit and rank-order logit. However, deep red flesh color is significantly different from pink red color in both tobit and rank-order logit model in terms of the contribution to the buyers' overall preference for the product.

The sign of the coefficient for fat content variables conforms to the theoretical expectations for both models. High fat content, moreover, is significantly different from medium fat content for product preference contribution in both models.

The tobit model indicates that head-off/2-3 kg size is significantly preferred to head-off/1-2 kg size. All other product forms/sizes were insignificantly different from the omitted form. Rank-order logit indicates that fillet, head-on/2-3 kg, head-on/3kg+, head-off 2-3 kg, and head-off/3kg+ are all significantly preferred to the omitted base product. Seasonal availability is significantly preferred to year-round supply for both tobit and rank-order logit.

## 7. SUMMARY AND CONCLUSIONS

This is the first effort to analyze the Japanese salmon market in terms of buyer's preference of salmon as a function of product attributes. In this approach, salmon is treated as a multiattribute product. Relative contribution of individual attributes to the product's overall preference was estimated through two model specifications; two-limit tobit and rank-order logit. Although the model could be further refined, the model estimated the buyer's preference function reasonably well despite the intertemporal difference among survey results from traders. Both model specifications are in general accordance with each other. Detailed information concerning how each product attribute contributes to the buyer's preference for the product is useful to the industry as well as researchers.

## REFERENCES

**Addelman S** (1962). "Orthogonal Main-Effect Plans for Asymmetrical Factorial Experiments". *Technometrics* **4 :** 21-46.

**Anderson J.L. and S.U. Bettencourt** (1991). "Using a Conjoint Approach to Model Product Preferences : The New England Market for Fresh and Frozen Salmon". University of Rhode Island Stuff Paper 91-3. Kingston, Rhode Island.

**Anderson J.L. and Y. Kusakabe** (1989). "Analysis of the Japanese Salmon Market. Economic and Commercial Analysis Report No. 56. Department of Fisheries & Ocean. Ottawa, Ontario. Canada .

**Anderson J.L.** (1988). "Current and Future Market for Salmon in the United States". in *Aquaculture International - Congress* Proceedings. Congress held in Vancouver, British Columbia, Sept. 6-9. Vancouver, B.C. : Aquaculture International Congress.

**Anderson J.L. and P. Brooks** (1987). "Conjoint Analysis of the New England Salmon Market". Prepared for Department of Fisheries and Oceans. Vancouver, British Columbia. Canada.

**Beggs S., S. Cardell and J. Hausman** (1981). "Assessing the Potential Demand for Electric Cars". *Journal of Econometrics* **16 :** 1-19.

**Green P.E. and V.R. Rao** (1971). "Conjoint Measurement for Quantifying Judgmental Data". *Journal of Marketing Research,* **8 :** 355-63.

**Green P.E. and V. Srinavasan** (1990). "Conjoint Analysis in Marketing : New Development with Implications for Research and Practice". *Journal of Marketing,* October : 3-19.

**Green P.E. and V. Srinavasan** (1978). "Conjoint Analysis in Consumer Research : Issues and Outlook". *Journal of Consumer Research,* **5 :** 103-123.

**Green P.E. and Y. Wind.** (1975). "New Way to Measure Consumers' Judgements". *Harvard Business Review,* **53 :** 107-117.

**Green W.H.** (1990a). Econometric Analysis. New York : MacMillian Publishing Co.

**Johnson R. M.** (1974). "Trade-Off Analysis of Consumer Values". *Journal of Marketing Research,* **XI :** 121-127.

**Kmenta J.** (1986). Elements of Econometrics. New York : Collier MacMillian Co.

**Kusakabe Y. and J.L. Anderson** (1992). "Conjoint Analysis of the Japanese Salmon Buyer's Preference : Market Analysis of Norwegian Farmed Salmon". Center for Research in Economics and Business Administration. Bergen. Norway .

**Kusakabe Y. and J.L. Anderson** (1989). "The Japanese Seafood Market : Salmon". Economic and Commercial Analysis Report No. 21. Department of Fisheries & Ocean. Ottawa, Ontario. Canada.

**Luce R.D. and J.W. Tukey** (1964). "Simultaneous Conjoint Measurement : A New Type of Fundamental Measurement". Journal of Mathematical Psychology, **1 :** 1-27.

**Maddala G.S.** (1990). *Limited-Dependent and Qualitative Variables in Econometrics.* New York : Cambridge University Press.

**Nakamura A. and M. Nakamura** (1983). "Part-Time and Full-Time Work Behavior of Married Women : A Model with A Doubly Truncated Dependent Variable". *Canadian Journal of Economics,* **16 :** 229-257.

**Rosett R.N. and F.D. Nelson** (1975). "Estimation of the Two-Limit Probit Regression Model". *Econometrica,* **43 :** 141-146.

**Mitchell R.C. and R.T. Carson** (1989). *Using Survey to Value Public Goods : The Contingent Valuation Method.* Washington D.C. : Resources for the Future .

**Tobin J.** (1958). "Estimation of Relationships for Limited Dependent Variables". *Econometrica,* **26 :** 24-36.

**TABLE 1.**
**A LISTING OF THE ATTRIBUTES AND ATTRIBUTE LEVELS.**

| ATTRIBUTE | LEVELS | NOTES |
|---|---|---|
| SPECIES | COHO | EXCEPT PRICE, ALL THE OTHER |
| | KING | VARIABLES ARE DUMMY VARIABLES |
| | SOCKEYE | WHERE 1 REPRESENTS PRESENCE OF |
| | CHUM* | THE LEVEL, 0 ITS ABSENCE |
| | PINK | |
| | ATLANTIC | * MARKED DUMMY VARIABLES ARE OMITTED |
| ORIGIN | CANADA | FROM EACH ATTRIBUTE CATEGORY IN THE |
| | ALASKA | REGRESSION |
| | JAPAN* | |
| | NORWAY | |
| | NEW ZEALAND | |
| | CHILE | |
| | WESTCOAST U.S. (NOT INCLUDING ALASKA) | |
| METHOD | SEINE | |
| | GILL NET | |
| | TROLL | |
| | FARMED* | |
| TYPE | FRESH | |
| | FROZEN* | |
| | SALTED | |
| QUALITY | LOW QUALITY | |
| | MED QUALITY* | |
| | HIGH QUALITY | |
| COLOR | PALE PINK | |
| | PINK RED* | |
| | DEEP RED | |
| FAT CONTENT | LOW FAT | |
| | MED FAT* | |
| | HIGH FAT | |
| APPEARANCE | DARK/ MARKED | |
| | SILVERY SKIN/ SOME SCALE LOSS* | |
| | BRIGHT SILVER/ MINIMAL SCALE LOSS | |
| FORM/SIZE | STEAK | |
| | FILLET | |
| | HEAD–ON 1–2KG | |
| | HEAD–ON 2–3KG | FOR REGRESSION, 3–4KG AND 4KG+ SIZE |
| | HEAD–ON 3–4KG | CATEGORIES WERE COMBINED FOR HEAD–ON |
| | HEAD–ON 4KG+ | AND HEAD–OFF |
| | HEAD–OFF 1–2KG* | |
| | HEAD–OFF 2–3KG | |
| | HEAD–OFF 3–4KG | |
| | HEAD–OFF 4KG+ | |
| SUPPLY | SEASONAL | |
| | YEAR ROUND* | |
| PRICE | PRICE DIFFERENCE | PRICE DIFFERENCE BETWEEN LISTED PRICE INCLUDED IN THE PRODUCT PROFILE AND THE BASE PRICES CALCULATED FOR EACH SPECIES OF SALMON |

**TABLE 2.**
**A SAMPLE OF THE HYPOTHETICAL PRODUCT PROFILES.**

| | |
|---|---|
| SPECIES: | KING SALMON |
| ORIGIN: | CANADA |
| METHOD: | FARM RAISED |
| TYPE: | FRESH |
| QUALITY: | MEDIUM QUALITY |
| COLOR: | PINK RED |
| FAT CONTENT: | HIGH |
| APPEARANCE: | BRIGHT SILVER/ MINIMAL SCALE LOSS |
| FORM/SIZE: | HEAD-OFF/ 3-4KG |
| SUPPLY: | SEASONAL AVAILABILITY |
| PRICE: | 1400YEN/KG |

**TABLE 3.**
**WEIGHTED AVERAGE OF THE DIRECT EVALUATION OF ATTRIBUTES AND ATTRIBUTE LEVELS IN THE SELF-EXPLICATED MEASURE.**

| SCALE OF 0–100 | | SCALE OF 0–10 | | |
|---|---|---|---|---|
| ATTRIBUTE | | ATTRIBUTE LEVELS | | |
| SPECIES | 86.40 | SPECIES | COHO | 6 65 |
| ORIGIN | 56.34 | | KING | 6 03 |
| METHOD | 57.34 | | ATLANTIC | 5 01 |
| TYPE | 78.26 | | CHUM | 4 08 |
| QUALITY | 94.30 | | SOCKEYE | 9 42 |
| APPEARANCE | 81.92 | | PINK | 3 89 |
| FLESH COLOR | 87.23 | | RAINBOW | 6.67 |
| FAT | 72.29 | ORIGIN | CANADA | 8.22 |
| SIZE | 66.81 | | BRISTOL | 6 65 |
| FORM | 66.52 | | LOCAL | 7.44 |
| PRICE | 97.41 | | JAPAN | 5.99 |
| SUPPLY | 57.64 | | NEW ZEALAND | 3.93 |
| | | | CHILE | 5 28 |
| | | | NORWAY | 5.48 |
| | | | WEST COAST | 6.27 |
| | | METHOD | SEINE | 6 84 |
| | | | GILL | 5.87 |
| | | | TROLL | 9.26 |
| | | | FARM | 7 35 |
| | | TYPE | FRESH | 7.22 |
| | | | FROZEN | 9.07 |
| | | | SALTED | 5.57 |
| | | QUALITY | LOW | 1.55 |
| | | | MED | 5.58 |
| | | | HIGH | 10.00 |
| | | APPEARANCE | DARK | 2.43 |
| | | | SILVERY | 6.92 |
| | | | BRIGHT SILVER | 10 00 |
| | | COLOR | PALE PINK | 2 40 |
| | | | PINK RED | 6.80 |
| | | | DEEP RED | 9 62 |
| | | FAT | LOW | 4.23 |
| | | | MED | 8.30 |
| | | | HIGH | 9.38 |
| | | FORM | HEAD ON | 7.92 |
| | | | HEAD OFF | 9.60 |
| | | | STEAK | 1.36 |
| | | | FILLET | 4.65 |
| | | SIZE | 1–2KG | 5.45 |
| | | | 2–3KG | 9.10 |
| | | | 3–4KG | 7.77 |
| | | | 4–5KG | 4.70 |
| | | | 5KG PLUS | 2.19 |
| | | PRICE | 580 | 10.00 |
| | | | 790 | 8.98 |
| | | | 1000 | 7.83 |
| | | | 1190 | 3.93 |
| | | | 1300/1400 | 3.77 |
| | | | 1700 | 1.33 |
| | | | 2000 | 0.15 |
| | | SUPPLY | YEAR ROUND | 7.17 |
| | | | SEASON | 6.88 |

**TABLE 4.**
**THE RESULTS OF CONJOINT ANALYSIS SPECIFIED IN TWO-LIMIT TOBIT AND RANK-ORDER LOGIT MODELS.**

MAXIMUM LIKELIHOOD ESTIMATES

| | TWO-LIMIT TOBIT MODEL | | RANK-ORDER LOGIT MODEL | |
|---|---|---|---|---|
| VARIABLE | COEFFICIENT | STD.ERROR | COEFFICIENT | STD.ERROR |
| LOG-LIKELIHOOD | | -1091.9 | LOG-LIKELIHOOD | 234.58 |
| ONE | 1.9994 | 22.1420 | | |
| COHO | 9.8070 | 11.8614 | 1.1499 | 0.6364 |
| KING | 19.3408 | 9.4653 | 1.2656 | 0.5475 |
| SOCK | 27.3911 | 10.9432 | 0.9745 | 0.5082 |
| ATL | 33.2667 | 13.6102 | 1.3571 | 0.6488 |
| PINK | -7.3120 | 9.0433 | -0.6263 | 0.4490 |
| CANADA | 9.69216 | 7.0242 | 0.9363 | 0.3532 |
| NRY | -7.5007 | 10.6750 | 0.1335 | 0.3232 |
| JAPAN | -0.3541 | 7.0647 | 0.0178 | 0.5077 |
| NZ | 19.3548 | 14.0340 | 0.9745 | 0.6659 |
| CHILE | 7.5376 | 11.1010 | -0.4362 | 0.6109 |
| WEST COAST US | -1.2250 | 8.7625 | -0.3616 | 0.4138 |
| SEINE | 11.8349 | 8.7478 | 0.2244 | 0.3506 |
| GILL | 1.2214 | 7.7867 | 0.0129 | 0.3744 |
| TROLL | 20.9440 | 8.0367 | 0.4201 | 0.3901 |
| FRH | 8.4389 | 5.6293 | 0.4217 | 0.2866 |
| SALT | 2.9018 | 6.2365 | -0.1322 | 0.2887 |
| LQUAL | -16.5093 | 6.1920 | -0.7234 | 0.2958 |
| HQUAL | 11.2022 | 5.8448 | 1.2230 | 0.2752 |
| DARK | -5.8699 | 6.5774 | -0.3540 | 0.2861 |
| BSIL | -1.9485 | 6.6932 | -0.4333 | 0.3261 |
| PALE | 11.5637 | 6.1530 | 0.2754 | 0.2933 |
| DRED | 14.7631 | 5.8966 | 0.6522 | 0.2593 |
| LFAT | -7.8145 | 6.0424 | -0.2328 | 0.2573 |
| HFAT | 4.0349 | 6.5188 | 0.6955 | 0.2831 |
| STK | 7.4373 | 16.5883 | 1.1775 | 0.6526 |
| FILT | 12.2432 | 16.0714 | 1.3283 | 0.5862 |
| HON2 | 13.9308 | 16.9911 | 1.1845 | 0.7239 |
| HON3 | 24.2455 | 17.2999 | 2.7494 | 0.6984 |
| HON4-5 | 7.7378 | 14.8449 | 1.2205 | 0.5213 |
| HOF3 | 46.8984 | 19.1607 | 2.6231 | 0.6407 |
| HOF4-5 | 7.3771 | 17.4277 | 1.5775 | 0.6658 |
| SEASN | 8.3618 | 4.7666 | 0.8347 | 0.2413 |
| PDIF | -0.0107 | 0.0072 | -0.0013 | 0.0004 |
| SIGMA | 31.6399 | 1.6480 | | |

# Seafood Consumption and Giffen Behavior

**Richard S. Johnston [a] and Douglas M. Larson [b] ***

[a] Department of Agricultural and Resource Economic, Oregon State University, BalE 213, Corvallis, OR 97331-3601, USA

[b] Department of Agricultural Economics, University of California, Davis, CA 95616, USA

ABSTRACT

*In recent years, at least in the U.S., consumption of several seafoods has increased at the same time as prices of these seafoods have risen. Some analysts suggest that this is a consequence of an increased demand for seafood. Explanations of this demand increase include rising prices of substitutes and changes in tastes and preferences that favor seafood because of health and nutrition issues. On the other hand, recent demand studies report that such a positive price-quantity relationship exists even in the absence of demand increases, suggesting that these seafoods may have the characteristics of Giffen goods.*

*In this paper, we provide a rationale for these findings. In particular, we expand the neoclassical model of consumer choice to embrace the notion of "local satiety," associated with upper bounds on the consumption of food due to physical limitations on ingestion. The model leads to the hypothesis that, for some configurations of the consumer's budget constraint, if several protein sources can be used to achieve local satiety, the consumer will expand purchases of the cheapest good when its price rises, as long as that price continues to be lower than those of its substitutes. The result is apparent Giffen behavior by the consumer.*

## 1. INTRODUCTION

In recent years, several apparent anomalies have been reported in empirical studies of food, including seafood, consumption. For example a number of econometric investigations report finding positive price elasticities of demand for particular food items. These include margarine in the U.K. (Stone), chicken and turkey in the U.S. (Lambert), and food

* Partial support for the research reported here was provided by the Agricultural Experiment Stations at Oregon State University (Regional Research Project S-216) and the University of California, Davis. Support was also provided by the Cooperative States Research Service, U S. Department of Agriculture (Agreement No. 92-34276-7140).

in total in the U.K. (Deaton and Muellbauer). A recent report on the increased demand for generic grocery items in the face of declining real incomes suggests negative income elasticities, if not Giffen effects (Feigenbaum, 1991). A 1988 study by Kim, et al. reported positive price elasticities of demand for some seafood in Japan. Many other examples are scattered throughout the literature, and are often dismissed as being associated with problems of data, of model specification, or of various econometric problems.

We propose an alternative explanation : namely, that particular food items may, over a range of prices, behave as if they were Giffen goods and that this phenomenon is more common than previously thought. We suspect that this may also help explain why per capita seafood consumption peaked in the U.S. in 1987 and has been declining since.

Our argument rests on a model of consumer behavior in which choice is constrained by two, not one, restrictions. This, then, is an extension of the neoclassical theory of demand, which derives from a model of individual choice in which a consumer seeks to maximize satisfaction subject to a single constraint on expenditures. The theory predicts a negative relationship between a good's relative price and the quantity of it demanded. Giffen behavior — that is, behavior that yields a positive relationship between prices and quantities demanded — can exist only if a positive income effect outweighs an always negative substitution effect. In the standard neoclassical framework, then, Giffen behavior is a phenomenon associated with highly restrictive — and, therefore, unlikely — characteristics of the consumer's utility function. Over the years there have been numerous attempts to uncover goods that are likely to give rise to such functions, with mixed results. A recent experiment shows that some animals demonstrate such behavior and suggests that economic theory must accommodate, not abandon, the phenomenon, despite "the very small likelihood of its existence" (Battalio et al., 1991, p. 969).

One difficulty with finding empirical examples of Giffen behavior in humans is that the neoclassical model provides few clues for locating either goods or individuals where the behavior is likely to be seen. Under what circumstances can one expect to observe not only positive income effects but also positive income effects that swamp substitution effects ? Hicks argued that, for a good to be Giffen, a high proportion of the consumer's income has to be spent on it (Hicks, 1956, p. 65). Ng (1972) suggested looking for this where consumers engage in stepwise optimization, with income being distributed initially among categories of goods, along lines first proposed by Strotz (1957). While the proportion of the consumer's income spent on a good may be low, the proportion of the expenditure assigned to each category could be high, increasing the likelihood of observing the Giffen phenomenon. This suggestion may help to narrow the search but, so far at least, it has provided no guidance for how to select either categories or goods to look for Giffen behavior. Thus Giffen goods continue to be viewed as theoretically possible but empirically unlikely.

In a recent article, Gilley and Karels (1991) (hereafter G-K) develop a convincing argument to explain Giffen behavior as a consequence not of preference characteristics but, rather, of a constraint on behavior : in particular, a nutrition constraint. Their results lead them to conclude that "the most likely place...to look for Giffen behavior...would be among the very poor, consuming a few staple items with limited substitution possibilities" (p. 189). Here, then, is a concrete guide for empirical discovery of the phenomenon, although they endorse the view that the behavior is probably rare.

We maintain that Giffen behavior may be a much more pervasive phenomenon than commonly believed and we suggest where it may be found [1]. We argue that, where preferences are characterized by local satiety, the associated behavior is restricted by an upper bound on consumption, allowing analysis to proceed along lines similar to those suggested by G-K. We therefore, focus the search for Giffen behavior through illustrating how a plausible characteristic of preferences, independent of specific functional form, can generate such behavior in a one constraint world.

The argument that local satiety may give rise to Giffen behavior was first advanced twenty years ago by Lipsey and Rosenbluth (1971) (hereafter L-R). While this work has been cited by almost all who have written in the area since, the principal idea of the piece — that Giffen behavior may be observed in goods whose characteristics (see Lancaster, 1965) are subject to satiation — has not been explored empirically. We suspect the reason is similar to that associated with the earlier argument about relationships between income and substitution effects : without guidance on where to find satiation in characteristics, the phenomenon remains only a theoretical possibility with little empirical relevance. The contribution of the present paper is to provide concrete suggestions for where and why one might locate local satiety and, in so doing, illustrate how the G-K framework generalizes to other areas that offer a high likelihood of finding Giffen phenomena.

1. Actually, G-K recognize that their model extends to other arenas, pointing to a study that found Giffen behavior among drug addicts who seek to achieve a minimum intoxication level with a limited budget. This example implies a belief, however, that the phenomenon is relatively rare.

It is useful to summarize the G-K model, in which the consumer seeks to maximize satisfaction from bundles of food, subject to two constraints : budget and subsistence. The former places an upper limit on the quantity of food consumed while the latter imposes a lower bound. Beginning with the case in which the consumer chooses among combinations of two goods, G-K illustrate their argument with the diagram that appears below, in expanded version, as Figure 1.

In Figure 1, quantities of the two goods, X and Y, appear on the horizontal and vertical axes, respectively (In G-K these goods are meat and potatoes.). Indifference curves $I_1$, $I_2$,... come from a utility function whose form, G-K argue, need not be specified[2]. Line MM is the consumer's budget constraint, while NN is the nutrition constraint, whose slope is the ratio of X's contribution (per unit) to nutrition to Y's unit contribution (e.g., calories per unit of X consumed / calories per unit of Y consumed). Note that the slope of line NN exceeds that of line MM. When both constraints are binding, the consumer maximizes satisfaction by consuming (Y', X'). Notice that the nutrition constraint and the budget line define the feasible set for consumption.

Suppose the price of X rises, shifting MM to MM'. The feasible set shrinks and the optimum bundle is now (Y",X"). Consumption of X rises and of Y falls : good X has the "appearance" of a Giffen good. Intuitively, this makes sense. Suppose X and Y were equal in their contributions to nutrition, so that the slope of NN were -1, and that the consumer views the two goods as close, but not perfect, substitutes. With a relatively small budget available for purchases of X and Y, the consumer will tend to select a bundle with more X, the cheaper good, than Y. If the price of X rises, *but remains lower than the price of Y*, the consumer will choose to substitute the cheaper good for the more expensive good in order to meet the nutritional constraint while staying within his or her budget.

## 2. GENERALIZING TO OTHER CONSTRAINTS

The G-K model is instructive in predicting Giffen behavior in the presence of a nutrition constraint. Our contention, however, is that the model can be modified to predict Giffen behavior in a variety of settings. G-K anticipate this generalization in their paper's abstract, wherein they speak of "a theory of Giffen behavior that results from a second rationing constraint" (p. 182). The particular second constraint they select imposes a minimum bound on the choice set. There are, however, at least two cases in which a second constraint, like the budget constraint, imposes an upper bound — a second upper bound — on the consumer's choice set. These are : time-constrained decision-making (Becker, 1965) and points rationing (Scitovsky, 1942 ; Tobin, 1952). The present paper suggests, following L-R, that Giffen behavior may also appear in the presence of another phenomenon, that of local satiation, in which the consumer's utility function is characterized by one or more upper bounds on consumption. We choose this case because it portrays some of the essential elements of the other cases and because it is easily exemplified by food, thereby preserving the G-K setting. In addition, by offering a specific rationale for and concrete example of local satiety, it helps to provide the L-R framework with a basis for hypothesis testing.

Notice that the satiation case presents a useful counterpoint to the G-K analysis, for two reasons. First, Giffen behavior is shown to arise because of a plausible characteristic of preferences (independent of specific functional forms), rather than because of the presence of an additional constraint. Second, it demonstrates that the phenomenon can occur equally well when there are two upper bounds to consumption, rather than with an upper and a lower bound as in the G-K model.

## 3. LOCAL SATIETY AND THE DEMAND FOR MEALS

In the standard exposition of the neoclassical theory of consumer choice little attention is paid to the phenomenon of satiation, largely on the grounds that "the interesting region (of the utility function) is where you have *less* than you want

2. Although, as discussed below, its properties play an important role in determining the likelihood of Giffen behavior. Note that, for the intersection of the constraints to be the consumer's choice position, the indifference curves from a quasi-concave, twice differentiable utility function must be flatter than both of the constraints throughout the feasible region. An observation by Lew Queirolo leads us to point out that, under G-K conditions, the indifference curves do not extend below NN because in the region ONN the consumer is either dead or suffering from malnutritution.

of most goods" (Varian, pp. 43-44). However, there are numerous goods for which consumption takes place at the point of local satiation. During a given time period, the average consumer is unlikely to purchase more typewriter ribbon, shoe polish, lawn fertilizer, attorney's services, or copies of today's newspaper in response to higher income levels or lower prices, even if the latter fell to zero [3]. Satiation is especially likely to be seen in the consumption of goods and services that are close substitutes for each other but which, as a group, have few close substitutes and are associated with a durable asset. This is especially true of goods for which storage is costly or impossible, including perishable goods. Perishability may be a property of either goods or their services, the former exemplified by some foods and the latter by newspapers. For the residential householder with a lawn in place, a reduction in the price of lawn fertilizer below some threshold level is unlikely to increase the quantity demanded in a given year (although this may not be the case for a particular brand of fertilizer). The same argument can be made for items such as typewriter ribbon and shoe polish, although contributing to the explanation in these cases is the relatively high cost of increasing their use (changing the typewriter ribbon frequently, polishing the shoes more often). Attorneys are hired to perform highly specific services, for which the quantity demanded is unlikely to rise if unit costs fall below some level at which it pays to hire the attorney in the first place but above the unit cost of other services that attorneys are able to perform, such as unskilled labor. One could employ the attorney to perform "non-legal" services but it is not clear why one would choose an attorney if other providers of the service are available at a lower cost.

A similar argument can be made for food, at least for some dining patterns. For physiological reasons there is an upper limit to the amount of food and beverage that a consumer can ingest during a short period of time. Economic manifestations of this include "all you can eat" offers in some restaurants and "free" refills of cups of coffee. If satiety were not a pervasive phenomenon, these restaurants would have high bankruptcy rates. The key here is the time dimension. "All you can eat" restaurants, in contrast to other restaurants, do not offer "doggie bags" to clients, permitting future consumption.

Thus satiety is a phenomenon for food consumption during short periods. But what about longer periods ? Would one not expect the annual consumption of a particular food to increase if its price were to fall ? Of course. But this is probably not the case for broad categories of food. Most food is consumed, at least in Western cultures, as part of a meal — and meals last a relatively short period of time. Furthermore, for most consumers, there are no more than three meals in any day. Thus, if satiety is an aspect of consumption for any given meal, it is an aspect of consumption during any given day and, by extension, for any time period. This argument lies behind the often-observed phenomenon of a highly price-inelastic demand for food in the aggregate. While the demand for any particular food item, such as beef, may be relatively price elastic, this is not the case for all food — or even groups of food — taken together. This relationship goes beyond the "number of substitutes" argument. Its explanation lies, as well, in the limited capacity of the human consumer to eat and drink.

This appears to be a concrete example of what L-R had in mind when they spoke of "satiation in characteristics" of goods as possible explanations of the Giffen phenomenon. Food's characteristics include flavor, color, texture and fragrance. But food also contributes to the feeling of fullness. At any meal additional units of food may provide utility to the diner through the flavor, texture, color and fragrance characteristics, but generate discomfort in the fullness dimension, generating pleas of "I'd love to have more but I'm stuffed."

Consider the average, middle-income American household. Most of its members consume three meals per day, or a total of twenty-one meals per week. Focus on the evening meal. That meal generally consists of an entree item (beef, pork, poultry, seafood), vegetables, salad, a beverage and, possibly, dessert. Of course there are exceptions, including meals prepared for vegetarians, but, in general, this is a reasonable description of the typical American dinner.

Reasons for this are partly cultural, partly habit-determined and partly economic, perhaps having to do with minimization of transaction costs. Consider the purchase problem faced by the individual having the responsibility for buying food to prepare the evening meal. Note that, even if the food for this meal were available at a zero price, no more than can be physically consumed would be purchased [4]. This is true for every meal : despite additional utility from flavor, etc., no

3. The consumer could purchase today for future consumption. Aside from the problem of storage there is the additional question of why the consumer would do this if the zero price were not expected to change.
4. This abstracts from storage possibilities. But it is not clear why, if the price of a food item falls and is expected to remain at its lower level, the consumer would choose to purchase now for future consumption, thus incurring a storage cost. Storage is more likely to occur to minimize transaction, including transportation, costs and/or because of expectations regarding future prices. At zero price, would the consumer not purchase

more would be purchased for each meal than can be physically consumed during that meal. Thus, for the average week, the typical food buyer will choose no more than seven entree items per week, having a combined maximum weight per person of, say, seven pounds [5].

For simplicity, suppose that each meal consists of only one item, the entree, but that the consumer can choose from among several foods for that entree. Examples include beef steak, hamburger, fish fillets, pork chops and other protein sources. Consider one such item, say, beef steak. Suppose, further, that for any dinner meal and a given household member, the utility of beef steak—such utility associated with flavor, color, texture, and fragrance — increases with the size of the portion. The beef steak also adds to utility through contributing to the feeling of fullness. In this dimension, however, there is a limit, beyond which the marginal utility is negative. In fact it may be so negative that it swamps the contribution of the other characteristics of a larger portion. The "net" marginal utility, then, is negative. Consumption is not observed in that range, a case of local satiety.

Next, introduce a second food that could also serve as an entree item, such as fish fillets, having similar characteristics. One could think of a given meal being designed to consist of a particular combination of beef and fish, where that combination may yield flavor, texture, color and fragrance levels that are different from those of other combinations. However, in the "feeling of fullness" dimension, any given volume of fish and beef will make the same contribution to utility as any other combination having the same volume. Thus, no matter whether the meal consists of only beef, only fish, or some combination of beef and fish, there is a physical limit to the size of the entree yielding positive net marginal utility to the consumer. Local satiety produces an upper bound on consumption. This argument extends to combinations of any of the foods included in the entree category but, for ease of graphical presentation, it is assumed that there are only two such foods. Figure 2 depicts the situation.

In Figure 2 the elliptical-shaped curves are indifference curves indicating levels of satisfaction realized by the individual for various combinations of beef (b) and fish (s, for seafood) consumed at a single meal. These curves are truncated at the line AB, along which the consumer is satiated [6].

The equation of line AB is $s + b = 1$. Thus, the consumer reaches satiety at one pound of food (combination of beef and seafood) [7].

Where $s + b < 1$, all of the marginal utilities are positive, by assumption. Note that AB itself is not an iso-utility contour, since utility is first increasing and then decreasing as one moves along its length. Line MM is the budget constraint in this two-good model.

In the Figure 2 case, it is drawn such that the price of beef exceeds the price of seafood. The feasible set, in contrast to that of G-K, is OMΘB. The utility-maximizing consumer selects s* pounds of seafood and b* pounds of beef. At a higher price of beef (no change in the consumer's budget or the price of seafood), represented by MM', the consumer chooses the combination (s', b'). This is a standard result : with an increase in the price of beef, consumption of beef falls and consumption of seafood rises.

However, this new combination is also the consumer's choice for the budget constraint given by MM'', along which the price of seafood is above its initial level, with the price of beef and the budget level unchanged. That is, an increase in the price of seafood, while reducing the feasible set to OM'ΦB, leads, in this case, to lower beef consumption and *higher* seafood consumption. The intuitive explanation is that, as long as the consumer maximizes satisfaction by consuming to satiation, more of the less expensive good will be chosen when the price of that good rises because, with a fixed budget,

---

more than can be eaten, finding some other use for the excess ? This could be the case if disposal costs were zero and/or if there were gains from this other use. Food, however, is perishable. If it is not eaten or stored, it spoils, creating discomfort that is costly. This plus disposal costs militate against excess food purchases.

5. The number is irrelevant to the argument but is provided to indicate that there is such a number, although it may vary among individuals. The point is simply that there is an upper limit, for both cultural and stomach capacity reasons, on the volume of dinner entrees that can be consumed by an individual in any given week. This capacity is not determined by economic considerations.
6. Note that AB is the crest of the "utility hill" and that it need not necessarily coincide with the line along which the marginal utility in the fullness dimension is zero. It is possible that, because of gains in utility from taste (or other characteristic) the consumer will endure some discomfort from being "full." Eventually some limit will be reached where the "net" marginal utility is zero and beyond which it is negative. The combinations of b and s for which this is true are those along AB. We expect that, in most cases, these will also be the combinations of b and s for which the marginal utility in the fullness dimension is zero. In any event, consumption will not be observed to the northeast of AB because of disposal, storage, or discomfort costs.
7. Alternatively, one could think of the selection of entrees for an entire week, or other time period. Using the numbers indicated in the text, the constraint would be $s + b \leq 7$.

the loss of effective income accompanying a price rise of either good requires that the less expensive good play a larger role in achieving satiation. It is as if the two goods were perfect substitutes in achieving satiation, so that the less expensive good would provide the least cost way of reaching satiation. The reason this good is not chosen to the exclusion of the second good is that the two goods are not perfect substitutes in the provision of taste, color, texture, and fragrance. In addition, local satiation is not associated with a single level of utility, analogous to a "bliss point." Rather, the consumer is satiated at all combinations of the two goods that sum to unity, and those combinations have different levels of utility associated with them that differ from those of adjacent combinations.

All of this is really the consequence of an income effect, since there is no substitution effect along AB, as noted by G-K [8]. By keeping prices at their original level and decreasing income appropriately, the consumer will move to (b',s'). With a lower entree budget, the consumer will substitute the lower priced seafood entree for beef.

These ideas can, perhaps, best be illustrated via an explicit utility function. It is also appropriate to introduce a third good to generalize the problem, enabling the consumer to spend part of his/her budget on that good.

For purposes of illustration, the following function is chosen :

$U = b^{0.5}s^{0.5} + z^{0.5}$, for $b + s \leq 1$, the local satiety condition on $s + b$, and for b, s and z all $\geq 0$.

This function has the property that, in consumption, b and s are independent of z but not of each other. The consumer is constrained to choose combinations of b, s, and z such that $b + s \leq 1$. The consumer also faces the budget constraint $P_s\, s + P_b\, b + P_z\, z \leq 0.5$, where P denotes price. Consumer choice is computed for different levels of $P_s$ but with $P_b = 1$ and $P_z = 9$. The results appear in Table 1.

As revealed by Table 1, when $P_s$ increases from.20 to.25, the consumer increases consumption of s from.719 to.739. At an even higher price, $P_s$ =.30, consumption of s is higher yet, at.758. Thus, in this range, the consumption of s and the price of s move in the same direction. When the price of s rises to.35, however, consumption of s declines to.659. This is because the consumer maximizes satisfaction by moving away from local satiety, consuming b and s such that $b + s < 1$. The situation is depicted in Figure 3, where, for purposes of illustration, it is assumed that the consumer's entire budget is spent on goods b and s.

In Figure 3, as $P_s$ increases from zero, consumption of s first exhibits no change (it remains at s*), then rises, and eventually declines. During the phase of rising consumption the consumer moves along the line $b + s = 1$. Total utility declines with the price increases, since b consumption declines, but local satiety is maintained. The consumer is simply trading off units of the higher priced good for units of the lower priced good, while maintaining local satiety. For a sufficiently high price of s, e.g., along MM", the consumer is induced to cut back consumption of both goods, and will leave the table hungry (i.e., not satiated). At (b", s") local satiation is not binding [9].

Here, then, is a possible explanation of the uncovering of positive price elasticities in empirical estimates of the demand for food items. Through the imposition of restrictions on meal purchases (because of either satiation considerations or custom), consumers may increase purchases of a food item when its price rises, as long as that item continues to be the least-cost way to satisfy those restrictions. In the U.S. this may help explain why per capita seafood consumption rose during the 1980s to its 1987 peak. Perhaps the period since 1987 has seen continued increases in seafood prices such that seafood no longer satisfied the least cost criterion, leading to declines in per capita consumption.

## 4. THEORETICAL CONSIDERATIONS AND EMPIRICAL COUNTERPARTS

Are there properties of the consumer's utility function and/or the constraints (s)he faces that make Giffen behavior more or less likely ? It has been argued above that, under conditions of local satiety, as in the case of some food consumption decisions, Giffen behavior is likely to be observed. When combinations of two (or more) goods lead to conditions of local satiety, the good with the lower price may bring forth Giffen behavior. This is even more likely when the consumer has a relatively low budget available for those goods. The demands for particular brands of a good exhibiting local satiation, ranging from cigarettes to newspapers, may be examples.

8. Although, in a sense, the goods are perfect substitutes in their contribution to fullness and, thus, local satiation.
9. Because there is a third good, the budget constraint would have to shift to reflect changes in expenditures on that good. Incorporating this consideration would unnecessarily complicate the graph while adding no new insights.

As illustrated in Figure 3 above, however, Giffen behavior is less likely to appear if local satiety is not an effective bound on consumption. This, in turn, is more likely the less substitutable the two goods, i.e., the more "bowed" the indifference curves where they cross the "iso-satiation" curve.

A second issue merits examination. Refer back to Figure 3. Note that, at both Giffen equilibrium positions (b'', s'') and (b''', s'''), the marginal rate of substitution of s for b (-db/ds) is less than the slope of AB. For quasi-concave, twice-differentiable utility functions, this means that both equilibrium positions must be to the southwest of point *, where * is the bundle yielding the highest satisfaction level subject only to the AB bound. If the intersection is to the left of *, as depicted in Figure 3, it is not an optimum for the consumer, who can increase satisfaction by moving to *, where the budget constraint is non-binding. In this case, when the price of s rises, as long as the new budget line does not intersect AB below *, the consumer will not change his or her consumption bundle in response to the price change [10].

With these caveats, the above analysis suggests that Giffen behavior is likely to appear more frequently than generally believed. It has been argued that, while Giffen behavior is a logical possibility for individuals, it cannot occur at the market level (Dougan, 1982). Nonetheless, as reported at the beginning of this paper, there has been increased reporting of estimated positive price elasticities. We believe the issue merits additional investigation. Perhaps the present paper, an extension of the G-K and L-R work, will stimulate a more thorough investigation of the issue.

## 5. CONCLUSION

Giffen behavior, far from being merely a theoretical oddity of little practical importance is an entirely plausible consequence of consumer choice in the presence of multiple constraints (G-K) or local satiety (L-R). There is both conceptual and empirical support for this contention, as illustrated for the case of food consumption. The search for examples of Giffen behavior may be more successful if it begins with examples of where either multiple constraints or local satiety exist. We believe the dining room may be one place to begin.

10. The argument is similar to the L-R requirement that Giffen goods have a "comparative advantage" in the satiated characteristic relative to the other characteristics in the utility function. In their model, the marginal contribution of each good to a given characteristic is constant, allowing them to determine comparative advantage in terms of relationships among the constant coefficients. Because we do not impose this condition on the contributions of goods to their characteristics, we require only that, in equilibria consistent with Giffen behavior, the slope of the "iso-satiation" curve AB exceed the slopes of the indifference curves where they meet AB.

## REFERENCES

**Battalio R., C. John, H. Kagel and C.A. Kogut** (1991). "Experimental Confirmation of the Existence of a Giffen Good." *The American Economic Review*, September, 961-970.

**Becker G.S.** (1965). "A Theory of the Allocation of Time." *The Economic Journal*, September, 493-517.

**Deaton A. and J. Muellbauer** (1980). "An Almost Ideal Demand System." *The American Economic Review*, June, 312-326.

**Dougan W.R.** (1982). "Giffen Goods and the Law of Demand." *Journal of Political Economy*, August, 809-815.

**Feigenbaum N.** (1991). "Pricey Snacks Victim of Recession." *The Oregonian*, September 24, C12.

**Gilley O.W. and G.V. Karels** (1991). "In Search of Giffen Behavior." *Economic Inquiry*, January, 182-189.

**Hicks J.R.** (1956). *A Revision of Demand Theory*. London : Oxford University Press.

**Kim S.-W., R.S. Johnston and O. Bergland** (1990). "The Demand for Surimi-Based Products in Japan." *Seafood Trade, Fishing Industry Structure and Fish Stocks : The Economic Interaction*. Proceedings of the Fourth Conference of the International Institute of Fisheries Economics and Trade, 1988. Esbjerg, Denmark. Pages 303-326.

**Lambert D.** (1991). The Role of Habit Formation in the Demand for Meat. Presented at the Annual Meeting of the Western Agricultural Economics Association. Portland, Oregon, July 1991.

**Lancaster K.J.** (1966). "A New Approach to Consumer Theory." *Journal of Political Economy*, April, 132-157.

**Lipsey R.G. and G. Rosenbluth** (1971). "A Contribution to the New Theory of Demand : A Rehabilitation of the Giffen Good." *Canadian Journal of Economics*, May, 131-163.

**Ng Y.-K.** (1972). "Step-Optimization, Secondary Constraints, and Giffen Goods." *Canadian Journal of Economics*, November, 553-560.

**Scitovsky T. de** (1942). "The Political Economy of Consumers' Rationing." *Review of Economic Statistics*, August, 114-124.

**Stone J.R.N.** (1953). *The Measurement of Consumers' Expenditure and Behaviour in the United Kingdom, 1920-1938*. Cambridge.

**Strotz R.** (1957). "The Empirical Implications of a Utility Tree." *Econometrica*, April, 269-280.

**Tobin J.** (1952). "A Survey of the Theory of Rationing." *Econometrica*, Octobe, 521-553.

**Varian Hal R.** (1978). *Microeconomic Analysis*. New York : W.W. Norton & Company.

TABLE 1.

| $P_s$ | s | b | z | M | U |
|---|---|---|---|---|---|
| 0.20 | .719 | .281 | .0084 | .500 | .541 |
| 0.25 | .739 | .261 | .0060 | .500 | .517 |
| 0.30 | .759 | .238 | .0038 | .500 | .487 |
| 0.35 | .659 | .231 | .0043 | .500 | .455 |

FIGURE 1.

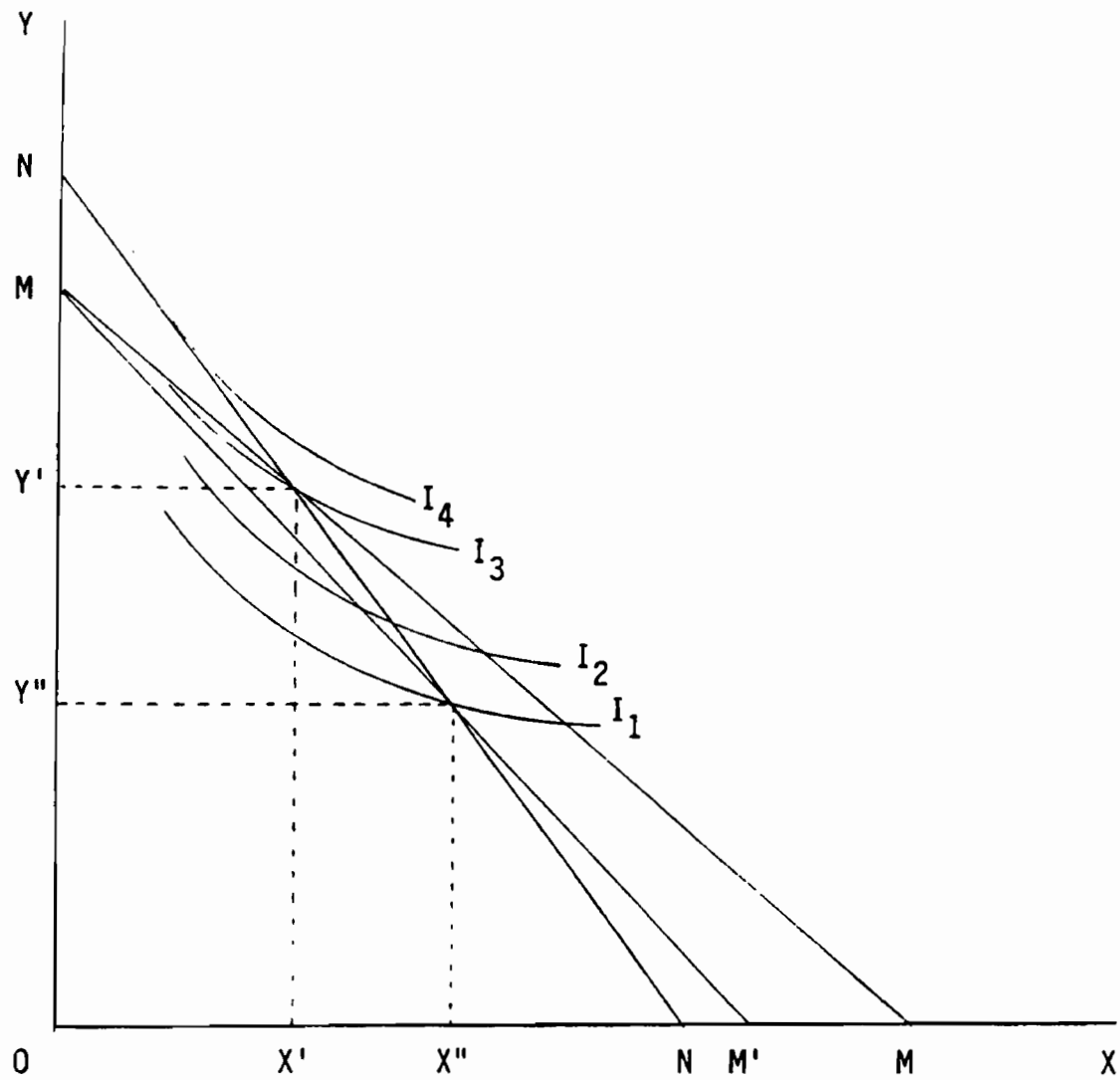


**FIGURE 2.**

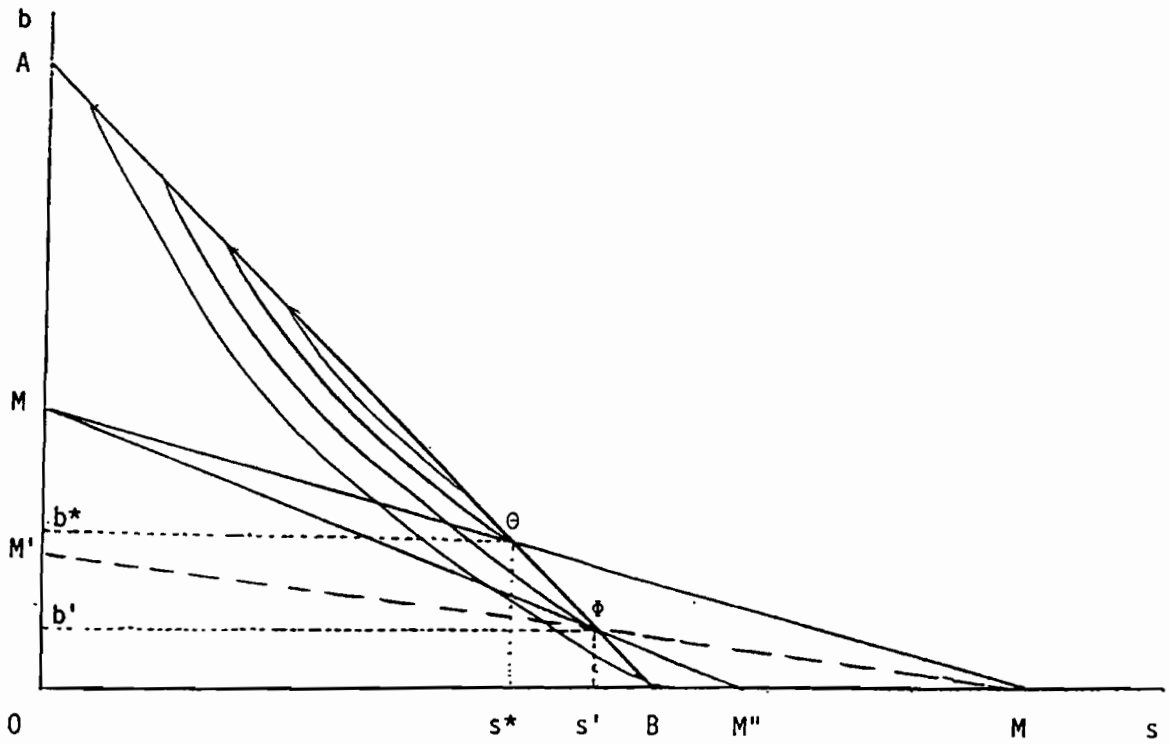
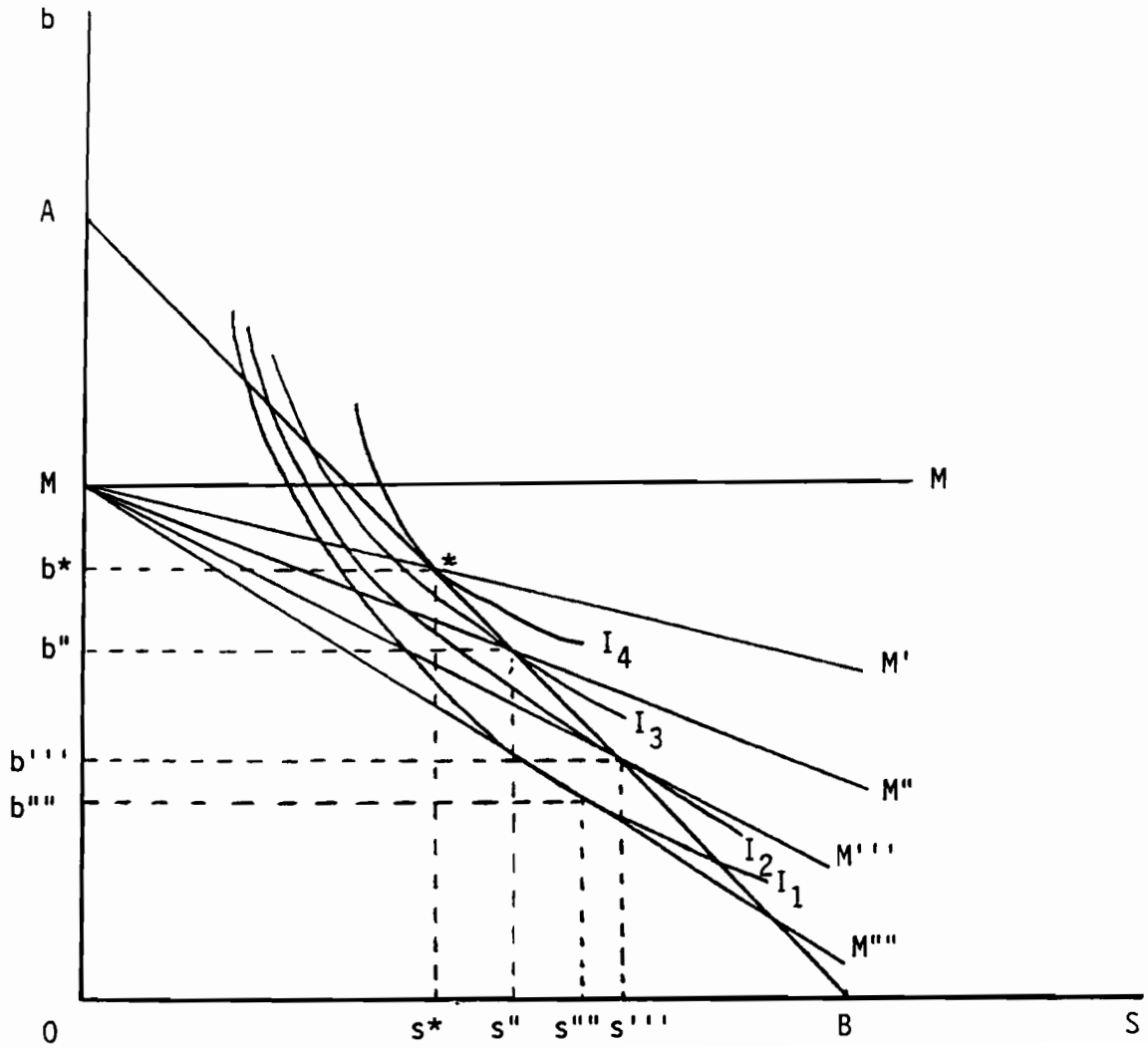


**FIGURE 3.**



# The Changes Affecting the Demand for Fish and Fishery Products in Poland

**Adam Gwiazda**

Dept of Fishery Economics, Morski Instytut Rybacki, Ul Kollataja, 81332 Gdynia, Poland

ABSTRACT

*This paper analyses the recent trends in the consumption of fish and fishery products on the basis of a survey carried out among 3 400 consumers and 200 fishmongers in Northern Poland.*

*It presents the changes both in the volume and structure of the consumption of those products and outlines the future possible trends in this field. The need for the adoption of an appropriate marketing strategy has been stressed as the further increase in the consumption of seafood in Poland can be expected when the incomes of the population will rise in the next few years.*

## 1. RECENT CHANGES ON CONSUMER MARKETS IN POLAND

The most visible achievements of the programme of a radical transition from centrally planned system into a market economy were : the reduction of the hyperinflation from the level of 1800 percent on an annual basis in 1989 to 584 percent in 1990 and about 4 percent on a monthly basis in 1991, the elimination of shortages, which, however, had been attained not through a substantial expansion of domestic industrial and agricultural production (the first one fell in 1990 by almost 30% and the second increased, due to the bumper harvest by 8%), but through wage freezes, price liberalization and the elimination - till August 1991 - of import restrictions. Another positive achievement was the introduction in January 1990 of the uniform exchange rate of polish zloty in relation to US dollar and other convertible currencies which have made Poland's domestic market very attractive to both domestic and foreign companies.

All those events have led to the collapse of the producer's market and the emergence of consumer's market with still rather limited consumer's sovereignty. This stems from the fact that, in the previous two years, Polish consumers were buying almost everything reagardless the price and quality because goods were better than zlotys with a triple-digit inflation. And these habits still prevail, although Poles are offered a wide choice of various consumer goods, including the imported foodstuffs in which a substantial part constitute the fishery products. It should be recalled that the fear of

inflation, unstable market conditions, recession in the national econmy and insufficient purchasing power in society [1] are all those factors which put the pressure on incomes and force families to cut their expenditures for various types of goods. Taking into account the fact that the overwhelming portion of the family budget goes towards food (52 - 60% compared to 33% in Czechoslovakia in 1990), so it is understandable that families as consumer group must refrain from buying many other articles and services. Therefore, their "free consumer choice" is rather limited. This is also visible on the most expanding foodstuff-market in Poland where the great variety of hardly available imported food-stuffs in the previous years makes this choice even more difficult.

## 2. THE IMPORTANCE OF FISH AND FISHERY PRODUCTS IN POLISH DIET

To some extent, the Polish consumer's demand for fish and fishery products is determined - as in other countries - by traditional preferences and tastes largely influenced by geography. To another extent the consumption of fish depends also on the availability and price of other basic protein foodstuffs, in particular meat and meat products, milk and eggs. Taking into account the first fact it can be said that Polish consumers were used mostly to consume fresh-water fish than the salt-water fish. In the inter-war period there was very poorly developed Baltic fishery (mostly coastal fishery) and after the second World War, the fishery industry continued to be an insignificant component of the Polish economy till the middle of the 1950's. Since that time, when Poland developed its deep-sea fishery, there has been a steady increase in the supply of fish and fishery products on the domestic market which expanded greatly in the last two years.

Generally speaking the fish and fishery products have been regarded by the polish consumers mostly as the substitutes of meat and meat products and not as healthier than meat foodstuffs.

It is interesting to note that in 1957-1960, the share of expenditures for fish and fishery products as compared to total expenditure for foodstuffs was rather very low (1,7-2,0%), so at the end of 1980s it was 5% and in the middle of 1991 almost 6,7%-9,8% (depending on the category of household) [2]. During the last few years the consumption of fish declined significanly by about 42% per cent in 1990 as compared to the 1970 level (see table 1).

On the other hand the consumer's expenditures for fish and fishery products increased at the same time which was due not to the increase in the per capita consumption but to the introduction in 1990 of more or less realistic market prices for those products.

It should be stressed on the fact that the consumption of fish and fishery products is still more occasional than regular in Poland. As the substitute of meat and meat products the fish and fishery products are very often consumed - mostly for religious reasons - once a week, i.e. on friday which is regarded by polish Catholics as a day of fasting. For the poor families (i.e. very low, low and middle-income households) fish and fishery products are also the substitute of other than meat products, such as eggs, dairy products and edible fats. This group of people consume more fresh (both salt-and-fresh water) fish than fishery products, which had become during 1990-1991 more expensive compared to the previous years.

On the other hand, the consumption of fresh fish is not so popular among better-off Polish consumers who prefer the fishery products and consume such products on a more regular basis i.e. not as the main dishes as it is the case in the poor families but as snacks, refreshments and side-dishes. According to the survey which comprised 3400 Polish consumers about 50,6% buy regulary fresh and frozen salt-water fish and 49,4% buy them only from time to time (the same indicators for the fresh-water fish are : 38,1% and 61,9% respectivly). On average Polish consumers purchased in the middle of 1991 about 0,4 kg of fish and fishery products per month. The most popular species and products bought by Polish consumers in the first half of 1991 were herring : 15% of all purchases ; frozen fillets (of hake and pollock) : 10% ; carp : 8% ; hake : 7% ; pollock : 6% ; mackerel : 6%.

According to the survey, about 70% of the respondents buy fish and fishery products because they consider them "healthier" than other foodstuffs and roughly 41% of Polish families buy fish because it corresponds to their consumption

1. According to the AMEX Bank Review, september 1991, n7, the per capita GDP in Poland was in 1990 about 3910 US dollars at purchasing power parity from 1988. This can be compared to other estimates the GDP per capita in Poland of 1850 dollars in the fist half of 1991.
2. According to the classification adopted by the Statistical Yearbooks and Statistical Bulletins the Central Statistical Office in Poland, the average per capita consumption of the selected foodstuffs is presented in four types of households : farmer's households, retired persons and pensioner's households, employee's and employees-farmers households.

habits and tastes. It is interesting to note that about 62% of the surveyed consumers considered the present prices of fish and fishery products "too high" compared to meat and meat products, whereas only 35% find these prices acceptable. No respondent characterized the prices of fish as too low. Further, the majority of Polish consumers were not satisfied with the structure of the fish market and the organisation of its distribution : 64% of all answers.

In that context the surveyed consumers are classified among these three opinions :

- 47% think that fish and fishery products should be sold exclusively in fishmongers,
- 35% think that fish and fishery products should be sold in most of the grocery shops (supermarket),
- 17% think that fish and fishery products should be sold in selected grocery shops.

Such recommendations are in sharp contrast with the typical pattern of Western European countries where fish and fishery products are increasingly being sold by supermarkets rather than by specialty shops. For example, in France, the share of supermarket chains in the seafood market is 34% while that of traditional fishmongers equals 32%.

The idea of distributing fish and fishery products predominantly through specialty shops in Poland is hardly consistent with another view expressed by the respondents. The majority of the respondents - 58,8% - were, namely willing to buy more fish and fishery products depending on their greater availability, while only 17,6% epoused no desire to buy more, 23,5% had no opinion. Another issue worth emphasizing is that 70,6% of the surveyed consumers deemed marketing of fish and fishery products highly unsatisfactory - this opinion pertains in particular to poor advertising and only 14,7% considered the expanded marketing effort appropriate with the remaining 14,7% who have no opinion on the subject.

## 3. CHANGING MARKET CONDITIONS FOR FISH AND FISHERY PRODUCTS

During 1990 and 1991, the major factor affecting the evolution of the fish and fish products market in Poland was the supply of these products and not necessarily the behavior of the consumers and their effective demand. The shifts in price and foreign exchange rate policies of 1989-1990 made Poland's domestic market more profitable to foreign and domestic fishing companies. However, it soon became evident that despite lower incomes and limited purchasing power of the society as a whole, the prices of fish and fishery products in Poland remained relatively high compared to those in the OECD countries.

Since the end of the 1980s until mid-1991, Poland increased its finfish exports to western countries in order to earn hard currency. For example, in 1987-1989 almost the entire Polish catch of Baltic cod was exported mainly to the Danish island of Bornholm. At the same time, however, there has been a significant increase in the imports of finish (table 2). Deliveries of fish and fishery products to the market by domestic suppliers decreased to 67 600 tonnes in 1990 from 88 200 tonnes in 1989. At the same time, exports of fish and fishery products remained more or less stable at 142 000 tonnes. It should be noted that the majority of the seafish supplies came from imports, while domestic supplies declined in 1990 from the previous year level. This was due to the decline of Polish catches on almost all distant water fishing grounds [3]. The gap has not been fully closed by increasing imports.

It should also be pointed out that the progressive disintegration of the state-owned handling and distribution network and a recession in the state fish processing industry had a big impact on the market situation. Until recently, fish processing has been an almost exclusive domain of the huge, "half-monopolistic" state companies, such as Centrala Rybna and Zakkady Rybne as of the end of 1991 these state entreprises were in disarray and numerous private processing and wholesale companies have been established. Needless to say, these companies are free to choose their supply sources, i.e. select either domestic or foreign fishing companies.

A similar process can be observed among fish retailers. According to a recent survey, more than 69% of formerly state-owned fish shops have been privatized. These outlets are mostly medium sized operations according to Polish

3. The highest catches by Polish vessels recorded in 1975, i.e. 816 thousand tonnes, compared to 429,7 thousand in 1990 and 395 thousand in 1991, in which 100 thousand accounted for Baltic Sea catches and 295 thousand tonnes for deep-sea catches. Compare with the Statistical Bulletins of the Sea Fisheries Institute in Gsynia. See also Gwiazda, 1992 : Polish fisheries : development trends ans prospects, *"World fishing"* 1992, (4) pp. 28-29.

standards, employ on the average two people excluding the owner and are equipped with the chilling, freezing and cold storage facilities much superior to those of the state-owned shops. The survey which was conducted among 200 selected fish retailers revealed that fresh and frozen fish accounted for 50,1 percent of total sales in mid-1991, with smoked fish representing another 19%, canned and marinades 19,1% and other fish products 11,7%.

According to this survey of fish retailers the most popular fish products among Polish consumers were the salt-water frozen fish. Smoked fish was ranked second, followed by the fresh-water fish which during the second half of 1990 and the first half of 1991 was less expensive than seafish. Fresh saltwater fish came next, especially cod which was in short supply in 1991, as well as herring and canned products. The preferences of Polish households differ significantly from German consumers who are probably among the most demanding in Europe. In (the Western part of) Germany, herring is still the most popular variety followed by salmon, cod, tuna and redfish. Further, the canned products represent in Germany 29% of the market, frozen fish account for 22%, the share of fresh fish is only 11% and smoked fish 5% [4].

Due to the previously mentioned decline in domestic production and insufficient imports, present supplies of fish and fish products lag behind the existing demand. Deliveries of fresh and frozen fish were estimated by the owners and managers of fish shops to be falling 50% below consumer demand, while for fish products the estimated shortfall was 20%. The limited domestic supplies of fish and fish products influenced Poland's pattern of consumption. However, the multiple increase in price also played a role. During 1990-1991 prices of fish and fishery products not only equalled the corresponding level of meat and meat products but with respect to certain varieties salmon, eel and other "luxury" species-greatly surpassed the average price of other competing food products. According to estimates by the Sea Fisheries Institute in Gydnia, between 5,7 and 9,8% of the monthly food expenditures by Polish households was during this period spent on seafood. Fish and fishery products are mostly consumed at home because of the highly underdeveloped infrastructure in Poland (lack of fish restaurants, small bars, fast-food outlets).

Moreover, recent changes in import tariffs encourage neither any rationalization of food consumption pattern in Poland nor any substantial growth of consumption growth of seafood-the import duties for fish and fish products brought into Poland were increased as of August 1, 1991 to 20% for whitefish and processed fish products and to 5-10% for other fish products - some tariffs are subject to seasonal adjustments like those imposed for imports of herring and sprats - 15% for the period June-February and 5% at other times. Other tariff rates have been temporarily "frozen" at a level of 10% until the end of 1991. Consequently, if the present relationship between the prices of basic foodstuffs is maintained, consumption of seafood in Poland might go down.

## 4. PROSPECTS FOR MARKETING SEAFOOD IN POLAND

As observed earlier, the per capita consumption of fish and fishery products in Poland declined in 1990 to 4,5 kg due to a fall in the household's disposable incomes and the consumer's perception that seafood prices are relatively high. This decrease was also due to the drop in deliveries of fish and fishery products to the market-certain species and products were hardly visible.

The fact is, however, that the total production of fish coming from capture fisheries (especially from deep-sea fisheries) will decrease in the near future. Moreover, the level of production provided by the Baltic Sea Fishery remains more or less fixed. Even if the Polish cutter fleet fully utilizes the catch quota allocated to Poland by the International Baltic Sea Fishery Commission the total catch from this fishing area cannot surpass the volume of 160 to 180 thousand tonnes a year. Thus, in order to meet the growing demand for seafood, more fish and fishery products will have to be imported. This, however, depends on Poland's ability to maintain at least the present (as of 1991) level and the accompanying growth of exports which would generate the balance of trade surplus.

Opportunities for expanding the consumption of seafood in Poland can improve greatly if and when the income of the population will start growing faster than in the first two years of the transition period. Much will depend also on the proper generic marketing/advertisement strategies of the polish seafood industry which should be more in promoting the

4 Compare with West German fish consumption up again in 1991, *"Eurofish Report" 1990,* (360), pp. SP1-SP2. and with German Pleasure, *"Fish International"* 1991, (3), July, pp. 45-48.

consumption of fish and fishery products and stress first of all on the health benefits of the regular consumption of those products. Also, the development of network of fish-restaurants and small bars can bring about a substantial increase in the consumption of seafood following the pattern of many Western countries.

Another opportunity lies in the development of the market for the ready-to-eat seafood products which are especially convenient for Polish consumers used to eating fish and fishery products market. Therefore, it would be highly desirable to continue the so called comparative market research of the seafood market in selected European countries whose level of per capita consumption of fish and fishery products varies from very low to a much higher level than in Poland. Needless to say, this would help to estimate the expected rise in consumption of seafood in Poland as well as possible structural changes.

## REFERENCES

**Agra Europe** : *"Eurofish Report"*, various issues,

**Bulletin of the Sea Fisheries Institute**, various issues,

**Ber M.** (1991). Reactions of consumers for price changes (in polish), *"Handel Wewnetrzny"* , n° 1 - 2, pp. 33-35.

**Fish International**, various issues.

**Households Economics in Poland and elsewhere** (Polish Quarterly) various issues.

**Kiezel E.** (1991). Covering the nutrituonal needs of the households under the present market conditions, *"Handel Wewnetrzny"* , n° 1-2, pp. 11-15 (in Polish).

**Rolny R.** monthly in Polish, various issue

**World fishing** various issues.

TABLE 1.
THE AVERAGE ANNUAL CONSUMPTION OF THE MAIN PROTEIN FOODSTUFFS IN EDIBLE WEIGH (KG) PER CAPITA.

| Type of foodstuff | 1970<br>In kg per capita | 1990 |
|---|---|---|
| Meat and meat products | 70,6 | 62,2 |
| Fish and fishery products | 7,3 | 4,5 |
| in which : salt-water fish | 6,3 | 3,2 |
| Edible fats | 24,9 | 22,4 |
| Dairy milk | 261 litres | 104 litres |
| Eggs | 218 pieces | 263 pieces |

Source : Statistical Yearbooks of GUS (Central Statistical Office), Warsaw ,1972-1990.

TABLE 2.
THE STRUCTURE OF POLAND'S FISH MARKET. DELIVERIES TO THE MARKET AND ESTIMATES OF THE TOTAL SUPPLY 1989-1990.

| | 1989 thousand | 1990 tonnes | 1990/1989 percent |
|---|---|---|---|
| Deliveries to the market from the central supply agencies | 166,8 | 90,1 | 54,0 |
| Other sources | 28,2 | 68,4 | 242,6 |
| Non-market buyers (consumer) | 10,0 | 10,0 | 100,0 |
| Total deliveries | 205,0 | 168,5 | 82,2 |
| of which/fresh-water fish | 12,9 | 7,5 | 83,8 |
| Sea water fish | 192,1 | 161,0 | 83,8 |
| imported fish | 103,9 | 93,4 | 89,9 |
| Supply from domestic production | 88,2 | 67,6 | 76,6 |
| Exports | 142,3 | 141,0 | 99,1 |
| Production of fish meal | 48,5 | 40,5 | 83,5 |
| Other side-products | 21,0 | 11,3 | 53,8 |
| Change in inventories | 9,5 | -2,5 | |
| Total supply | 309,5 | 257,9 | 83,3 |
| Assortment structure | | | |
| - whole and gutted fish | 46,9 | 51,8 | 110,4 |
| - salted fish | 32,6 | 17,3 | 53,1 |
| - fillets | 92,9 | 79,1 | 85,1 |
| - smoked fish | 18,5 | 17,0 | 91,9 |
| - canned products | 24,6 | 17,2 | 69,9 |
| - marinades | 12,5 | 11,7 | 93,6 |
| - ready-to-serve-dishes | 12,0 | 12,0 | 100,0 |
| - fish meal | 48,5 | 40,5 | 83,5 |
| - other by-products | 21,0 | 11,3 | 53,8 |

Source : Calculations of the Sea Fisheries Institute in Gydnia

# Testing the Consistency of Fish Consumption Data with Neo-Classical Demand Theory

**M. Burton and T. Young**

Department of Agricultural Economics, University of Manchester, Manchester, England. M13 9PL.

ABSTRACT

*In earlier work (Young and Burton, 1988), several different demand systems were applied to quarterly data on fish consumption in the UK. A common feature of this work was the difficulty in obtaining statistically significant results that did not violate the fundamental restrictions suggested by demand theory. In this paper we return to this data set but apply an alternative, non-parametric, technique, that of revealed preference. The advantage of using the theory of revealed preference is that it allows one to test the data for consistency with demand theory, without making any assumption about the underlying functional form (Varian 1982). Tests which rely on a specific demand system are necessarily conditional on the validity of the restrictions imposed by the parametric structure of that system. In addition, the approach offers a convenient means of investigating the appropriate aggregation of fish products (e.g by species or form of presentation).*

## 1. THE THEORY OF REVEALED PREFERENCE

Revealed preference theory dates from the work of Samuelson (1938). It is based solely on observed and measurable phenomena, namely the commodity bundles actually purchased by consumers and prevailing prices and consumer income or total expenditure. Early empirical work on the subject includes that of Koo (1963) and Mossin (1972). Recently, there seems to have been a revival of interest, following significant contributions in the field (regarding the specification of non-parametric tests), from Varian (1982,1985). An empirical analysis, relevant in the present context, was undertaken by Chalfant and Alston (1988), who apply non-parametric methods in their study of meat consumption in the United States and Australia. The work reported here follows similar lines of enquiry.

The theory may be briefly outlined as follows. If the consumer chooses a bundle of goods (**a**) when an alternative bundle of goods (**b**) is obtainable with the same budget outlay, the consumer is revealing a preference of bundle **a** over bundle **b**. In conventional jargon, **a** is "revealed preferred" to **b** (usually denoted **aRb**). The theory of revealed preference requires two consistency conditions on consumer choice.

The **Weak Axiom** states that if **a** is revealed preferred to **b**, then **b** cannot be revealed preferred to **a**. In other words, bundle **b** will only be chosen when it is cheaper than **a** (bundle **a** is not obtainable with the same outlay). Figure 1 illustrates situations in which the axiom is satisfied and in which it is violated. Assuming only two goods, X1 and X2, the line through **a** represents the budget line when the consumer chooses bundle **a**, and the line through **b** is the budget line, for a different set of prices and total expenditure, when bundle **b** is chosen. The weak axiom would be satisfied if commodity bundle **a** is chosen when **b** is available ( **b** is in the budget set bounded by the budget line through **a**), and **b** is chosen when **a** is unattainable with the given budget ( **a** is outside the budget set). On the other hand, the weak axiom would be violated if bundle **a'**, rather than **a**, is chosen when **b** lies within the budget set but **b** is chosen when **a'** is available.

The axiom can be expressed in terms of expenditures. For **a** to be revealed preferred to **b**, then both **a** and **b** must be available for a given outlay :

$$P^a.\mathbf{a} \geq P^a.\mathbf{b}$$

where $P^a$ denotes the set of prices when **a** is chosen. Thus the expenditure on **a** is at least as great as expenditure on **b**. If the weak axiom is satisfied (**a** R **b** and **b** R **a**), then

$$P^a.\mathbf{a} \geq P^a.\mathbf{b} \text{ and } P^b.\mathbf{b} < P^b.\mathbf{a}.$$

In other words, for **b** to be chosen, **a** must involve a greater outlay at the ruling prices.

The second consistency condition, the **Strong Axiom**, concerns transitivity of consumer choices. It states that if **a** is revealed preferred to **b** and **b** is revealed preferred to a third bundle **c**, then bundle **c** cannot be revealed preferred to bundle **a**. This condition can be extended to any number of bundles. The two axioms are related in so far as a violation of the weak axiom implies a violation of the strong axiom, but not vice versa[1]. It is therefore not sufficient to test only for violations of the weak axiom.

If consumer choices satisfy the Strong Axiom, then they are consistent with the hypothesis that the consumer acts "as if" maximising a stable utility function, with conventional, neoclassical properties. Hence, if no violations to this axiom are uncovered in the data, it is possible to find a stable demand system, for which the general restrictions of neo-classical demand theory hold.

## 2. DATA

The data set, supplied by the Sea Fish Industry Authority, comprises quarterly observations on expenditure and prices of various fish products in the U.K. for the period 1980.2 to 1986.2. In Young and Burton (1988a) these data were aggregated by form of presentation into 'wet', 'frozen', 'shell' and 'processed'. As a multi-stage budgeting procedure was assumed (see Annex), the frozen fish data were subsequently sub-divided into 'white', 'fat' and 'other'; wet fish data were apportioned conformably. The analysis reported in Young and Burton (1988b) was conducted on the same data for wet and frozen fish but aggregated by species (cod, haddock, plaice, whiting and 'other'); shellfish and processed fish were excluded.

In this exercise, the non-parametric tests were applied to both forms of data -

a) aggregated by form of presentation, *viz.* :

i) 'wet', 'frozen', 'shell' and 'processed',

ii) wet 'white', 'fat' and 'other',

iii) frozen 'white', 'fat' and 'other',

b) aggregated by species, *viz.* cod, haddock, plaice, whiting and 'other'. In addition, the analysis was conducted using the disaggregated wet and frozen fish data in which 22 categories of fish are identified.

1. When the number of commodity bundles being compared is reduced to two, the strong and weak axioms are equivalent.

## 3. THE NON-PARAMETRIC TESTS

The test of the Weak Axiom proceeds as follows. Firstly, given a data set of n commodities and T time periods (in the present context, n ranges from 3 to 22; T = 25), define the vectors of prices (dimension [1,n]) and quantities (dimension [n,1]) at time t as $P_t$ and $Q_t$. These are then used to construct a matrix M with elements $M[i,j] = Q_i.P_j$. Each element in column j represents the expenditure if the period i quantities were valued at period j prices. The leading diagonal M[i,i] represents the actual expenditure in each period i.

Now, define a matrix Z such that elements $Z[i,j]=M[i,j]/M[j,j]$. If any element $Z[i,j]\leq 1$, then $Q_j$ has been revealed preferred to $Q_i$ (i.e. commodity bundle i was affordable at period j prices, but bundle j was selected). If $Z[i,j]\leq 1$ and $Z[j,i]\leq 1$, then the weak axiom is violated. Hence the elements of matrix Z provides the basis for the test of the Weak Axiom.

The test of the Strong Axiom, an axiom of transitivity, is more complex. Firstly, a matrix X is defined such that $X[i,j]=1$ if $Z[i,j]\leq 1$, otherwise $X[i,j]=0$. Then the algorithm suggested by Varian (1982) can be applied :

For i,j,k =1,..,T : if $X[i,k]=1$ *and* $X[j,k]=1$, then $X[i,j]=1$.

Having manipulated the matrix in this way, its elements are then scanned for violations of the strong axiom[2]. These occur where : $X[i,j] = X[j,i] = 1$. A full explanation is given in Varian (1982).

## 4. RESULTS AND CONCLUDING REMARKS

In each of the three sets of non-parametric tests - on the data aggregated by form of presentation, on the data aggregated by species, and on the disaggregated data - no violations of either of the axioms of revealed preference were found. The data are therefore consistent with the neoclassical theory of consumer behaviour.

This conclusion does, of course, rest on the power of the non-parametric tests. If real expenditure rises over time then the budget lines depicted in Fig. 1 may never cross, thus making it impossible to identify violations of the theory even in those cases where actual purchases are not made in a rational and consistent manner. Some indication of whether meaningful results are obtainable is given by inspection of the elements of the Z matrix. If real expenditure on fish had risen consistently over the sample period, then all the upper triangle elements would have a value less than 1 and all the lower triangle elements would be greater than 1. In this case, no violations of the axioms could be detected. If real expenditure on fish had fallen consistently over the data period, the distribution of elements greater than and less 1 would have been reversed and again the tests would have no power.

For the data set on which this exercise has been based, there are 600 off-diagonal elements in the (25x25) Z matrix. An examination of the disaggregated data set reveals 303 off-diagonal elements greater than 1, with 86 of these (28%) lying above the diagonal. This suggests that there has been some increase in real fish expenditure over the data period but that there is perhaps adequate scope for detecting violations of the axioms. Inspection of the more aggregated data sets yielded similar results.

Since the data appear to be consistent with demand theory, the anomalous results evident in our earlier work could have been eradicated if alternative empirical specifications of the demand system had been employed. However, the approach offers no guidance as to the form of the empirical specification and it could be very highly parameterized.

2. A violation of the Weak Axiom implies a violation of the Strong Axiom, but not *vice versa*.

## REFERENCES

**Bewley R.** (1986). *Allocation Models. Specification, Estimation and Applications*. Ballinger Publishing Company.

**Chalfant J.A. and J.M. Alston** (1988). Accounting for Changes in Tastes. *Journal of Political Economy,* **96** (2), pp 391-410

**Koo A.Y.C.** (1963). An Empirical Test of Revealed Preference Theory. *Econometrica,* **31,** pp 646-664.

**Mossin A.** (1972). A Mean Demand Function and Individual Demand Functions confronted with the Weak and Strong Axioms of Revealed Preference : An Empirical Test. *Econometrica,* **40,** pp 177-192.

**Samuelson P.A.** (1938). A Note on the Pure Theory of Consumer's Behavior. *Economica,* **5,** pp 67-71.

**Varian H.** (1982). The Non-Parametric Approach to Demand Analysis. *Econometrica,* **50 :** (4), pp 945-973.

**Varian H.** (1985). Non-Parametric Analysis of Optimising Behaviour with Measurement Error. *Journal of Econometrics,* **30,** pp 445-458.

**Young T. and M. Burton** (1988a). An Analysis of Market Shares of Fish Products. *SFIA Fisheries Economics Research Unit, Economics Research Paper*, N°. **5**, 37p.

**Young T. and M. Burton** (1988b). Extension and Development of an Analysis of Market Shares of Fish Products. *SFIA Fisheries Economics Research Unit, Economics Research Paper*, No. **6**, 38p.

# ANNEX

In a previous study (Young and Burton,1988a), an attempt was made to determine the major economic factors influencing the composition of the demand for fish products over time. A basic premise of the approach was that consumers adopted a budgeting procedure in making their purchase decisions. With regard to food products, it was posited that the consumer first decided how much of a total food budget should be spent on broadly-defined food products, given their prices : dairy products, meat, fish etc. Having determined the allocation of funds to fish expenditure, a secondary, independent decision was how much to spend on each of four fish categories : processed, frozen, wet and shell. In the third stage of the process, expenditures on wet fish and on frozen fish were further subdivided among 'white', 'fat' and 'other' fish.

The empirical model chosen to satisfy the econometric requirements was the *Generalised Addilog Demand Systems* (GADS). The explanatory variables were the prices of the subset of commodities and the expenditure allocation at each stage. The models of fish demand were estimated over the period 1980-1986 using quarterly data. Although on the whole the analysis established a plausible set of economic relationships determining the composition of the demand for fish, at some levels of the budgeting procedure and for some individual fish products, the restrictions suggested by economic theory were rejected by the data and so in these cases the response of the consumer to economic stimuli appeared to be perverse.

Specifically, in the sub-model in which fish expenditure was allocated to frozen, processed, wet and shell fish, the own substitution effects were found to be positive, but not significantly different from zero. The more disquieting case arose in the sub-model in which wet fish expenditure was allocated amongst 'white', 'fat' and 'other' fish. Here the substitution effect for the 'other' fish was positive, significantly different from zero and the implied own-price elasticity was positive (around 0.02). There could be no reasonable explanation for this perverse response and yet experimentation with alternative specifications failed to alter the result. Given that the chosen methodology was such that a complete, consistent system of demand was being estimated, this anomaly cast some doubt on the validity of the other findings in the study.

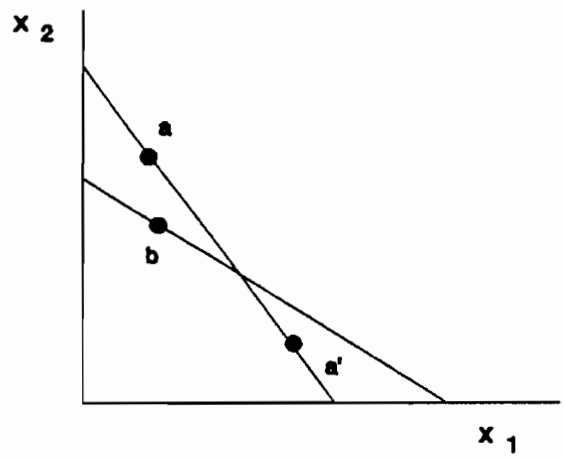
A follow-up study (Young and Burton,1988b) focused on the inadequacies of the chosen empirical model and of data as possible causes of the perverse results noted in the previous study. More specifically two alternative empirical models of demand have been utilised : the *Rotterdam Model*, which was developed in the mid 1960s and the *Almost Ideal Demand System* (AIDS) of much more recent origin.[3] In addition, although the quality of the raw data was taken as given, in some of the analyses these data were grouped in a different manner (by species - cod, plaice etc. - rather than by the form in which fish was presented to the consumer - fresh, frozen etc.) and were handled differently in the investigation of their seasonality.

Of the three models, the Rotterdam approach proved to be the most successful both in meeting the requirements of the theory and in generating a plausible set of consumer responses with respect to price and expenditure changes. The GADS and AIDS failed to produce negative substitution effects for all products at both levels of the budgeting procedure.

Although none of the absurd results encountered in the previous study were replicated by the Rotterdam model applied to the re-classified data and although the model was able to mimic the historical pattern of market shares reasonably well, nonetheless the analysis had a major shortcoming in that few of the price coefficients were statistically significant. In other words, the explanatory power of the system rested with the seasonal dummies and the expenditure variables.

3 Details of the GADS, AIDS and Rotterdam model can be found in Bewley (1986).

**Figure 1 The Weak Axiom**



# The Northeast United States Market for Blue Mussels : Consumer Perceptions of Seafood Safety and the Demand for Mussels

**Priscilla M. Brooks and James L. Anderson ***

Department of Resource Economics, University of Rhode Island Kingston, Rhode Island 02881 USA

ABSTRACT

*A survey of consumers was conducted in the northeastern United States to examine consumer perceptions of seafood safety and the impact of those perceptions and other factors on demand for mussels. This paper analyzes the first stage of the consumer's decision process : the initial choice by the consumer to participate in the market for mussels. Results indicate that consumers perceive some risk in eating mussels and that this perceived risk has a negative and significant impact on the probability that a consumer will participate in the market for mussels.*

## 1. INTRODUCTION

Unlike many European countries where there exists a rich tradition of mussel aquaculture and consumption which spans centuries, the United States has a mussel industry which is relatively young, with significant production occurring only in the last two decades. Despite the recent expansion of the U.S. market, production of mussels fell significantly in 1989 and 1990 and real wholesale and ex-vessel prices have declined steadily since 1987. This decline in the market has occurred despite innovative marketing campaigns by the nation's largest mussel producers. All of this lends doubt to the continued expansion of this relatively underdeveloped U.S. market and the viability of this industry.

* Funding for this research was generously provided by the URI/NOAA Cooperative Marine Education and Research Program. The authors are thankful to Cathy R. Wessells and Joan G. Anderson for their ongoing assistance in this research. The enormous cooperation of Great Eastern Mussels Farms of Maine is gratefully acknowledged.

Continued development of the U.S. market for mussels faces two major obstacles :

i) a lack of market information on consumer preferences for and attitudes towards mussels which limits the effectiveness of marketing efforts; and

ii) a perceived health risk from eating mussels, exacerbated by recent incidents of shellfish poisoning and adverse media publicity about seafood safety.

To address this lack of market information and evaluate the impact of consumer perceptions of seafood safety on demand for mussels, a survey of consumers was conducted in supermarkets in the northeast United States. The focus of this paper will be to analyze the first stage of the consumer decision process: the initial choice by the consumer to participate or not participate in the market for mussels. The key question to be answered is whether consumers perceive some risk in consuming mussels and to what extent these perceptions impact their decision to buy mussels.

The paper is organized as follows. First, trends in world and U.S. production of mussels will be discussed. Current issues regarding seafood safety and inspection in the U.S. will then be outlined. Next the model of consumer choice will be developed followed by a description of the supermarket survey and general results regarding seafood safety perceptions. Finally, the estimated model, results and conclusions will be presented.

## 2. WORLD AND U.S. PRODUCTION OF MUSSELS

World landings of mussels increased about 100 percent during the 1980s, from 620 thousand tonnes in 1980 to 1.24 million tonnes in 1989 (FAO 1991). The world catch of mussels consists of 12 species; blue mussels (*Mytilus edulis*) are the primary species produced with at least 40 percent of the total catch[1], followed by the Mediterranean mussel (*Mytilus galloprovincialis*) with 9.4 percent (FAO). Spain is the largest European producer of mussels with 194 thousand tonnes produced in 1989, followed by the Netherlands with 107 thousand tonnes, Italy with 101 thousand tonnes, Denmark with 76 thousand tonnes and France with 59 thousand tonnes.

The United States also saw tremendous growth in mussel production in the 1980s, although production levels are small compared to that of the major European producers. U.S. landings of mussels increased over 270 percent from about 6.8 thousand tonnes in 1980 to a record 25.4 thousand tonnes in 1988, at a value of U.S. $4.6 million (Alaska Dept. of Fish and Game; Collins; Lukas; U.S. Dept. of Commerce 1991a and 1991b; Washington State Dept. of Fisheries). Since then, production has fallen a total of 14.3 percent to 21.7 thousand tonnes landed in 1990. While U.S. mussel landings have a long history of sporadic increases and decreases in annual production, the past two percentage decreases in annual landings for 1989 and 1990 proceed 14 years of near continuous growth in landings. Although 1991 landings figures are still preliminary, they suggest a continued decline in production.

Accompanying this fall in landings is an equally disturbing fall in the value of landings, and perhaps more importantly, the value per pound landed. In 1988, despite record quantities of mussel landed, total value of landings fell about two percent to US $4.6 million from a record US $4.7 million set in 1987. Total value of landings continued to fall a total of 16.9 percent in 1989 and 1990. Furthermore, the total real value of U.S. mussel landings fell 30.2 percent from 1987 through 1990.

The decline in total value of landings is exacerbated by a concurrent fall in the per pound value of landings. The average nominal value per pound landed was US $0.080 in 1990, a 16.7 percent change from US $0.096 in 1987. However, in real dollars, the average value per pound landed declined 29.4 percent. Furthermore, real wholesale prices for mussels sold at the New York City Fulton Fish Market declined approximately 22.8 percent in the period 1987 to 1990 (Urner Barry Publications, Inc.).

No single factor can explain the fall in landings and value. From conversations with fishery managers and members of the mussel industry, the natural supply of mussels is abundant and hence a decline in stocks is not likely to be a serious

1. The reported percentage of blue mussels in the total world catch is likely to be underestimated, as China, the world's largest producer of mussels, reported production of 490.5 thousand tonnes of unspecified sea mussels in 1989, most of which are known to be blue mussels (De Franssu, 1990).

factor. Some members in the industry claim decreased landings in response to a decline in demand caused by a fear of seafood safety on the part of the consumer and the general economic malaise brought on by the current recession in the U.S. economy.

## 3. ISSUES IN SEAFOOD SAFETY

Despite the rapid growth and development of the U.S. mussel industry, declines in production, landings value and wholesale prices are not indicators of a healthy and thriving industry. Recent incidents of shellfish poisoning and the media focus on seafood safety may be contributing to the weakness in the mussel market and may hamper its continued expansion.

One of the most serious incidents regarding seafood borne illness specifically related to mussels occurred in November of 1987 when 103 people became sick and three died after eating cultivated mussels from Prince Edward Island, Canada (Committee on the Evaluation of Safety of Fishery Products 1991). This outbreak was attributed to an unusually high level of domoic acid, an algal toxin, and resulted in a temporary shutdown of the regional industry and substantial though temporary declines in demand in both Canada and the U.S (Seafood Business). The public was reminded of the Prince Edward Island mussel incident almost three years later when the nationally broadcast television news program "20/20" aired a story in June 1990 about the domoic acid outbreak. Mussel producers also experienced temporary declines in demand due to the much publicized incidents of medical waste washing onto Mid-Atlantic and New England shores in the summer of 1988 (Blue Gold Sea Farms). Currently, the U.S. is experiencing a wave of media publicity sparked by a seafood safety study published nationwide in the magazine *Consumer Reports*. The study claimed that much of its limited sample of seafood was "spoiled" or "contaminated" (Consumer Reports). This study continues to receive widespread media attention.

These consumer reactions result from a perceived risk from eating mussels, influenced by actual incidents of health problems as well as media attention and consumer ignorance. Shellfish, particularly bivalve mollusks such as clams, oysters and mussels, have long been associated with such health problems as paralytic shellfish poisoning caused by red tide and hepatitis due to pollution of shellfish beds. The Centers for Disease Control found shellfish to be the cause of 66 percent of all seafood related illness cases from 1978 to 1987 (Committee on the Evaluation of Safety of Fishery Products 1991). However, during that same period, shellfish and finfish accounted for only about 3.6 percent of all cases of foodborne illness.

Currently there is no mandatory seafood inspection program in the United States similar to that in place for the inspection of red meats and poultry. The lack of mandatory inspection and the media focus on seafood safety has led to increasing public pressure for a mandatory seafood inspection system. The debate on seafood inspection has focused on the need to ensure a safe and wholesome seafood supply and to protect the public health. Another benefit to mandatory seafood inspection, often overlooked by policy makers, is renewed consumer confidence in seafood and a potential increase in the demand for seafood. This lack of confidence in the safety and quality of seafood, particularly shellfish, poses a threat to the seafood industry in terms of reduced or stagnant demand. The seafood industry needs to understand consumer perceptions of seafood safety so that it can educate consumers and help them make more informed purchase decisions.

Incorporation of consumer perceptions in retail demand analysis is rarely found in the fishery economics literature, yet perceptions play a critical role in consumption behavior. Two notable exceptions are studies done by Kinnucan and Venkateswaran, and Lin. It is important to note that an individual's response to external stimuli depends not only on the specific stimuli but also on his or her often unique perceptions of those stimuli (McNeal). It is perceptions that are incorporated into the consumer's purchase decision. In the case of risk perceptions, it is not the objective risk that consumers react to (consumers often lack information on the true risk), rather it is the subjective or perceived risk that is incorporated into the purchase decision. Furthermore, each consumer develops his or her own set of individual perceptions about seafood safety, based on what they know about the objective risk, and many other factors including prior illness with the particular seafood, health status, and the perceived controllability of the seafood-borne illness (Lin).

## 4. THEORETICAL FRAMEWORK

Mussels are a relatively unusual food product in the U.S. Unlike such staples as bread and milk, mussels are not a product which is consumed by virtually every consumer. If mussels are consumed, they are typically consumed infrequently and often not at home. Results from a supermarket survey of consumers in the Northeast indicate that about 74 percent of the sample had consumed mussels before, but only 50 percent of these respondents currently ate mussels at home. Moreover, the majority of at-home mussels consumers ate mussels six or less times per year. Interestingly, it is only in the last decade that mussels have become widely available in supermarkets, due mainly to the recent proliferation of full service wet seafood counters in supermarkets and the marketing efforts of the large mussel companies.

In gauging potential demand for mussels, the first question which must be asked of consumers is not how many pounds of mussels would the consumer buy at a given price, but rather would the consumer ever consider buying mussels at all ? The demonstration program allowed for the unusual opportunity of surveying consumers in a supermarket setting as they were offered free samples of freshly steamed mussels and were faced with a real purchase decision. After being offered a sample of mussels, consumers were asked whether they would buy Great Eastern mussels if they were available in their local supermarket. Both consumers who sampled the mussels and those who did not were interviewed.

There is a wealth of theoretical (Cragg; Amemiya; Blundell and Meghir) and empirical (Haines *et . al.*; Gould) literature which models the food consumption decision as a multi-step process in which consumers first decide whether to participate in the market, and then decide on the frequency or amount of purchase. Most of these models are based on secondary consumption data where the researcher observes (a) whether a purchase was made and (b) how often and how much was purchased over a specified time period.

What the researcher cannot observe in this secondary data, however, is whether the non-buyer of a specific product would ever purchase that product. All the researcher can observe is that the consumer did not purchase the product during a specified time period. Usually the researcher must speculate on the meaning of the zero consumption values. Are these zero observations true corner solutions or are they the result of infrequent purchasing behavior and a short survey period ? Moreover, are the zero values the result of a discrete choice to participate or not participate in the market ?

In the case of mussels, many consumers have made the decision to never buy the product for home consumption, and in the case of some consumers, never at all. The primary data gathered in this supermarket survey allowed the researchers to separate would-be buyers of mussels from non-buyers. It is this initial decision to consider or not consider buying mussels, and the factors affecting this decision, that is the focus of this paper. The general model of consumer choice to buy mussels or not buy mussels is based on the probit model. Following Greene (1990), consider the unobservable variable, $Y_i^*$, as the measure of an individual's buying potential or desire to buy mussels. If an individual's desire to buy mussels is greater than some threshold level, say 0, then the individual will buy mussels. $Y_i^*$ is a linear function of the explanatory variables $X_i$ and the unknown parameter vector $\beta$ and the random error term $e_i$, which is assumed to be independently and normally distributed with mean zero, and variance equal to one :

$$Y_i^* = \beta' X_i + e_i$$

One cannot observe an individual's degree of buying potential, one can only observe, in this case, the consumer's verbal reply to the question, "Would you ever buy these mussels if they were available in your store." The observable binary variable is $Y_i$, equal to 1 if the individual responds that he or she would buy the mussels, and zero if he or she responds negatively. The observable binary variable $Y_i$ is related to the unobservable $Y_i^*$ as follows :

$$Y_i = 1 \text{ if } Y_i^* > 0$$

$$Y_i = 0 \text{ if } Y_i^* \leq 0$$

The probability that an individual responds yes to an interest in purchasing mussels is equal to :

$$\Pr [Y_i = 1] = \Pr [Y_i^* > 0] = \Pr [\beta' X_i + e_i > 0] = \Pr [e_i > -\beta' X_i]$$

If the distribution is symmetric, as is the normal distribution :

$$\Pr [Y_i = 1] = \Pr [\ e_i < \beta' X_i\ ] = \Phi(\beta' X_i)$$

where $\Phi(.)$ is the cumulative distribution function of the standard normal distribution. The joint probability for all individuals or the likelihood function is :

$$L = \Pi_i [\Phi (\beta' X_i)]^{Y_i} [1 - \Phi (\beta' X_i)]^{1 - Y_i}$$

Taking the natural log results in the log-likelihood :

$$ln\ L = \Sigma_i [Y_i\ ln\ \Phi (\beta' X_i) + (1 - Y_i)\ ln\ (1 - \Phi (\beta' X_i))]$$

This model can be estimated with maximum likelihood techniques.

The marginal effects of changes in the explanatory variables on the predicted probability of saying yes are calculated as :

$$\frac{\partial \Phi (\beta' X_i)}{\partial X_i} = \phi (\beta' X_i)\beta$$

where $\phi(.)$ is the standard normal density function..

## 5. DATA COLLECTION : THE SUPERMARKET SURVEY OF CONSUMERS AND CONSUMER PERCEPTIONS OF SEAFOOD SAFETY

In order to investigate consumer attitudes toward and demand for mussels, an extensive in-person survey of 401 consumers was conducted in conjunction with Great Eastern Mussel Farms of Maine who were then engaged in a supermarket demonstration program of their fresh mussels. Great Eastern has long been conducting supermarket demonstrations of their mussels as a way to

(i) educate consumers and retail sellers about the handling and preparation of mussels and

(ii) to stimulate demand.

Surveys were conducted in the fall and winter of 1989 and 1990 during 36 demonstrations in stores associated with five supermarket chains located from a Virginia suburb of Washington D.C. to Maine.

In designing the survey to gather information on mussel demand, individual demand for mussels was hypothesized to be a function of retail price, the retail prices of substitutes, the perceived risk from consuming mussels, prior and current experience with mussels, an individual's overall seafood consumption, and demographic variables. During the survey, consumers were offered an opportunity to sample freshly steamed mussels and were then interviewed whether they sampled the mussels or not.

After being offered a sample of mussels, consumers were asked whether they would buy mussels. Consumers were then interviewed about their attitudes toward and experience with mussels. Of particular interest were consumer perceptions regarding the safety of mussels. In an effort to avoid an emphasis on seafood safety problems in the sensitive setting of a supermarket, questions regarding seafood safety perceptions were limited to gathering information on media exposure to seafood related issues, fears of eating mussels and risk perceptions of eating various foods.

Analysis of the data indicates that consumers perceive some risk from eating mussels and that this risk is significantly higher than the perceived risk from eating some other foods. Furthermore, perceived risk from eating mussels is higher among consumers who have never eaten mussels and consumers who say that they would never buy mussels. (See Brooks (1993) for a more detailed discussion of the findings on consumer perceptions of seafood safety.)

When asked about what they had seen or heard in the media regarding seafood, most responses concerned some negative aspect of seafood. The most prevalent issue was pollution and the contamination of seafood, mentioned by 37.6 percent of the respondents, followed by red tide mentioned by 22.5 percent of respondents. The red tide response is not surprising

in the Northeast where shellfish beds are routinely closed in the summer due to red tide. There was frequent mention of contaminated seafood, particularly shellfish. Only 8.7 percent of the respondents mentioned any positive health aspects of seafood.

When asked why they do not eat mussels or eat them more often, the responses to this open-ended question varied, but 8.6 percent of the respondents claimed that they were afraid to eat mussels. These consumers were then asked what they were afraid of; 31 percent said that they were afraid that the mussels were contaminated by pollution, while another 27.6 percent said that they were afraid of the mussels being tainted with red tide. Fourteen percent of the respondents were wary of where mussels come from, many having seen mussels exposed on the beach at low tide or clinging to docks and pilings. Another 14 percent of the respondents could not pinpoint a specific reason.

Consumers were then asked what they perceived to be their chances of getting sick from eating the following foods: cod, clams, mussels, bluefish, lobster, salmon, chicken and beef. They were asked to rate their chances on a scale of 0 to 100, where 0 was no chance at all and 100 was a certain chance. This question was left purposefully open-ended regarding the definition of "sick" so as to elicit the consumer's overall perceived risk. Note that the relative perceived risk of eating mussels compared to other seafood is the key issue here, rather than the absolute level of risk perception, since the 0 to 100 scale is not appropriate for eliciting realistic risk estimations.

Clams and mussels scored higher risk ratings than the other foods, with average risk ratings of 26.9 and 23.7, respectively. Furthermore, mussels were rated as having a significantly greater health risk (at the 95 percent or better significance level, based on a two-tailed t-test) than all other foods except for clams.

The relatively high risk rating of mussels compared to other foods is made even more clear when one examines the standardized risk rating of mussels, STDMUSS. In order to compensate for the differences in the individual respondent's subjective scale as well as the differences in their subjective origin (zero point), each individual's risk rating of mussels, $RISKMUSS_i$, was standardized over the set of each individual's risk ratings of all foods using the mean ($AVGRISK_i$) and standard deviation ($STDRISK_i$) of the individual's set of risk ratings :

$$STDMUSS_i = \frac{RISKMUSS_i - AVGRISK_i}{STDRISK_i}$$

A standardized risk rating ($STDMUSS_i$) greater than zero indicates that the consumer perceives mussels to have a higher risk of getting sick than all of the rated foods averaged together. The mean standardized risk rating of mussels for the total sample was 0.36, indicating that consumers, on average, perceive mussels to be a relatively risky food.

The sample was then divided between those consumers who said that they would buy mussels (75 percent of the total sample) and those who said that they would never buy mussels (25 percent of the total sample). Not surprisingly, the mean standardized risk rating of 0.57 by non-buyers of mussels is significantly greater (at the 99 percent significance level) than the mean risk rating of 0.30 by buyers of mussels. In addition, the mean standardized risk rating of 0.45 by consumers who had never eaten mussels (26 percent of the sample) was greater than the mean rating of 0.33 by those who had eaten mussels (74 percent of the sample), although this difference was only significant at the 80 percent significance level.

## 6. THE ESTIMATED MODEL AND RESULTS

The consumer decision to consider buying mussels or to not consider buying mussels is modeled as a function of age, education, income, geographic area of residence, number of children in the household, standardized perceived risk rating of mussels, previous mussel consumption experience, overall seafood consumption, exposure to negative media reports concerning the safety of shellfish, whether or not the individual consumes bivalve mollusks, and current home consumption of mussels. The list of explanatory variables and their construction are found in Table 1.

Perceived risk, STDMUSS, is expected to be negative implying that the greater the perceived risk from eating mussels, the less likely one would be to purchase mussels. The same is true of the dummy variable, NEGMEDIA, exposure to negative media reports regarding the safety of shellfish. The dummy variable EATEVER, signifying whether or not an individual has consumed mussels before, is expected to be positive; individuals who have had previous consumption

experience with mussels are expected, on average, to be more likely to buy mussels. Individual overall consumption of seafood, CONSUMHR, is hypothesized to have a positive impact on the probability that an individual will buy mussels; consumers who eat seafood more frequently may be more likely to buy this relatively unusual seafood. At-home mussel consumption, HOMEFREQ, is expected to be positive. There are no *a priori* expectations regarding the significance or sign of the demographic variables on age, education or geographical area. Income is expected to be positive, as one would expect that higher income individuals would be more likely to allocate part of their budget to this unusual and non-essential food. The variable representing the number of children at home, KIDS, is expected to be negative, as many consumers expressed reluctance to buy mussels saying that their children would not eat mussels. An individual's predisposition towards eating bivalves, BIVALVE, is expected to be positive, as one would expect that consumers of bivalves such as oysters and clams, might also consider eating mussels.

Results are presented in Table 2. As expected, perceived risk from eating mussels has a negative and significant influence on the decision to buy mussels. Figure 1, presents the effect of prior mussel consumption experience and perceived risk on the probability that consumers will buy mussels. AGE, EDUC, INCOME, KIDS, CONSUMHR, and HOMEFREQ are held equal to the sample means, while NEGMEDIA, BIVALVE, NYNJ, and WASHDC are held equal to zero. As is illustrated in the figure, perceived risk has a greater impact on those who have never eaten mussels than those who have, all else held equal.

Age was found to have a significant and positive influence on purchase probability, while education, income, geographical area, and number of children did not. EATEVER was positive and very significant, as expected, as was home consumption of mussels, HOMEFREQ. BIVALVE was of the correct sign, but only bordered on significance. NEGMEDIA and CONSUMHR were insignificant.

## 7. CONCLUSIONS

Results from a supermarket survey of consumers in the northeastern U.S. indicate that consumers perceive some risk in consuming mussels and that this risk is greater for mussels than for some other foods. Also, perceived risk from eating mussels has a negative and significant impact on the probability that a consumer will participate in the market for mussels. This impact is accentuated in the case of consumers who have never eaten mussels.

Mandatory seafood inspection could help reduce consumers' perceived risk by instilling confidence in the seafood supply, while consumer education by both government and industry could help eliminate misconceptions about seafood safety. The net result would be more informed purchase decisions, greater benefits to the consumer and increased demand for seafood. The mussel industry can help achieve these results through strict enforcement of rigorous quality and safety standards for their products.

## REFERENCES

**Alaska Department of Fish and Game, Division of Fishery Rehabilitation, Enhancement and Development** (1991-1992). *FRED Annual Report.* Juneau : AK Dept. of Fish and Game, FRED.

**Amemiya T.** (1984). "Tobit Models : A Survey." *Journal of Econometrics,* **24 :** 3-61.

**Blue Gold Sea Farms** (1989). Personal communication.

**Blundell R. and C. Meghir** (1987). "Bivariate Alternatives to the Tobit Model." *Journal of Econometrics*, **34** : 179-200.

**Brooks P.M.** (1993). "The Northeast U.S. Market for Blue Mussels : Consumer Perceptions of Seafood Safety and Implications for Aquaculture." In U. Hatch and H. Kinnucan (Eds.), *Aquaculture : Models and Economics*. Boulder, CO : Westview Press Inc.

**Collins R.** (1991). Personal Communication. Sacramento : California Department of Fish and Game.

**Committee on the Evaluation of the Safety of Fishery Products** (1991). In F.E. Ahmed (Ed.), *Seafood Safety*. Washington, D.C. : Food and Nutrition Board, Institute of Medicine, National Academy of Sciences.

**Consumer Reports** (1992). "Is Our Fish Fit To Eat ?" *Consumer Reports*, **57** (2) : 103-114.

**Cragg J.G.** (1971). "Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods." *Econometrica*, **39** (5) : 829-844.

**De Franssu L.** (1990). *The World Market for Bivalves* . Rome : FAO.

**Food and Agriculture Organization of the United Nations** (1990). *Yearbook of Fishery Statistics*, FAO Fisheries Series No. 36-37, Vol. 68-69. Rome : FAO.

**Gould B.W.** (1992). "At Home Consumption of Cheese : A Purchase Infrequency Model." *American Journal of Agricultural Economics*, **74** (2) : 453-459.

**Greene W.H.** (1990). *Econometric Analysis*. New York : Macmillan Publishing Co.

**Haines P.S., D.K. Guilkey and B.M. Popkin** (1988). "Modeling Food Consumption Decisions as a Two-Step Process." *American Journal of Agricultural Economics*, **70** (3) : 543-552.

**Kinnucan H. and M. Venkateswaran** (1990). "Effects of Generic Advertising on Perceptions and Behavior : The Case of Catfish." *Southern Journal of Agricultural Economics*, **22 :** 137-151.

**Lin C.-T. J.** (1991). *Consumer Shellfish Safety Perceptions and Consumption Behavior*. Unpublished Ph.D. Dissertation, University of Florida.

**Lukas J.** (1991). Personal Communication. Portland : Oregon Department of Fish and Wildlife.

**McNeal J.U.** (1982). *Consumer Behavior : An Integrative Approach.* Boston : Little, Brown and Company.

**Seafood Business** (1988). "Shellfish Scare Hits Atlantic Canada." *Seafood Business*, **7**(1) : 28-31.

**U.S. Department of Commerce, National Marine Fisheries Service, Northeast Fisheries Center** (1991a). Personal Communication. Woods Hole : NMFS.

**U.S.Department of Commerce, National Marine Fisheries Service, Fisheries Statistics Division** (1991b). Personal Communication. Washington, D.C. : NMFS.

**Urner Barry Publications, Inc.** (1984-1990). *Seafood Price-Current.* Toms River, NJ : Urner Barry Publications, Inc.

**Washington State Department of Fisheries** (1992). Personal communication. Seattle : Washington State Department of Fisheries.

TABLE 1
LIST OF VARIABLES INCLUDED IN THE PROBIT MODEL (N=344).

**Table 1: List of Variables Included in the Probit Model (N=344).**

| Variable | | Name | Mean | Std.Dev |
|---|---|---|---|---|
| **BUYEVER** (Dependent Variable)<br>1=would buy mussels<br>0=would not buy mussels | | BUYEVER | 0.76 | |
| **Age**<br>1=Under 25<br>2=25-34<br>3=35-44 | 4=45-54<br>5=55-64<br>6=65 and older | AGE | 3.57 | 1.40 |
| **Education**<br>1=some highschool<br>2=highschool degree<br>3=some college | 4=college degree<br>5=some grad school<br>6=graduate degree | EDUC | 3.48 | 1.36 |
| **Household Income**<br>1=Under $20,000<br>2=$20,000-29,999<br>3=$30,000-$39,999 | 4=$40,000-49,999<br>5=$50,000-75,000<br>6=over $75,000 | INCOME | 3.89 | 1.58 |
| **No. of Children Living at Home** | | KIDS | 0.77 | 0.99 |
| **Perceived Risk Rating of Mussels** | | STDMUSS | 0.37 | 0.76 |
| **Prior Mussel Consumption**<br>1=eaten mussels before<br>0=never eaten mussels | | EATEVER | 0.75 | |
| **Total Weekly Seafood Consumption**<br>Total days/week home or restaurant | | CONSUMHR | 1.92 | 1.34 |
| **Exposure To Negative Media About Shellfish**<br>Mentioned negative report about shellfish (1=yes, 0=no) | | NEGMEDIA | 0.31 | |
| ***Bivalve Shellfish Eater***<br>Listed clams, mussels or oysters as one of three seafoods eaten most often (1=yes, 0=no) | | BIVALVE | 0.58 | |
| **Geographical Area of Residence**<br>New York-New Jersey (1=yes, 0=no)<br>Washington, D.C. (1=yes, 0=no)<br>(New England is the base area) | | NYNJ<br>WASHDC | 0.22<br>0.08 | |
| **Annual Home Consumption of Mussels**<br>Number of occasions per year | | HOMEFREQ | 3.26 | 8.15 |

TABLE 2.
PROBIT MODEL RESULTS.

**Table 2: Probit Model Results**

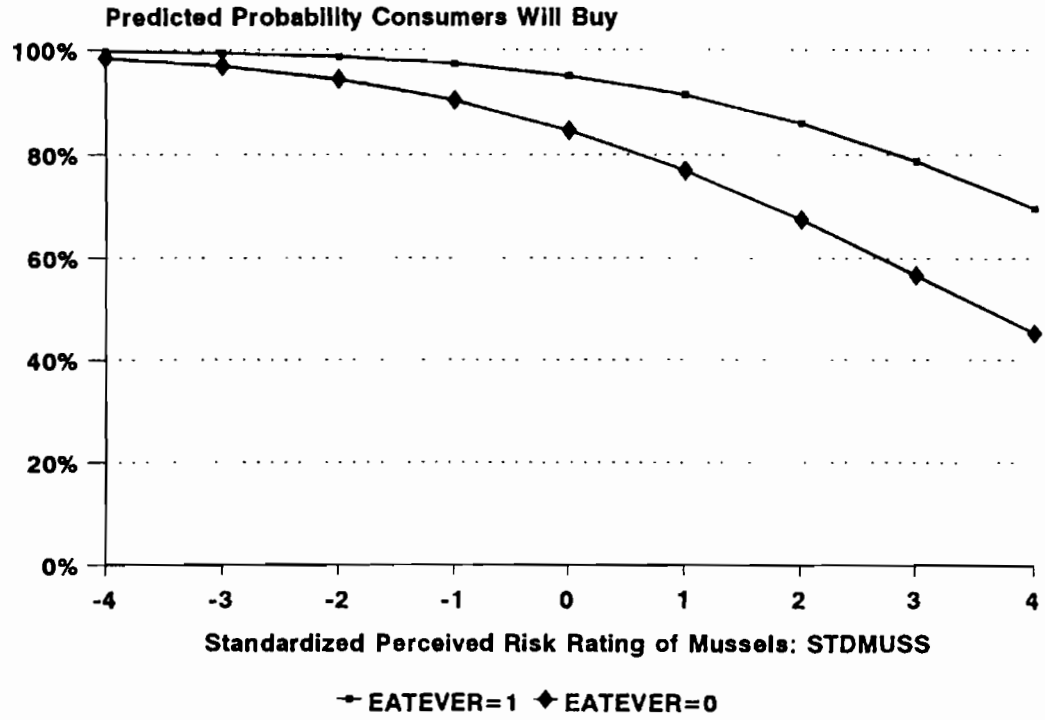
**Binary Dependent Variable: BUYEVER**

| Variable | Estimated Coefficient | T-Statistic |
|---|---|---|
| INTERCEPT | -0.913 | -2.002** |
| AGE | 0.171 | 2.523** |
| EDUC | 0.057 | 0.773 |
| INCOME | -0.006 | -0.093 |
| KIDS | -0.019 | -0.197 |
| STDMUSS | -0.285 | -2.340** |
| EATEVER | 0.631 | 3.323*** |
| CONSUMHR | -0.003 | -0.042 |
| NEGMEDIA | 0.254 | 1.293 |
| BIVALVE | 0.271 | 1.497 |
| NYNJ | 0.111 | 0.446 |
| WASHDC | 0.357 | 1.011 |
| HOMEFREQ | 0.358 | 3.972*** |

N=344
Log-Likelihood = -142.60
Restricted Log-Likelihood (Slopes=0) = -191.21
Likelihood Ratio Test = 97.24*** (Ho: $\beta$=0)
McFadden $R^2$ = 0.25
Proportion of Correct Predictions: 76.7%

** 95 percent significance level
*** 99 percent significance level

FIGURE 1.
EFFECT OF PRIOR CONSUMPTION EXPERIENCE AND PERCEIVED RISK ON THE PREDICTED PROBABILITY THAT CONSUMERS WILL BUY MUSSELS*.




*AGE, EDUC, INCOME, CONSUMHR, HOMEFREQ, and KIDS held equal to the sample means. Dummy variables were held equal to the following: NEGMEDIA=0, BIVALVE=0, NYNJ=0, WASHDC=0.

# Seafood Safety Assurances : Implications for Seafood Marketing and International Trade

**Cathy Roheim Wessells[a] and Joan Gray Anderson[b] ***

[a] Department of Resource Economics, University of Rhode Island, Kingston, RI 02881, USA

[b] Consumer Affairs Program, University of Rhode Island, Kingston, RI 02881, USA

ABSTRACT

*Worldwide, seafood safety has received increased attention. The recent cholera epidemic in South America has generated concerns among exporting and importing countries that unsafe product will slip through the safety net of inspection and regulations. In the U.S., deaths from raw shellfish consumption and negative publicity, such as advertisements displaying fish with hypodermic needles protruding from their bodies, have increased safety concerns. In U.K. supermarkets, farmed salmon with chemical residues above permissible levels were discovered. Each of these incidents has decreased seafood sales. As seafood consumers have been exposed to seafood safety concerns, they have reacted by demanding industry and government protection from unsafe or poor quality seafood, both domestic and imported. This is particularly true in the U.S. where there is no mandatory inspection program for seafood.*

*The objective of this paper is to investigate the factors which influence consumers' preferences for alternative types of safety assurance information and their consequent willingness to pay for that information. Consumer preferences for safety assurance information were revealed using a contingent valuation survey given to U.S. consumers which determined the consumer's willingness to pay for each of ten alternatives. Alternatives included information such as : inspection by a government agency, inspection by the retailer ; or, catch date, catch site, and handling procedures since caught. Consumers were asked to specify the additional amount, over the price of non-labeled seafood, they would be willing to pay per pound for seafood labeled with each of ten alternatives. Results indicated that consumers were willing to pay more for information regarding catch date, site and handling. Willingness to pay for government inspection was lower. Consumers were willing to pay little, if anything, for assurances of safety from retailers/processors/wholesalers. Factors such as seafood consumption patterns and demographic characteristics which influence willingness to pay for one type of information versus another were analyzed using limited dependent variable techniques. These results and their implications for seafood marketing, regulation of quality and safety, and international trade will be delineated.*

* The authors gratefully acknowledge the research assistance of Jeffrey Kline.

## 1. INTRODUCTION

Worldwide, seafood safety has received increased attention. The recent cholera epidemic in South America made some importing nations fearful that contaminated seafood products would slip through the safety net of inspection and regulations. In the United Kingdom, farmed salmon containing chemical residues above permissible levels were pulled off supermarket shelves. These chemicals included antibiotics and a feed additive designed to enhance the flesh pigmentation of the salmon. While the long-run effects of these and other chemicals are still not fully understood by the scientific community, episodes such as those described create concern about seafood safety among consumers. This may negatively affect sales of imported and domestic seafood products.

In the U.S. extensive media publicity focusing on the safety and quality of fish and shellfish have increased safety concerns. In the summer of 1988, as medical waste and pollution were found on Atlantic Coast beaches, numerous stories began to appear in the popular press and on television. Water pollution and its effect on the fish growing in contaminated waters were emphasized. The role of PCB's, heavy metals, and bacterial and viral contamination in the seafood supply were discussed. Such stories, in combination with closed beaches and fishing grounds, caused seafood consumption to drop by about 6 percent on a national per capita basis (Burros, 1988)[1]. In addition to the dangers occurring from polluted waters, articles detailed unclean processing facilities and the near absence of inspections of processing plants. Most recently, media attention has focused on improper handling of seafood at retail outlets throughout the U.S. Reports have concluded that supermarkets, even those believed to be quality seafood vendors, often sell poor quality fish.

Confused and frustrated by what they have seen and read in the media, some consumers have looked to the government to assure them that the seafood they consume is safe. Some states have enacted their own laws. For example, the state of California, in response to worry over the dangers of consuming raw oysters from the Gulf of Mexico, requires that prominent warning signs be placed in restaurants which serve this product. These signs, with bright red backgrounds and bold black writing, warn of the dangers of eating raw oysters from the Gulf of Mexico.

The implementation of a mandatory seafood inspection program at the Federal level might alleviate public fears. Such a program does not currently exist. However, before a program can be instituted, several issues must be resolved. Implementation of a seafood inspection program will not automatically communicate to the consumer that seafood is safe. Both government agencies[2] and the seafood industry must find methods to communicate seafood safety to the consumer. The means of communicating must include signals that the consumer both understands and believes. It may be that consumers require more specific information than simply, for example, a stamp of inspection similar to that found on beef. For example, some consumers might demand information such as catch site and catch date, which the consumers would evaluate as indicators of seafood safety and quality.

The objective of this paper is to investigate the factors which influence consumers' preferences for alternative types of safety assurance information and their willingness to pay for that information. The first section of this paper provides background information on seafood safety issues in the U.S. Next, the survey procedures are discussed, and in the following section, qualitative results are explored. Then, the consumers' willingness to pay for the added information is econometrically analyzed using a limited dependent variable technique with seafood consumption patterns and demographic characteristics of the consumers as explanatory variables. The final section concludes with a discussion of the implications for seafood marketing, regulation of quality and safety, and international trade.

## 2. THE FACTS ABOUT SEAFOOD SAFETY IN THE U.S.

Various agencies of the U.S. government have studied the actual health risks posed by the consumption of fish and shellfish. Reports have been released by the Government Accounting Office (GAO), the Food and Drug Administration (FDA), the Center for Disease Control (CDC), and, most recently, by the National Academy of Sciences (NAS).

1. The 6 percent drop in consumption per capita nationwide understates the drop in some areas of the nation. For example, several merchants on the East Coast claimed sales were off 25 to 50 percent (Burros 1988).
2. Which agency will ultimately be in charge of seafood inspection is a subject of heated debate in Congress and within the industry. The primary seafood inspection vehicle of the past has been the National Marine Fisheries Service of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, which runs a voluntary, fee-based inspection system. Recently, the Food and Drug Administration has teamed up with NMFS to introduce an expanded, voluntary, fee-based seafood inspection program. Several bills have been introduced in Congress (although none have passed to date) proposing mandatory seafood inspection. Some of the bills have advocated the U.S. Department of Agriculture as the lead inspection agency, others advocate either NMFS or the FDA.

The 1988 GAO study concluded, based on data from the CDC and the FDA, that there was no evidence of a widespread problem with the nation's seafood supply. CDC data indicated that seafood accounted for only five percent of all foodborne illness and only five deaths between 1978-84. The majority of problems that did exist were related to three specific cases : raw molluskan shellfish (microbial pathogens), ciguatoxin and scombrotoxin.

The following year, the FDA convened its own Seafood Task Force. This group concurred with the conclusions of the GAO study. Their major conclusions were :

i) Harvesting and production of aquatic species as a source of human food has reached record levels and will continue to increase in the future.

ii) Some microbial contaminants, natural toxins and decomposition products associated with seafood do represent a serious threat to human health. These problems are, however, isolated to identifiable portions of the industry, leaving the majority of seafood to represent no greater hazard than the food supply in general.

iii) Inspection activities could, however, be significantly expanded to provide increased consumer protection for this important commodity.

iv) Aquaculture presents concerns relating to the safe use of feed additives and drugs.

v) Public health problems connected with seafood would not be solved by a federal seafood inspection program similar to USDA's meat and poultry inspection program. (pp. iv-v).

Like its predecessors, the report on seafood safety compiled by the National Academy of Sciences (NAS, 1991) concluded that, overall, the U.S. seafood supply is safe, however, there are some risks involved in seafood consumption. In addition to risks mentioned in previous studies, "some risks, in particular those associated with environmental contamination, may be increasing" (p. 3). Environmental contamination is a problem in both commercially and recreationally caught fish. Therefore, the report emphasized the need for a comprehensive monitoring system of the water supply.

## 3. METHODOLOGY

The focus of this paper is a subset of a larger on-going study at the University of Rhode Island. The larger study was partitioned into two phases. In Phase I, data was collected from randomly sampled Rhode Island consumers using a telephone survey. The telephone survey of 256 Rhode Island consumers contained detailed questions pertaining to :

i) seafood consumption;

ii) factors which might increase or decrease consumption;

iii) attitudes regarding seafood safety; and,

iv) demographic characteristics.

Phase II brought a sample of 55 consumers to a survey site at the University of Rhode Island Food Science laboratory. The purpose was to present respondents with an experimental market-like setting in which they could view actual pieces of seafood in a manner similar to what they face when making selection and purchasing decisions at the store. Five experiments were conducted.

One component of the experimental section focused on respondents' willingness-to-pay for alternative pieces of consumer information, including mandatory inspection and labeling information. The following questions were asked :

i) what specific information will most assure consumers that seafood poses little health risk; and,

ii) how much are consumers willing to pay for this information? Data gathered from a random telephone survey of Rhode Island residents was used to determine specific information alternatives which would communicate seafood safety. These alternatives included information stating that seafood had been inspected (with a choice of five different inspection entities), information regarding catch date, site and handling, and money-back guarantees. The actual task for respondents in the experimental, market survey was to evaluate the alternatives.

The technique used to elicit the information regarding willingness-to-pay (WTP) was based on contingent valuation techniques. Contingent valuation (CV) methods use surveys rather than market data to determine willingness-to-pay for a composite good. It is often used to analyze non-market goods or goods which are not currently on the market, for example, in environmental economics to value the potential benefits from a particular change of policy. Contingent valuation is based on the assumption that "individual responses to hypothetical markets are comparable to actual markets" (Mitchell and Carson 1989). Contingent valuation is often used to value non-market goods, such as air quality, but has also been used to establish values from reducing health risk (Tolley and Babcock 1986) and for estimating consumer's willingness-to-pay for reductions in foodborne risk (Hammitt 1986). Other studies of seafood consumption using survey data have also followed these techniques (Lin 1991).

Within the contingent valuation framework, the respondent is given a detailed description of the good being evaluated and the hypothetical circumstances under which it is made available. Questions are asked to elicit the respondent's WTP for specific well-defined changes. A "valuation" function can be estimated where valuation characteristics and certain other preference and use characteristics are the independent variables.

To implement this CV experiment, the respondent was asked to consider a pound of flounder selling at the current market price ($4.50)[3]. Respondents were told the flounder fillet carried with it no consumer information other than price, and the store clerk would not be able to provide any additional information. However, they could purchase an additional piece of information regarding the quality of the seafood from a list of 10 possibilities (listed in Table 1) [4].To do this, they were asked first to rank the ten pieces of information from most to least desired. Having all ten pieces of information in order, respondents were then asked how much, if anything, they were willing to pay per pound above $4.50 for their most desired piece of information. Next, they were asked what, if anything, they would pay for their least desired piece of information. They were then asked to assign a WTP value to each of the remaining pieces of information. Respondents were told that they could use the same amount, including zero, as often as they wished. The only restriction was that the magnitude of the values must decrease with the rank of the information. They were free to re-arrange their initial ranking until they were satisfied that the rankings and WTP values were representative of their preferences.

## 4. QUALITATIVE RESULTS

Results from the respondent ranking of the alternatives are displayed in Table 1. Forty percent of the sample ranked catch data as the most important information. Information that the flounder had been inspected by the National Marine Fisheries Service (NMFS) was ranked first by 12.7 percent of the sample. Eleven percent of the sample ranked information regarding where the flounder was caught as most important. Inspection by the U.S. Department of Agriculture (USDA), FDA and a money-back guarantee of quality were each ranked first by 9.1 percent of the sample. Storage temperature was ranked first by 5.5 percent. Only one respondent ranked inspection by retailer and processor as their first choice. None of the respondents ranked money back guarantee of safety first.

Table 1 also lists the average additional amount respondents were willing to pay per pound for the various information alternatives with a reference point of flounder selling at $4.50 per pound. The most highly valued piece of information was when the fish was caught. Consumers would be willing to pay an average of 47 cents above $4.50 for this indicator of quality/safety. The next highest valued pieces of information were the temperature at which it had been stored and where it had been caught. Both of these pieces of information reflect quality as well as safety factors. The sample was willing to pay an average of 34 cents additional for each of these. The next three ranked pieces of information were related to inspection.

Respondents indicated a willingness to pay an additional 31 cents per pound if the product were inspected by NMFS, 23 cents per pound if it were inspected by the FDA and 22 cents per pound for inspection by the USDA. The next highest

3. Flounder was chosen because virtually 100% of the sample eat flounder either at restaurants or at home, thus consumers are familiar with the item. It was felt that it is important to provide the respondent with a product they are familiar with in order to derive a reasonably accurate measure of their willingness to pay for the information. It is possible that the results would be different if an alternative species had been chosen, for example, shellfish.

4. Only one piece of information was allowed to keep the experiment simple, however, it is likely that consumers would have liked some combination of the choices. This is being incorporated into the next endeavor.

valued piece of information were money-back guarantees. Apparently, the respondents did not place much value in the seller's ability to inspect his own product. It is interesting to note that consumers appear to put far more credence in the government's inspection process than in the industry's.

## 5. REGRESSION RESULTS

To evaluate the factors which affect respondents' willingness to pay for the individual pieces of information, a limited dependent variable technique was used. Since the values for the survey respondents' willingness to pay is either zero, or some value greater than zero, a limited dependent variable technique is the most appropriate for statistical analysis of the data. In particular, the Tobit, or censored, regression model is required. For a censored sample such as this, suppose $y_i$ has a normal distribution, with mean $\mu$ and variance $\sigma^2$. We consider a sample of size N, and record only those values of $y_i$ greater than a constant 0, otherwise record the value 0. The Tobit model then is specified as :

$$\begin{aligned} y_i &= x_i\beta + \epsilon_i \quad \text{if} \quad x_i\beta + \epsilon_i > 0 \\ &= 0 \qquad\qquad\quad \text{otherwise} \end{aligned}$$

where $\beta$ is a K x 1 vector of unknown parameters, $x_i$ is a K x 1 vector of known constants and $\epsilon_i$ are residuals that are independently and normally distributed with mean zero and common variance $\sigma^2$. An important characteristic of this model is that we actually know the values of the explanatory variables, $x_i$, for the individuals who are not willing to pay for a particular piece of information. The Tobit models are solved in a maximum likelihood framework, and the software package SHAZAM was used[5].

Due to the small sample size, the results should not be generalized beyond the sample of Rhode Island residents. There are two primary reasons for the small sample size. First, this survey was done in an experimental setting which attempted to simulate a true market setting. Since this was the first time an experiment of this type had been attempted by the project researchers, the study itself was viewed as experimental, to serve as a trial for future work. Second, it was extremely difficult to convince consumers to travel to the URI Food Science laboratory to spend two hours on a Saturday afternoon being surveyed about seafood. This was a major commitment on the part of the participants. To somewhat offset their personal costs, each respondent was given a $10 gift certificate from a local seafood retail outlet.

The demographic makeup of the sample was compared to the demographic profile of the population of Rhode Island, and the sample was found to be quite representative. The largest differences were that the sample was more educated than the average Rhode Islander, and tended to reside in the southern portion of the state, whereas most of Rhode Island's population resides in the northern portion of the state.

Therefore, while the results should be interpreted with caution, they provide an indication of the expected success of a larger scale experiment of the sort undertaken here. In addition, the results present an indication of which factors (explanatory variables) most strongly affect Rhode Island consumers' willingness to pay for seafood quality information. These factors may or may not be the same for other U.S. consumers.

Models of willingness to pay were run for five of the ten pieces of information individually. In addition, willingness to pay information was grouped into average willingness to pay for private information, which contained catch site, catch date, and temperature held since caught, and for government inspection, including NMFS, FDA and USDA. The written survey from Phase I of the project was also given to each respondent. This provided data on the explanatory variables for the respondents' willingness to pay.

Five models were run to estimate respondents' willingness to pay. These models represent those pieces of information respondents chose as the most important, based on their average willingness to pay presented in Table 1. These include models for catch date (DATE) and catch site (SITE) where the average WTP was $.47 and $.34, respectively. A model for temperature held information was not run because, while this information is interesting, it is not currently feasible

5. It can be argued that, due to the conditional nature of the willingness to pay data (i.e. the willingness to pay for the second ranked choice is dependent on the willingness to pay for the first ranked choice), a system of regressions should be estimated simultaneously. While this is true, with the limited sample, it is doubtful that much efficiency would be gained.

to provide it to the consumer. The length of time which it takes for a fish to reach a consumer from the time it was caught, together with the processing it may go through, makes it difficult to document the temperature levels. However, a model for all private information (PRINFO) which includes average willingness to pay for information on catch date, catch site and temperature was run. In addition, since it seems likely that government inspection will be mandatory, a model was run for average willingness to pay for government inspection by the three agencies (GOVINSP). Of those agencies, the willingness to pay for inspection was highest for fish inspected by NMFS, so a model was included for this information as well. The results of these models are presented in Table 2.

The independent variables used in the analysis include : MANDINSP = 1 if consumers responded that their seafood consumption would increase given a mandatory inspection program, 0 if consumption would not increase; FREQSHELL = number of times per month the consumer's household consumed shellfish; FREQFIN = number of times per month the consumer's household consumed finfish; KNOW = the respondent's relative knowledge of seafood, 5 if extremely knowledgeable, 0 if know nothing (each respondent subjectively answered this question); HOME = 1 if consumers eat flounder at home, 0 otherwise; SAFE = 1 if consumers answered they thought seafood was very safe, 0 if they felt it was somewhat unsafe or unsafe; INC = income level of the respondent's household; PERINSP = percent of seafood supply respondent believes is inspected. There are many other possible explanatory variables which could be used from the written survey, however, the variables listed above were believed to be the most important.

Across the board, the consumer's rating of their seafood knowledge had a negative effect on their willingness to pay extra for information beyond that which they can see or smell when looking at the fillet. In other words, the more knowledgeable they felt they were about seafood, the less they were willing to pay for additional information. The magnitude if the coefficients are relatively large, and with the exception of the GOVINSP equation, were marginally significant. Conversely, if the respondent indicated that they eat flounder at home (i.e. prepare it within the home), the effect on willingness to pay is positive, but only significant in the SITE equation. In addition, if the respondent felt seafood is safe, there is a negative effect on WTP for information on catch site or date. If the respondent indicated he/she would increase consumption with the implementation of a mandatory seafood inspection program, this would translate into a higher willingness to pay for information that inspection by a government agency had indeed occurred, as indicated by the positive coefficient on MANDINSP. Finally, the percent of seafood respondents believe is inspected is positively related to their WTP and generally significant. This seems somewhat counterintuitive. However, it is possible that, if the respondents believe a large percentage of the seafood supply is inspected, yet they are continually hit by negative reports on seafood safety, then they may be willing to pay for information that they can use to personally evaluate the safety of the seafood they are purchasing.

Note that the willingness to pay for government inspection in general is not significant, however, willingness to pay for information that NMFS was the inspection agency is significant. There was little correlation between the demographic characteristics and seafood consumption habits of the respondents and their willingness to pay for information that either the USDA or FDA had inspected the fish. For this particular sample of individuals, that should be of interest to those who are debating the appropriate agency to head a mandatory inspection system.

## 6. CONCLUSION AND IMPLICATIONS

The United States does not currently have a mandatory seafood inspection program in place. However, it seems inevitable that one will be in place within the near future. In fact, the "Consumer Seafood Safety Act of 1992" bill is now before the Senate. This legislation calls for the administration of a national seafood safety program which will set tolerances for contaminants in seafood, monitor growing areas and fishing grounds for water pollution, and devise processing and handling requirements and an inspection system. The safety program would be a cooperative effort between NMFS, the FDA and to a lesser extent, USDA, at the national level, and the states. Imported seafood will be required to meet the same specifications as domestic products[6] and seafood importers must register with the U.S. government. The FDA will

6. Currently, domestic standards differ from those of other nations, in particular, Canada. The free trade agreement between the U.S. and Canada, which became effective in 1989, requires that the two nations adopt the same product quality guidelines. To date, no agreement on product standards has been reached. Similarly, product standards differ substantially between the U.S. and Europe. Differences such as these often lead to disputes since product standard differences are sometimes interpreted as non-tariff trade barriers.

evaluate foreign seafood inspection programs, and develop inspection agreements with other nations. The Food Safety and Inspection Service, a branch of the Department of Agriculture, will conduct inspections overseas and at the port of entry. The product will be required to be labeled with the country of origin.

While policy makers have justifiably been concerned with public health as the primary issue, and have reacted by proposing bills of the sort discussed above, in doing so, they have given less attention to the area of consumer perceptions of seafood quality. It is interesting to note that nowhere in the bill is there any reference to the communication of the safety of the product to the consumer. While the government may not be cognizant of the importance of consumer perceptions of seafood quality and safety, the seafood industry has recently come to understand that safety perceptions may be as important, if not more important, than the actual hazards arising from unsafe seafood. Even when a mandated seafood inspection system is in place, unless it is designed based on research regarding consumer information needs, it may not be sufficient to change negative perceptions, increase seafood demand or increase profits.

Therefore, the results of this trial study provide some important initial insights to both domestic producers and those who export to the U.S. in terms of marketing strategies. The industry must alleviate consumer perceptions of the health risks from consuming seafood. To do so, they must provide information to the consumer in which the consumer will place some credence, such as the purity of the waters from which the fish or shellfish was harvested, or the rigorousness of the inspection system. Some marketing campaigns have been successful with these strategies. For example, Norwegian salmon is perceived to have high product standards and product quality which emphasizes clean Arctic waters in its marketing campaigns. However, much of this information generally only goes to the wholesalers or restauranteurs, and does not reach the average consumer. Educating the consumer through package presentation and through advertisements may be a smart marketing strategy.

## REFERENCES

**Burros M.** (1987). Reports of Parasites Rekindle a Debate about Raw Fish. *The New York Times*. October 14 :C1.

**Hammitt, J.K.** (1986). Estimating Consumer Willingness to Pay to Reduce Food-Borne Risks. Report to the U.S. Environmental Protection Agency (R-3447-EPA), Santa Monica, CA : Rand Corporation.

**Lin C.-T.J.** (1991). Consumer Shellfish Safety Perceptions and Consumption Behavior. Unpublished Ph.D. dissertation, University of Florida, Gainesville, Florida.

**Mitchell R.D. and R.T. Carson** (1989). *Using Surveys to Value Public Foods : The Contingent Valuation Method.* Washington, D.C. : Resources for the Future.

**National Academy of Sciences, Committee on Evaluation of the Safety of Fishery Products, Food and Nutrition Board, Institute of Medicine** (1991). *Seafood Safety.* Farid E. Ahmed, editor Washington, D.C.

**National Oceanic and Atmospheric Administration** (1988). Analysis of Consumer Attitudes toward Fish and Seafood. Report for the National Fish and Seafood Promotional Council, Washington, D.C.

**Tolley G.S. and L. Babcock** (1986). Valuation of Reductions in Human Health Symptoms and Risks. University of Chicago. Final Report to the Office of Policy Analysis, U.S. Environmental Protection Agency.

**U.S. General Accounting Office** (1988). Seafood Safety : Seriousness of Problems and Efforts to Protect Consumers. Report to the Chairman, Subcommittee on Commerce, Consumer and Monetary Affairs, Committee on Government Operations, House of Representatives. (RCED-88-135).

TABLE 1.
RANK AND WILLINGNESS TO PAY FOR SELECTED PIECES OF INFORMATION FOR FLOUNDER SELLING AT $4.50 PER POUND.

| Information | Frequency as #1 Choice | Percent of Sample Choosing Item #1 | Average WTP/lb. | Minimum WTP/ lb | Maximum WTP/ lb |
|---|---|---|---|---|---|
| Catch date of fish | 22 | 40.0 | $0.47 | $0.00 | $2.00 |
| Inspected by NMFS | 7 | 12.7 | $0.31 | $0.00 | $1.75 |
| Catch site of fish | 6 | 10.9 | $0.34 | $0.00 | $2.50 |
| Inspected by USDA | 5 | 9.1 | $0.22 | $0.00 | $1.75 |
| Inspected by FDA | 5 | 9.1 | $0.23 | $0.00 | $1.50 |
| Money-back guarantee of top quality | 5 | 9.1 | $0.19 | $0.00 | $1.75 |
| Storage temperature since caught | 3 | 5.5 | $0.34 | $0.00 | $2.00 |
| Inspected by retailer | 1 | 1.8 | $0.14 | $0.00 | $1.25 |
| Inspected by processor | 1 | 1.8 | $0.15 | $0.00 | $1.25 |
| Money-back guarantee of safety | 0 | 0.0 | $0.18 | $0.00 | $1.00 |

TABLE 2.
TOBIT REGRESSION RESULTS FOR WILLINGNESS TO PAY FOR INFORMATION.

| Variable | Equation PRINFO | SITE | DATE | GOVINSP | NMFS |
|---|---|---|---|---|---|
| INTERCEPT | 2.45** | 1.97** | 2.52** | -0.38 | -1.01 |
| | (2.73) | (2.17) | (2.79) | (0.29) | (0.73) |
| MANDINSP | | | | 0.15 | 0.38 |
| | | | | (0.57) | (1.30) |
| FREQSHELL | 0.15** | 0.12** | 0.14** | -0.10 | -0.16 |
| | (2.30) | (1.72) | (2.19) | (1.03) | (1.58) |
| FREQFIN | -0.12 | -0.10 | -0.13 | 0.04 | 0.10 |
| | (1.40) | (1.17) | (1.59) | (0.55) | (1.45) |
| KNOW | -0.41* | -0.33 | -0.39 | -0.05 | -0.38 |
| | (1.71) | (1.46) | (1.65) | (0.21) | (1.54) |
| HOME | 0.61 | 0.83* | 0.36 | 0.46 | 0.49 |
| | (1.42) | (1.89) | (0.85) | (1.06) | (1.09) |
| SAFE | -0.61 | -0.94* | -0.54 | | |
| | (1.38) | (1.92) | (1.22) | | |
| INC | -0.42* | -0.34 | -0.38* | 0.2 | 0.33 |
| | (1.99) | (1.61) | (1.81) | (0.94) | (1.44) |
| PERINSP | 0.01* | | 0.01* | 0.01 | 0.01** |
| | (1.74) | | (1.72) | (1.38) | (2.07) |
| Log-Likelihood Function | -213.78 | -182.68 | -210.19 | -185.88 | -158.04 |
| Proportion non-zero obs. | 0.98 | 0.77 | 0.93 | 0.84 | 0.65 |

Asymptotic t-ratios in parentheses

** indicates significant at the 5% level

* indicates significant at the 10% level

# Development of the International Trade in Seafood Products in the Context of European Economic Integration

**Jean Pierre Boude and Patrice Guillotreau**

ENSAR, environmental and natural resources Dept, 65 rue de S[t] Brieuc, Rennes, France

ABSTRACT

*Theoretically, spatial integration of economic activity has a twofold effect : re-allocation of productive resources due to the free movement of goods, and factors and potential linked to the economies of scale inherent in the extension of the market and strengthening of international competition.*

*When applied to the seafood processing industries, the combination of these effects should lead to changing specialization within Europe and an acceleration of intra-European trade.*

*Observation of the structural development of international trade in several production sectors (fresh, chilled and frozen products ; dried, salted and smoked fish ; prepared and tinned products etc.) validates or undermines certain theoretical suggestions and allows some explanation of the framework of international trade flows.*

## 1. INTRODUCTION

According to the FAO, the proportion of seafood products traded throughout the world represents about 30 % of nominal global catches. In Europe, this share has been increasing for slightly more than a decade : from 35.8 % in 1976, the share of exports by volume reached 41.6 % of Community production in 1990, in spite of a stable situation concerning territorial stocks of primary resources.

The purpose of this paper is to interpret the development of international seafood product trade, in order to highlight the factors determining international mobility of goods.

The scope of the study is the EEC countries from 1976-1990. During this period, institutional factors, such as the creation of Exclusive Economic Zones (EEZ), European economic integration and the assertion of the Common Fishing Policy (CFP) were combined with the specific features of the goods traded in an explanation of trade (derivatives of a renewable natural resource, which must satisfy high internal demand with sustained growth etc.)

However, in this paper, specialization is aproached in a simplified manner, since only the commercial aspect of internationalization is considered. As revealed by international trade flows, specialization is above all the result of the internationalized action of companies and notably movements of capital and technology [1].

Part One therefore suggests an economic interpretation of the dynamics of seafood product trade, complemented in Part Two by a discussion of the impact of institutional decisions on the observed development.

## 2. ECONOMIC INTERPRETATION OF THE DYNAMICS OF SEAFOOD PRODUCT TRADE IN THE EEC

The empirical data concerning international trade in seafood products was processed using factor analysis methods. It is therefore important to present the principles of these methods in order to assess their scope and limits (2.1). The results are then presented for all EEC countries, followed by the disparities observed between different countries (2.2).

### *2.1 Method*

The choice of method, which partly depends on the type of data used, is discussed in terms of the scope and limits of factor analysis.

#### 2.1.1 Type of data

The data available for the whole period (1976-1990) have two sources : the FAO and EUROSTAT. The data from the first source concerns the territorial stock of seafood products represented by quantities landed (DOTA), the level of domestic production (PROD), as well as apparent consumption of countries expressed as the sum of non-exported domestic production and imports (CAPA) [2]. The second source provides all overall and broken-down data for the main international trade product categories [3].The variables obtained are :

Exports (X) and Imports (M)
X and M301 : Fresh, chilled, frozen fish
X and M302 : Dried, salted, smoked fish
X and M303 : Fresh, chilled, frozen crustaceans and molluscs
X and M604 : Prepared and preserved fish
X and M605 : Prepared and preserved crustaceans and molluscs

It should be noted that the aggregated FAO data (production and apparent consumption) includes, in addition to these product categories, oils and meals from aquatic animals. This difference represents another possiblity for analysis if the importance of these products in Denmark, for example, is considered.

The EUROSTAT aggregrated trade data was used to derive several other variables such as :

- average import price (PIMP)
- average export price (PEXP)
- intra-EEC share of imports (PICI)
- intra-EEC share of exports (PIEX)
- the proportion of intermediate goods imported (PABI) ; this calculation assumes that this proportion applies to categories 0301 and 0303.

1. Concerning international investment flows, P. Guillotreau "A Meso-Systemic Analysis of the International Specialization Process Applied to the EC Seafood Processing Industry", paper for the 4th EAFE conference, Salerno, Italy, 22nd-24th April 1992.
2. FAO statistical directories 1976-1990.
3. Due to a change in the European seafood products schedule in 1987 (division of certain categories), the series were reformed in 1998.

- external balance X-M (SOLD).

Except for average trade prices expressed in ECU per kg, all values and percentages are based on quantities of thousands of tonnes, in order to minimize any price effect.

The individual elements in the data table are countries and years identified by three characters [4]

### 2.1.2 Choice of analysis tool

Due to the configuration of the data table (individual elements in rows and continuous variables in columns), the *Principle Component Analysis* (PCA) was the *ad hoc* tool for factor analysis.

• Presentation and scope of PCA in the study

Factor analysis is a data analysis method. Its main advantage is a *multi-dimensional* approach to a phenomenon and geometrical representations which can easily be interpreted.

Among the numerous factor analysis tools, Principle Component Analysis allows assessment of the similarities between individual elements and assessment of the links between variables. These assessments can also lead to typologies base on multiple criteria. These typologies contribute to an interpretation of a complex reality so as to distinguish strategies or economic policies according to the type of the groups of elements thus defined[5].

Put simply, the PCA uses a matrix calculation to project the elements (variables and individual elements) of an n-dimensional space onto a two-dimensional factor plane. Therefore, each axis of the factor plane represents a factor which synthesizes in a more or less pronounced manner a set of variables.

In an PCA, the variable coordinates on the axes represent the correlation of these variables with the factor considered and therefore express the explanatory power of the variable relative to the weight of the factor itself in the overall explanation of the phenomenon. The weight of the factor is linked to its *inertia* observed by the relative size of calculated *eigenvalues*.

The analysis uses 32 describable values as follows : 10 product trade active variables (two types of flow - import and export - and five product categories) and 22 illustrative variables. Only the active variables are used to construct factors, whereas the illustrative variables are projected onto the factor plan thus defined. The latter variables therefore appear as explanatory variables and the former as explained variables.

The illustrative variables concern total trade flows (XVOL and MVOL), primary resource stocks (DOTA), the internal market (CAPA), the variables described above (PIMP, PEXP, PICI, PIEX, PABI, SOLD) as well as some basic ratios concerning International Economics (coverage ratio by product category (TC0i), export effort ratio (TEFF), import penetration ratio (TPEN) and ratio of domestic needs coverage by national production (TPNA). Two qualitative variables (PAYS and ANNEE) have also been integrated into the analysis in order to highlight two important effects : the marked territorial disparities and the dynamic prospects for trade growth.

The questions approached are part of the issue set forth in the introduction : what are the dynamics of Community seafood product trade and what are its determining factors ? It is linked more to the territorial resources available or to the size of the internal market ? What is the direction of trade flows and how does it develop ?

• Limits of analysis

The major limit of the data analysis, apart from the statistical reliability of the figures themselves, certainly stems from the arbitrary choice of variables. This choice is not neutral with respect to the answers to the previous questions.

The results must therefore be referred to the territorial industrial structures and markets considered, because trade is only the tangible manifestation of these.

4. Examples : F76 (France 1976), D85 (Denmark 1985). The initials of the countries are as follows : France (F), Belgium/Luxembourg (B), Netherlands (N), Germany (A), Italy (I), United Kingdom (U), Ireland (R), Denmark (D), Greece (G), Portugal (P) and Spain (S).
5. B. ESCOFIER, J. PAGES 1990 "Analyses factorielles simples et multiples" Dunod Paris, 2nd ed.

In addition, the analysis shows very large differences in national situations, and each country, by its size and its involvement in exploitation of seafood resources, represents a particular case. A more detailed analysis should therefore be carried out by considering specific products.

Finally, an approach based on clear division of Europe into nations for all product categories is a little simplistic to the extent that production activity is highly regionalized within countries and is transnational for many companies which trade. Certain flows registered in imports or exports therefore occur within a single company.

### *2.2 Results of factor analysis*

The interpretation of factors initially reveals the variables which determine trade dynamics and the nature of the different apparent specializations, before providing the elements required for country typology.

#### 2.2.1 Decisive factors for all countries

Firstly, the eignenvalues indicate that the first three factors contain 81 % of total inertia, *i.e* . 4/5 of the explanatory power of the analysis. This inertia is made up of : 41 % for the first factor, 25 % for the second, and 15 % for the third ; the weight of the fourth factor is not negligible (9 %). In other words, strong correlation between the variables and the first factor will have a great significance for revelation of key variables.

Put simply, the first factor corresponds to exports, while the second refers to imports of all products[6].

The strongest correlations concerning the first axis of the factor plane (figure 1) correspond to fresh, chilled and frozen products, both fish and crustaceans/molluscs.

The important intra-industry trade (crossed flow of similar products), represented by this axis, is significant. By pivoting the axis to the left by a few degrees, the projection of variable coordinates onto the new axis obtained (F1) accentuates the contribution of imports to the first factor, in particular for fresh, chilled and frozen fish, and tinned crustaceans/molluscs.

In other words, *countries with high exports also have high goods imports*, notably of intermediate goods. These countries import to supply an extensive internal market (judging by the proximity of M301 and CAPA) but also to produce and re-export (positions of PROD and XVOL).

Nearly all the trade aggregates are positioned on the same side of the axis, which represents the size effect on the analysis (disparities between "large" producing countries, such as Denmark, Spain, the Netherlands, France etc. and the "small" countries like Belgium, Greece, Portugal and Ireland). In this respect, it is observed that the small countries favour trade with their European partners over trade with the other countries, especially for imports (contrast on axis of DOTA, PROD and PICI, PIEX variables). Their trade therefore appears "tied" to their close neighbours (Portugal and Spain, Ireland and the United Kingdom, Belgium and the Netherlands).

Concerning the second axis, dominated by imports, it is also possible to interpret the position of the variables more precisely, by interpreting F2 perpendicular to F1. For this factor, variable X302 appears to be an exception, like M301 for the first factor.

This particularity in fact expresses the regional character of the production and consumption of dried, salted and smoked products. The phenomenon thus reflects the historical nature of specialization in these products in the Northern European countries (fishing and processing of herring in the North Sea) and in Portugal (dried cod). A similar, but less pronounced, situation is observed for preserved products in the Iberian Peninsula and Italy. The apparent specialization in these countries is therefore linked to the traditions of production and consumption.

On the other hand, for fresh, chilled and frozen fish, *the trade flows which result in specialization are more determined by the process of internationalization*, itself driven by generalized use of refrigeration techniques.

6. See the variable coordinates on axes 1 to 5, in the appendix.

Concerning the illustrative variables which are strongly correlated to the second factor, the marked contrast between the external balance (SOLD) and the average import price (PIMP) is significant. It reflects the link between the size of the deficit expressed in physical quantities and the price of imported products. In fact, an increase in the value of the deficit is caused both by an increased volume of seafod product imports and by higher import prices. This result must be qualified, since the data table considers series of current average prices.

Finally, the fourth factor is also notable for the product categories which are contrasted (imports and exports being correlated in the same direction) - fresh, chilled and frozen crustaceans and molluscs, and tinned fish - but especially for the test values of the PAYS variables (see table in appendix). The test values measure the distance between the individual elements-countries and centre of gravity of the individual element cloud. Two national situations are contrasted in this fourth factor : those of Spain and Germany. This contrast is explained by the fact that these two countries have record deficits in each category (respectively crustaceans/molluscs and tinned fish), but which are nevertheless compensated for by a high level of exports.

### 2.2.2 Type of specializations apparent in different countries : a typology test

Based on the first two factors (representing 2/3 of total inertia by themselves), an initial typology of individual element (figure 2), largely determined by a size effect, can be built up.

| COUNTRY | SIMILARITY CRITERIA |
|---|---|
| 1) Netherlands, Denmark | Characterized respectively by export dynamism and high stocks. |
| 2) Spain, United Kingdom | Strong intra-industry trade at a high level of exchange, high stocks and extensive internal market. |
| 3) France, Germany, Italy | Very high deficit, average stocks but different characteristics*. |
| 4) Ireland, Greece, Portugal, Belgium | Small countries with low stocks. Low exports, except for Ireland. |

* France : higher primary resource stocks and apparent consumption than the other two countries.Germany : low stocks balanced by a high level of production and trade.

Italy : very low exports.

Italy is not positioned lower on the second axis because a large part of its deficit is due to imports of dried, salted and smoked fish, a variable which is weakly correlated with factor 2. On the other hand, on axis 3 where this correlation is -0.90, the test value for Italy is very high, like Portugal (imported dried cod) and unlike the United Kingdom. However, in this latter traditional exporting country, the trade balance in dried, salted and smoked fish is tending to settle at a very low level (the surplus fell from 22000 t in 1976 to 3000 t in 1990.)

To summarize, these countries all have very specific features. It would be interesting to develop the analysis by creating data indices to highlight the characteristics of "small" countries which are masked by the size effect.

### Intermediate conclusion

Although the "country effect" appears more important than the "year effect", representing relative structural stability with time, diagram 3 describes a marked development during the period.

This trend is clearly situated in the south-west quadrant of the chart. It indicates both a growth in the volume of imports and exports, but also a more sustained growth in imports, since the balance has deteriorated. Likewise, the development of the external EEC trade in seafood products appears to be more due to apparent consumption growth than to that of production or the level of quantities landed, notably since the entry of Spain in the Community.

It should also be noted that the apparent specialization of countries in fresh, chilled and frozen products is increasingly produced by the process of internationalization and the level of domestic demand (which contributes to the marginalization of traditional goods production in Europe) and less by stocks of primary resources.

However, relatively clear changes of rate are observed on the factor plane. After a period of relative trade stability up until 1984, their growth increased, both for imports and exports.

Institutional aspects may be advanced to explain this.

## 3. DEVELOPMENT OF EUROPEAN SEAFOOD PRODUCT TRADE IN THE CONTEXT OF SOME INSTITUTIONAL EVENTS

Certain institutional events explain the development of European seafood trade (3.1) and the development of apparent territorial specializations (3.2).

### *3.1 Development shaped by three major events*

The analysis clearly reveals that the development of international seafood trade has been shaped by three major events : creation of the Exclusive Economic Zones (EEZ) on 1st January 1977 (agreements in the Hague in 1976), agreement of 25th January 1983 which created, after years of adjustment, Blue Europe, the extension of the EEC to include Spain and Portugal on 1st January 1986.

Figure 3 illustrates the impact of these events during the period. In this respect, the most spectacular changes concern the creation of the EEZ (1977) and the entry of Spain and Portugal into the common market. The development of international seafood products trade increasingly depended on the growth of internal markets such as those of the countries in categories 2 and 3 of the above typology.

For all EEC countries, demand for seafood products increased thoroughout the period. Trade deregulation since the end of the 1960s has favoured the rise of international trade despite the fact that world supply has grown less quickly over the last decade. This growth has generated large price increases and increasingly frequent product substitutions, including food products other than seafood.

#### 3.1.1 Creation of the EEZ in 1977

The almost general introduction of EEZ in 1976 and 1977 resulted in important structral changes in primary product supply. Concerning catches within the European EEZ, certain fleets, and in particular those of the Eastern European countries, were quickly withdrawn. These Eastern European fleets concentrated their efforts mainly on well identified stocks to allow large catches by volume at low cost. This withdrawal produced a reallocation of catches which benefitted member countries, but this reallocation concerned stocks which were often fully exploited, and even over-exploited, and the effects for the whole Community were quickly stabilized. ICES data indicates these developments well. At the same time, access to distant fishing areas outside European seas and in the EEZ of third party countries, was heavily restricted.

European countries with fleets traditionally devoted to this type of fishing experienced a very rapid falling off of quantities landed from distant areas. The countries most concerned were France, the United Kingdom, West Germany and Italy. Although trends vary significantly according to species, the creation of the EEZs resulted overall in a sharp reduction in EEC supply, compared to the previuos decade.

It is difficult to distinguish the supply structure changes due to the EEZ from those due to continuous deterioration of certain stocks. However, the 1977 situation represented a clear break compared to 1976, and the relative stabilization of positions seems to favour the EEZ effect as an explanatory factor. Increased imports, where possible, were therefore a solution to the problem of reduced supply. This solution still, however, depended on both available world supply and the evolution of international prices. When substitution by imported products was not possible, the consequences for national markets were marked : price rises, changes of consumption habits from fresh products to processed products, market division etc. The development of the national markets in mackerel, sardines and herring is very representative.

### 3.1.2 Implementation of the Common Fisheries Policy in 1983

The break in 1983 was less clear, but was sufficently significant to be taken into consideration. It corresponded to the creation of Blue Europe, which covered both aspects of resource control and the assertion of a joint organization of markets and producers. 1983 represents more the creation of Blue Europe as an administrative reality than as a profound change in practices, since the agreements implemented on 1st January were the result of twelve years of negotiations and gradual adjustments.

For everything concerning external resources, the European entity replaced the member states. Therefore, negotiating power was strengthened and improved access to distant resources in certain cases. In particular, the adoption of common rules for market organization seems decisive. They had two objectives : to stabilize the markets by guaranteeing supplies and a fair standard of living for the fishermen ; and secondly to ensure reasonable consumption prices, whilst increasing sector productivity. These two objectives could therefore sometimes produce a conflict of interest between European producers and consumers.

The system created - Community price scheme and marketing standards - no doubt allowed markets to be extended and a certain number of products to be standardized. But numerous regulations dated from before 1983, in particular concerning the price scheme. In addition, each country could use health and hygiene requirements to erect non-tariff barriers, often very effectively. The United Kingdom thus prohibited import of salmonids and fresh molluscs (diseases of fish acts (1937) and sea fisheries shellfish acts (1983)), Germany introduced specific rules on the use of additives and their labelling (December 1991), and the Netherlands introduced regulations concerning fish (visbesheit) which were relatively vague on the specification of harmful substances and colourings etc. Concerning marketing, Community directives were not systematically applied. For example, in Germany, the production and import of seafood products are subject to special packing and labelling conditions.

The system of subsidies was intended to adjust and reorganize fishing activities by fleet restructuring. Subsidies allowed : temporary or permanent stoppage of ship activity, construction of new ships, creation of companies in conjunction with third party countries, financing of experimental fishing seasons etc. In a situation where catches were stabilizing, they also improved the financial results of fishing companies more than creating non-tariff barriers to the development of international trade.

### 3.1.3 Extension of the EEC in 1986

The break in 1986, linked to the entry of Spain and Portugal into the common market, is far more significant. By themselves, these two countries had a fishing fleet of 875 000 gross tons at this time, equivalent to that of the ten other countries combined. The situation was similar concerning engine power, the number of sailors (140 000 men) and catches. In 1986, the Spanish and Portuguese markets represented 30 % of the total EEC market expressed in tonnes. Between 1961 and 1989, their markets grew by +60 %, while the overall European markets only grew by +47 %.

The inclusion of Spain and Portugal in the EEC, combined with the growth in their internal demand, favoured the development of both intra and extra-European imports. In 1986, Spain had a external trade coverage ratio of 55 % for an import value of 720 million dollars and Portugal a 57 % coverage ratio for an import value 260 million dollars. This ratio has consistently worsened since and the total imports of Spain and Portugal represented in 1990 20 % of total EEC imports by value compared to only 13 % in 1985 (source : EUROSTAT).

## *3.2 Effects on development of territorial apparent specializations*

Examination of the apparent specializations of different countries reveals four groups of countries (see part I). Based on a detailed analysis of these groups, national "routes" were mapped out which trace the development of behaviour according to the variables in the analysis.

### 3.2.1 Netherlands, Denmark group

The first group concerns the Netherlands and Denmark. Their route shows a strong contribution to axis 2 (imports) at the start of the period, moving towards a strong contribution to axis 1 (exports) at the end of the period. In both cases, but more clearly for Denmark, the change occurred in 1982 and 1983.

This development towards the edge of the north-west quadrant of the factor plane is more significant for Denmark, whose position with respect to axis 2 changes from 1.32 to 2.31, while the Netherlands fluctuate between 2.19 and 2.11. On the other hand, on axis 1 the respective figures are 0.08 to -5.04 and -0.82 to -5.16. The route of these countries - with high primary resource stocks - towards high levels of exports between 1976 and 1990 is very clear. The Danish situation is due to its meal production and exports.

In both these cases, the export effort ratio is notable, as well as the ratio of domestic needs coverage by national production. Relative specialization towards export of salted, dried and smoked fish and crsutaceans/molluscs seems to be increasing.

### 3.2.2 Italy, France, Germany group

The second group of countries is Italy, France and Germany. Their routes represent an increasing contribution to axis 2 for France, Italy and Germany. For the latter two countries, axis 4 (crustacean/mollusc and tinned fish trade) increasingly affects the explanation from 1984. The period 1980-84 was a time of relative stability of observed developments.

The change of direction from the centre-east to the south-west quadrant of the factor plan is especially significant for France. The other two countries experience more of a descent down axis 2, reflecting the stronger correlation with this factor (increasing imports).

The route of these countries with average stocks, or with Mediterranean or extra-EEC fishing areas (Italy) towards an increasingly high external trade deficit by value is explained by the characteristics of their internal markets with high purchasing power (France, Germany and Northern Italy). Developments were accentuated after 1984, although they occurred at different rates. In France, for example, limited resources and increased requirements for products with high import value, as well as the supply of intermediate goods for its processing industry, were the main factors explaining this trend.

### 3.2.3 Spain, United Kingdom group

The third group is Spain and the United Kingdom. The contribution to axis 2 is decisive here and there is no break in the trend as previously. This indicates that penentration of their respective markets was continuous over the period studied[7].

The gradual opening of Community waters to Spain from 1986 did not satisfy this country's internal market. On the contrary, the integration of Spain into the European Community appears to have helped increase penetration of this market by goods from other partner countries. For the United Kingdom, the level of intra-industry trade increased during the period, driven by a larger volume of imports[8]. In both cases, the internal market remained very extensive.

### 3.2.4 Portugal, Ireland, Greece, Belgium group

The fourth group is a set of "small" countries : Portugal, Ireland, Greece and Belgium. Their contributions to the axes vary very little. It will simply be noted that axis 3 is important for Portugal (imports of salted, dried and smoked fish), but that its contribution fell between 1984 and 1989 (7.10 to 8.50) ; the importance of axis 1 for Greece which fluctuated between 1.30 and 1.10 ; that of axis 5 for Belgium which increased from 1.00 to 1.80 (exports of crustaceans and molluscs) as well as that of export axis 1, which changed from 1.10 to 0.50.

Ireland nevertheless stands out from these countries with an increase in the quantities landed and with its remarkable export dynamism, mainly to EEC partners (in 1989, France, the United Kingdom, Germany and Spain absorbed nearly 2/3 of Irish exports by value[9]).This observation tends to undermine the theory that an extensive domestic market affects export performance.

7. Only after 1984 for Spain.
8. The Grubel-Lloyd index (1 - IX - MI/(X+M)) measuring the intensity of two-ways trade in similar products, calculated for the United Kingdom from FAO external trade data, nearly doubled from 1970 to 1988 (0.32 ot 0.62).
9. Source : Bord Iascaigh Mhara 1990 "Irish Fish Exports/Imports in 1989 and Previous Years".

The position of Greece hardly changed during the period considered. That of the three other countries moved to the west with a slight growth in exports. Only Portugal shifted south-west.

**Intermediate conclusion**

The study of each individual country reveals three types of route :

(i) A trend towards an increasingly large external deficit, both by volume and by value (see the level of average import price on axis 2 for these countries) : France, Italy, Germany, United Kingdom and Portugal ("march" to the south-west).

(ii) A trend towards increased export effort : Denmark, Netherlands and Ireland ("march" to the north-west).

(iii) Maintenance of positions, mainly due to a size effect : Belgium and Greece.

## 4. MAIN CONCLUSION

The analysis of the international EEC seafood product trade highlights the very different situations in member countries. Although a typology could be described according to the type of external balance, primary resource stocks or the size of the domestic market, each country has it own structural characteristics and a certain type of trade dynamics. This great disparity makes implementation of Community fishing and seafood product processing policy more difficult.

It appears that the apparent specialization of member countries can no longer be interpreted only according to territorial seafood stocks.

Firstly, its interpretation requires other types of economic factors. Therefore, it is the multi-dimensional internationalization process itself (flow of goods, capital and technology etc.) which seems to condition the development of trade. This is because countries import to produce and then re-export ; processing companies are not longer satisified by resources which are landed locally. The generalized application of refrigeration techniques has made a large contribution to the division of the production process of seafood goods, and to the modification of European food behaviour. The increase in production and consumption of chilled and frozen products tends to marginalize traditional production (such as tins and herring curing) which face strong competition from new producing countries. These phenomena are relatively clearly reflected in the type of goods traded. Concerning these traditional products, the regional aspect of specialization is very marked (dried-salted fish in Portugal, smoked fish in Northern Europe) and the goods are distinguished from each other (according to species and processing mode).

Secondly, institutional factors seem to have significantly influenced the direction, structure and intensity of seafood product trade flows. These elements can be referred to three key dates which mark changes in the internationalization trend : creation of the EEZ in 1977, extension of the EEC to include Spain and Portugal in 1986, and to a lesser extent, the implementation of the common Fisheries Policy in 1983.

The deregulation of the seafood product trade and its rapid increase in volume, in particular that of the extra-Community share of the goods flow, shows that Community regulations alone cannot regulate the markets (notably concerning the sales policy applied to these products) and modify the trend towards internationalization of activity.

However, such an analysis, based on the commercial aspect of internationalization, still deserves to be complemented with a study into the production/marketing structures existing in the different countries and a study into transnational capital flows.

## REFERENCES

**Bord Iascaigh Mhara** (1990). *Irish Fish Exports/Imports in 1989 and Previous Years*, Market Research Series, Dublin, Ireland, 32 p.

**Escofier B. and J. Pages** (1990). *Analyses factorielles simples et multiples*, Dunod Paris, 2nd Edition, 267 p.

**EUROSTAT** (1992). *Statistiques du commerce international.*

**FAO** *Statistical Yearbooks*, Produits de la pêche et de l'aquaculture.

**Grubel H.G. and P.J. Lloyd** (1975). *Intra-Industry Trade*, Mac Millan London, 150 p.

**Guillotreau P.** (1992). *A Meso-Systemic Analysis of the International Specialization Process Applied to the EC Seafood Processing Industry*, Paper for the 4th EAFE Conference, Salerno, Italy, 22-24 April, 12 p.

**OECD** (1982). *Echanges internationaux des produits de la pêche : conséquences des zones des 200 milles*, Paris, 208 p.

**OECD** (1985). *Problèmes des échanges de produits de la pêche*, Paris, 432 p.

**OECD** (1989). *Questions liées aux pêcheries* , Paris, 338 p.

**TABLE 1**

COORDINATES OF VARIABLES ON AXES 1-5

| VARIABLES | COORDINATES | | | | | VARIABLE FACTOR CORRELATION | | | | | OLD UNITARY AXES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IDEN , SHORT DESC. | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| ACTIVE VARIABLES | | | | | | | | | | | | | | | |
| X301 Export FCF (Fresh Chilled and Frozen fish) | -.83 | .28 | .26 | .09 | -.25 | -.83 | .28 | .26 | .09 | -.25 | -.41 | .18 | .21 | .09 | -.38 |
| M301 Import FCF (Fresh,Chilled and Frozen fish) | -.69 | -.62 | -.17 | .17 | .06 | -.69 | -.62 | -.17 | .17 | .06 | -.34 | -.40 | -.14 | .18 | .09 |
| X302 Export DSS (Dried,Salted and Smoked fish) | -.70 | .61 | .09 | -.10 | -.05 | -.70 | .61 | .09 | -.10 | -.05 | -.35 | .39 | .07 | -.10 | -.07 |
| M302 Import DSS (Dried Salted and Smoked fish) | .07 | -.27 | -.90 | .05 | -.29 | .07 | -.27 | -.90 | .05 | -.29 | .03 | -.17 | -.72 | .05 | -.44 |
| X303 Export CM (Crustaceans and Molluscs) | -.85 | .22 | -.04 | -.29 | -.30 | -.85 | .22 | -.04 | -.29 | -.30 | -.42 | .14 | -.03 | -.30 | -.46 |
| M303 Import CM (Crustaceans and Molluscs) | -.32 | -.57 | -.28 | -.68 | .12 | -.32 | -.57 | -.28 | -.68 | .12 | -.16 | -.36 | -.22 | -.72 | .19 |
| X604 Export TF (Prepared and Preserved fish) | -.64 | .11 | -.52 | .49 | .18 | -.64 | .11 | -.52 | .49 | .18 | -.32 | .07 | -.42 | .52 | .27 |
| M604 Import TF (Prepared and Preserved fish) | -.34 | -.77 | .42 | .25 | -.17 | -.34 | -.77 | .42 | .25 | -.17 | -.17 | -.49 | .34 | .26 | -.27 |
| X605 Export TCM (Prepared and Preserved Crustaceans and Molluscs) | -.80 | .43 | -.12 | -.09 | .30 | -.80 | .43 | -.12 | -.09 | .30 | -.40 | .28 | -.10 | -.09 | .46 |
| M605 Import TCM (Prepared and Preserved fish Crustaceans and Molluscs) | -.65 | -.63 | .30 | .00 | .15 | -.65 | -.63 | .30 | .00 | .15 | -.32 | -.40 | .24 | .00 | .22 |
| ILLUSTRATIVE VARIABLES | | | | | | | | | | | | | | | |
| DOTA - Landings | -.68 | .06 | -.14 | -.06 | .13 | -.68 | .06 | -.14 | -.06 | .13 | | | | | |
| CAPA - Apparent consumption | -.74 | -.42 | -.11 | .28 | .03 | -.74 | -.42 | -.11 | .28 | .03 | | | | | |
| PROD - Quantities produced | -.75 | .03 | -.21 | .14 | .20 | -.75 | .03 | -.21 | .14 | .20 | | | | | |
| PIMP - Import price | .02 | -.60 | .07 | -.27 | .16 | .02 | -.60 | .07 | -.27 | .16 | | | | | |
| PEXP - Export price | .02 | -.13 | -.12 | -.02 | .63 | .02 | -.13 | -.12 | -.02 | .63 | | | | | |
| PICI - Intra-EC import | .24 | .23 | -.38 | -.10 | -.05 | .24 | .23 | .38 | -.10 | -.05 | | | | | |
| PIEX - Intra-EC export | .25 | .08 | -.09 | -.07 | .69 | .25 | .08 | -.09 | -.07 | .69 | | | | | |
| SOLD - Balance of trade | -.13 | .91 | .27 | .09 | -.17 | -.13 | .91 | .27 | .09 | -.17 | | | | | |
| PABI - Imports of interermediate goods | -.56 | -.05 | -.10 | -.20 | .21 | -.56 | -.05 | -.10 | -.20 | .21 | | | | | |
| XVOL - Quantities exported | -.89 | .31 | .13 | .07 | -.20 | -.89 | .31 | .13 | .07 | -.20 | | | | | |
| MVOL - Quantities imported | -.61 | -.75 | -.19 | -.04 | .02 | -.61 | -.75 | -.19 | -.04 | .02 | | | | | |
| TPNA - Coverage rate by National Production | -.21 | .51 | -.10 | .03 | .01 | -.21 | .51 | -.10 | .03 | .01 | | | | | |
| TEFF - Effort ratio | -.08 | .61 | .27 | -.07 | -.30 | -.08 | .61 | .27 | -.07 | -.30 | | | | | |
| TPEN - Penetration ratio | .26 | -.53 | -.26 | -.31 | .10 | .26 | -.53 | -.26 | -.31 | .10 | | | | | |
| TCOU - Coverage ratio | .08 | .55 | .29 | -.03 | -.20 | .08 | .55 | .29 | -.03 | -.20 | | | | | |
| TC01 - Coverage ratio 301 | .18 | .41 | .27 | -.04 | -.12 | .18 | .41 | .27 | -.04 | -.12 | | | | | |
| TC02 - Coverage ratio 302 | .06 | .43 | .46 | .05 | -.22 | .06 | .43 | .46 | .05 | -.22 | | | | | |
| TC03 - Coverage ratio 303 | .25 | .39 | .28 | .00 | -.15 | .25 | .39 | .28 | .00 | -.15 | | | | | |
| TC04 - Coverage ratio 604 | .14 | .05 | -.43 | .18 | -.18 | .14 | .05 | -.43 | .18 | -.18 | | | | | |
| TC05 - Coverage ratio 605 | -.04 | .64 | .02 | -.07 | .04 | -.04 | .64 | .02 | -.07 | .04 | | | | | |

**TABLE 2.**

COORDINATES AND TEST VALUES FOR MODALITIES ON AXES 1-5

| MODALITIES | | | | COORDINATES | | | | | TEST VALUES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IDEN., DESCRIPTION | EFF. | ABS. W. | DISTO | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 22 . Country | | | | | | | | | | | | | |
| PAY1 - France | 15 | 15.00 | 7.66 | -.81 | -2.45 | .71 | -.62 | .09 | -1.6 | -6.3 | 2.3 | -2.6 | .5 |
| PAY2 - Belgium/Luxembourg | 15 | 15.00 | 5.47 | 1.99 | -.04 | .79 | -.23 | .83 | 4.0 | -.1 | 2.6 | -1.0 | 5.1 |
| PAY3 - Netherlands | 15 | 15.00 | 10.30 | -2.21 | 2.14 | .27 | -.53 | -.63 | -4.5 | 5.5 | .9 | -2.3 | -3.9 |
| PAY4 - Germany | 15 | 15.00 | 5.56 | -.08 | -1.35 | -.69 | 1.71 | .31 | -.2 | -3.5 | -2.3 | 7.3 | 1.9 |
| PAY5 - Italy | 15 | 15.00 | 5.28 | 1.00 | -1.09 | -1.29 | -.90 | -.54 | 2.0 | -2.8 | -4.2 | -3.9 | -3.4 |
| PAY6 - United Kingdom | 15 | 15.00 | 6.69 | -1.24 | -.88 | 1.81 | .74 | -.73 | -2.5 | -2.3 | 5.9 | 3.2 | -4.5 |
| PAY7 - Ireland | 15 | 15.00 | 7.54 | 2.06 | 1.50 | .94 | -.09 | -.17 | 4.2 | 3.9 | 3.1 | -.4 | -1.1 |
| PAY8 - Denmark | 15 | 15.00 | 11.29 | -2.59 | 1.81 | -.61 | .60 | .70 | -5.2 | 4.7 | -2.0 | 2.5 | 4.4 |
| PAY9 - Greece | 10 | 10.00 | 7.69 | 2.53 | .84 | .40 | -.22 | .52 | 4.1 | 1.7 | 1.1 | -.8 | 2.6 |
| PA10 - Portugal | 7 | 7.00 | 18.02 | 2.08 | .18 | -3.28 | 1.05 | -.89 | 2.8 | .3 | -7.1 | 3.0 | -3.7 |
| PA11 - Spain | 7 | 7.00 | 10.38 | -1.68 | -.60 | -1.44 | -2.19 | .44 | -2.3 | -1.0 | -3.1 | -6.2 | 1.8 |
| 23 Year | | | | | | | | | | | | | |
| AN76 - 1976 | 8 | 8.00 | 1.42 | .92 | .48 | .29 | .11 | -.08 | 1.3 | .9 | .7 | .3 | -.4 |
| AN77 - 1977 | 8 | 8.00 | 1.13 | .91 | .30 | .31 | .17 | .03 | 1.3 | .6 | .7 | .5 | .1 |
| AN78 - 1978 | 8 | 8.00 | .71 | .71 | .27 | .27 | .12 | -.09 | 1.0 | .5 | .6 | .4 | -.4 |
| AN79 - 1979 | 8 | 8.00 | .45 | .46 | .19 | .29 | .17 | -.18 | .7 | .4 | .7 | .5 | -.8 |
| AN80 - 1980 | 8 | 8.00 | .26 | .28 | .10 | .29 | .10 | -.17 | .4 | .2 | .7 | .3 | -.7 |
| AN81 - 1981 | 9 | 9.00 | .47 | .49 | .21 | .37 | .10 | -.12 | .8 | .4 | .9 | .3 | -.5 |
| AN82 - 1982 | 9 | 9.00 | .32 | .37 | .21 | .29 | .07 | -.04 | .6 | .4 | .7 | .2 | -.2 |
| AN83 - 1983 | 9 | 9.00 | .17 | .18 | .19 | .29 | .02 | -.05 | .3 | .4 | .7 | .1 | -.2 |
| AN84 - 1984 | 11 | 11.00 | .21 | .28 | .15 | -.12 | -.22 | -.04 | .5 | .3 | -.3 | -.8 | -.2 |
| AN85 - 1985 | 11 | 11.00 | .13 | -.03 | .12 | -.30 | -.06 | -.06 | -.1 | .3 | -.8 | -.2 | -.3 |
| AN86 - 1986 | 11 | 11.00 | .17 | -.27 | .01 | -.21 | -.09 | .02 | -.5 | .0 | -.6 | -.3 | .1 |
| AN87 - 1987 | 11 | 11.00 | .31 | -.41 | -.16 | -.25 | -.11 | .10 | -.7 | -.4 | -.7 | -.4 | .5 |
| AN88 - 1988 | 11 | 11.00 | .61 | -.56 | -.41 | -.28 | -.12 | .15 | -1.0 | -.9 | -.8 | -.4 | .8 |
| AN89 - 1989 | 11 | 11.00 | 1.33 | -.95 | -.51 | -.30 | -.07 | .17 | -1.6 | -1.1 | -.8 | -.3 | .9 |
| AN90 - 1990 | 11 | 11.00 | 2.38 | -1.31 | -.68 | -.36 | .04 | .19 | -2.2 | -1.5 | -1.0 | .1 | 1.0 |

**FIGURE 1.**
**ACTIVE/ILLUSTRATIVE VARIABLES.**

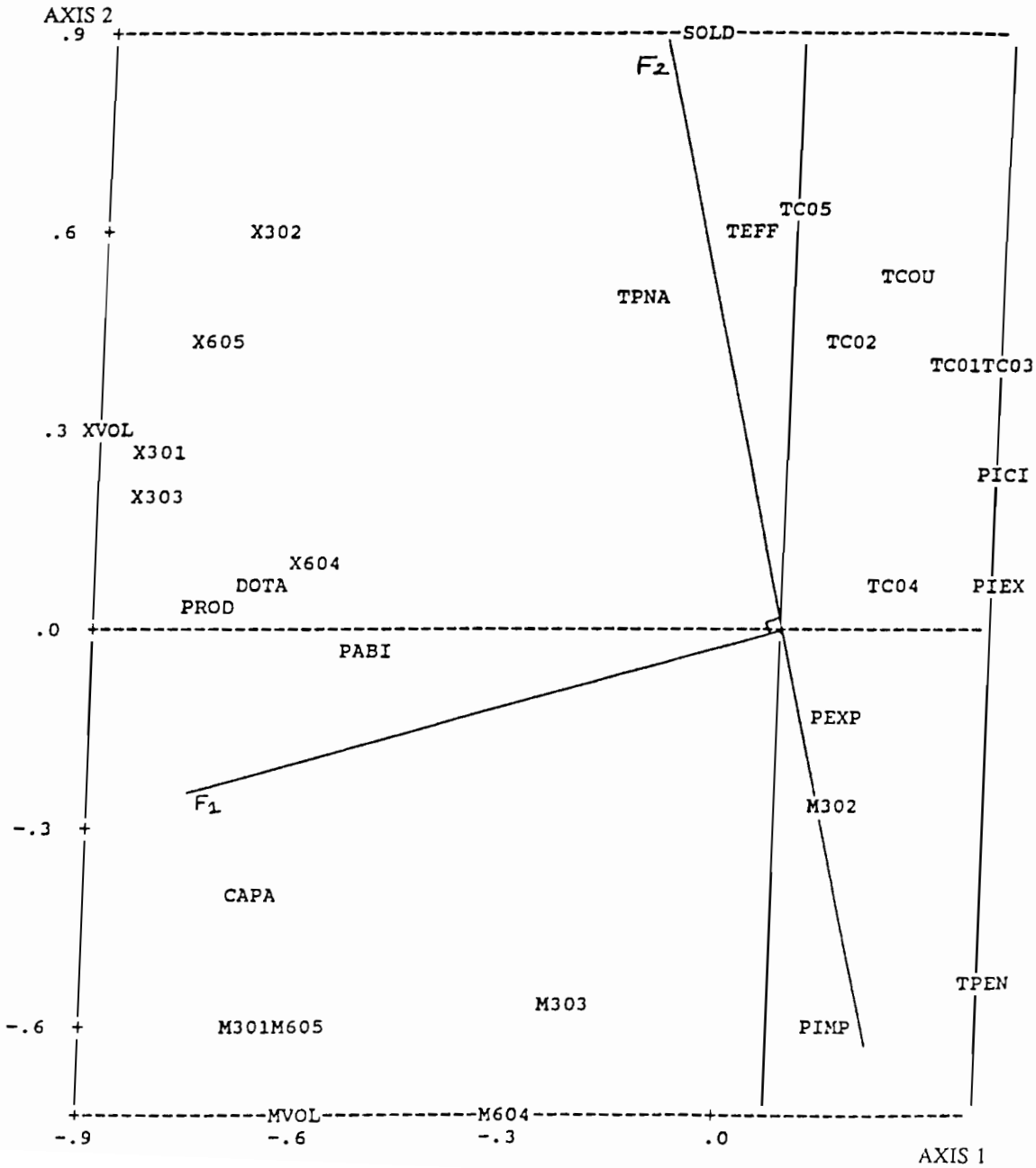


**FIGURE 2.**
**INDIVIDUAL ELEMENTS.**

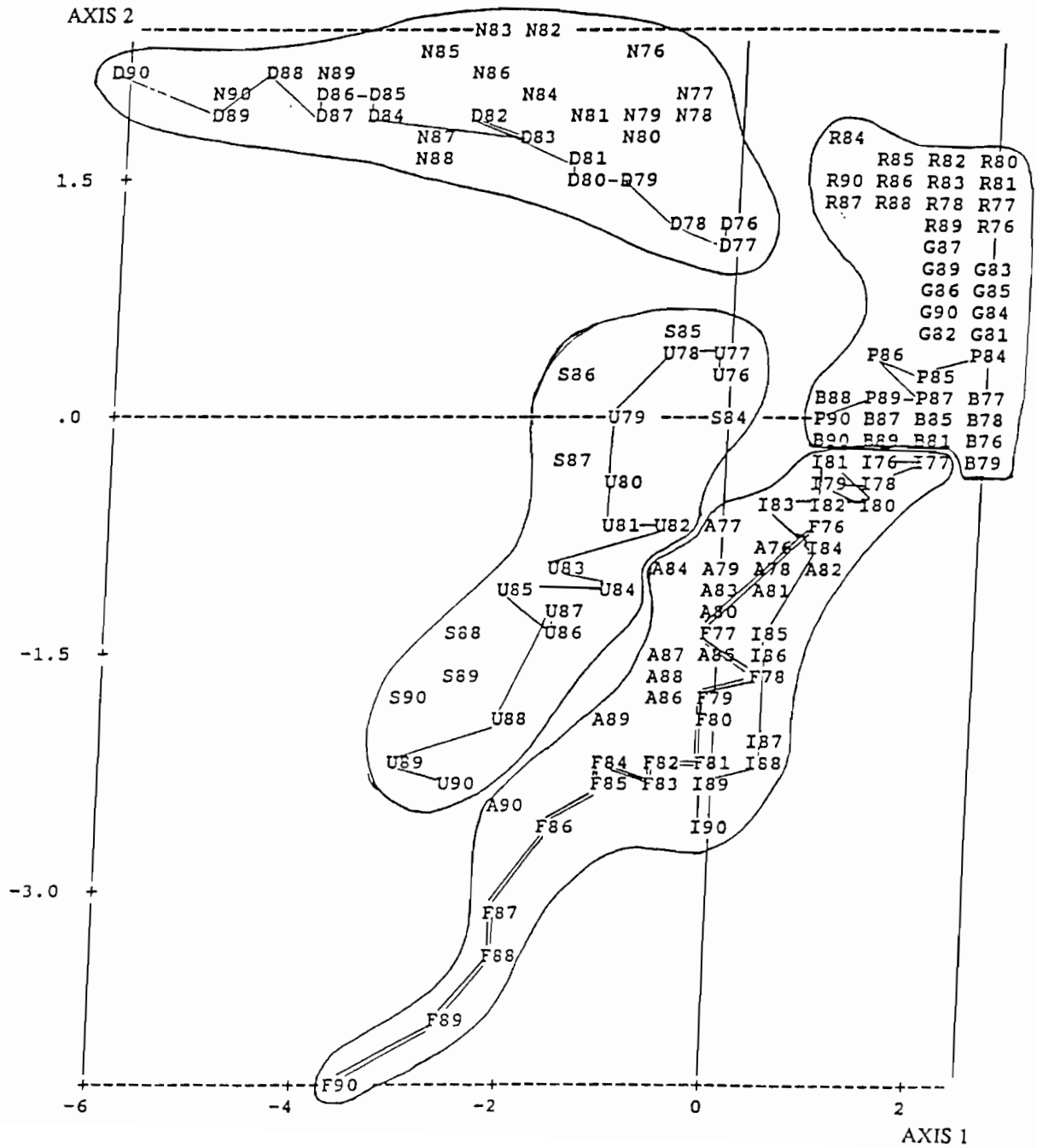
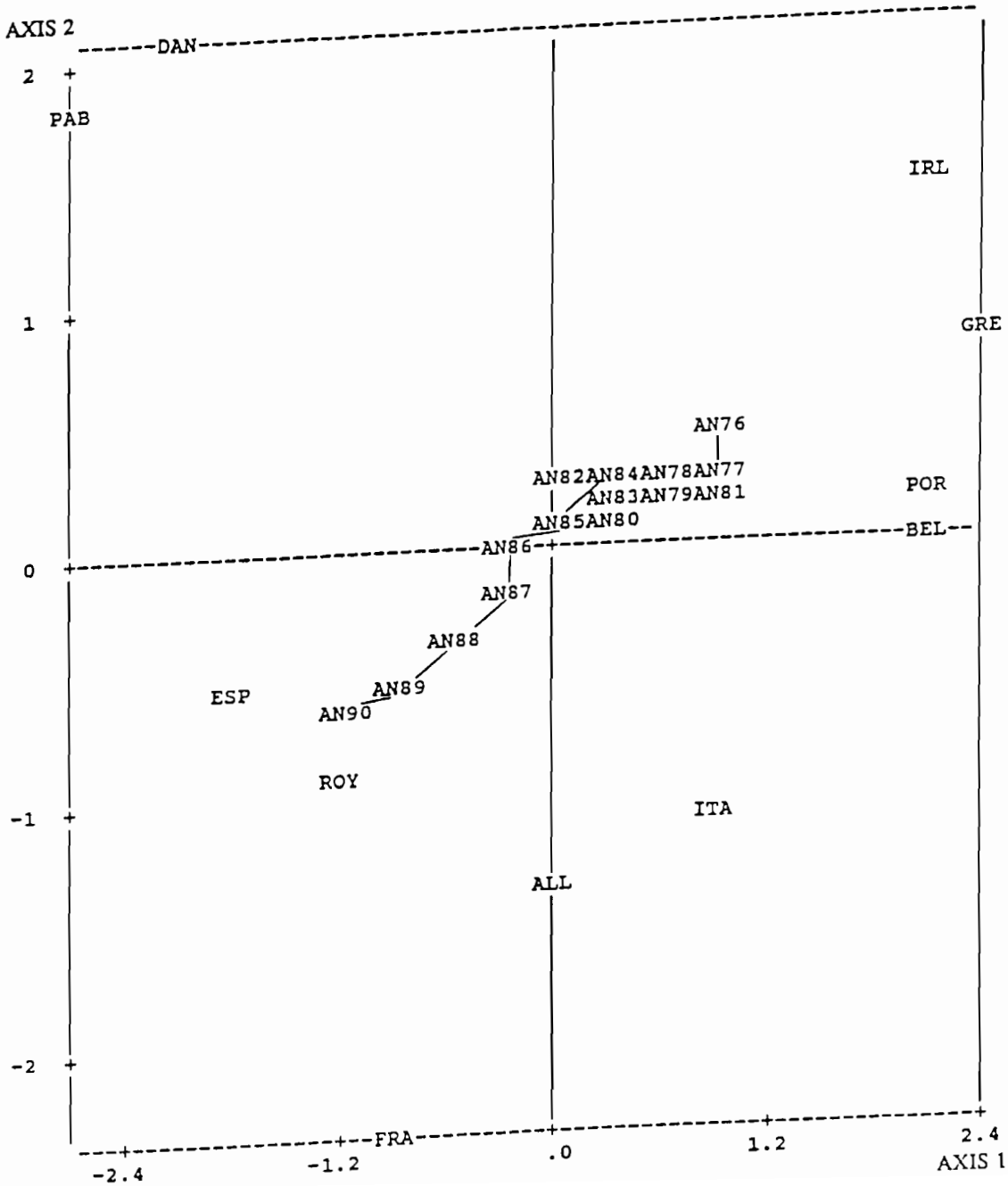


**FIGURE 3.**
**"COUNTRY" AND "YEAR" VARIABLES.**



# U.S. Demand for and Canadian Supply of Fish Products

**R. Leigh Mazany[a], Noël Roy[b] and William E. Schrank[b] ***

[a]Department of Economics, Dalhousie University, Halifax, Nova Scotia, Canada B3H 3J5, 902-494-2026

[b]Department of Economics, Memorial University of Newfoundland, St. John's, Newfoundland, Canada A1C 5S7

ABSTRACT

*The establishment of coastal nations' exclusive economic zones in the late 1970s resulted in major shifts in the structure of production and trade in fish products as distant water fleets lost access to traditional fishing grounds. Canada is the world's largest exporter of fish products. The U.S. is Canada's major market.*

*In this paper, we model the supply of and demand for Canadian frozen fish products in the U.S. market. Earlier work has estimated demand equations for the U.S. market, but few have looked at the supply side. We estimate a simultaneous equation system using Three-Stage Least-Squares for a number of species-product types. We obtain estimates of own-price and cross-price elasticities for both supply and demand, allowing us to say something about substitutes in production and in consumption. For example, cod fillets are found to be a substitute for cod blocks in consumption, but not vice versa. Our results are consistent with institutional studies that argue the block market is a more homogeneous commodity market, while the frozen fillet market allows for more product differentiation. Our model extends current work and provides a more complete analysis of the groundfish market.*

## 1. INTRODUCTION

The establishment of coastal nations' exclusive economic zones in the late 1970s resulted in major shifts in the structure of production and trade of fish products in the world as distant water fleets lost access to traditional fishing grounds. While total fish catches rose by 36.6 percent from 1977 to 1987, international trade in fish products increased by 73.5 percent in volume and 198.3 percent in value. For frozen fish products over the same period, production increased by 39.8 percent, while trade increased by 64.7 percent (FAO, 1987).

* This research was supported in part by Social Sciences and Humanities Research Council of Canada research grant n° 410-89-1193.

This shift in the volume and pattern of trade in fish products has increased interest in understanding how the markets for fish products work. This has been particularly true in countries such as Canada and Norway, where fishing, while not large on a national scale, is important on a regional basis, and Iceland, where fishing is the major industry. Canada, while only the sixteenth in the world in terms of landings, is the world's largest exporter of fish products. For this reason, understanding world fish products markets is important for Canada.

Previous studies of fish products markets have almost all considered only the demand side of the market [1]. The few simultaneous models which have been developed (e.g., Paez, 1981 ; Crutchfield and Gates, 1983) have incorporated supply considerations, but at a highly aggregated level, without distinguishing among species or product forms (an exception is Schrank et al., 1984). In this paper, we develop a simultaneous equations model of both the supply of and demand for Canadian frozen groundfish products in the U.S. market, and estimate it for four groundfish species : cod, haddock, redfish, and flatfish [2] Our approach is unique in that we explicitly incorporate the supply side into the model and that we explicitly model different product types rather than an aggregate "fish product". Although we include the supply side of the market, the model is still a partial equilibrium one in the sense that we treat the demand for and supply of other countries' products and the demand for and supply of Canadian products to other countries as exogenous to the model [3]. In addition, the markets for non-frozen fish products (e.g., fresh) are also treated as exogenous. In essence, this model can be thought of as a submodel of a more general equilibrium model of world groundfish supply and demand, and as a prototype module of a global model of world groundfish trade.

## 2. THE ATLANTIC CANADA GROUNDFISH PROCESSING INDUSTRY

Over 97 percent of Canadian groundfish landings occur on the Atlantic coast. For this reason, we concentrate on the Atlantic Coast industry. In terms of landed value, cod made up nearly 65 percent of groundfish landings in 1988, while haddock accounted for 6.7 percent, redfish, 7.6 percent, and flatfish, 9.9 percent. In terms of production, for cod, frozen blocks make up nearly 35 percent of production, followed by frozen fillets at 30 percent, then salted cod at 21 percent, fresh fillets (9 percent), and fresh and frozen whole fish. For flatfish, frozen fillets accounted for nearly 81 percent of production, followed by frozen blocks (9 percent), and fresh fillets and fresh and frozen whole fish. In redfish production, fresh and frozen fillets comprised the bulk of production (nearly 95 percent). For haddock, fresh and frozen fillets accounted for 79 percent of the value of production (DFO, 1989a).

The United States absorbs 65 percent of Canadian groundfish exports by value (DFO, 1989a). Frozen and fresh products move through different marketing channels into the United States (Mazany et al., 1987). Salt fish products are sold primarily in the Caribbean and Portugal. As there is no U.S. demand to speak of (outside of immigrant groups, primarily in New York, and demand in Puerto Rico), we do not estimate equations for salt cod. The fresh market involves primarily local (Canadian) demand, as well as fish trucked from mainly Nova Scotia to New England markets. Because of the relatively low volumes of fresh products, we limit our analysis to the frozen market for the four species.

## 3. MODEL

An important characteristic of the Atlantic Canada groundfish processing industry is that it produces a variety of end-product forms, sold in distinct markets. Thus, the processors must decide whether to process and market the raw fish as, for example, fresh fillets, frozen fillets, frozen blocks, or other product. Clearly, then, it is appropriate to view the processing of groundfish as a multi-product technology.

The processors can be viewed as processing a multi-output profit function $\Pi(p,w)$, where p is a vector of product prices and w is a vector of factor prices. To be consistent with profit maximization, this function must be convex, positively

1. There are a number of studies of groundfish markets. Summaries of earlier studies are found in Nash and Bell (1969) and Roy et al. (1991).
2. Flatfish is actually a category containing a number of different species.
3. U.S. production of frozen products is small and therefore is not modelled.

linearly homogeneous, non-decreasing in p, and non-increasing in w (McFadden, 1978). If the profit function is differentiable, then by Hotelling's Lemma, the supply function for the ith product, $y_i$, can be derived by differentiating the profit function with respect to the price of the ith product, $p_i$.

$$y_i = \partial\Pi / \partial p_i = y_i(p,w) \tag{1}$$

The supply of the ith product is thus a function of own price, the price of alternative products produced by the processor, and input prices.

There is one respect in which this specification of the model does not adequately reflect the institutional structure of the Atlantic Canada groundfish processing industry. Processors' decisions are conditioned not only by price levels, but also by a supply of raw fish that is irregular, unpredictable, and perishable. This would be of no consequence if local port markets established market-clearing prices promptly. Then the effect of fluctuations in landings on supply decisions would be reflected perfectly through the resultant change in the ex-vessel prices. The level of landings per se would have no independent influence on supply. But port markets in Atlantic Canada do not have this required degree of sensitivity to market forces (DFO, 1989b). In Newfoundland, ex-vessel prices in the inshore sector are determined through collective bargaining at the beginning of the season. While technically these are minimum prices, in practice, deviations from negotiated levels are infrequent. In Nova Scotia, substantial amounts of inshore groundfish are sold through non-market transactions. For both provinces, the ex-vessel price in the offshore sector is an internal transfer price set within vertically integrated companies.

Thus, the ex-vessel price of landings is an imperfect indicator of the supply of raw groundfish to processors. At the same time, we cannot preclude its having a significant influence on supply decisions, if only because if affects the relative profitability of various products. Consequently, we modify the supply function of equation (1) to include the level of landings, L, as a variable. Our modified supply function is therefore of the form

$$y_i^s = s(L, p, w) \tag{2}$$

The Canadian processors sell their production to wholesalers, retail outlets, and institutions in the U.S. (Mazany et al., 1987). The demand for frozen products at the processor level is thus a derived demand, as the buyers, in turn, sell to other companies or directly to the local consumer. We specify a standard demand function as a function of own-price, the price of alternative products, and income.

$$y_j^d = d(q, I) \tag{3}$$

where q is a vector of appropriate prices on the demand side and I is income.

We assume that market prices adjust so that supply is equated to demand. While this is not an unrealistic assumption in the fresh fish market, where the products must be sold quickly or they will not be saleable, it is not always appropriate for the frozen market, where inventories can be held. Nevertheless, we impose the assumption as a first approximation.

In order to estimate the model, we need to specify function forms for the supply and demand equations. We chose a log-linear form, with homogeneity of degree zero in all prices imposed on the supply equation and homogeneity of degree zero in prices and income imposed on the demand equation.

The regression equations for each particular product are

$$\ln y_{it}^s = \alpha_i + \beta_i \ln L_t + \sum_j \gamma_{ij} \ln p_{jt} + \sum_k \delta_{ik} \ln w_{kt} + \sum_k D_{kt} + u_{it} \sum_j \gamma_{ij} + \sum_k \delta_{lk} = 0 \tag{4}$$

and

$$\ln y_{it}^d = a_i + b_i \ln y_{i,t-1}^d + \sum_j c_{ij} \ln q_{jt} + d_i \ln P_t + e_i \ln I_{t-1} + \sum_k D_{kt} + v_{it} \sum_k c_{ij} + d_i + e_i = 0 \tag{5}$$

where

$y_{it}$ is the production of the ith product in time t ; i = 1, 2 for frozen fillets and frozen blocks, respectively ;

$L_t$ is landings of the species in time t ;

$p_{jt}$ is the price of the jth product produced by the processor in time t ;

$w_{kt}$ is the price of the kth factor of production in time t ; k = 1, 2 for labor and raw fish, respectively ;

$u_{it}$ is the random disturbance term in the ith equation in time t ;

$\beta_i$ is the elasticity of supply of the ith product with respect to landings ;

$\gamma_{ij}$ is the elasticity of supply of the ith product with respect to the jth product price ;

$\delta_{ik}$ is the elasticity of supply of the ith product with respect to the price of the kth factor of production ;

$y_{i,t-1}$ is the quantity of the ith product lagged one period ;

$q_{it}$ is the price of the jth product demanded in time t

$P_t$ is the U.S. Consumer Price Index for all items ;

$I_{t-1}$ is U.S. disposable income lagged one period ;

$D_{kt}$ are monthly dummy variables, k = 1,...,11 ;

$v_{it}$ is the random disturbance term in the ith equation in time t ;

$c_{ij}$ is the elasticity of demand for the ith product with respect to the jth product price ;

$e_i$ is the elasticity of demand for the ith product with respect to income ;

$b_i$ is the partial adjustment coefficient for the ith product.

A few words of explanation are needed for the demand equation. We estimate the model using monthly data. We thus include the variable, $y^d_{it-1}$, the quantity demanded in the previous month, in order to reflect habit persistence. That is, the quantity demanded in the current month is partially determined by what was demanded in the previous month. Further, when the time period is a month, it is reasonable to assume that immediate past income rather than current income determines demand (cf. Tsoa et al., 1982). The dummy variables are included to capture seasonal fluctuations in supply and demand. There is evidence of seasonal fluctuations in both U.S. imports and prices (Mazany, 1986), although these fluctuations diminished to some extent in the late 1980s.

For the estimation of supply, we use Canadian production as the dependent variable. Because there is not an observable quantity for demand, a proxy is needed, if quantity supplied and quantity demanded are specified as distinct variables. Since most Canadian production is exported to the U.S., we felt Canadian production was not an unreasonable proxy for U.S. demand for the Canadian product. Further, the alternative quantity variable to use is U.S. imports of Canadian product [4]. Use of import data requires the demand function to be specified as a semi-reduced form incorporating supply, domestic final demand and inventories. Such a specification detracts from the stability and adds to the complexity of the estimated form. For this reason, we preferred to use production rather than import data as the dependent variable in both the supply and demand equations.

A related issue is the role of inventories. Unlike fresh fish, frozen fish products can be stored. Thus, demand can be satisfied either by current production or inventories. Similarly, current production can be put into inventories if market conditions warrant. For the moment, however, we abstract from the effects of inventories [5].

4. Alternatively, Canadian exports of the product to the U.S. could be used but these data appear to be inferior to import data. For a discussion of the issue of using export versus import data, see Georgianna and Dirlam (1983).

5. There are serious data problems with inventories of fish products. First, it is not possible to distinguish among inventories of fish products from different countries. Secondly, both Canadian processors and U.S. buyers hold inventories. This complicates the modelling process even further.

## 4. DATA

We estimated the model for both frozen fillets and frozen blocks of cod, haddock, redfish, and flatfish. Because we are looking at the market at the processor-wholesaler level and concentrating on U.S. demand for Canadian products, we use as the producer price for these products the U.S. wholesale price, converted into Canadian dollars at the prevailing exchange rate. Monthly data are available for the period 1972-1987 for U.S. wholesale prices of frozen cod and haddock products, from 1974-1987 for redfish products, and from 1975-1987 for frozen flatfish products [6]. From the processor's point of view, substitutes in production include fresh product forms and, in the case of cod, salt fish. We include the prices of fresh fillets (and salt fish) in the supply equations. Since a continuous series on wholesale prices of fresh fillet products is not available, we use U.S. import prices of fresh fillets of each species for this product [7]. In the case of cod, salt cod is sold on a variety of markets, so we use the Canadian export price for this product [8]. We use as input prices the ex-vessel price of the species [9] and average hourly earnings in the fish processing industry for the Atlantic region [10]. Monthly data on landings are available [11], as are monthly production data[12].

On the demand side, prices are as on the supply side, except that substitution among products is assumed to occur not only for different products of the same species, but also for the same product from Canada's main competitors in the U.S. frozen groundfish market : Iceland and Denmark [13]. The income variable is U.S. disposable income lagged one period, and the general price variable is the U.S. Consumer Price Index for all items [14].

## 5. ESTIMATION RESULTS

The model for frozen fillets and blocks was estimated in blocks using Three-Stage Least Squares. The demand and supply equations for each species were estimated as a block. Landings and ex-vessel prices were treated as endogenous, as were Canadian product prices and production. The results are found in Tables 1 through 8.

### *5.1 Cod*

For frozen cod fillets, the coefficient of landings is significant at the 1 percent level and positive. It is close to unity, as we would expect. The coefficient of the wage rate is not significantly different from zero. The coefficient on the ex-vessel price, while significant at the 1 percent level, is positive rather than negative. One reason for this could be that the ex-vessel prices tend to be set for the season, based on the previous year's product prices and an estimate of what the product prices will be this year. Since processors buy the whole boatload from the fisherman, even if they do not need all of the fish, one would expect to find a positive correlation between the two sets of prices.

The coefficient of the own-price is significant at the 5 percent level and positive. The coefficient is greater than one, suggesting production is sensitive to changes in price. A one percent increase in the wholesale price of frozen cod fillets will cause nearly a 3 percent increase in frozen cod fillet production.

The coefficients of the prices of alternative cod products are significant and negative, as expected, except for fresh fillets. Frozen cod fillet production is elastic with respect to changes in the price of cod blocks and salt cod.

6. These were obtained from *Food Fish Situation and Outlook* and the *Bloston Blue Sheets* .
7. These are derived implicitly as value divided by volume, both figures coming from unpublished data provided by the U.S. Department of Commerce.
8. This is derived implicitly as value divided by volume, both figures from Department of Fisheries and Oceans, *Canadian Fisheries Exports and International Trade*, various issues.
9. This was calculated as value of landings divided by volume for the Atlantic Region, both figures obtained from Department of Fisheries and Oceans, *Canadian Fisheries : Landings by Month.*
10. Statistics Canada, *Employment Earnings and Hours*, cat. no. 72-002.
11. Department of Fisheries and Oceans, *Canadian Fisheries : Landings by Month.*
12. Department of Fisheries and Oceans, *Canadian Fisheries : Product and Stocks.*
13. The same products, but different species, e.g., using frozen flatfish fillets as a substitute for frozen cod fillets, were left out for two reasons. First, inclusion of too many price variables introduces severe multicollinearity, rendering elasticity calculations imprecise. Second, earlier specifications indicated little or no substitutability between products (see also, Tsoa et al., 1991). Although in the last few years Alaskan pollock has threatened to displace cod in the U.S. market, for the period under consideration, it was not a threat.
14. The U.S. Consumer Price Index and disposable income variables were obtained from U.S. Department of Commerce, *Survey of Current Business*, various issues.

The specification for the supply of frozen cod blocks differs from that of frozen cod fillets in that the specification of the supply function was better without seasonal dummies. One reason for this might be that cod blocks are more a utility product, with less specific uses than cod fillets. The coefficient of landings for cod blocks is also significant, positive, and close to unity. The wage coefficient is negative but not significantly different from zero. The coefficient of the ex-vessel price is also negative and significant at the 1 percent level. It is not entirely clear why the coefficient should be positive for cod fillets, yet negative for cod blocks.

The coefficient of own-price is positive and significant. As with the frozen cod fillet own-price coefficient, the coefficient for the price of frozen cod blocks is greater than one, again implying that production is sensitive to changes in the price of the product. The frozen fillet price is negative and significant at the 10 percent level, suggesting substitution in supply as relative product prices change. The coefficients for salt cod and fresh fillets are not significantly different from zero, suggesting these products are not substitutes in supply for blocks.

The results for the demand equations for frozen cod fillets and blocks are found in Table 2. The results for frozen cod fillets are good. The coefficient of own-price is significant at the 1 percent level and negative, as expected. The coefficient is considerable greater than one, suggesting U.S. demand for Canadian frozen cod fillets is highly price elastic. A one percent increase in the price of frozen cod fillets causes demand to decrease by 5.8 percent. This would suggest the presence of many substitutes in the market. The cross-price elasticities with respect to cod block and fresh cod fillets prices are significant at the 1 percent level and positive, with values of 1.9 and 2.6, respectively, suggesting they are substitutes, at least at the wholesale level, for frozen cod fillets. With respect to other countries' frozen cod fillets, only the coefficient of the price of Icelandic frozen cod fillets is significant. It is less than one, suggesting that changes in the price of Icelandic frozen cod fillets have a smaller effect on the demand for Canadian frozen cod fillets than do changes in either Canadian cod block or fresh cod fillet prices. This may be because Icelandic (as well as other foreign) cod products move through different marketing channels or enter different markets.

The coefficient on the Consumer Price Index and lagged disposable income are as expected. The results suggest demand for frozen cod fillets is income-elastic. The coefficient of lagged quantity is significant at the 1 percent level and lies between zero and one. This implies response in demand to changes in the market does take place over a period of time. The estimated coefficient implies half the discrepancy between long-run and short-run demand is eliminated within one month.

With respect to cod blocks, the own-price coefficient is not significantly different from zero, while the coefficient on frozen cod fillet prices is negative and significant. This anomalous result suggests there might be a misspecification of the function. The coefficients on the fresh fillet price, and Icelandic and Danish frozen cod blocks, are significant and positive, as expected. This implies that Canadian frozen cod block production does compete in the U.S. wholesale market against cod blocks from these two countries. The coefficients are less than one, though, suggesting buyers are not that sensitive to price changes.

The coefficient on both the CPI and lagged income are again significant and of the expected sign. The coefficient of lagged quantity is also significant and less than one, again implying a lag in the response of demand to changes in the market.

### *5.2 Haddock*

The results for the haddock model are found in Tables 3 and 4. The wage rate and monthly dummies were excluded from the supply equation, as this provided a better specification. For the supply of frozen haddock fillets, the coefficient of landings is significant at the 1 percent level and positive, but less than one. One possible explanation for this result is limits on freezing capacity. When this capacity is exceeded, production must be diverted to other product forms. This does not explain, however, why a similar result is not found for the other species. The coefficient on ex-vessel price is significant at the 1 percent level and positive. Again, this may reflect the market structure, as discussed above for cod.

The price coefficients are disappointing, as the signs are the reverse of what would be expected. This suggests there is some sort of identification problem, in that the price coefficients of the supply equation have signs suggesting a demand equation has been estimated. This is also true for blocks.

The demand equations are not much better. Although the coefficients on the price variables are of the correct sign, in the case of frozen fillets, only the own-price coefficient is significantly different from zero. The block equation is somewhat better, but has a calculated negative $R^2$. The results suggest that the specification is incomplete. For example, inventories have been excluded. More work clearly needs to be done on this part of the model.

*5.3 Redfish*

The supply and demand equations for frozen redfish fillets and blocks are found in Tables 5 and 6. The supply equation for blocks is not very satisfactory. Only the landings and ex-vessel price coefficients are significant. This may reflect the fact that frozen redfish blocks form only a small proportion of production. With respect to the supply equation for frozen redfish fillets, the landings coefficient is significant at the 1 percent level. and close to one, as expected. The ex-vessel price coefficient is significant at the 1 percent level and of the correct sign. Again, the preferred specification excluded the wage rate variable. The own-price coefficient is significant at the 1 percent level and greater than unity, suggesting production of redfish fillets is sensitive to changes in the wholesale price. The coefficients of the prices of alternative cod products are significant and negative, as expected, except for the coefficient on the fresh fillet price, which is just under the 10 percent level of significance. In the case of redfish products, there is no large competitor of Canadian product on the U.S. market. Frozen redfish fillet production is inelastic with respect to changes in the price of redfish blocks, but elastic with respect to changes in fresh redfish fillet prices. It is not unreasonable to think that fresh fillets are a closer substitute to frozen redfish fillets than are blocks.

With respect to demand, the own-price coefficient is significant at the 10 percent level and positive. This suggests there is some specification problem, especially as the coefficients on the prices of alternative products are negative, rather than positive. The results for blocks show similar problems. The low $R^2$ (in the case of blocks, a negative $R^2$) reinforces this conclusion.

*5.4 Flatfish*

The results of the estimation of the supply and demand equations for flatfish are found in Tables 7 and 8. With respect to the supply of frozen flatfish fillets, the landings coefficient is significant at the 1 percent level and close to unity. The wage rate coefficient is also significant at the 1 percent level and of the expected sign. The coefficient on ex-vessel price is significant at the 10 percent level and positive. This may again reflect the way ex-vessel prices are set, as discussed under cod, above. In the fillet equation, none of the price coefficients is significant. For blocks, only the own-price coefficient is significant. It is greater than unity, suggesting processors are sensitive to wholesale price changes.

With respect to demand for frozen flatfish fillets, the own-price coefficient is significant at the 10 percent level, but of the wrong sign. Part of the difficulties with the flatfish results may be because "flatfish" comprise a number of different species, so the price and production variables reflect an aggregation of over 20 different species within the category of "flatfish". The coefficient on Danish flatfish fillets is significant and of the correct sign. It is less than one, suggesting there is not much substitution between Danish and Canadian frozen flatfish fillets. This again may reflect species mix, or that the two countries sell through different marketing channels or in different markets. The coefficients on the CPI and lagged disposable income are significant, but only the coefficient on the CPI is of the correct sign. The coefficient on lagged quantity is significant, but low. This suggests only 20 percent of the discrepancy between long-run and short-run demand is eliminated within a month.

With respect to blocks, there is again a problem with the signs on the price coefficients. Given the low proportion of production that goes into flatfish blocks, and the difficulties with species mix, this suggests more work needs to be done on the specification of the model for flatfish.

## 6. CONCLUSIONS

In this paper we estimated a simultaneous equations model of the U.S. demand for and Canadian supply of frozen groundfish products. The results were mixed and indicate more work needs to be done on specification of the supply and demand equations, especially for haddock and flatfish. Our results suggest the following implications for modelling :

i) Different product types of a given species interact with one another on both the demand and the supply side, making a simulaneous approach essential.

ii) Market structure is complex and product-dependent. Some products face more competition in the market from other product forms and other countries' products than do other products.

A complete model of the U.S.-Canada trade in groundfish products must include the market for fresh and other products, since these interact with the demand for and supply of frozen products. However, data considerations would force us either to use annual data or to use import data rather than production data. Using annual data would mean a small number of degrees of freedom. In addition, it is not clear which aggregation of the price variable is the economically relevant definition. The price data used in this model are monthly series and already reflect a substantial aggregation. Taking a simple average would hide substantial variations in montly prices. If we wish to construct a weighted average, it is not immediately obvious what to use for weights.

The other alternative is to use import data for quantity. This means we are no longer estimating a supply function but an import function. This complicates the model and introduces additional estimation problems in that some of our price variables are import unit values.

Nonetheless, our model represents a first step towards building a more complete model of U.S.-Canada groundfish trade. It allows us to say something about supply responses to market changes as well as demand responses. It shows that there are differences in different product markets in terms of price responsiveness. Thus, it is not accurate to talk about effects of changes on the groundfish market as if it were a single market. The markets are connected, but still distinct.

## REFERENCES

**Crutchfield S.R. and J.M. Gates** (1983). "Tariffs, quotas and U.S. groundfish imports : an applied welfare analysis", Kingston : University of Rhode Island, Department of Resource Economics, mimeo.

**Department of Fisheries and Oceans** (1989a). *Canadian Fisheries Statistical Highlights*, 1989, Ottawa : Supply and Services.

**Department of Fisheries and Ocean** (1989b). *An Analysis of Price Formation in Port Markets in Atlantic Canada*, Economic and Commercial Analysis Report No. 3, Ottawa, Supply and Services.

**Food and Agricultre Organization** (1987). *Yearbook of Fisheries Statistics*, Rome : FAO.

**Georgianna D. and J. Dirlam** (1983). "The Canadian export -U.S. import groundfish and scallop trade", Final Report submitted to the National Marine and Fisheries Service, Contract no. NA-82-FA-C-00059.

**Mazany R.L.** (1986). "Patterns of fish products trade between Atlantic Canada and New England", Dalhousie University, Deparment of Economics, Working paper no. 86-07.

**Mazany R.L., L.G. Barrett, and R.A. Apostle** (1987). "Market segmentation : Nova Scotia fish processing and the U.S. Market", *Marine Policy*, January, 29-44.

**McFadden D.** (1978). The general linear profit function", in M. Fuss and D. McFadden, eds., *Production Economics : A Dual Approach to Theory and Applications*, New York : North-Holland.

**Nash D.A. and F.W. Bell** (1969). "An inventory of demand equations for fishery products", Washington, D.C. : Bureau of Commerical Fisheries, Division of Economic Research, Working Paper no. 10.

**Paez M.L.** (1981). "An econometric analysis of some factors associated with the international trade flows of frozen groundfish blocks", Oregon State University, Corvallis, Oregon, Ph.D. thesis.

**Roy N., E. Tsoa and W.E. Schrank** (1991). "What do statistical demand curves show ? A Monte Carlo study of the effects of single equation estimation of groundfish demand functions", in W.E. Schrank and N. Roy, eds., *Econometric Modelling of the World Trade in Groundfish*, Dordrecht : Kluwer Academic Publishers, 13-46.

**Schrank W.E., E. Tsoa and N. Roy** (1984). "An econometric model of the Newfoundland groundfishery : estimation and simulation", Memorial University of Newfoundland, Department of Economics, mimeo.

**Tsoa E., W.E. Schrank and N. Roy** (1982). "U.S. demand for selected groundfish products, 1967-1980", *American Journal of Agricultural Economics*, **64** (2) : 483-89.

**Tsoa E., N. Roy and W.E. Schrank** (1991). "Alternative approaches to the econometric estimation of demand functions", in W.E. Schrank and N. Roy, eds., The *Econometric Modelling of the World Trade in Groundfish* , Dordrecht :Kluwer Academic Publishers, 55-70.

**TABLE 1.**
**SUPPLY OF FROZEN COD PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Landings | 0.8734* (8.2684) | 0.9282* (14.510) |
| Wage rate | 0.0312 (0.1512) | -0.2165 (-1.2715) |
| Ex-vessel price | 0.9697* (2.5245) | -0.8116* (-2.6411) |
| Frozen fillet price | 2.9503** (1.7807) | -2.1956*** (-1.5784) |
| Frozen block price | -1.6866*** (-1.2952) | 2.4726* (4.1896) |
| Salt cod price | -1.2952* (-3.8681) | 0.2011 (0.6969) |
| Fresh fillet price | -0.9694 (-1.0776) | 0.5500 (0.6829) |
| D1 | 0.1442 (1.0212) | |
| D2 | 0.0808 (0.5320) | |
| D3 | 0.1282 (0.8206) | |
| D4 | -0.0539 (-0.3580) | |
| D5 | -0.2040 (-1.1815) | |
| D6 | -0.3655** (-1.9817) | |
| D7 | -0.5922* (-2.8850) | |
| D8 | -0.6892* (-3.4426) | |
| D9 | -0.6960* (-4.1195) | |
| D10 | -0.5922* (-4.0838) | |
| D11 | -0.2782* (-2.1123) | |
| Constant | 5.9836*** (1.3873) | -4.3213 (-1.0801) |
| $R^2$ | 0.7678 | 0.7658 |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 2.**
**DEMAND FOR FROZEN COD PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Lagged quantity | 0.5092* (7.4850) | 0.4646* (7.5390) |
| Frozen fillet price | -5.8382* (-4.3208) | -5.7992* (-4.0887) |
| Frozen block price | 1.8560* (2.8186) | -0.0318 (-0.0217) |
| Fresh fillet price | 2.6322* (3.0255) | 2.7853* (2.9551) |
| Icelandic price | 0.5540* (2.1498) | 1.3300* (2.6697) |
| Danish price | 0.2276 (0.9007) | 1.2472* (2.1464) |
| CPI | -1.2117* (-2.3562) | -0.8786** (-1.9026) |
| Lagged disposable income | 1.7801* (3.9987) | 1.3472* (3.5275) |
| D1 | -0.3631* (-2.2894) | -0.3895* (-2.3379) |
| D2 | 0.3439** (2.1870) | 0.5552* (3.4577) |
| D3 | 0.3352** (2.0536) | 0.0905 (0.5313) |
| D4 | 0.1340 (0.8171) | 0.2221 (1.3425) |
| D5 | 0.5960* (3.4953) | 0.6976* (3.9854) |
| D6 | 0.4200* (2.3269) | 0.7990* (4.2918) |
| D7 | 0.3357** (1.8784) | 0.8733* (4.6732) |
| D8 | 0.1818 (1.0307) | 0.4860* (2.5156) |
| D9 | 0.1097 (0.6284) | 0.2529*** (1.3586) |
| D10 | -0.0008 (-0.0052) | 0.1016 (0.6011) |
| D11 | -0.2054*** (-1.3336) | -0.0639 (-0.4059) |
| Constant | -16.530* (-3.6390) | -13.276* (-2.6694) |
| $R^2$ | 0.6104 | 0.6290 |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 3.**
**SUPPLY OF FROZEN HADDOCK PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Landings | 0.6299*<br>(7.5119) | 0.3030*<br>(2.5326) |
| Ex-vessel price | 0.9759*<br>(2.2499) | 0.9419**<br>(1.6519) |
| Frozen fillet price | -3.1285**<br>(-2.8426) | -5.1252*<br>(-3.4316) |
| Frozen block price | 2.1206**<br>(1.8983) | 3.8973*<br>(2.5682) |
| Fresh fillet price | 0.0320<br>(0.0558) | 0.2860<br>(0.3799) |
| Constant | 5.3171*<br>(3.9415) | 9.3793*<br>(4.8674) |
| $R^2$ | 0.4349 | 0.1177 |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 4.**
**DEMAND FOR FROZEN HADDOCK PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Lagged quantity | 0.1830** | 1.0859* |
| | (2.1480) | (2.3287) |
| Frozen fillet price | -4.3908* | 7.3335 |
| | (-3.0019) | (1.1833) |
| Frozen block price | 2.1574 | -22.208** |
| | (0.9747) | (-1.8214) |
| Fresh fillet price | 1.1150 | 8.3103** |
| | (1.0315) | (1.9760) |
| CPI | 0.0834 | 3.4549 |
| | (0.0722) | (1.0065) |
| Lagged disposable income | 1.0349 | 3.1088*** |
| | (1.1767) | (1.3230) |
| D1 | -0.1262 | -0.3570 |
| | (-0.4382) | (-0.4197) |
| D2 | 0.6768** | -0.8605 |
| | (2.1690) | (-0.8500) |
| D3 | 0.4628*** | -0.6733 |
| | (1.4972) | (-0.7299) |
| D4 | 0.3799 | -0.0357 |
| | (1.2695) | (-0.0427) |
| D5 | 0.4583*** | 0.4245 |
| | (1.6209) | (0.5232) |
| D6 | 0.6676* | -0.0892 |
| | (2.3996) | (-0.1120) |
| D7 | 0.6192** | 0.1169 |
| | (2.0837) | (0.1442) |
| D8 | 0.5683** | 0.0691 |
| | (1.9904) | (0.0863) |
| D9 | 0.6207** | -0.2852 |
| | (2.1253) | (-0.3312) |
| D10 | 0.6213** | -0.0085 |
| | (2.1354) | (-0.0103) |
| D11 | 0.1120 | -0.0300 |
| | (0.3830) | (-0.0359) |
| Constant | 3.0688 | -28.147*** |
| | (0.5140) | (-1.3986) |
| $R^2$ | 0.4078 | -- |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 5.**
**SUPPLY OF FROZEN REDFISH PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Landings | 1.1950* (7.8386) | 1.2443* (3.4892) |
| Ex-vessel price | -1.4131* (-3.4770) | -4.6023* (-4.8351) |
| Frozen fillet price | 3.7350* (2.4206) | 3.3309 (0.9219) |
| Frozen block price | -0.5850*** (-1.3462) | -0.2750 (-0.2702) |
| Fresh fillet price | -1.7369 (-1.2801) | 1.5464 (0.4864) |
| D1 | -0.5329** (-2.0047) | 0.2624 (0.4213) |
| D2 | -0.3045 (-1.2377) | 0.5914 (1.0258) |
| D3 | -0.5589* (-2.9113) | -0.3243 (-0.7208) |
| D4 | -0.5471* (-2.9422) | -0.4831 (-1.1088) |
| D5 | -0.5471* (-2.8851) | 0.2394 (0.5389) |
| D6 | -0.3956** (-1.8654) | 0.3427 (0.6900) |
| D7 | -0.6334* (-2.3726) | -0.5054 (-0.8088) |
| D8 | -0.5061** (-1.9775) | -0.4576 (-0.7637) |
| D9 | -0.8026* (-2.9503) | -0.3281 (-0.5152) |
| D10 | -0.6236* (-2.4253) | -0.0797 (-0.1324) |
| D11 | -0.4677* (-2.3042) | -0.03507 (-0.7376) |
| Constant | -0.0949 (-0.0161) | -28.198** (-2.0407) |
| $R^2$ | 0.7261 | 0.2573 |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 6.**
**DEMAND FOR FROZEN REDFISH PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Lagged quantity | 0.7264 * (5.3597) | 0.2717** (1.6758) |
| Frozen fillet price | 12.190*** (1.4708) | -5.7194 (-0.3799) |
| Frozen block price | -1.9255*** (-1.6120) | 11.606*** (1.3845) |
| Fresh fillet price | -7.9770*** (-1.3825) | -1.3316 (-0.1024) |
| Icelandic price | -0.5624 (-0.7008) | -4.8344*** (-1.3602) |
| CPI | -4.5804*** (-1.5720) | 1.4129 (0.2507) |
| Lagged disposable income | 2.8555*** (1.5072) | -1.1335 (-0.2989) |
| D1 | -0.3894 (-1.0268) | 2.5390*** (1.4136) |
| D2 | 0.4484 (0.8286) | 2.1128 (1.2348) |
| D3 | 0.1544 (0.5653) | 1.4493 (1.2325) |
| D4 | -0.1679 (-0.6706) | 1.0784 (1.0937) |
| D5 | -0.0554 (-0.2221) | 2.1277** (1.8845) |
| D6 | 0.6701* (2.6659) | 1.5765** (2.1162) |
| D7 | 0.3204 (1.1358) | 2.5222** (1.9624) |
| D8 | 0.5714** (2.2126) | 1.8356** (1.7376) |
| D9 | 0.1492 (0.5602) | 2.1805** (2.1084) |
| D10 | -0.0967 (-0.2872) | 2.1829** (2.0475) |
| D11 | -0.3789*** (-1.3356) | 1.2231*** (1.4668) |
| Constant | 21.855*** (1.5725) | 21.529 (0.5400) |
| $R^2$ | 0.0914 | -- |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 7.**
**SUPPLY OF FROZEN FLATFISH PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Landings | 0.8883*<br>(4.3647) | 0.9953*<br>(10.500) |
| Wage rate | -1.1450*<br>(-2.3077) | -0.4935<br>(-0.6739) |
| Ex-vessel price | 0.6455***<br>(1.3576) | -1.2019**<br>(-1.9079) |
| Frozen fillet price | 0.9492<br>(1.0704) | -0.6943<br>(-0.5457) |
| Frozen block price | -0.2903<br>(-0.3768) | 2.0163**<br>(1.8490) |
| Fresh fillet price | -0.1594<br>(-0.5120) | 0.3733<br>(0.9591) |
| D1 | -0.3182<br>(-1.1359) | |
| D2 | -0.0785<br>(-0.4086) | |
| D3 | 0.1521<br>(0.8269) | |
| D4 | -0.1301<br>(-0.6848) | |
| D5 | -0.2862<br>(-1.0791) | |
| D6 | -0.3598<br>(-1.2524) | |
| D7 | -0.4329***<br>(-1.4362) | |
| D8 | -0.5227**<br>(-1.7923) | |
| D9 | -0.4978**<br>(-1.8377) | |
| D10 | -0.1783<br>(-0.6906) | |
| D11 | -0.0222<br>(-0.1117) | |
| Constant | 4.3146<br>(1.2101) | -6.8312**<br>(-1.8888) |
| $R^2$ | 0.7380 | 0.6352 |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

**TABLE 8.**
**DEMAND FOR FROZEN FLATFISH PRODUCTS**

| | Fillets | Blocks |
|---|---|---|
| Lagged quantity | 0.1837* (3.1269) | 0.2403* (4.1451) |
| Frozen fillet price | 1.7409*** (1.6074) | -0.8705 (-0.7569) |
| Frozen block price | -0.4269 (-0.4323) | 2.2371** (2.1620) |
| Fresh fillet price | -0.2647 (-0.6491) | 0.2596 (0.5931) |
| Danish price | 0.3101*** (1.5202) | |
| CPI | -1.1796** (-1.6988) | -1.1669*** (-1.3682) |
| Lagged disposable income | -0.1799* (-3.640) | -0.4594 (-0.8707) |
| D1 | -1.3209* (-5.4552) | -1.4003* (-5.5568) |
| D2 | -0.1396 (-0.5305) | -0.2369 (-0.8707) |
| D3 | 0.1879 (0.7459) | 0.0661 (-0.2563) |
| D4 | 0.2530 (1.0182) | 0.2936 (1.1480) |
| D5 | 0.6581* (2.6191) | 0.7600* (2.9147) |
| D6 | 0.6360* (2.4947) | 0.8192* (3.0588) |
| D7 | 0.5808* (2.2486) | 0.7662* (2.8002) |
| D8 | 0.3896*** (1.3837) | 0.6501** (2.1780) |
| D9 | 0.2985 (1.1707) | 0.4184*** (1.5527) |
| D10 | 0.4081*** (1.5896) | 0.1711 (0.6402) |
| D11 | 0.2415 (0.9627) | 0.1046 (0.4047) |
| Constant | 14.995* (3.4633) | 12.930* (3.0106) |
| $R^2$ | 0.5611 | 0.6180 |

T-statistics in parentheses.

* significant at the 1 percent level.
** significant at the 5 percent level.
*** significant at the 10 percent level.

# Price Fluctuation and Substitution in the Groundfish Market

**Torbjørn Trondsen** *

The Norwegian College of Fishery Science, University of Tromsø, N-9000 Tromsø Norway

ABSTRACT

*Prices of groundfish products have fluctuated substantially over the last few years, but the general trend has been upward. New groundfish species from the Pacific and South Atlantic oceans have penetrated the groundfish market.*

*The paper explains the price fluctuation as a function of total supply and demand for groundfish, substitution between cod, pollack, hake and hoki in the markets for frozen fillet/block/H & G, fresh, salted and surimi products. The paper also discusses barriers against substitution in the market, and technical barriers in the production which create market segments with different price developments. Understanding the marketing barriers is important when companies and countries are planning the most profitable marketing and production strategies in the long term.*

## 1. INTRODUCTION

The term Groundfish cover all white fleshed salt-water species which live in the bottom area of the sea. The main species are Cod, pollock, saithe, haddock, hake, whiting, flatfish, redfish, hoki and lings. In addition many groundfish species can be found in warm water areas as grouper, snapper and seabreams (see appendix 1).

Prices of groundfish products as fillets, salt-fish, surimi and stockfish, have fluctuated substantially in the last years, but in an upward movements. New groundfish species from both the Pacific and south Atlantic Oceans have penetrated the market.

In this paper price fluctuation is explained as a function of the total global supply and demand for groundfish and substituion between different groundfish species and products in the markets.

* The author thanks for the financial supported from the Norwegian Counsil of Fisheries Research, which has made this research possible.

Barriers against substition are focused on production, distribution and markets which create market segments with different price pictures and fluctuations. Understanding the marketing barriers is important when companies and countries are planning the most profitable marketing and production strategies in the long term.

The theoretical perspective used is based on industrial organizational behaviour (Porter 1980), which when applies in the fisheries means understanding the behaviour of the actors engaged in fishing, processing, distribution and marketing between dynamic fish stocks and markets.

## 2. DATA SOURCES AND METHODS

The research methods used are a combination of exploratory and descriptive ones and aimed at discovering ideas and insights ( Churchill 1983, p62). Catch and production data in the period 1984-1989 come from FAO statistics and 1990-1991 from different national sources. US price information comes from National Marine Fisheries Services/Urner Barry price list. Norwegian export prices comes from the new Export database at the Norwegian College of Fishery Science. Japanese wholesale information comes from industry sources in Japan. Information from trade journals, newspapers and companies are used.

In addition the analysis is based on experience survey through extensive interviews with several leaders in the seafood processing and distribution industry in the USA, Japan, France, Great Britain, Germany, Italy and Norway done through our research-program : "Competition in the groundfish market."

## 3. FLUCTUATION OF PRODUCTION AND PRICES IN THE 1980'S

In the early 1980's the demand for seafood products started to increase. Health and weight consciousness among consumers coupled with enhancing purchasing power are anticipated to be the main forces behind the increased demand for seafood. Formerly fish was seen as cheap food for low income people. On the contrary, during the 1980's, prices for high quality seafood increased so much, that seafood more and more was seen as food for the more wealthy in the society. This gave signals to processors and fishermen to increase the catch and processing efforts.

Frozen fillet block is a globally standardized product which traditionally was made from Atlantic cod, saithe and haddock. But also other kind of groundfish species have been used in recent years. Frozen fillet block can be seen as a true free market product because the global trade has few restrictions. Frozen fillet block is therefore a good indicator for the price-level of groundfish.

In the following, we will explore the correlation between the prices of cod-block, total production and other groundfish products.

Figure 1 showns the correlation between prices and production of frozen cod fillet. Both the prices and production of cod-fillets increased in 1985, 1986 and 1987 and decreased in 1988 and 1989. The production was on the decline until 1991, but the prices showed only a slight decrease until 1988, when they started rising again. The price increase from 1989 to 1990 did not cause any production growth as was the case in 1985-1987.

This figure indicates, that the processors reduced production the same year as prices started falling. The interesting pattern is that production still reduced the following year even though prices were stable and then started increasing. How can it be explained ?

A comparison between figure 2 and figure 1 shows that the production of frozen groundfish fillets as a product-group increased from the year 1987 to 1988 (when the cod fillet production went down). After 1988 the production went down and levelled off to the 1987 level. This development is logical according to economic theory. The increased prices gave incentives for increased production. But it took time between the point for production and to the point or sale. The processors act on current prices. Products go first for freezing and storage, from where it can be sold. Frozen groundfish can be stored for at least a year and still be of good quality. When most processors make products for storage at current

prices, the accumulated impact is that production increases over the quantity which can be sold at the price they were made for. Then the prices start to fall until the present products can be sold and the production decreases until the supply to current prices again is too low and the prices will again increase to stimulate production.

But opposite to cod block production, correlation is positive between the price of cod-fillet block and the total production of all frozen groundfish fillets in the period 1989-1991. This indicates that increased prices of cod-fillet block also is correlated with increased production of frozen fillet block based on other groundfish species. This can be confirmed in figure 3.

Figure 3 shows that frozen fillet has gained an increasing share of the total catch of groundfish over the period : from 5,7 % in 1984 to 6.6 % in 1991. During the same period as the fillet-production increased, figure 4 show that the share of codfish[1] used in frozen fillets decreased from 45 % in 1981 to around 32 % in 1991. Production of pollock and hake fillets grew in the same period. The share of pollock-fillet increased 1981-1991 from 4 % to 20 % and hakefillet from 13 % to 22 % of total frozen fillet production.

The changed production level of frozen fillets can be explained as a function of catch. Figure 5 shows the yearly relative change in catch of different groundfish species related to 1984. The figure shows that the yearly catch of most coldwater species (except redfish), increased from 1984 to 1989. The major contribution to the increased catch came from Alaskan pollock with hake in the second poition. But in the period 1989 to 1991 the cod catch were reduced. The catch-growth of alaskan pollock has in the same period been reduced to the 1984 level. Hake kept its gain all through the years to 1991. Flatfish contributed to the catch growth up to 1990, but was reduced in 1991.

The accumulated impact on the total production of groundfish is seen in figure 6. The total production increased strongly in 1984 -1987, but fell again. There seems to be a good correlation between catch and the prices on both cod and pollock block.

But the processors of frozen fillets have to compete with other type of processors in the raw fish market.

The situation in the early 1980's was that technical improvements in the production processes and marketing effort had made a number of groundfish species actual to be supplied into the global market for frozen fillets if the demand and prices were interesting enough. Catch and production all over the world were influenced, because of few barrier in the global trade of frozen fish.

Figure 7 and 8 show the correlation between the prices of different groundfish products.

Figure 7 show that the prices of all chosen groundfish products have the same form. It indicate that the total groundfish market influences all products. Figure 8 show that surimi lost its relative strength to cod block 1984-1990. The prices on surimi started to increase later than the other groundfishes. The reason was that the surimi factory trawlers did not have enough equipment onboard to make fillets. But when the prices of frozen fillets came up to almost the same level as surimi which only gave 60 % of the yield, the owners of the US factory trawlers started to invest in the necessary equipment and increased the production of cod and pollock fillet. The result was that the production of surimi decreased substantial, and the surimi-prices increased more than 50 % in 1991 to keep up with the competition from the fillet market.

## 4. IMPACTS ON PRODUCT-MIX FROM FISHING REGULATIONS AND THE STRUCTURE OF THE INDUSTRY

A key to understanding the competition in the product-markets is the understanding the competitive advantages of the structure of the supplying fishing industry (Porter, 1985). The present pattern of production in the market, is a result of developments in the industry over the years.

The fishing industries have faced to big difficulties during the 1980's. First, extention of the the 200 n miles Economic Zones in 1978 which started a process that changed the fishing rights to the coastal states. The resources had earlier been

1. Codfish defined as : Cod, haddock, saithe, whiting, hoki, ling, tusk, argentinas.

exploited of long distance fleets from a few nations. Second, it emerged that more and more fish stocks were overexploited. The governments had to intervene with catch restrictions, which created overcapacity in most fishing sectors. Even higher prices on frozen fillets could not compensate that catch per unit effort went down. This was a new situation in the groundfish-fishery. Increased catch effort without changing the product-mix has traditionally always been the variable by which the fishermen could regulate their income. When the quota is given, all actors had to give priority to the product-mix which could give best profit with the technology and raw materials available.

### *4.1 Supply of atlantic frozen fillets*

The distribution chain for frozen products has developed after the World War II in all industrialised countries. This gave incentive to the building up of a freezing and cold storage industry. In all north Atlantic countries, the seafood sector has made hugh investment in filleting and freezing factories. This production method combined with investment in trawler fleets, made it possible to process, store and distribute high quality products independent of seasonal catch pattern and distances between consumers and catching grounds.

Frozen fillets blocks are still a main frozen fish product in Norway, Denmark, Faroe Island and Canada. In Iceland the production is more changed to frozen single fillets (Geirson & Trondsen 1991).

Fillet blocks were used as raw material in fish-sticks production. When the blocks are cut in small sticks and breaded. The fish sticks production grew very fast in the 1950 and 1960's and can now be seen as a mature industry. But development of new frozen fish products both made from blocks, single fillets and made direct from wet fish, has contributed to a steady growth in the frozen fish markets.

Most of the fish sticks processing industry which utilize frozen fillet block as raw material, are located in the USA and EEC. The industry in Europe is dominated by big multinational companies as Nestle and Unilever (Ottesen G 1992). These companies controlled earlier their own trawler fleets in Germany and Great Britain. But after the extension of the 200 mils economic zones, this fleet lost their traditional fishing grounds to Norway, Iceland and Canada which became the winners in the resource battle.

The big multinational processing and marketing companies in the frozen food sector, had to change their strategy. Vertical integration was partly given up. The trawler fleet were scraped or sold and the strategy focused on value added processing and marketing of products made from imported fillet blocks.

On the other hand the coastal Atlantic nations which gained control over most quotas, concentrated their strategy on fillet block production for the big fish sticks processors. Relative advantages and import duties of fish sticks and similar consumer products into the EEC and US markets, may explain this development.

### *4.2 Supply of surimi*

When the European dried and salted groundfish, the Japanese washed the fish flesh and preserved it as "surimi". This methods which was invented for many hundred years ago, made it possible to keep good quality fish without chilling facilities. Over the years, the Japanese have developed hundreds of products ( mainly kamaboko products) where surimi makes a main ingredient. The latest success product is crab sticks, which also has gained popularity in US and Europe.

When the Japanese learned methods to store frozen surimi products, it became possible to develop a huge factory trawler operation in Northern Pacific mainly in the Bering Sea in the early 1960's. Yearly, the Japanese made 400.000 tons of surimi and 800.000 tons of kamaboko products from more than 2 mill tons of Alaskan Pollock.

The extension of the economic zones to 200 nautical miles resulted in restructuring of the fisheries in the Pacific. The Japanese fleet of surimi factory trawlers and processing ships in the northern Pacific, were forced out of the US-economic zone in the late 1980's. After some years survival in international waters in the Bering Sea (dough-nut hole) and JV operations in Russian and Southern Pacific waters, most of the vessels in this fleet were sold or scrapped. The main Japanese fishery companies have changed their strategy from fishing to processing and trading.

Other nations as South Korea and Poland did also operate in this area. The Korean fleet has survived by JV operations in Russian waters. The Polish fleet which mainly has made fillet block out of Alaskan Pollock, has also big economic difficulties in the Northern Pacific. The restructuring of the Polish economy, will put a stronger economic pressure on this fleet. It may result in disorganization of the fleet.

The main force behind outfacing of the Japanese, Korean and Polish fleet from the US- Economic Zone, was the build-up of an American factory trawler fleet. The entrepreneurs behind this American fleet were partly Japanese, Korean and Norwegian, because foreign ships were not allowed to fish in US Zone. Today 100 % of the US groundfish quota is caught by US-flagged vessels ( Arnarson & Trondsen 1990).

### *4.3 Supply of Pacific frozen fillets*

Changed ownership of the Northern Pacific fleet also meant introduction of new processing methods. The Norwegian fishermen who engaged in this fishery, were experienced in fillet production onboard factory trawlers. The yield to surimi from whole fish is only 60 % ( yield 17-20 %) of the yield to fillet (yield 30-35 % ). The investment needed to make fillets are lower than to surimi, but the labour cost is higher. So, when the fleet became restructured through the Americanization process in the Alaskan fisheries, the knowledge and technology were also present to change production from surimi to fillets when the prices on fillet increased to more than 60 % of surimi- price.

The first entrepreneurs in filleting and freezing operations for Pacific cod started in the early 1980's. But the cod season was too short to make good profitability. Acceptance of frozen fillet from Alaskan pollock in the market was necessary before a filleting and freezing year around operation onboard factory trawlers became profitable.

During the 1980's pollock fillets produced onboard factory trawlers were introduced. These fillets were of a much better quality than the pollock fillet earlier known in the market. But there were problems with the use of pollock fillets in catering operations, because the breading busted under cooking. But through improving and adjustment of the breading and handling process, pollock fillets are now widely accepted in certain segments in the market.

In the 1970 and 1980's it was also invested heavily in filleting and freezing operations in New Zealand and Southern America. In the late 1980's some of Norwegians factory trawlers for filleting and freezing moved over to New Zealand and Australia and participated in successful JV and trial operations. The main groundfish species in New Zealand were mainly Orange Roughy and Hoki.

### *4.4 Supply of frozen hake fillet*

Hake is another group of groundfish which are mainly caught in southern America and southern Africa. Most filleting and freezing are done on land-based plants. In the 1970's and 1980's hake became more and more present in the frozen fillet market (Cerda & Anderson 1991). Initially, hakefillet was seen as low quality products. Among other things, hake had a fat layer between the skin and flesh, which lowered the storing time if it followed the fillet. But substantial quality upgrading, both handling of the raw material and deep skinning which removed the fat-layer, made frozen hake fillet block a good substitute for cod fillet block.

### *4.5 Supply of saltfish, klippfish and stockfish (Conventional cod products)*

Figure 8 shows that the Norwegian export prices of saltfish and klippfish (dried saltfish) follow the general trend, but the relative prices have increased compared with frozen cod block.

Salting and drying of groundfish has been the traditional preservation methods in Norway. Dried cod as stockfish are a very old products invented by the first Norwegians, have been an important protein source for Catholics in southern Europe, who do not eat meat in certain periods (Lent). The production method is simply to hang the fish on a drying rack until the water content is reduced to 20 percent. This product can be stored for years without any temperature control. Before it can be consumed, it has to be put into water to swell out. This product is still very popular especially in Italy and is at present the highest paying cod product in Norway.

In southern Europe wet salt-fish and dried salt-fish (klippfish) are still very popular products. Klippfish with a water content of 30-40 % can as stockfish, be distributed and stored without any chilling facilities. Main markets are Portugal, Brazil and southern Italy.

The markets for saltfish, klippfish and stockfish have been very competitive in the raw fish market for cods. An important factor is that Alaskan pollock, hake and the other "new" species which have penetrated the frozen fillet market, have not

succeeded in penetrating the markets for conventional products. It has been impossible to make a good quality saltfish from pollock and hake. The only substitutes to Atlantic cod in the saltfish market have been Pacific cod and Atlantic saithe, ling and tusk (Asgeirson A 1992). In the stockfish markets, it is the excellent condition for fish drying, which can be found in northern Norway (Lofoten area) and to some degree Iceland, which gives this countries absolute advantages in production. These mobility barriers based on accessibility of specific kinds of raw material and production conditions, have limited the competition in these markets to the suppliers of Atlantic cod. The low degree of substitution and the strong purchasing power especially in northern Italy and Spain and to some degree in Portugal and Brazil, have pushed the prices of saltfish, klippfish and stockfish to record heights.

The industry for conventional products have consumed 50-60 % percent of the Norwegian, 30-40 percent of the Icelandic and 30-40 percent of the Canadian cod quota.

Anticipated reasons for the difference are that Iceland has a more competitive frozen fish industry than Norway, due to higher output of more diversified products as fillets for catering etc.

The Canadian has also a competitive frozen fish industry, and access to a strong US-market for fresh groundfish with limited competition (Mazany, Barrett & Apostle 1987).

### *4.6 Supply of fresh fish*

Fresh fish belongs to a separate product-market segment.

The marketing area is limited to markets which can be reached few days after catch. The markets could also be seasonal due to catch -variations. Fresh wild groundfish are mainly consumed some distance from the coastal areas which can be reached within 7-8 days. Improvements in the distribution systems as chilled trucks and airplanes, have increased the distribution distance of fresh fish. But the costs increase strongly when airplanes are used (Trondsen 1989). Almost all fresh groundfish consumed in Europe are caught in Europe and most fresh groundfish consumed in the USA are caught in North America. These barriers in the market, limit possible competitors and keep fresh fish on a high price level. Whilst the prices of frozen cod fillet in Europe is dependent on the supply of fillet in both the Atlantic and the Pacific regions, the prices of fresh fish in Europe are mainly dependent on the Atlantic catch.

### *4.7 Segmentation and positioning strategies*

The increased demand and entry of new species have increased the competition in the global groundfish market. To keep the competitive positions, the industries have developed new segmentation and differentiating strategies.

The segments were pollock and hake fillet block have gained foothold at the expense of cod fillet block, are in products like breaded fish sticks. Product labelling strategies have made it difficult for consumers to notice what kind of whitefish is used in fish sticks. Many processors label their products as "whitefish". Such labelling in the low-price market-segments make it possible to introduce frozen fish sticks made from the cheapest groundfish. In some markets for example France, there are regulations that call for labelling of the specific species used as raw material of the fish-sticks. But these labelling-law had no observable effect on the rate of consumption of frozen fillet blocks produced from pollock and hakes.

The high prices of cod fillets compared with pollock and hake fillets, have forced the processors to differentiate these products into market segments which are willing to pay premium prices.

The first step the processors of fish sticks made, was to differentiate fish sticks by labelling the products as fish sticks made from Atlantic cod, Alaskan pollock or hake. The prices of fish sticks processed from alaskan pollock and hake are much lower than those processed from Atlantic cod. Because of this price-difference, the fish sticks processors have been able to focus on different consumer groups with different price and quality preferences related to pollock, hake and cod.

The first step in this direction taken by the primary processors of cod fish block was to reduce the production of block and increase the production of frozen single fillet (IQF or layer-pack).

Frozen single fillets are sold directly to the final user (for instance to the Catering industry) without any further processing. The consumers preference for *natural* products, has favoured the single frozen cod fillets at the expense of breaded products. Especially Iceland has succeeded with this strategy (Geirson & Trondsen 1990).

Another strategy has been to make consumer packs of frozen fillets for supermarket distribution directly from fresh fish. By this production strategy, the primary processors can increase their prices of fillet and secure a bigger share of the value chain.

The increased prices of surimi block due to competition with fillet block, have forced the Japanese surimi industry to lay down several production units for low-priced traditional surimi-based kamaboko products and focus the marketing effort on more high quality and priced products. Higher prices of surimi block has also reduced the growth in the US and European crab sticks-market.

Increased rawfish prices on cod, has also forced the saltfish processors to change. Increased access to chilling facilities and demand for higher quality products have opened up markets for wet-salted codfish with shorter shelf life. Spain and northern Italy are the main markets. In Iceland processors have developed a higher quality saltfish for these markets. This product which is lightly salted and need chilling facilities during distribution, sells for 30 % higher price than traditional saltfish cod in the Portuguese market. So far there are few other processors besides the Icelandic who have succeeded in getting a foothold in the lucrative Spanish saltfish market.

Meals based on dried and salted products demand long preparation time. The main buyers of the products were housewives who had the day available to prepare dinner. Nowadays, women in southern Europe do more and more as women in northern Europe and the US : They find jobs outside home. Everyday food has to be done in short time after work. This change in buying habit, has given incentive for a substantial development of the supermarket sector in Spain, Portugal and Italy. A few saltfish processors have positioned themselves to this segment and offer diluted salt-fish in consumer packs, chilled or frozen through the supermarkets. This kind of products are also able to carry the high prices of the raw material.

New groundfish products have also been introduced into the fresh fish markets. Fresh fillets, skin-packed fillets, modified atmosphere packed fillets and Norwegian made sous vide- fresh products[2] are among new products which are under way to the market place. Common to all these products, are that they need fresh raw fish. This would give all coastal regions absolute competitive advantages on the big consumption regions in central Europe, the USA and Japan.

## 5. CONCLUSIONS

Changes in prices and production of frozen fillets are explained by the changes in total global catch during the 1980's (Figure 1-6).

Prices started to increase due to increased demand. These increased prices gave incentives to increased fishing effort and total catch. But in the 1987/88 the production was so big that the prices started to fall. At the same time, over-exploitation of the Atlantic cod stocks became evident and catch restriction was imposed in Canada, EEC, Iceland and Norway.

When the prices started rising again in 1989, the total catch of groundfish did not increase due to catch-restriction. But the frozen fillet production is kept at a high level because a bigger share of the catch is utilized in frozen fillets. The shortages in supply and high prices of cod-fish opened up the market for cheaper raw fish.

The price-curves on Alaskan pollock and cod block have the same form, but pollock prices are approximately 60 % of the cod price. It indicates that frozen fillet block of cod and pollock are substitutes. Some market segments are willing to pay a premium price for cod even if they can get pollock block at a lower price. This mean that prices influence each other even if the products are sold in different market-segments.

The same substitution and price correlation effect can be found between cod fillet block and hake fillet block.

The increased demand for groundfish products, the acceptance of new species in the market and changed ownership and access to the catching grounds, have also changed the supplying industry. The Japanese, German and British long distance trawler fleet are disorganized. The Polish and Russian fleets are in the process of disorganization. New suppliers of frozen fillets from south America, New Zealand and USA have emerged.

2. Sous vide is French and means *without air* . Pieces of fresh fish is vacuum packed and warmed to 90-100 degree Celsius. The shelf-life of cod can by this method be increased from 10 to 20-30 days and the waste in the cooking process is reduced.

When the demand and production of frozen fillet increased, the supply of raw fish to other products fell. Processors and traders of saltfish, klippfish, stockfish and fresh fish products, had therefor to pay more to be competitive in the rawfish market which affected the prices of other end- products (see also Hanneson 1991). Therefore, prices and production of all groundfish -products are influenced by the total demand, preferences and substitution of all main groundfish-products together with catch production capacity and strategies, natural stock fluctuations and governmental regulations of the groundfish fisheries (see also Johnston, Arnarson and Ziezula 1991).

To defend the price position in the markets the processors of cod-products have developed segmentation strategies. Segmentation and positioning limit the competition and create different prices on groundfish. These strategies rely on absolute, relative and competitive advantages.

Absolute advantages can be found in processing of saltfish, klippfish, stockfish and freshfish :

(i) Cod, tusk, lings and saithe have quality advantages in the saltfish, klippfish and stockfish markets.

(ii) Cod stockfish has an absolute advantage in the drying climate in Norway and Iceland

(iii) Fresh groundfish has a limited shelf-life and quality increases with increased freshness. This gives an absolute advantage for processors near the markets.

In the freezing industry the specialization between block processors and fish sticks processors can be seen as a function of comparative advantages. The fish sticks processors with limited access to fish stocks, have invested in marketing and fish sticks plants which rely on economics of scale. The primary processors in the coastal areas with access to catch, have concentrated their strategy on block and single fillet production.

Increased competition from new species, have given incentives to develop new competitive marketing strategies based on segmentation and product development. We have identified the following new marketing and production strategies in the cod processing industry :

(i) frozen single fillet-products for the catering-market.

(ii) frozen consumerpacks packed from wet fish for supermarkets.

(iii) different pieces of cod fillets (tail, centrecut and loins) for supermarkets and catering

(iv) Light saltfish for the Spanish and Italian market.

(v) Diluted saltfish in consumer packs for European supermarkets

(vi) Vacuum packed fresh fish

(vii) Sous vide packed fresh fish

All this strategies will reduce the competition and sustain price differences between the groundfish products, even if the price-trend interact over time.

It is also interesting to note that the fishing industry, which on the processing side traditional has been very conservative, now have taken use of product-development as an active competition tool. Our observations underscore Porters statement that "the rate and direction of improvement and innovation is a function of attention and effort" (Porter 1990,p83). Limited quotas and increased competition between different species, have changed the direction of innovation in the fishing industry. The attention and effort are changed from the volume of catch and processing of a given product- mix, to improvement of the product-mix based of a limited volume. This change in the direction of innovations has as Porter put it " often results from pressure, necessity, or even adversity" (ibid p49) from the changing market-forces.

## REFERENCES

**Arnarson I. and T. Trondsen** (1990). Groundfish Fisheries in the North-East Pacific. Paper to the fifth IIFET conference, Santiago, Chile.

**Asgeirson A.** (1992). Produktdifferensiering som konkurransestrategi i det europeiske saltfiskmarkedet. (Product differentiation as competitive strategy in the european saltfish market) MA-thesis, the Norwegian Science of Fisheries Science, Universitet i Tromsø

**Cerda R.J. and E. Anderson** (1991). Overview of the Chilian groundfish industry. Landing, processing and marketing. In W.E. Schrank & N. Toy (eds). *Economic Modelling of the World Trade in Groundfish.* p 255-283. Kluwer Academic Publishers, The Netherlands.

**Churchill Jr. and A. Gilbert** (1983). *Marketing Research. Methodological Foundations.* The Dryden Press, New York

**Geirson M. and T. Trondsen** (1991). Frozen cod products in the US market. In W.E. Schrank & N. Roy (eds). *Economic Modelling of the World Trade in Groundfish.* p 189-210. Kluwer Academic Publishers, The Netherlands

**Hanneson R.** (1991). The Norwegian supply of Groundfish with emphasis on the supply of frozen fillets to the United States. In W.E. Schrank & N. Roy (eds). *Economic Modelling of the World Trade in Groundfish.* p 355-362. Kluwer Academic Publishers, The Netherlands.

**Johnston R.S., I. Arnarson and J. Ziezula** (1991). Extended Fishery Jurisdicion and the internationalization of groundfish market channels. In W.E. Schrank & N. Roy (eds). *Economic Modelling of the World Trade in Groundfish.* p 127-137. Kluwer Academic Publishers, The Netherlands.

**Mazany R.L. Arnett and Apostle** (1987). Market segmentation : Nova Scotia fish processing and the U.S. Market. *Marine Policy* **11 :** 29-44

**Ottesen G.** (1982). En vurdering av attraktivitet ved salg av blokkbaserte fiskeprodukter til supermarkedskjeder i EF. (An analyses of attractiveness for sale of white fish products based on frozen fish blocks to EC supermarket chains) MA-thesis, the Norwegian Science of Fisheries Science,University of Tromsø.

**Porter M.E.** (1980). *Competitive Strategy : Techniques for Analysing Industries and competitors.* The Free Press., New York

**Porter M.E.** (1985). *Competitive Advantage ; creation and sustaining superior performance.* The Free Press, New York.

**Porter M.E.** (1990). *Competitive Advantages of Nations.* The Macmillan Press Ltd. London.

**Trondsen T.** (1989). Transport of fresh fish in modified atmosphere. Report Forut, Tromsø.

**APPENDIX 1**

GROUNDFISH SPECIES USED IN THE ANALYSES :

Alaska pollock

Codfish

- Atlantic Cod
- Pacific Cod
- Haddock
- Atlantic Pollock (Saithe)
- Whiting
- Hoki
- Tusk
- Ling
- Argentine (Silver smelt)

Hakes

Redfish (sebastes)

- Atlantic redfish
- Pacific redfish
- Cape redfish
- Orange Roughy

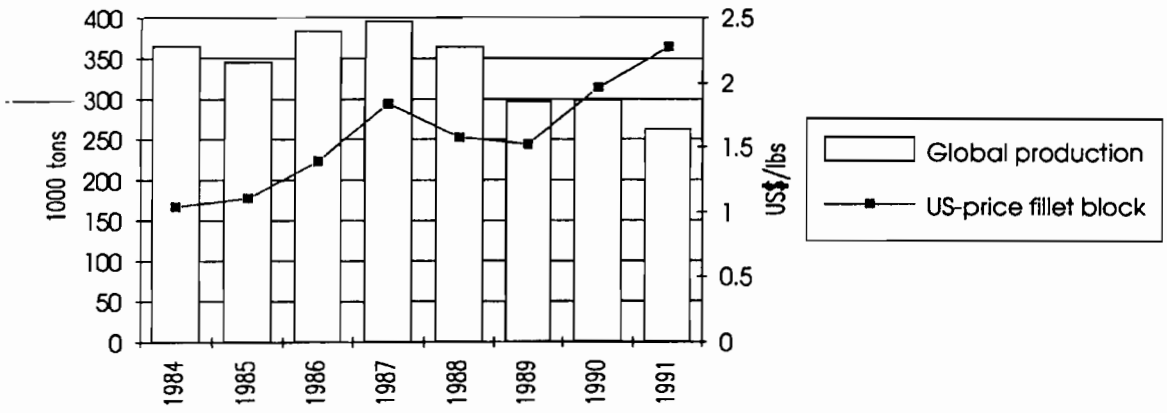
Flatfish

- flounder
- sole
- plaice
- dab
- halibut
- turbot

Warm water groundfish

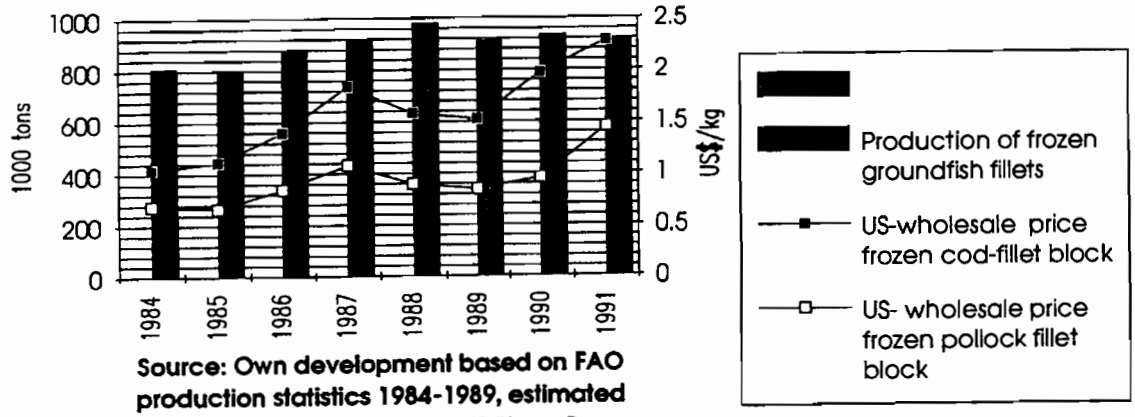
- Catfish
- Dories
- Groupers
- Seabass'
- Snappers
- Croakers
- Seabream
- Kingklip
- Lingcod
- Sablefish

FIG. 1.
FROZEN COD FILLETS GLOBAL PRODUCTION AND US WHOLESALE PRICE.



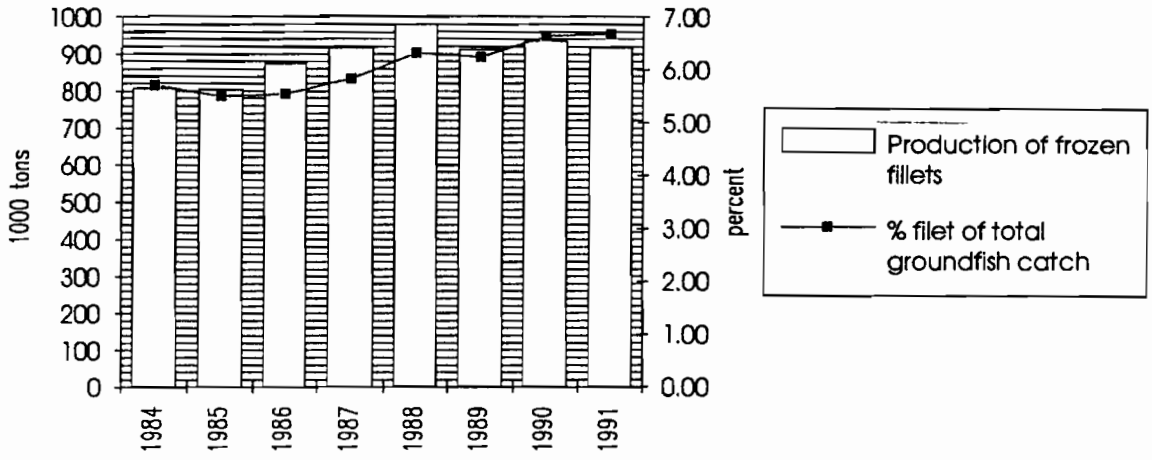

Source: Own development, based on FAO production statistics and NMFS/Urner Barry price information

FIG. 2.
FROZEN GROUNDFISH FILLETS GLOBAL PRODUCTION AND PRICES OF COD AND POLLOCK FILLETS.



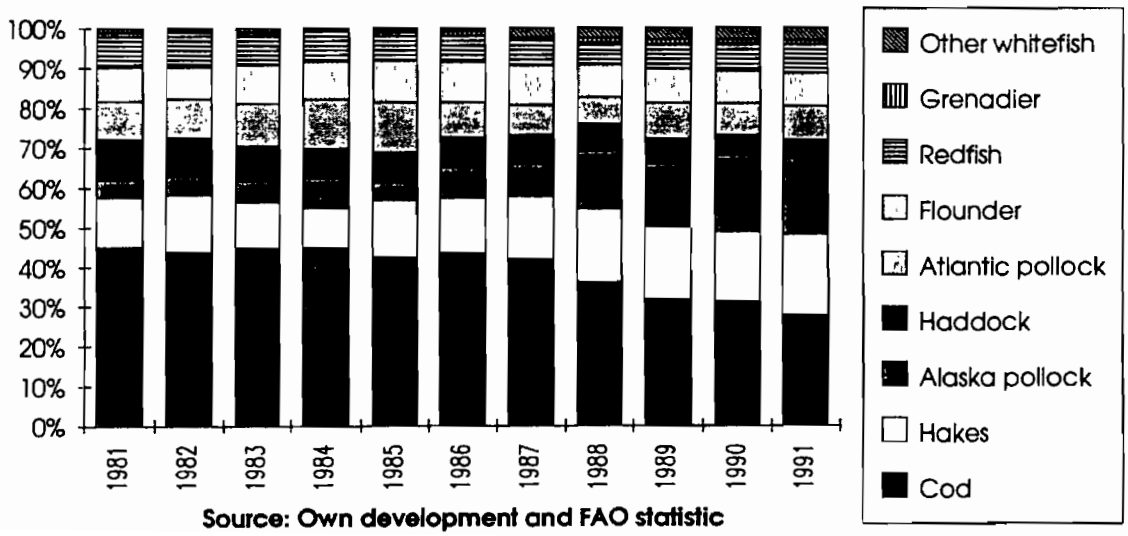

Source: Own development based on FAO production statistics 1984-1989, estimated production 1989-91 and NMFS/Urner Barry price information

FIG. 3.
GLOBAL PRODUCTION OF FROZEN GROUNDFISH FILLETS.



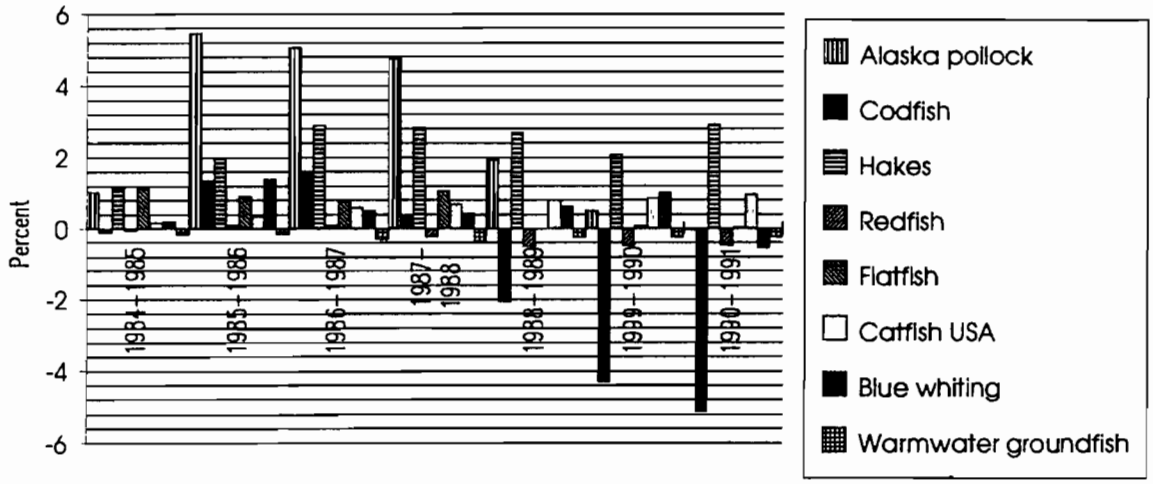

Source: Own development from FAO statistics 1984-1989 and estimated production 1990-1991

FIG. 4.
GLOBAL PRODUCTION OF FROZEN FILLET FROM GROUNDFISH.



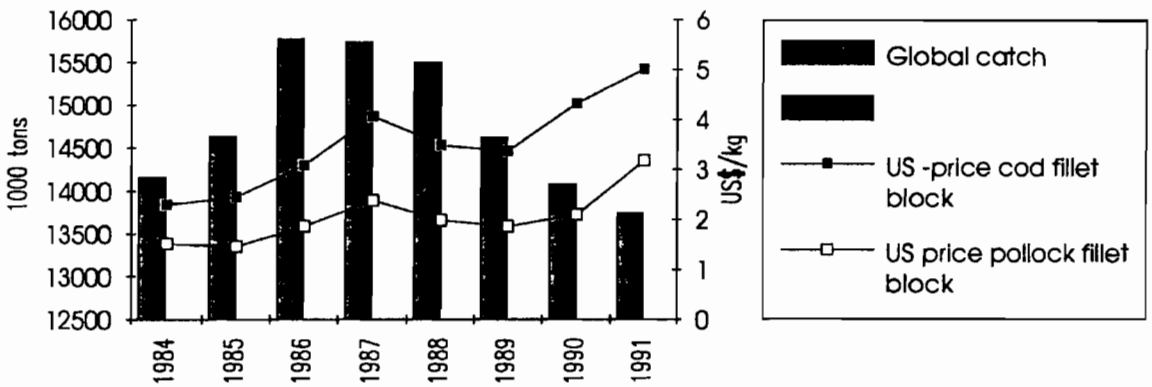

Source: Own development and FAO statistic

FIG. 5.
CHANGE IN CATCH OF GROUNDFISH-SPECIES (TOTAL CATH 1984 = 100).



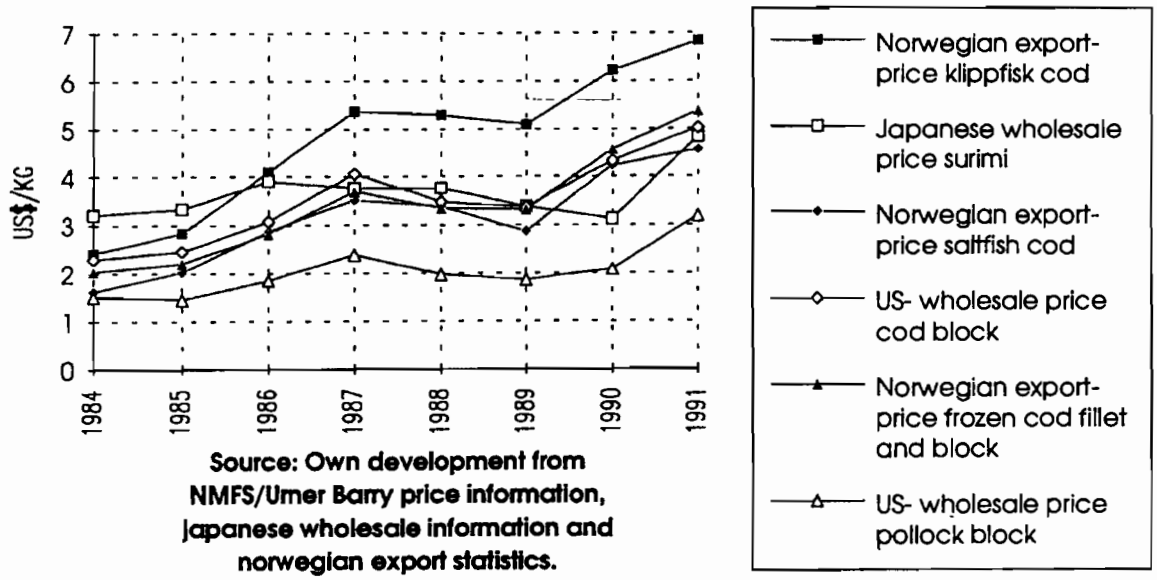

Source: Own development

FIG. 6.
GLOBAL CATCH OF GROUNDFISH AND US-WHOLESALE PRICES OF COD AND POLLOCK FILLET BLOCKS.



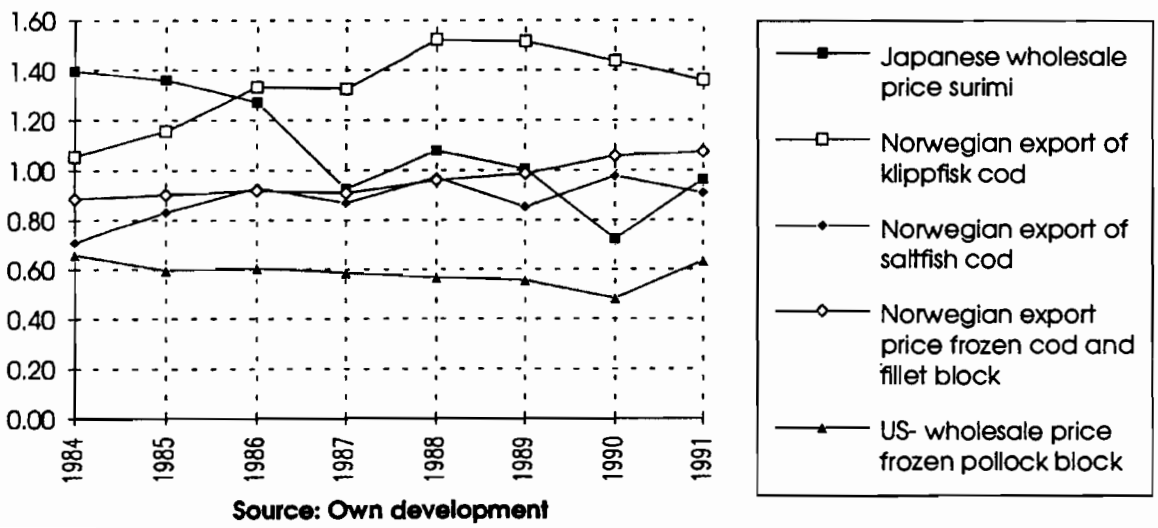

Source: Own development, based on FAO catch statistics 1984-1989, catch 1989-91 from different sources and NMFS/Urner Barry price informations.

FIG. 7.
PRICE-FLUCTUATION GROUNDFISH PRODUCTS.




Source: Own development from NMFS/Urner Barry price information, Japanese wholesale information and norwegian export statistics.

FIG. 8.
RELATIVE PRICES GROUNDFISH PRODUCTS WHERE US PRICE FROZEN COD FILLET BLOCK = 1.




Source: Own development

# The Icelandic Cod Trade : An Econometrically Based Simulation Model

**Ragnar Arnason [a] and Tryggvi Felixson[b] ***

[a]University of Iceland, Dept of Economics, 101 Reikjavik, Iceland

[b]Nordic Council of Ministers, Store Standstraede 18, DK 1255 Copenhagen, Denmark

ABSTRACT

*This study is a part of the Global Groundfish Market Research Group efforts to model the world groundfish trade. An econometrically based simulation model of the Icelandic Cod trade is developed. The model is basically structured as a collection of supply and demand relationships determining the production of various cod products, their subsequent supply to different international markets and the resulting market prices. The model, more precisely, explains the allocation of the icelandic cod catch to the freezing and saltfish production process as well as the export of fresh fish. The model comprises four markets for icelandic cod products - the fresh cod markets in the United Kingdom, the markets for frozen cod blocks and fillets in the United States and the United Kingdom and saltfish products to Spain and Portugal.*

*Altogether the model contains 43 equations. Most of these are identities of various kinds but there are 14 "behavioural" equations that have to be estimated with econometric methods. The demand equations are expressed in a price dependant form. Preliminary simulations indicate a strong negative relationship between the cod catch and the market price of cod products. Personal income variations in main market areas also appear to have a major impact on cod prices.*

## 1. INTRODUCTION

This paper reports on an ongoing work on developing an econometrically based simulation model of the Icelandic cod trade. This type of modelling obviously incorporates two distinct but related activities. The first concerns the estimation

* We would like to gratefully acknowledge the financial support of Vísindasjóður (The Icelandic Science Fund) and the excellent research assistance of Sigurgeir B. Kristgeirsson and Magnús Skúlason.

of the model. This involves the estimation of the relationships determining the production of various cod products, their subsequent supply to markets and the associated market prices.The second activity concerns the construction of a simulation model to predict the evolution of the endogenous variables in response to exogenous shifts.

The model consists essentially of a number of supply and demand relationships. It contains 43 equations. Most of these are identities of various kinds. There are, however, 14 "behavioural" equations that have to be estimated with econometric methods. The demand equations are expressed in a price dependent form. Preliminary simulations indicate a strong negative relationship between the cod catch and the export price of cod products. Personal income variations in main market areas also appear to have a major impact on cod prices.

As mentioned above, the model is still under development. In particular, as should be clear from what follows, the statistical estimation process is far from complete. Consequently, this paper should be regarded as progress report.

The paper is divided into 5 main sections. The following section provides a brief overview of the markets for North-Atlantic cod and the production and exports of Icelandic cod products. The next section contains a description of the essential structure of the model followed by a section on the estimation of the model relationships. Finally, some simulations results are presented in section 5.

## 2. CATCH, PRODUCTION AND EXPORTS OF COD PRODUCTS

The average annual catch of cod in the North-Atlantic has in recent years been around 2 million MT (metric tonnes). Iceland is one of the largest harvesters of North-Atlantic cod with about 1/5 of total landings. Thus, of the 1.97 million MT of North-Atlantic cod landed in 1988 Iceland caught 18 %, Canada 24 %, Norway 13 %, United Kingdom 5 % and Denmark 5 %[1]. Slightly more than 1/3 of the cod catch is marketed as frozen products, about 30 % is salted and 30 % is consumed fresh[2]. About 56 % of the total catch of Atlantic cod is consumed within the European Community where Britain stands for the largest share[3]. The second most important market is the United States, where the total consumption of cod is almost the same as in Britain (but considerably less per capita). Portugal and Spain constitute by far the largest markets for salted cod.

Thus, the main markets for Atlantic cod products are in the economically most advanced regions of the world with a strong transportation and communication infrastructure. As a result, cod products are traded in a highly integrated and efficient markets[4]. It should be noted, that Iceland's share in the total supply, although substantial, does not provide the country with a dominant position in the cod trade.

### *2.1 The process allocation of the Icelandic cod catch*

The annual Icelandic groundfish catch has in recent years been about 600.000 tons. About 60 % of this has been cod, 8 % haddock, 10 % saithe and 13 % redfish. Table 1. shows the evolution of the total cod catch and its allocation to different processes.

According to the information contained in Table 1, the share of the freezing industry in the cod catch declined from about 60 % in 1972 to a record low of 34 % in 1982, but has recovered to 40-50 % in recent years. The emergence of freezer trawlers, that process and freeze the catch on board, may explain this increase. Quarterly figures reveal that, while the cod catch is greater in the first half of the year, the fraction of the catch that is allocated to the freezing industry is greater in the latter half of the year that the first. This is probably due to the economic importance of maintaining a reasonably steady operating rate in the freezing plants.

1. See OECD, Review of Fisheries.
2. See e g. FAO's Globefish databank, World Fisheries data Center, Memorial University, Newfoundland.
3. See OECD, Review of Fisheries.
4. For a more complete discussion on this see Johnston (1991).

The share of fresh cod in the total catch show a rather dramatic increase during the period from 1971. Until 1980 very negligible amounts of cod was exported fresh[5]. From 1980 exports of fresh cod have increased steadily to reach 15 % of the total cod catch in 1989.

Stockfish constitutes most of the other processes listed in Table 1. The Nigerian stockfish market was accessible for a period of five years from 1978 yielding high profit to the stockfish process and a dramatic increase in stockfish production. Since 1983 this market has been largely closed, and the stockfish process has contracted again.

Compared to the other processes, the share of the cod catch allocated to the saltfish process has been fairly steady during the period since 1971 with an average share of 39 %. Table 1., however, shows a sudden jump in this share to 47 % in 1982. This increase can be explained by the unforeseen closing of the Nigerian stockfish market at the time of strong cod catches. As stockfish and saltfish are relatively easily substitutable in production a good deal of the cod catch originally intended for the stockfish process was diverted to the saltfish process.

The information contained in Table 1 shows substantial variability in the allocation of the Icelandic cod catch to processes. A major objective of this study is to explain these fluctuations in terms of exogenous variables.

### *2.2 Export of Cod Products*

In 1990 the total value of seafood exports from Iceland was about 1.3 billion USD. Cod products constituted 42 % of this export.

The most important markets for Icelandic cod products are Great Britain (UK), Spain, Portugal and the United States (US). In 1990, UK accounted for 1/3 of the total value of cod exports from Iceland, the South-European countries, mostly Spain and Portugal accounted for 30 % and the remaining EC countries for 21 %[6]. It should be noted, in this context, that some of Iceland's cod exports to Britain are later re-exported to other EC countries. The US received about 16 % of the Icelandic cod exports in 1990.

As previously mentioned the US, UK, Spain and Portugal provide the most important markets for North-Atlantic cod. Broadly speaking, the US and the UK constitute the import markets for frozen cod products, Spain and Portugal for saltfish and the UK for fresh cod.

The UK and the US import approximately the same quantity of frozen Atlantic cod products ; about 100.000 MT annually. In fact, the consumption of frozen Atlantic cod products in these two markets amounts to some 80 % of the total world consumption. This quantity represents about 30 % of the total annual North-Atlantic cod catch. The market share of Icelandic cod producers has been about 20-25 % in both markets.

The model to be described below differentiates between the export of frozen cod fillets and blocks to the US and the UK. Table 2 shows the relative shares of these two markets in the Icelandic exports. over the last 10 years.

As shown in Table 2, the US market has accounted for about 60 % of the total export of frozen cod blocks and 57 % of frozen cod fillets over the last 10 years. Corresponding numbers for the UK market are 25 % and 39 % respectively. The importance of the US market has declined dramatically since 1981. At the beginning of the period the US market account for 62-70 % of the frozen cod exports. In 1990, the US market accounted for only 24-38 % of these exports.

The UK receives almost all the frozen fillets exported to the European market. The share of UK in cod block exports has declined slightly in recent years due to an increase in block exports to France.

## 3. THE MODEL : ESSENTIAL STRUCTURE

As explained above, Icelandic cod products constitute a significant fraction of the total supply in the respective markets. For this reason, the market prices of cod products are undoubtedly dependent on the total Icelandic supply, although individual fish processing firms may well be justified in regarding them as exogenous to their own supply. It follows that a reasonably complete model of the trade in Icelandic cod products must include both supply and demand relations.

5. These statistics ignore direct landings of cod from Icelandic fishing vessels abroad.
6. This and the following export statistics are obtained from the publications of the Icelandic Statistical Bureau.

### *3.1 Supply*

To model the supply of Icelandic cod products it is necessary to have a certain understanding of the structure of the fishing industry. The essentials of this structure are as follows :

The fishing industry is characterized by numerous relatively small firms exhibiting a high degree of vertical integration in the harvesting and processing sectors and a few large organizations in the marketing sector. There are no dominant firms in harvesting and processing. In fact, apart from the marketing sector, there is little horizontal integration in the fishing industry. The revenues of the largest firms is close to 4 % of total industry revenues. The marketing organizations, on the other hand, are large relative to the size of the industry. They are not independent firms, however. They are owned by the processing firms and exist only to serve the marketing needs of the processing sector.

The typical firm in the fishing industry is based in one fishing village or town. The firm operates one or more processing plants that are capable of producing one or more of the basic output categories ; frozen, saltfish and stockfish products. The firm also runs one or more fishing vessels that usually supply most of its wetfish[7] needs. Additional needs are met by purchasing fish from independent vessels usually on the basis of implicit or explicit long term contracts. In fact, in most smaller fishing towns, the fish processing firms customarily purchase whatever volume of fish supplied by local vessels. Finally, the products are marketed by the appropriate market organization to which the firm belongs.

The key players in the supply process, therefore, are the fish processors. In the short run the fish processors have little control over the quantity of catch they process[8]. This depends largely on fishing conditions and the number of fishing vessels operated by the processor and those with which they have made a long term catch purchase contract. Given the exogenous catch quantity, the fish processors must allocate this catch to processes. This they do on the basis of relative processing costs and the prices they expect the products to fetch on the export markets.

Given the processed products, the fish processors must make decisions concerning the supply of products to markets. This they presumably do on the basis of existing relative market prices, storage and transport costs. It should be noted, however, that in the allocation of products to markets the processors are constrained by the previous processing decisions. The reason is that not all cod products are suitable for all markets. In fact, most of the products are specialized for certain markets. Thus, for instance, once cod has been turned into certain salted products there is basically only one market, i.e., Portugal/Spain.

Thus, the fish processors essentially make two decisions. First, the allocation of cod catch to processes and second, the supply of products to markets. The essential structure of this supply process is further illustrated in the figure 1.

Assuming profit maximization the aggregate process allocation equations take the form :[9]

$$q(i) = Q(q, \mathbf{p}, \mathbf{w}, \mathbf{z}, u(i)), \text{ all } i, \tag{1}$$

where q(i) denotes the allocation of cod catch to process i and q represents the total cod catch,
**p** the vector of product prices,
**w** the vector of input costs,
**z** other relevant variables and
u(i) a stochastic disturbance term.

Similarly, the market supply equations are specified broadly as :[10]

$$s(i, j) = S(q(i), \mathbf{p}, \mathbf{w}, \mathbf{z}, u(i, j)), \text{ all } i \text{ and } j, \tag{2}$$

where s(i, j) denotes the supply of product i to market j,
q(i) is as before the allocation of cod catch to process i,

7. I.e. landed catch.
8. At least not during the period under study.
9. These process allocation functions are basically derived demand functions whose derivation is fairly standard in elementary micro-economic textbooks. See e.g. Varian (1984).
10. The derivation of these supply functions is also a standard exercise in micro-economic textbooks. See e.g. Varian (1984).

the vector **p** represents product market prices,
**w** costs
**z** other relevant variables and
u(i, j) a stochastic disturbance term. It should be noted that the vector **p** contains the product prices specified in expression (1) above.

Equations (1) and (2) are theoretical derivations. In the estimation procedure, the set of explanatory variables is severely constrained by data availability. In addition it turns out that many of the available explanatory variables are not in fact statistically significant. Therefore, the final estimated equations differ from the general form above and vary a good deal across markets and products.[11]

### *3.2 Demand*

In this paper, demand is modelled in a fairly simplistic way. Three market areas are considered Ê the UK market, the US market and the Portugal/Spain market Ê and four cod products Ê fresh, frozen fillets, frozen cod blocks and salted cod. Together these 3 markets account for well over 90 % of Iceland's cod exports of the respective products. Consequently, due to trading arbitrage, the prices in these markets seem plausible representatives for the available prices for the respective products.

The fundamental demand relation employed is as follows :[12]

$$p(i, j) = P(\mathbf{q}(j), \mathbf{y}(j), \mathbf{p}(j), \mathbf{z}(j), u(i, j)), \text{ all i and j} \quad (3)$$

where p(i,j) refers to the price of cod product i to market j.
The vector **q**(j) represents the quantity of cod products in market j,
**y**(j) is a vector of income variables in market j.
p(j) and **z**(j) are vectors of other relevant prices and variables in market j.
Finally u(i, j) is a stochastic disturbance term for product i in market j.

As in the case of the supply functions specified above, the inverse demand functions in (3) are theoretical constructs. Due to data constraints and statistical considerations, the estimated demand equations differ somewhat from equations (3).[13]

### *3.3 The Model as a Whole*

The complete model consists of 43 equations. Most of the equations are either definitions or technical or numerical identities. There are, however, 14 "behavioural" equations that have to be estimated with statistical methods. These equations correspond to equations (1)-(3) above, describing the allocation of catch to processes, the supply of products to markets and the adjustment of market prices to supply and other factors.

The model equations are listed in Appendix 1.

## 4. ESTIMATION

The model contains, as discussed above, 14 estimation equations. There are 2 estimation equations describing the allocation of cod catch to processes. Due to the summing-up constraint the third allocation equation does not have to be estimated. There are 5 equations describing the exports of cod products to markets. Again, summing-up constraints reduce the number of independent equations to be estimated. Finally, there are 7 price equations, one for each market and one basic cod price equation. These equations are listed in Appendix 1.

11. The estimated supply equations are given in the Appendix 2.
12. Derivation of this type of an inverse demand function from first principles can be found in most micro-economic textbooks. See e.g. Varian (1984).
13. The estimated price equations are given in the Appendix 2.

The estimation was based on quarterly time series observations on the relevant variables for the period 1981-1990. However, as the length of the available data series differed from one variable to another, the actual number of data points used in the estimation of individual equations ranges from 20 to 39.

The functional forms employed are mostly the linear and logarithmic[14]ones. These forms are, of course, not satisfactory from a theoretical point of view. One obvious reason is that some of the dependent variables are ratios that are supposed to be constrained to the interval [0,1]. This restriction, however, is not satisfied by the linear and logarithmic functional forms although, as it turned out, they fitted the available observations reasonably well. Further estimation work employing the multiple logistic or logit functional form[15] is currently underway.

The estimation methods are also, at this stage of the work, somewhat unsophisticated. The main estimation method is Ordinary Least Squares (OLS) and variants thereof. It is clear that for this task the OLS estimator does not coincide with the Maximum Likelihood one. Among other things, the OLS estimator ignores the fact that several of the estimation equations contain endogenous explanatory variables variables. Consequently, the resulting estimates are in general inconsistent. It may be noted, however, that estimation of the model using statistically more appropriate estimation techniques [16] did not materially affect the parameter estimates. It follows that the numerical results of the simulation experiments reported in the next section are not much affected by the use of a more sophisticated estimation technique.

The OLS estimation results and some relevant statistics are presented in Appendix 2. Note, however, that although the parameter estimates appear reasonably reliable the same does not necessary apply to the other statistics not least the t and Durbin-Watson statistics.

## 5. SIMULATIONS

The main objective of this work is to construct a model that can be used to predict the effects of exogenous changes on the pattern and evolution of the Icelandic cod trade. For this purpose, a special computer simulation model has been developed based on the cod trade model and the parameter estimates discussed in previous sections.

To illustrate its workings of this simulation model, the following 4 exogenous shifts are considered :

1 : 10 % increase in Icelandic cod catch.
2 : 10 % reduction in the exchange value of the USD.
3 : 5 % increase in Icelandic real wage rates.
4 : 5 % increase in real personal income in all cod market areas.

In all cases the exogenous shift occurs in period 1 and the respective exogenous variable remains at the new level henceforth.

### *5.1 Run 1 : The Icelandic catch increased 10 %*

In simulation 1, the Icelandic cod catch is assumed to increase by 10 %. The simulated effects of this shift calculated as deviations from the base case (where no such shift occurs) are given in the Table 3.

It is interesting to note that, according to this simulation, an increase in the cod catch reduces the share of the freezing industry in the cod processing but increases that of the other processes. The reason is due to a combination of comparatively more stringent capacity constraints in freezing and the price elasticity with respect to supply in the respective markets. Notice that the share of the freezing industry in cod processing is reduced less than the increase in catch. Hence the actual quantity processed is increased.

It is also interesting that the value of cod exports increase less than the increase in the catch. This, no doubt is due to the export price elasticity and the allocation of a larger share of the catch to lower priced products.

14. Sometimes also referred to as the log-log or Cobb-Douglas form.
15. See e.g. Theil (1969).
16. I e , 2SLS and 3SLS.

Finally, it should be noted that the adjustment dynamics of an increase in the cod catch are quite long, requiring over 5 years to reach an equilibrium.

### *5.2 Run 2 : US dollar exchange rate reduced by 10 %*

In this simulation the USD exchange rate drops by 10 %. The simulated effects of this change are listed in Table 4.

According to these simulations, a reduction in the exchange rate of the USD, not surprisingly, reduces the price in IKR for frozen products. Consequently, it shifts cod production away from frozen products and reduces the US share in the exports of frozen cod products. Notice, however, that there is also a change in the combination of export of frozen products to the US with frozen block actually increasing its relative share although not volume. This is probably due to a comparatively high price elasticity of frozen block demand relative to that of frozen fillets.

Notice also that although the US is a very important market for Icelandic cod products, substitution in production and exports markets largely eliminate effects of USD currency changes on the total value of cod exports.

### *5.3 Run 3 : Icelandic Wage rates increased by 5 %*

Let us now consider the effects of an increase in the real Icelandic wage rate of 5 %. This, obviously affects the production economics and, consequently, the pattern of cod production and trade. The simulation results are illustrated in Table 5.

The simulation results reported in Table 5 show that an increase in the Icelandic wage rate shifts the cod production mix away from the freezing and fresh/other processes to saltfish production. This is readily understandable as the saltfish process is the least labour intensive of the three. The saltfish price is reduced but, the prices of the other products does not rise. As expected there is no shift in the allocation of frozen products to the two main markets. Finally, the increase in the Icelandic wage rates leads to a small reduction in the total value of cod exports. This is due to the shift to saltfish and the consequent drop in its price.

### *5.4 Run 4 : Personal income in export markets increased by 5 %*

In this simulation the effects of a 5 % increase in personal income in the market areas is considered. This may affect the Icelandic cod trade via the income term in some of the demand functions. The simulation results are listed in Table 6.

The simulation results in Table 6 indicate a quite pronounced positive income elasticity of the Icelandic cod trade. As income in the cod markets rises there is a substantial increase in the price of frozen and saltfish products. Consequently a higher fraction of the cod catch is allocated to saltfish and, in particular, frozen products. There is also a substantial increase in the value of the cod exports. In fact, elasticity of the value of cod exports with respect to disposable income in the market areas exceeds unity.

## 6. CONCLUSIONS

The model described in this paper is in many respects inadequate. In particular, it is clear that there is a need for considerable improvements in the statistical part of the model. This applies not only to the parameter estimates discussed at some length above, but also to the stochastic properties of the simulation model. At the moment, the simulation model is entirely nonstochastic. However, the stochastic features of the data generating process revealed by the econometric estimation process could be used to add the appropriate stochasticity to the simulation model. In this way, simulations could include estimates of the probability distributions of the outcomes and the associated statistics.

As mentioned at the outset, the paper reports on work still in progress. The plan is to continue to improve the model *inter alia* along the lines suggested above. The progress made so far, however, appears to demonstrate the feasibility of constructing medium-scale fish trade models capable of seemingly reasonable predictions.

## REFERENCES

**Theil H.** (1969). A Multinomial Extension of the Linear Logit Model, *International Economic Review* **10** : 382-94.

**OECD** (1990). *Review of Fisheries*, OECD, Paris.

**Johnston R.** (1991). Extended Fisheries Jurisdiction and the Internationalization of Groundfish Markets and Channels. In W.E. Schrank (ed.) *Econometric Modelling of the World Trade in Groundfish*, Kluwer.

**Varian H.** (1984). *Microeconomic Analysis*, Norton.

**TABLE 1.**
**THE ALLOCATION OF THE ICELANDIC COD CATCH.**

Table 1.
**The allocation of the Icelandic cod catch**

| Year | Catch 1000 MT | Allocation to processes: Frozen % | Salted % | Fresh % | Other % |
|---|---|---|---|---|---|
| 1971 | 255 | 60,3 | 34,9 | - | 4,8 |
| 1972 | 229 | 54,3 | 41,1 | - | 4,6 |
| 1973 | 237 | 50,5 | 42,3 | - | 7,2 |
| 1974 | 242 | 47,8 | 45,5 | - | 6,7 |
| 1975 | 266 | 51,5 | 44,7 | - | 3,9 |
| 1976 | 284 | 52,8 | 37,9 | - | 9,3 |
| 1977 | 330 | 54,5 | 36,4 | - | 9,0 |
| 1978 | 320 | 60,8 | 32,6 | - | 6,5 |
| 1979 | 360 | 56,3 | 32,0 | - | 11,7 |
| 1980 | 429 | 46,9 | 33,6 | 5,2 | 14,3 |
| 1981 | 461 | 35,8 | 38,3 | 3,8 | 22,1 |
| 1982 | 382 | 34,4 | 47,0 | 3,7 | 14,9 |
| 1983 | 294 | 47,7 | 44,5 | 4,3 | 3,5 |
| 1984 | 282 | 55,4 | 35,6 | 6,1 | 2,9 |
| 1985 | 323 | 48,6 | 39,4 | 9,7 | 2,3 |
| 1986 | 366 | 47,2 | 37,1 | 14,2 | 1,5 |
| 1987 | 390 | 42,9 | 41,2 | 13,4 | 2,5 |
| 1988 | 376 | 42,6 | 41,0 | 14,2 | 2,2 |
| 1989 | 354 | 43,9 | 37,5 | 15,0 | 3,6 |
| 1990 | 333 | 51,1 | 31,8 | 12,4 | 4,7 |
| Average: | | | | | |
| 1971-90 | 325 | 49,3 | 38,7 | | 12,0 |
| 1971-79 | 280 | 54,3 | 38,6 | | 7,1 |
| 1980-90 | 363 | 45,1 | 38,8 | 9,3 | 6,8 |
| 1980-83 | 392 | 41,2 | 40,8 | 4,2 | 13,8 |
| 1986-90 | 364 | 45,5 | 37,7 | 13,8 | 3,0 |

Source: Fiskifélag Íslands

**TABLE 2.**
**EXPORTS OF FROZEN COD PRODUCTS.**

Table 2
**Exports of frozen cod products**

| Year | Total block Tonnes | Total fillet Tonnes | Block USA % | Block UK % | Fillet USA % | Fillet UK % |
|---|---|---|---|---|---|---|
| 1981 | 19060 | 35215 | 62 | 25 | 70 | 29 |
| 1982 | 11834 | 30784 | 76 | 14 | 62 | 33 |
| 1983 | 13799 | 28312 | 73 | 18 | 68 | 31 |
| 1984 | 16883 | 28250 | 81 | 10 | 66 | 34 |
| 1985 | 17183 | 38745 | 77 | 15 | 61 | 38 |
| 1986 | 16859 | 40931 | 76 | 18 | 55 | 43 |
| 1987 | 10371 | 42376 | 61 | 30 | 53 | 40 |
| 1988 | 14874 | 34272 | 42 | 42 | 50 | 43 |
| 1989 | 17015 | 35931 | 47 | 39 | 52 | 39 |
| 1990 | 22975 | 35975 | 24 | 38 | 36 | 52 |
| Average | | | 60 | 25 | 57 | 39 |

Source: National Economic Institue

**TABLE 3.**
**COD CATCH INCREASED BY 10 %. PERCENTAGE DEVIATIONS FROM BASE CASE.**

Table 3
**Cod catch increased by 10%**
Percentage deviations from base case

| | 1. year | 2. year | 3. year | 4. year | 5. year |
|---|---|---|---|---|---|
| **Allocation:** | | | | | |
| Freezing | -4,0 | -3,3 | -3,2 | -3,2 | -3,2 |
| Salting | 0,3 | 0,7 | 0,9 | 1,0 | 1,1 |
| Fresh/Other | 9,2 | 6,2 | 5,7 | 5,6 | 5,7 |
| **Price:** | | | | | |
| Frozen | -0,5 | -1,4 | -1,9 | -2,3 | -2,5 |
| Salted | -1,1 | -3,4 | -4,3 | -4,8 | -5,1 |
| Fresh | -0,7 | -1,5 | -1,9 | -2,2 | -2,4 |
| **USA share in cod exports:** | | | | | |
| Fillets | -1,2 | -1,4 | -1,4 | -1,4 | -1,4 |
| Block | -0,2 | -0,5 | -0,7 | -0,8 | -0,9 |
| **Value of cod exports** | 9,0 | 7,9 | 7,1 | 6,7 | 6,5 |

TABLE 4.
US DOLLAR EXCHANGE RATE REDUCED BY 10 %. PERCENTAGE DEVIATIONS FROM BASE CASE.

Table 4
**US dollar exchange rate reduced by 10%.**
Percentage deviations from base case

| | 1. year | 2. year | 3. year | 4. year | 5. year |
|---|---|---|---|---|---|
| **Allocation:** | | | | | |
| Freezing | -1,9 | -1,7 | -1,6 | -1,6 | -1,6 |
| Salting | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Fresh/other | 4,8 | 3,8 | 3,7 | 3,8 | 4,0 |
| **Price:** | | | | | |
| Frozen | -2,6 | -2,0 | -2,0 | -2,0 | -2,0 |
| Salted | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Fresh | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| **USA share in cod exports:** | | | | | |
| Fillet | -1,0 | -0,9 | -0,9 | -0,9 | -0,9 |
| Block | 1,1 | 0,6 | 0,6 | 0,6 | 0,6 |
| **Value of cod exports** | -0,9 | -0,7 | -0,7 | -0,8 | -0,8 |

TABLE 5.
ICELANDIC WAGE RATE INCREASED BY 5 %. PERCENTAGE DEVIATIONS FROM BASE CASE.

Table 5
**Icelandic wage rate increased by 5%**
Percentage deviations from base case

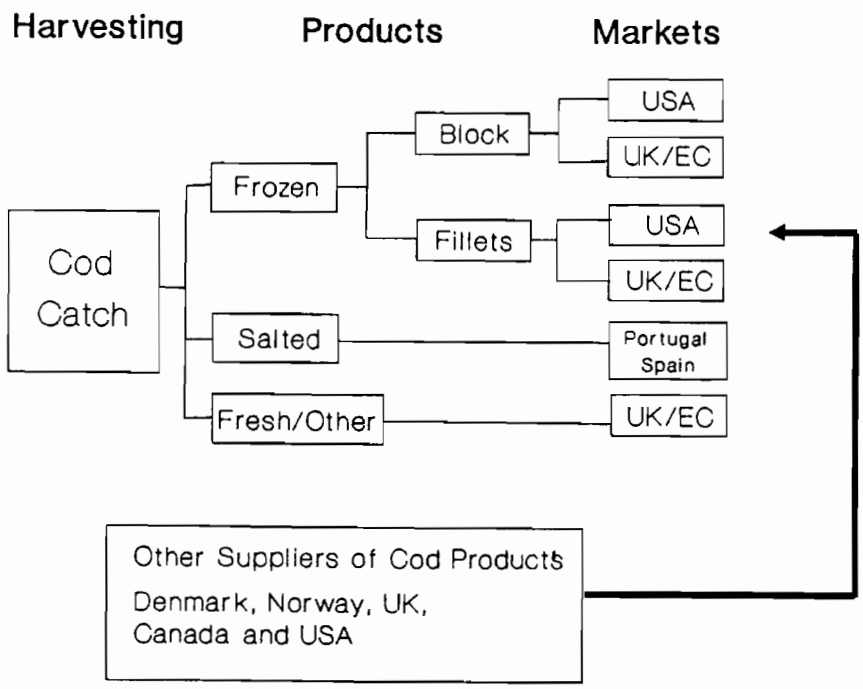
| | 1. year | 2. year | 3. year | 4. year | 5. year |
|---|---|---|---|---|---|
| **Allocation:** | | | | | |
| Freezing | -1,4 | -1,2 | -1,1 | -1,1 | -1,1 |
| Salting | 2,4 | 2,4 | 2,4 | 2,4 | 2,4 |
| Fresh/other | -1,6 | -1,9 | -1,8 | -1,8 | -1,7 |
| **Price:** | | | | | |
| Frozen | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Salted | -0,2 | -0,5 | -0,5 | -0,5 | -0,5 |
| Fresh | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| **US share in cod exports:** | | | | | |
| Fillets | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Block | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| **Value of cod exports:** | -0,2 | -0,2 | -0,2 | -0,2 | -0,2 |

**TABLE 6.**
**PERSONAL INCOME IN EXPORT MARKETS INCREASED BY 5 %. PERCENTAGE DEVIATIONS FROM BASE CASE.**

Table 6
**Personal income in export markets increased by 5%**
Percentage deviations from base case

| | 1. year | 2. year | 3. year | 4. year | 5. year |
|---|---|---|---|---|---|
| **Allocation:** | | | | | |
| Freezing | 2,9 | 3,7 | 3,7 | 3,7 | 3,6 |
| Salting | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 |
| Fresh/other | -8,5 | -9,5 | -9,5 | -9,8 | -10,0 |
| **Price:** | | | | | |
| Frozen | 6,5 | 7,8 | 7,9 | 7,9 | 7,8 |
| Salted | 3,6 | 4,8 | 5,0 | 5,0 | 5,0 |
| Fresh | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| **US share in cod exports:** | | | | | |
| Fillets | 0,6 | 1,1 | 1,2 | 1,2 | 1,2 |
| Block | -9,7 | -11,7 | -11,7 | -11,7 | -11,7 |
| **Value of cod exports:** | 4,9 | 6,0 | 6,1 | 6,2 | 6,3 |

**FIG. 1.**
**ESSENTIAL MODEL STRUCTURE.**



# Appendix 1: Model equations

The following lists the equations of the model and defines the respective variables.

## I. Process allocations (ratios)

| | | | |
|---|---|---|---|
| Eq. 1 | R1=F1(CA,PSPF, WPF,S3,S4,D86) | Freezing | Estimated |
| Eq. 2 | R2=F2(PRPS,WPS,S1,S2,S3) | Salting | Estimated |
| Eq. 3 | R3=1-R1-R2 | Other processes | identity |

## II. Product quantity (volumes)

| | | | |
|---|---|---|---|
| Eq. 4 | QF=CA*R1*0.3227 | Frozen products | Technical identity |
| Eq. 5 | QFF=QF*0.692 | Frozen fillets | Technical identity |
| Eq. 6 | QFB=QF*0.308 | Frozen block | Technical identity |
| Eq. 7 | QS=CA*R2*0.384 | Saltfish | Technical identity |
| Eq. 8 | QO=CA*R3 | Other products | Technical identity |

## III. Supply of Products to markets (volumes and ratios)

### Frozen fillets

| | | | |
|---|---|---|---|
| Eq. 9 | QXFF=F3(QXFF(-1),(QFF),S1,S2,S3,S4) | Total exports of fillets | Estimated |
| Eq. 10 | R4=F4(R4(-1),PEPU(-1),TRC,CAT(-1),S2,S3) | Share exported to USA | Estimated |
| Eq. 11 | QXFFUS=QXFF*R4 | Volume exported to USA | Identity |
| Eq. 12 | QXFFUK=QXFF*(1-R4) | Volume exported to UK | Identity |

### Frozen block

| | | | |
|---|---|---|---|
| Eq. 13 | QXB=F5((QXB),QFF,S1,S2,S3,S4) | Total exports of block | Estimated |
| Eq. 14 | R5=F6(PBEPBU,TRC,S1) | Share exported to USA | Estimated |
| Eq. 15 | QXBUS=QXB*R4 | Volume exported to USA | Identity |
| Eq. 16 | QXBUK=QXB*(1-R4) | Volume exported to UK | Identity |

### Saltfish

| | | | |
|---|---|---|---|
| Eq. 17 | QXS=F7((QS),S1,S2,S3,S4) | Volume | Estimated |

### Other products

| | | | |
|---|---|---|---|
| Eq. 18 | QXO=QO | Volume | Technical identity |

## IV. Price equations

### Basic Cod Price

| | | | |
|---|---|---|---|
| Eq. 19 | LP=F8(LP(-1),CDT) | UK base cod price | Estimated |
| Eq. 20 | LPIS=LP*VGB*IKRGBP/VISL | UK cod price Icel. cur. | Identity |
| Eq. 21 | LPUS=LP*VGB*USUK/VUS | UK base cod price in USD | Identity |

### Saltfish

| | | | |
|---|---|---|---|
| Eq. 22 | PSS=F9(PSS(-1),LPIS,KPO,KESP,QXS(-1)) | Saltfish price | Estimated |
| Eq. 23 | PS=VISL*PSS | Saltfish in Icel. cur. | Identity |

### Fresh Cod

| | | | |
|---|---|---|---|
| Eq. 24 | PRUK=F10(LP.VGB,UHD) | UK fresh cod price | Estimated |
| Eq. 25 | PR=PRUK*VGBP*IKRGBP | UK fresh cod, Icel. cur. | Identity |

### Frozen fillets

| | | | |
|---|---|---|---|
| Eq. 26 | PFUS=F11(PFUS(-1),LPUS,WUS) | Price of cod fillets in USA | Estimated |
| Eq. 27 | PU=PFUS*VUSD*IKRUS | US fillet price in Icel. cur. | Identity |
| Eq. 28 | PFUK=F12(LP,LCT) | UK fillet price | Estimated |
| Eq. 29 | PE=PFUK*VGBT*IKRGBT | UK fillet price in Icel. cur. | |

### Frozen block

| | | | |
|---|---|---|---|
| Eq. 30 | PBUS=F13(PBUS(-1),LPUS,WUS,VUS) | Price of block in USA | Estimated |
| Eq. 31 | PBU=PBUS*VUS*IKRUS | US block price in Icel. cur. | Identity |
| Eq. 32 | PBUK=F14(PBUK(-1)LP,LCT) | UK block price | Estimated |
| Eq. 33 | PBE=PFUK*VGBT*IKRGBT | UK block price in Icel. cur. | Identity |

## V. Export of Cod Products (Values, Icel. currency)

| | | | |
|---|---|---|---|
| Eq. 34 | VXF= QXBUK*PBE+QXBU*PBU+QXFFUK*PU+QXFFU*PE | Frozen products | Identity |
| Eq. 35 | VQS=QXO*PS | Saltfish | Identity |
| Eq. 36 | VQR=QXO*PR | Othr cod products | |

## VI. Various Price Identities and Definitions

| | | | |
|---|---|---|---|
| Eq. 37 | PF=VXF/(QXBUK+QXBU+QXFFUK+QXFFU) | Average price of frozen cod | Identity |
| Eq. 38 | PSPF=PS/PF | saltfish/frozen price ratio | Identity |
| Eq. 39 | PSPF=PR/PS | fresh/saltfish price ratio | Identity |
| Eq. 40 | WPF=KAUPM/PF | real wage/frozen price ratio | Identity |
| Eq. 41 | WPF=KAUPM/PF | real wage/frozen price ratio | Identity |
| Eq. 42 | PEPU=PE/PU | UK/US fillet price ratio | Identity |
| Eq. 43 | PBEPBU=PBE/PBU | UK/US block price ratio | Identity |

Definition of variables

### I. Catch volumes

| | |
|---|---|
| CA | Total cod catch in Iceland |
| CAT | Catch by trawlers in Iceland |
| CDT | Total cod catch in Denmark, Iceland, Norway and UK |
| UHD | Haddock catch in UK. |

### II. Costs

| | |
|---|---|
| FLUK | Freight rates for frozen products from Iceland to UK. USD/MT |
| FLUS | Freight rates for frozen products from Iceland to UK. USD/MT |
| TRC | FLUS/FLUK Relative US/UK freight rates |
| KESP | Hourly real wage rate in Spain. |
| KPO | Hourly real wage rate in Portugal. |
| W | Hourly nominal wage rate in Iceland |
| WPF | W/PF |
| WPS | W/PS |
| WUS | Hourly nominal wage rate in USA. |
| LCT | Real private consumption in UK |
| KAUPM | Real disposible income in Iceland |

### III. Price Indices

| | |
|---|---|
| VGB | UK comsumer price index (CPI). |
| VUS | US consumer price index (CPI). |
| VISL | Icelandic consumer price index (CPI). |
| IKRGPB | Icelandic UK exchange rates; IKR for GBP. |
| IKRUSD | Icelandic US exchange rates: IKR for GBP |
| USUK | US UK exchange rates: USD for GBP |

### IV. Prices

| | |
|---|---|
| LP | UK basic real cod price. Defined as the total average cod price in UK deflated by the UK CPI. |
| LPIS | UK basic real cod price in Icelandic currency. |
| LPUS | UK basic real cod price in USD |
| PBE | Average price for Icelandic cod block exported to Europe; in IKR. |
| PBUK | Average real price for Icelandic block exported to Europe; in GBP. |
| PBU | Average price for Icelandic block exported to USA; in IKR |
| PBUS | Average real price for Icelandic block exported to USA; in IKR |
| PBEPBU | PBE/PBU |
| PE | Average export price for Icelandic frozen fillets to Europe, in IKR |
| PFUK | Average real export price for Icalandic frozen fillets to Europe in GBP |
| PU | Average price for Icelandic frozen fillets in USA in IKR. |
| PFUS | Average real price for Icelandic frozen fillets in USA in USD |
| PEPU | PE/PU |
| PF | Average export price for frozen cod products in IKR |
| PS | Average export price for salted cod in IKR |
| PSS | PS/CPI |
| PR | Average price for fresh cod in UK in IKR |
| PRUK | Average real price for fresh cod in UK in GBP. |
| PSPF | PS/PF |

| | |
|---|---|
| PRPS | PR/PS |

## V. Quantities and quantity ratios

| | |
|---|---|
| QF | Total production of frozen cod products in Iceland. |
| QFB | Total production of cod blocks in Iceland. |
| QXB | Total exports of cod blocks from Iceland |
| QXBUK | Total exports of cod blocks from Iceland to UK. |
| QXBUS | Total exports of cod blocks from Iceland to US. |
| QFF | Total production of frozen fillets in Iceland, |
| QXFF | Total exports of frozen fillets from Iceland |
| QXFFUK | Total exports of cod fillets from Iceland to UK. |
| QXFFUS | Total exports of cod fillets from Iceland to US. |
| QS | Total output of salted cod products in Iceland. |
| QXS | Total exports of salted cod from Iceland |
| QO | Total output of other cod products in Iceland. |
| QXO | Total exports of other cod products from Iceland. |
| R1 | Fraction of total cod catch in Iceland allocated to freezing |
| R2 | Fraction of total cod catch in Iceland allocated to the saltfish process. |
| R3 | Fraction of total cod catch in Iceland allocated to other processes. |
| R4 | Fraction of Icelandic fillet production exported to the USA. |
| R5 | Fraction of Icelandic block production exported to the USA. |

## VI. Export Values

| | |
|---|---|
| VXF | Total value of frozen cod exports. |
| VQS | Total value of saltfish exports. |
| VQO | Total value of other cod exports. |

## VII. Dummy variables

| | |
|---|---|
| S1-S4 | Quarterly dummies |
| DCQ86 | Dummy for the introduction of trawlers equipped to process frozen cod, 1 as of 1 quarter 1986 |

## Notation

| | |
|---|---|
| Z(-1) | Variable Z lagged one period. |
| {Z} | Distributed lags of variable Z. |

## Abbreviations

| | |
|---|---|
| GBP | British pound |
| IKR | Icelandic kronur |
| USD | US dollars |
| CPI | Consumer price index |

## APPENDIX 2: ESTIMATION RESULTS

The following lists the estimation results. 14 equations were estimated. Unless otherwise stated all equations are estimated in log-log form. Estimation method was OLS. Equation numbers correspond to those in the complete model defined in Appendix 1.

**Equation 1; Function F1: Allocation of cod to freezing**

LS // Dependent Variable is R1
SMPL range: 1982.1 - 1990.1
Number of observations: 33

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | 3.6645986 | 1.3789509 | 2.6575266 | 0.013 |
| CA | -0.4068069 | 0.1201811 | -3.3849491 | 0.002 |
| PSPF(-1) | -0.5490090 | 0.1666549 | -3.2942869 | 0.003 |
| WPF | -0.2792016 | 0.1398669 | -1.9961944 | 0.056 |
| S3 | 0.3598915 | 0.0429956 | 8.3704329 | 0.000 |
| S4 | 0.1688632 | 0.0879814 | 1.9193059 | 0.066 |
| DCQ86 | 0.2083173 | 0.0386257 | 5.3932248 | 0.000 |

| | | | |
|---|---|---|---|
| R-squared | 0.928454 | Mean of dependent var | -0.783718 |
| Adjusted R-squared | 0.911944 | S.D. of dependent var | 0.255510 |
| S.E. of regression | 0.075821 | Sum of squared resid | 0.149468 |
| Durbin-Watson stat | 2.328789 | F-statistic | 56.23405 |

**Equation 2; Function F2: Allocation of cod to salting**

LS // Dependent Variable is R2
SMPL range: 1983.1 - 1990.1
Number of observations: 29

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | -2.1344867 | 0.2677886 | -7.9707913 | 0.000 |
| PRPS | -0.4747406 | 0.2195261 | -2.1625699 | 0.041 |
| WPS | 0.4173125 | 0.2519258 | 1.6564900 | 0.111 |
| S1 | 0.8019765 | 0.0736385 | 10.890720 | 0.000 |
| S2 | 0.7078426 | 0.0767317 | 9.2249095 | 0.000 |
| S3 | 0.1660791 | 0.0716724 | 2.3171962 | 0.030 |

| | | | |
|---|---|---|---|
| R-squared | 0.905458 | Mean of dependent var | -1.056597 |
| Adjusted R-squared | 0.884906 | S.D. of dependent var | 0.388006 |
| S.E. of regression | 0.131633 | Sum of squared resid | 0.398529 |
| Durbin-Watson stat | 1.564878 | F-statistic | 44.05571 |

**Equation 9; Function F3: Total exports of frozen fillets (linear form, restrictions on parameters)**

```
NLS // Dependent Variable is QXFF
SMPL range: 1985.1 - 1990.2
Number of observations: 22
QXFF=C(1)*QXFF(-1)+C(2)*QFF+(1-C(1)-C(2))*QFF(-1)+C(4)*S1+C(5)*S2+C(
6)*S3-(C(4)+C(5)+C(6))*S4
Equation is linear - 1 iteration
```

| | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C(1) | 0.3391021 | 0.1927521 | 1.7592658 | 0.097 |
| C(2) | 0.9013997 | 0.1855109 | 4.8590123 | 0.000 |
| C(4) | -2205.6412 | 688.11674 | -3.2053299 | 0.005 |
| C(5) | 5.9640017 | 597.06464 | 0.0099889 | 0.992 |
| C(6) | 1266.1972 | 669.06518 | 1.8924871 | 0.076 |

| | | | |
|---|---|---|---|
| R-squared | 0.819989 | Mean of dependent var | 9454.460 |
| Adjusted R-squared | 0.777633 | S.D. of dependent var | 2200.047 |
| S.E. of regression | 1037.450 | Sum of squared resid | 18297129 |
| Durbin-Watson stat | 1.424699 | F-statistic | 19.35964 |

**Equation 10; Function F4: Exports of cod to USA (ratio USA/total)**

```
LS // Dependent Variable is R4
SMPL range: 1982.1 - 1989.4
Number of observations: 32
Convergence achieved after 3 iterations
```

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | 1.8559280 | 1.0708054 | 1.7332076 | 0.096 |
| R4(-1) | -0.3440875 | 0.1641079 | -2.0967148 | 0.047 |
| PEPU(-1) | -0.2483552 | 0.1710330 | -1.4520896 | 0.159 |
| FLUSUK | -0.6202042 | 0.1081552 | -5.7343905 | 0.000 |
| CAT(-1) | -0.2263459 | 0.0991180 | -2.2836013 | 0.032 |
| S2 | 0.1495661 | 0.0640410 | 2.3354753 | 0.028 |
| S3 | -0.2144824 | 0.0560915 | -3.8237950 | 0.001 |
| AR(3) | -0.4403208 | 0.1697958 | -2.5932378 | 0.016 |

| | | | |
|---|---|---|---|
| R-squared | 0.817308 | Mean of dependent var | -0.536836 |
| Adjusted R-squared | 0.764023 | S.D. of dependent var | 0.213005 |
| S.E. of regression | 0.103472 | Sum of squared resid | 0.256957 |
| Durbin-Watson stat | 1.924544 | F-statistic | 15.33838 |

**Equation 13; Function F5: Exports of block (linear form, restrictions on parameters)**

```
NLS // Dependent Variable is QXB
SMPL range: 1981.1 - 1990.2
Number of observations: 38
QXB=+C(2)*QB+C(3)*QB(-1)+(1-C(2)-C(3))*QB(-2)+C(4)*S1+C(5)*S2+C(6)*S
3-(C(4)+C(5)+C(6))*S4
Equation is linear - 1 iteration
```

| | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C(2) | 0.5300235 | 0.2230962 | 2.3757622 | 0.023 |
| C(3) | 0.3381408 | 0.1907497 | 1.7726936 | 0.086 |
| C(4) | -579.81358 | 365.50779 | -1.5863235 | 0.122 |
| C(5) | -99.436823 | 329.81387 | -0.3014938 | 0.765 |
| C(6) | 210.16748 | 296.80852 | 0.7080911 | 0.484 |

| | | | |
|---|---|---|---|
| R-squared | 0.341217 | Mean of dependent var | 3816.990 |
| Adjusted R-squared | 0.261364 | S.D. of dependent var | 1077.586 |
| S.E. of regression | 926.1198 | Sum of squared resid | 28304029 |
| Durbin-Watson stat | 1.410564 | F-statistic | 4.273085 |

**Equation 14; Function F5: Exports to the USA (ratio USA/total)**

```
LS // Dependent Variable is R5
SMPL range: 1982.1 - 1989.4
Number of observations: 32
Convergence achieved after 3 iterations
```

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | -0.4514189 | 0.0793507 | -5.6889115 | 0.000 |
| PBEPBU | 0.4264927 | 0.1884943 | 2.2626288 | 0.032 |
| FLUSUK | -0.6590512 | 0.1860225 | -3.5428582 | 0.001 |
| S1 | -0.1300049 | 0.0521990 | -2.4905643 | 0.019 |
| AR(2) | 0.4829711 | 0.1489021 | 3.2435487 | 0.003 |

| | | | |
|---|---|---|---|
| R-squared | 0.751331 | Mean of dependent var | -0.444255 |
| Adjusted R-squared | 0.714492 | S.D. of dependent var | 0.269003 |
| S.E. of regression | 0.143736 | Sum of squared resid | 0.557822 |
| Durbin-Watson stat | 1.533826 | F-statistic | 20.39455 |

**Equation 17; Function F7: Total exports of salted cod (linear form - restriction on parameters)**

```
NLS // Dependent Variable is QXS
SMPL range: 1985.1 - 1989.3    1990.4 - 1990.4
Number of observations: 20
QXS=+C(3)*QS(-1)+(1-C(3))*QS(-2)+C(4)*S1+C(5)*S2+C(6)*S3-(C(4)+C(5)+
C(6))*S4
Equation is linear - 1 iteration
```

| | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C(3) | 0.8897391 | 0.2227290 | 3.9947160 | 0.001 |
| C(4) | 3890.9501 | 1167.3423 | 3.3331699 | 0.004 |
| C(5) | 1427.2776 | 3774.3472 | 0.3781522 | 0.710 |
| C(6) | -4072.6990 | 1050.3816 | -3.8773517 | 0.001 |

| | | | |
|---|---|---|---|
| R-squared | 0.909232 | Mean of dependent var | 13872.07 |
| Adjusted R-squared | 0.892213 | S.D. of dependent var | 5538.329 |
| S.E. of regression | 1818.281 | Sum of squared resid | 52898355 |
| Durbin-Watson stat | 2.433107 | F-statistic | 53.42475 |

**Equation 19 : Basic referance price**

```
LS // Dependent Variable is LP
SMPL range: 1981.2 - 1990.1
Number of observations: 36
```

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | 0.3987633 | 0.4934146 | 0.8081707 | 0.425 |
| LP(-1) | 0.8786567 | 0.0759254 | 11.572634 | 0.000 |
| CDT | -0.0810838 | 0.0209676 | -3.8670997 | 0.000 |

| | | | |
|---|---|---|---|
| R-squared | 0.805538 | Mean of dependent var | -4.930764 |
| Adjusted R-squared | 0.793753 | S.D. of dependent var | 0.098744 |
| S.E. of regression | 0.044844 | Sum of squared resid | 0.066363 |
| Durbin-Watson stat | 1.745421 | F-statistic | 68.34954 |

**Equation 22; Function F9: Average price for salted cod**

LS // Dependent Variable is PSS
SMPL range: 1981.2 - 1990.4
Number of observations: 39

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | 1.8045892 | 0.5385258 | 3.3509801 | 0.002 |
| PSS(-1) | 0.6007060 | 0.1109394 | 5.4147247 | 0.000 |
| LPIS | 0.3926308 | 0.1632856 | 2.4045649 | 0.022 |
| KPO | 0.1895707 | 0.1302974 | 1.4549084 | 0.155 |
| KESP | 0.2405875 | 0.1786623 | 1.3466050 | 0.187 |
| QXSL(-1) | -0.0936185 | 0.0267379 | -3.5013424 | 0.001 |

| | | | |
|---|---|---|---|
| R-squared | 0.719929 | Mean of dependent var | -2.164280 |
| Adjusted R-squared | 0.677494 | S.D. of dependent var | 0.118758 |
| S.E. of regression | 0.067442 | Sum of squared resid | 0.150098 |
| Durbin-Watson stat | 2.144942 | F-statistic | 16.96548 |

**Equation 24; Function F10: Average price for fresh cod in the UK**

LS // Dependent Variable is PRUK
SMPL range: 1981.1 - 1990.1
Number of observations: 37

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | -2.3603176 | 0.9684107 | -2.4373106 | 0.020 |
| LP | 0.7460567 | 0.0991432 | 7.5250398 | 0.000 |
| VGB | 0.2854681 | 0.0798493 | 3.5750853 | 0.001 |
| UHD | -0.0144781 | 0.0339958 | -0.4258805 | 0.673 |

| | | | |
|---|---|---|---|
| R-squared | 0.835347 | Mean of dependent var | -4.876880 |
| Adjusted R-squared | 0.820379 | S.D. of dependent var | 0.112550 |
| S.E. of regression | 0.047700 | Sum of squared resid | 0.075086 |
| Durbin-Watson stat | 1.816429 | F-statistic | 55.80734 |

**Equation 26; Function F11: Average price for Icelandic frozen fillets in the USA**

```
LS // Dependent Variable is PFUS
SMPL range: 1981.2 - 1990.1
Number of observations: 36
```

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | -0.7430629 | 0.3754703 | -1.9790192 | 0.056 |
| PFUS(-1) | 0.5352129 | 0.1275998 | 4.1944658 | 0.000 |
| LPUS | 0.2212771 | 0.0737634 | 2.9998244 | 0.005 |
| WUS | 0.6726569 | 0.6490899 | 1.0363078 | 0.308 |

| | | | |
|---|---|---|---|
| R-squared | 0.617021 | Mean of dependent var | -3.359053 |
| Adjusted R-squared | 0.581116 | S.D. of dependent var | 0.091813 |
| S.E. of regression | 0.059423 | Sum of squared resid | 0.112994 |
| Durbin-Watson stat | 2.046700 | F-statistic | 17.18513 |

**Equation 28; Function F12: Average price for frozen fillets in the EC**

```
LS // Dependent Variable is PFUK
SMPL range: 1981.1 - 1989.4
Number of observations: 36
```

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | -3.6341092 | 0.9671032 | -3.7577263 | 0.001 |
| LP | 0.8281647 | 0.0744012 | 11.131074 | 0.000 |
| LCT | 0.3214945 | 0.0661864 | 4.8574143 | 0.000 |

| | | | |
|---|---|---|---|
| R-squared | 0.894473 | Mean of dependent var | -4.207722 |
| Adjusted R-squared | 0.888077 | S.D. of dependent var | 0.114274 |
| S.E. of regression | 0.038230 | Sum of squared resid | 0.048231 |
| Durbin-Watson stat | 2.064201 | F-statistic | 139.8574 |

**Equation 30; Function F13: Average price for Icelandic block in the USA**

LS // Dependent Variable is PBUS
SMPL range: 1981.3 - 1990.1
Number of observations: 35
Convergence achieved after 3 iterations

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | -3.5860525 | 2.6846977 | -1.3357379 | 0.192 |
| PBUS(-1) | 0.3215153 | 0.2088264 | 1.5396299 | 0.134 |
| LPUS | 0.5655098 | 0.1606978 | 3.5190897 | 0.001 |
| WUS | 3.6137284 | 1.6787670 | 2.1526086 | 0.040 |
| VUS | 0.5921821 | 0.4454443 | 1.3294191 | 0.194 |
| AR(1) | 0.5242401 | 0.2378806 | 2.2037952 | 0.036 |

| | | | |
|---|---|---|---|
| R-squared | 0.859794 | Mean of dependent var | -3.626911 |
| Adjusted R-squared | 0.835620 | S.D. of dependent var | 0.170746 |
| S.E. of regression | 0.069227 | Sum of squared resid | 0.138978 |
| Durbin-Watson stat | 1.553580 | F-statistic | 35.56769 |

**Equation 32; Function F14: Average price for Icelandic block in the EC**

LS // Dependent Variable is PBUK
SMPL range: 1981.2 - 1985.4 1986.2 - 1989.4
Number of observations: 34

| VARIABLE | COEFFICIENT | STD. ERROR | T-STAT. | 2-TAIL SIG. |
|---|---|---|---|---|
| C | 0.4795534 | 2.5919059 | 0.1850196 | 0.854 |
| PBUK(-1) | 0.3330056 | 0.1121824 | 2.9684304 | 0.006 |
| LP | 1.0247502 | 0.2176972 | 4.7072264 | 0.000 |
| LCT | 0.1570864 | 0.1825305 | 0.8606039 | 0.396 |

| | | | |
|---|---|---|---|
| R-squared | 0.759813 | Mean of dependent var | -4.295885 |
| Adjusted R-squared | 0.735795 | S.D. of dependent var | 0.187717 |
| S.E. of regression | 0.096488 | Sum of squared resid | 0.279300 |
| Durbin-Watson stat | 1.433857 | F-statistic | 31.63430 |

# An Approach to the Management of Market and Resource Uncertainties : The Globalisation of Trade Information

**Jean-François Mittaine** *

Fish Meal Exporters Organization, 67, boulevard Haussman, 75008 Paris, France

ABSTRACT

*The fish meal industry processes about 1/3 of total world fish catches to produce over 6 million Mt of fish meal, of which about 1/2 is marketed worldwide. Although fish meal, as a commodity, represents a very small part of the world protein feed disappearance (estimated at about 135 million Mt/year), it remains an important source of high quality proteins for certain categories of animals (pigs and poultry starters, cultivated fish and shrimps). The industry is constituted of a large number of companies of all sizes, the largest of which participate directly to the world trade flows, largely from Chile, Peru and Scandinavia.The industry is submitted to uncertainties on both sides of its activity : - the supply : the fish resources destined to processing fluctuate unexpectedly from one month to the other. Thus supply variations on the market are important ; - on the demand side, fish meal traditionally competes with the dominant protein sources such as the vegetal meals (particularly soybean meals) on the feed market which, in turn, is strongly linked to the evolution of the animal productions.*

*In order to ascertain a better valorization of their products, the producers/exporters of fish meal had, 30 years ago, the first idea to globalize their information network by creating the F.E.O. in 1960 (which was then a very new approach). For many years, the institution was the "meeting point" of the fish meal producers, and allowed them to exchange views as well as to meet and know each other. Quickly, the problem of how to manage the uncertainties of the market emerged as a central point. Among the various answers, a promotion programme was launched in Germany, then the largest net-exporters market, in association with the importers. Other answers were also found particularly through new products (special fish meals) and new logistical concepts (terminals). More recently, producers realized they also had to manage the supply side uncertainties (associated with the resources). They became more interested in sharing information on the evolution of fishing. It is now becoming a central problem.*

* Prepared in association with Mr J. Bololanik, Secretary general FEO Paris France.

*With a very pragmatic approach, the presentation shows how, an organization with limited resources, can contribute to the management of some market uncertainties through an information network and market analysis. A description of its working philosophy and methodology is included, as well as some results recently obtained.*

## 1. INTRODUCTION

It is an honor to participate to this Conference. The topic of this presentation may appear quite far away from many other preoccupations discussed in this Forum. As you will see later, the fishmeal manufacturers/exporters of the world, and particularly those who are members of our organization, are very much concerned by the general evolution of their "breadmaker" : the pelagic fish. But at the same time, they are faced with another world : the commodities trading environment, a global activity of prime importance to many countries (both importers and exporters) in which fishmeal is only a small part.

Consequently, the fishmeal exporters we represent must at the same time manage the uncertainties of their raw-material and face the great risks of the protein-for-feed market. This unique position has led to unique answers. This is what I invite you to review with me.

## 2. THE WORLD FISHMEAL PRODUCTION AND TRADE A BRIEF REVIEW OF ITS STRUCTURE AND ORGANIZATION

### *2.1 Catches and Production*

The 1991 world fish catches moving into the production of fishmeal are estimated at about 30.0 Million MT representing about 1/3 of the estimated world total catches. Fishmeal production is largely, though not solely, based on the "reduction" of 4 species of pelagic fish : Anchovies, Sardines, Horse Mackerel and Capelin. Traditionnally, fishmeal was marketed within the fishing countries (like for example Japan and Germany) as a feed ingredient for monogastric animals (essentially pigs). But fishmeal started entering massively the international trade when some producing countries largely exceeded the consumption capacity of their own domestic market. It is the case of Chile and Peru. At the same time, the development of the world pig and poultry productions led to a huge demand of proteins for feed use. The fishmeal trade benefited from both situations. After some ups and downs (sometimes spectacular like in the 70's) the trade stabilized to the present level of about 3.0 million MT which is a remarkably high share of the production (more than 50 %).

Nowadays, the main fishmeal producing countries include :

(i) countries who have had a traditional usage of fishmeal consumption in their own markets : Japan, the ex-USSR, the U.S.A., South Africa, and, until recently, China.

(ii) countries who have seen production exceed their domestic requirements : Chile, Peru and some Scandinavian countries (Denmark, Iceland and Norway).

The structure of the industry is extremely diversified depending upon the fishing and trading traditions of the countries involved. For example, in Iceland, about 40 fishmeal plants buy the raw material from about 200 independent fishermen on a day-to-day basis ; in the north of Chile about a dozen plants usually own the vessels ; in Peru, the fishermen are usually independent and deliver to the about 80 plants located in the vicinity of their port of call.

Also, in terms of sales, many plants export through local and/or international buyers/brokers on a FAS or FOB basis. They frequently rely on the market informations supplied by these clients. A notable exception lies with the terminals which some producers have organized at the port of unloading within some major consuming countries (particularly in Europe).

As the situation of the market is largely dependent upon the importance of the catches, any resource uncertainty in one production area will affect the entire fishmeal market. For example, the recent outbreak of the El-Niño phenomenon has led to much uncertainties on the resource availability in South America, the largest exporting area. Thus the knowledge of all these changes have become key factors in the commercial management of the individual plants.

### *2.2 The World Trade of Fishmeal*

Tonnagewise, fishmeal is one of the "small" commodity entering the world markets of protein for feed. However, it has the richest protein level (between 64 % and 72 % protein).
Until the late 80's, Europe was the largest outlet for the major fishmeal exporters (with about one half of total world trade). As a consequence, the Hamburg market has been the site of the only worlwide public fishmeal quotation. Germany and the U.K. continue to be the largest european importers followed by Holland, Italy and France. In fact, all those countries are known for their important livestock industries, particularly for pigs, poultry and even aquaculture in the U.K., Italy and France.
Nowadays, the fishmeal trade flows have changed dramatically away from Europe toward the major consuming markets of the Far-East, particularly China (which in 1991 took alone about 1/6th of all world exports), Japan (which became a net-importer 2 years ago) and Taiwan.
The fishmeal market is much more technically oriented than for other commodities. Its origin (type of fish, mode of production, country of origin,...) gives the fishmeal an identity, if not a trade mark, which reflects in the world trade patterns in relation to usage requirements.
Also, as fishmeal is mainly used as a protein complement, i.e. with relatively low incorporation rates, its technical specifications must both adapt closely to the end-users' needs and remain constant in quality. Freshness of the raw material, digestibility are some of the characterisitics frequently required by the end-user, aside from the more traditional specifications such as protein, ash, moisture. This tendency has led the producer to adapt to individual needs and manufacture either "Special Fishmeals" or fishmeals with guaranteed specifications (such as,for example, in amino-acids, vitamins, minerals,....) in order to allow them obtain the best valorization possible of their production.
All this shows how crucial, but also how difficult, market information is.

### *2.3 The Competing Commodities*

The competing protein meals constitute a market which can be divided into three categories :

- **the oilseedmeals** constitute the bulk of it in tonnage. Total world production in 1991 reached about 133 million MT of which 52 % was soyabeanmeal. The world trade of oilseedmeals represents about 45 million MT (only 34 % of production) of which 58 % is soyabeanmeal.
  These meals differenciate themselves from fishmeal in two respects :
  (i) their protein level is generally lower than fishmeal (soyabeanmeal protein is between 44 % and 48 %)
  (ii) as year crops, they are renewable productions obbeying to the classical yearly supply/demand laws.
- **Meatmeals**, the only other animal proteinmeals obeying are becoming an increasing market factor within the consuming countries as, with the help of improved technology, it is now possible to process all meat industry by-products into meals acceptable by the feed industry. In Europe alone, for example, meatmeal production represent more than 2.5 million MT.
  However, this market factor is limited to the countries with large animal production. It is not a worldwide traded commodity such as fishmeal.
- **Synthetic amino-acids** are chemicals, not commodities but compete significantly on the markets of supplement feed.

## 3. GLOBALIZATION OF TRADE INFORMATION

### *3.1 The importance of Market Information in the Fishmeal Trade from the Producer's Standpoint*

As shown earlier, fishmeal is deeply involved in the world of commodities : the major origins are very dispersed in various parts of the world ; consumption is also very diversified both geographically and by type of use. Whether we consider the common grade fishmeal or the special quality grades, the experience shows that, overall, these products respond to the basic supply/demand laws, with price as the main selecting factor.

The fishmeal operator has to manage two major uncertainties linked, on one hand, to the resource and, on the other hand, to the market while at the same time he has to generate a return on large investments at the plants level.

As a result, he requires a host of informations which usually come from three sources :

(i) the fishermen,

(ii) the trade,

(iii) the competitors.

Since, the fishmeal market is not organized or "transparent" as in the oilseed markets, it does not participate to the classical network of price quotations and other market information networks such as those located in Chicago or in other markets. This situation explains partly the use of a private network as the F.E.O.

### *3.2 The Creation of F.E.O. and its Original Mode of Operations*

32 years ago, a private initiative of the, then, largest fishmeal exporters initiated the idea of setting up an informal and private information pool.

The main purpose of this initiative was twofold :

(i) create the opportunity for all the producers/ exporters to benefit from a structure where they could meet twice a year and exchange views on both the production side and the market side.

(ii) progressively set up a statistical base allowing a permanent and objective evaluation of the fishmeal market, particularly in terms of Supply/Demand analysis.

This very original approach to market information, the only one existing in the commodity business, led to the constitution of a small private organization, registered under the French Association laws which serves as a commodity analysis department for about 25 fishmeal groups or individual companies in six countries of the world.

### *3.3 The Present Operations of F.E.O.*

With the advent of the fax, as well as the generally improved communication networks available at a modest cost, the organization has developped a professional reporting system which, through weekly and monthly reports, allows the members to keep permanently updated on the major market trends and to permanently evaluate their positions in face of other competing commodities.

This structure also allows each individual member to compare his own activity to the group of all the members. In this respect, the organization contributes to the market transparency allowing the members to permanently adjust to the changes of supply/demand.

At last, through its market comments, the structure supplies the members with a variety of selected and objective market informations.

Through contacts with the end-users and with the major trading entities, in association with a sister organization, the International Fishmeal Manufacturers Association, as well as with international organizations (like the F.A.O.), the Fishmeal Exporters Organization is at the center of an International Information Network geared to the needs of its members, the major fishmeal producers/exporters of the world.

One important point should be stressed : the organization is, in no way, a marketing tool for the members. F.E.O. is only managing market information and analysis ; each individual member handles the marketing activity on his own.

## 4. A NEW APPROACH : THE MANAGEMENT OF INFORMATIONS ASSOCIATED WITH THE RESSOURCES

### *4.1 Over the past 18 months*

the F.E.O. has progressively developped an interest in following and, eventually, participating into the analysis of informations associated with the evolution of the pelagic ressources.

This interest grew as the 1991/1992 El-Niño developped in South America. As early as December 1990, the members started to follow the early developments of the phenomenon in the western Pacific. Through various contacts among the scientific community it was possible to assess regularly its evolution across the Pacific Ocean, until it hit the South American coast. At the same time, it was possible to evaluate, through our members, the real impact on the availabilities of pelagic resources.

Although this permanent exchange of information was based on more qualitative than quantitative informations, it led to a permanent contact between the scientific community and the fishmeal exporters. In fact, it is the first time that the latter were able to follow the developments of this phenomenon nearly in real time.

*4.2 This interest on the permanent evaluation of stocks and fishing resources*

has not been limited to the development of El-Niño along the South American coast. For example, the recent developments of the capelin stock in the North Atlantic and in the Barentz sea and the associated relationship with fishing quotas and availabilities is regularly reviewed. Also, a permanent follow-up of the government decisions concerning the management of ressources, such as the establishment of fishing bans, the launching of stock surveys or the changes in the national fishing policies, are analyzed in terms of their impact on raw material availability and more generally on the supply-side of the markets.

All these informations are integrated into the analytical tool of the Organization which is constituted of :

(i) weekly fishing, production and sales reports

(ii) estimates of the overall physical stocks situation, on a quarterly basis

(iii) analysis of the price ratio between fishmeal and soyabeanmeal, the competing protein.

This analytical tool provide some production perspectives and is regularly used by the members to manage 1) the short-term uncertainties of the trading and 2) the medium term uncertainties of the production.

*4.3 Overall*

through a better knowledge of the basic dynamics of the fish stock, the organization keeps in touch with the most important events affecting fishing. Unlike the cash crops being traded in the world, which all can be analyzed on the basis of the effective crops, this approach to the supply-side of the fishmeal market has to be continuously updated, in as much as the fish stocks are only becoming market factors when the fish has been landed, i.e. only few days/weeks prior to effectively entering the world markets. This very short notice, combined with the extreme fishing variability from one week to the other, gives importance to all reliable informations helping the producers to manage supply uncertainties.

## 5. CONCLUSION

This brief review has shown how a major part of the fish resources relates to the mainstream commodity business. It also shows how a small organization supported by active members may be the center of a dynamic information network. In this respect, at F.E.O., we believe that still a lot of useful work can be done, particularly in the analysis of raw material availabilities because we are at the cross-roads of the effective worldwide fishing/production and of the realities of the protein-rich markets. We welcome any opportunities to maintain close contacts with all the professionals (scientists, fishermen, plant operators, governments, international organizations) interested by this entire sector. We believe that the establishment of such close links with various professional categories can help feed constructive views in such a dispersed environment.

# The Market Outlook for Shrimp

**Maw-Cheng Yang** *

International Trade Division World Bank 1818 H Street, NW, Washington, DC 20433, USA.

ABSTRACT

*Shrimp is the leading product in world fisheries trade, with world imports exceeding US$4.4 billion in 1988. About 90 % of world shrimp exports originate from developing countries. Industrial countries are the major consumers, accounting for about 90 % of world imports.*

*Cultured shrimp production has grown rapidly since the early 1980s (5.4 % of total production in 1980) to reach a 22 % share of total production in 1988. This rapid increase was in response to the substantial increase in real prices in the 1970s. Shrimp prices peaked in 1979 and have been declining since then in terms of real prices. With almost all cultured shrimp produced in the developing countries, further investment in this sector should be based on a market outlook analysis. The objective of this study was to build a world shrimp model to use as a framework for analyzing the long-term outlook.*

*Simulations with the model indicate that cultured shrimp production over the 1990s will expand at 13.6 % p.a. as compared to 25.4 % over the 1980-88 period. With sea-harvested shrimp production growing at only 2.6 % p.a., cultured shrimp production is projected to exceed sea-harvested shrimp by the year 2000. With total production of shrimp growing at 6.8 % p.a. over the 1990s, US shrimp prices in real terms decline by 4.6 % p.a. If cultured shrimp production increases at 10 % per year, real shrimp prices would decline by 14 % over this projection period. But, if cultured shrimp production expands at only 5 % per year, then real shrimp prices by the year 2000 are projected to be 23 % higher than the 1988 levels.*

## 1. INTRODUCTION

Shrimp is the leading product in world fisheries trade. In 1988 total world imports of shrimp exceeded US$4.4 billion, or 20 % of international fisheries trade. Approximately 75 % of world shrimp production is by the developing countries. Over 60 % of the world shrimp consumption is in the industrial countries. Thus, shrimp is mainly (about 90 %) exported by the developing countries and most imports go to the industrial countries.

* The views expressed in the paper are those of the author and should not be attributed to the World Bank, its Board of Directors, its management or any of its member countries.

The world shrimp market over the past decade was characterized by rapid expansion of cultured shrimp production and sustained growth in catches. Cultured shrimp accounted for less than 1 % of world shrimp supplies in 1970 but its share increased to 22 % in 1988. Annual growth in cultured shrimp production over the 1980-88 period was 25.4 %. Almost all cultured shrimp are produced in the developing countries -- in 1988 Asia accounted for 80 % and Latin America accounted for 17 %. The expansion of cultured shrimp production was encouraged by increasing real shrimp prices and progress in cultured technology. However, since the mid-1980s shrimp prices have been more or less constant in nominal terms and appear to have declined a little in real terms, even though landings have been stagnant since 1985. If the expansion in cultured shrimp production continues, the trend in real prices might be significantly reversed. An earlier Bank study[1] suggested that real prices of shrimp could decline by 6-10 % annually over the next few years should supplies increase at 5-7 % annually. This marked change in the market and in the market outlook point to the need for a comprehensive evaluation of the market outlook as a guide to investment in cultured shrimp production in the developing countries.

This paper reports on the construction of a world shrimp model suitable for making long-term price projections and for investment policy simulations. The organization of the paper is as follows. The world shrimp economy is described more fully in Section II, while the model constructed is specified in Section III. Empirical results and validation of the model are discussed in Section IV. Projections and sensitivity analysis are presented in Section V.

## 2. SALIENT FEATURES OF THE WORLD SHRIMP INDUSTRY

### *2.1 Supply*

World shrimp landings increased from one-half million tons in 1960 to about two million tons in 1988, representing an average growth rate of 5 % p.a. Encouraged by the increase in shrimp prices in the 1970s and the development of cultured shrimp technology, production of cultured shrimp grew rapidly in the 1980s. It increased from 90,000 tons in 1980 to 560,000 tons in 1988. Thus the share of cultured shrimp in world shrimp supply increased from less than 1 % in 1970 to over 22 % in 1988.

Almost all cultured shrimp are produced in developing countries in the Asian and Latin American regions. Cultured shrimp production in Asia accounts for more than 80 % of the world's cultured shrimp supply while production in Latin America accounts for about 17 %. China is the leading producer of cultured shrimp with production of 180,000 tons in 1988, followed by Indonesia, Ecuador, Philippines, Thailand and Taiwan, China.

Of total shrimp production, developing countries supply about 75 %. The leading suppliers are China (accounting for 19.4 % in 1987), India (9.2 %), Indonesia (7.7 %), Thailand (6.3 %) and Taiwan, China (5.4 %). The major industrial country suppliers are the United States (7.0 %), Greenland (2.7 %), Japan (2.0 %) and Norway (1.8 %).

The shrimp life cycle is less than a year. They are harvested or die from natural causes within this time. Because of this characteristic, the shrimp yield in one year does not affect the yield in the following year. The maximum possible yield for a given year is essentially all shrimp available for harvest, given current technology. However, some time an increase in yield can be achieved by better resource management, such as closed seasons and coastal pollution control.

### *2.2 Consumption*

World consumption of shrimp increased from 677 million pounds (head-off weight) in 1960 to 3,491 million pounds in 1988. Shrimp is a relatively highly priced product. Therefore, it is usually consumed by high income earners. The United States is the largest shrimp consuming country, accounting for 729 million pounds in 1988 (21 % of world consumption). The second largest consumer is Japan, taking 654 million pounds (19 %) in 1988. Consumption growth in Japan has been much faster than in the United States, 6.6 % as compared with 3.5 %. Growth in per capita consumption in Japan has also been much faster than in the United States. In 1988 per capita consumption in Japan was estimated at 5.3 pounds as compared with 3.0 pounds in the United States.

1. World Bank, *Asia-Wide Shrimp Agro-Industry Sector Study*, September 1989.

The other major shrimp consuming region is Western Europe. Accurate estimates of total consumption in Western Europe are not available. However, it is estimated that Western Europe has accounted for approximately 12 % of total consumption in recent years.

Another, approximately 40 % of shrimp are consumed in producing countries, mainly in developing countries. Most are consumed by the high income groups in these countries.

### *2.3 Trade*

The world shrimp trade flows primarily from developing countries to industrial countries. The developing countries are best endowed with natural resources for marine shrimp as well as for cultured shrimp. World exports of fresh, chilled and frozen shrimp (the principal product in world trade) increased from 322,000 tons in 1977 to 666,000 tons in 1986, at an average growth rate of 8.4 % p.a. In terms of value, they increased from $1,353 million to $4,241 million. The major exporting countries are China, India, Indonesia, Thailand, Ecuador, Mexico, Denmark, and Taiwan, China.

World imports are dominated by Japan and the United States, though their share has been declining (from 81 % in 1977 to 71 % in 1986 in terms of value). The other major importing region is Western Europe.

For many years the increased demand for shrimp in Japan, the United States and Western Europe has been satisfied by imports. Domestic landings in Japan have been relatively stable at around 60,000 tons since 1970. During this time, net imports have increased from 90,000 tons to 422,000 tons so that the share of imports in total Japanese consumption has increased from 61 % to 91 %. Japanese imports are mostly sourced from Indonesia, Thailand, India, China, the Philippines, and Vietnam. In the United States domestic landings provided over one-half of total consumption until 1979. Since then, imports have accounted for an increasing share. Currently, imports account for over 70 % of US consumption. Net imports of shrimp increased from 137,000 tons in 1970 to 412,000 tons in 1988. Imports are mainly shipped from Ecuador, Thailand, China, India, Mexico, and Indonesia. Consumption in Western Europe has been mainly of cold water shrimp caught in the North Atlantic Ocean. However, consumption of tropical shrimp has been increasing rapidly in recent years due to shortfalls and higher prices of cold water shrimp. In recent years approximately one-half of shrimp consumption in Western Europe is cold water shrimp. The main sources of imports of cold water shrimp are Greenland, Faeroe Islands, and Argentina and of tropical shrimp are Thailand, India, Bangladesh, Senegal, and Cuba. Approximately two-thirds of shrimp consumption in the EC is supplied by imports.

### *2.4 Prices*

Shrimp prices in current dollar terms in the US market had a rapid upward trend through the 1970s until 1979. Since then the trend has been constant. In real terms (deflated by US wholesale price index) it is somewhat more obvious that there has been a decline in US prices since 1979. This appears to be because demand outstripped supply before 1979 after that supply increased substantially due to the increase in aquaculture production. Some studies (Doll, 1971, Adams, Prochaska and Spreen, 1987) have indicated that ex-vessel prices, wholesale prices, and retail prices have moved closely in the same direction and that they have been determined simultaneously in the US market. Shrimp prices in Japan, in terms of US dollars, are generally lower than in the United States except for the last few years due to the devaluation of the dollar. However, prices in the two markets have moved closely on a directional basis.

## 3. THE ECONOMETRIC MODEL

### *3.1 Demand function*

Demand for shrimp is hypothesized to be determined by income, shrimp prices, prices of substitutes, and habit. The demand function can be postulated as follows :

$$Q_i^a = f(P_i, P_{i'}^s, Y_r, Q_i^a(t\text{-}1))$$

where,

$Q_i^a$ = per capita consumption of shrimp for country i
$P_i$ = shrimp prices for country i
$P_i^s$ = prices of substitute for country i
$Y_i$ = per capita disposable income in constant $ for country i
$Q_i^a(t\text{-}1)$ = $Q_i^a$ lagged one year, a variable representing habit persistence

Per capita consumption should be negatively related to its own price and positively related to prices of substitutes and disposable income. The consumption level of the previous year is used to represent habit persistence. It should be positively related to current consumption. Total consumption of a country is the product of per capita consumption and population ($POP_i$) :

$$Q_i = Q_i^a * POP_i$$

The world demand (Q) is the summation of demand in all countries :

$$Q = \sum_{i=1}^{n} Q_i$$

*3.2 Supply Function*

There are two sources of supply of shrimp : one is marine catches, the other is aquaculture. The two sources are modeled separately. Because of the short life cycle (less than a year) of shrimp, the shrimp yield in one year does not affect the population of the next year. Therefore, production of shrimp is determined by the costs of production (for sea catches largely fuel costs, for aquaculture largely feeding costs), current and expected prices, and other factors such as technology, pollution, and rainfall. Shrimp production equations are specified as follows :

SHL = f(SHL(-1), P, P(-1), C, T)
SHCU = f(SHCU(-1), P(-1), C)

where,

SHL = shrimp landings
SHCU = cultured shrimp harvest
P = shrimp price
C = cost of production
T = time trend
(-1) = variables lagged one year

Total supply of shrimp is the sum of landings and cultured production, i.e.,

S = SHL + SHCU

In equilibrium, total demand equals total supply, i.e.,

Q = S

*3.3 Price Linkage Equation*

The average price of the two major markets, the United States and Japan is created to represent the world price. The world price, which equates world demand with world supply, is solved with the model. Prices in the United States and Japan are linked through a regression equation :

SHP$JAP = f(SHPUS)

where,

SHP$JAP = Japanese shrimp prices in US dollars
SHPUS = US shrimp prices.

## 4. EMPIRICAL RESULTS

### *4.1 Estimated Equations*

The model is comprised of three demand equations for the United States, Japan, and the rest of the world ; two supply equations, one for landings and one for cultured production ; and a price linkage equation.

The demand equation estimated for the United States is as follows :

$$\underset{}{LN(SHCAUS) = -8.297} + \underset{(-6.7)}{0.988} * \underset{(4.4)}{LN(PCEUS)} \underset{(-4.7)}{-0.380} * LN(SHPDUS) + \underset{(3.2)}{0.531} * LN(OFWPIDUS)$$

$R^2 = 0.92$ DW = 1.2 period = 1962-1988

where,

SHCAUS = per capita consumption of shrimp in the United States
PCEUS = US private consumption expenditure per capita in constant dollars
SHPDUS = US wholesale price of shrimp deflated by the US wholesale price index
OFWPIDUS = US wholesale price index of other fish deflated by the US wholesale price index

The lagged dependent variable SHCAUS(-1) was dropped from the equation because its coefficient was not significant and it did not affect the $R^2$. All coefficients in the equation are significant with the sign as expected. The equation implies an income elasticity of 0.99, an own price elasticity of -0.38, and a cross-price elasticity of 0.53.

The demand equation estimated for Japan is as follows :

$$\underset{}{LN(SHCAJAP) = -14.903} + \underset{(20.6)}{1.246} * \underset{(-24.0)}{LN(PCEJAP)} \underset{(-4.3)}{-0.360} * LN(SHPDJAP) + \underset{(3.3)}{0.347} * LN(BFPDJAP)$$

$R^2 = 0.98$ DW = 1.37 Period = 1965-1988

where,

SHCAJAP = per capita consumption of shrimp in Japan
PCEJAP = Japanese private consumption expenditure per capita in constant prices
SHPDJAP = Japanese shrimp wholesale prices deflated by the Japanese wholesale price index
BFPDJAP = Japanese beef wholesale prices deflated by the Japanese wholesale price index

All coefficients in the equation are significant with the expected sign. The lagged dependent variable SHCAJAP(-1) is not included in the reported equation because its coefficient was not significant and it did not contribute to the $R^2$. The equation implies that the income elasticity for Japan is 1.25, higher than that for the United States. The own-price elasticity is -0.36. Beef is a substitute for shrimp with a cross-price elasticity of 0.35.

The demand equation estimated for the rest of the world is as follows :

$$\underset{}{LN(SHCARW) = 11.909} + \underset{(2.8)}{0.451} * \underset{(-3.3)}{LN(SHCARW(-1))} + \underset{(3.3)}{1.528} * LN(GNPRW)$$

$R^2 = 0.97$ DW = 2.0 Period = 1965-88

where,

SHCARW = per capita consumption in the rest of the world
GNPRW = GNP per capita in constant dollars in market economies in the rest of the world

The coefficients of the lagged consumption and income variables have the expected signs and are significant. The equation implies income elasticity of 1.5. The price variable was dropped from the equation because it did not have the expected sign and was insignificant.

The estimated equation for shrimp landings is as follows :

$$\begin{aligned} LN(SHLW) = {} & 1.695 + 0.510 * LN(SHLW(-1)) + 0.094 * LN(SHPDW) + 0.209 * LN(SHPDW(-1)) \\ & (1.8) \quad (3.0) \qquad\qquad (1.2) \qquad\qquad (2.2) \\ & -0.012 * RINR + 0.017 * T \\ & (-1.8) \qquad\quad (2.1) \end{aligned}$$

$R^2 = 0.98$ DW = 2.3 Period = 1966-1988

where

SHLW = world shrimp landings
SHPDW = world shrimp prices deflated by the World Bank's manufactured unit value of exports (MUV)
SHPDW(-1) = lagged shrimp prices deflated by the MUV
RINR = real interest rate
T = time trend

All coefficients in the equation have the expected signs and are significant, except for the current price variable. Although fuel costs accounts for a large part of shrimping costs, the coefficient of the fuel variable did not have the expected sign, and was dropped from the equation. The results imply a short-term price elasticity of 0.09 and a long-term price elasticity of 0.62.

The cultured shrimp production equation estimated is as follows :

$$\begin{aligned} LN(SHCUW) = {} & -0.008 + 0.973 * LN(SHCUW(-1)) + 0.313 * LN(SHPDW(-1)) \; -0.034 * (RINR) \\ & (-0.01) \quad (40.6) \qquad\qquad (1.6) \qquad\qquad (-3.6) \\ & - 0.239 * LN(FMEALPD) \\ & (-2.7) \end{aligned}$$

$R^2 = 0.997$ DW = 1.8 Period = 1966-1988

where,

SHCUW = world cultured shrimp production
SHPDW = world (averaged US and Japanese) shrimp prices deflated by the MUV
RINR = real interest rate
FMEALPD = international fishmeal prices deflated by the MUV

The real interest rate is used to measure the opportunity cost of investment in shrimp production. With feed the major part of operating costs, fishmeal prices are used as the indicator price. All coefficients are significant with the expected signs. The results imply a short-term elasticity of 0.31 and a long-term elasticity of 11.5.

The price linkage equation for US and Japanese prices is estimated as follows :

$$\begin{aligned} LN(SHP\$JAP) = {} & 0.116 + 0.966 * LN(SHPUS) \\ & (0.7) \quad (34.0) \end{aligned}$$

$R^2 = 0.98$ DW = 1.7 Period = 1965-88

where

SHP$JAP = Japanese shrimp prices in US dollars
SHPUS = US shrimp prices

The equation indicates that both prices move closely together.

### *4.2 Performance of the Model*

In order to validate the specification of the equations as well as the overall performance of the model an ex-post simulation was run dynamically for the period 1965-1988. The simulated observations were compared with the actual

observations to derive statistics for evaluating the performance of each variable. The summary statistics from the simulation are shown in Table 1. As seen there the root mean square percentage error ranges from 3 % to 10 % for all endogenous variables except for US prices and cultured shrimp production. The Theil inequality coefficients are close to zero, indicating that the simulation values are close to actual values. The mean-square error is decomposed into the bias and regression proportions, that the values for these statistics are close to zero is an indication that there are no systematic errors. Also most of the residual proportions of the model are close to one, indicative of the good performance of the model.

## 5. PROJECTIONS AND SENSITIVITY ANALYSIS

### *5.1 Projections*

Projections of exogenous variables - including population, GNP growth for the United States and Japan, price deflators, exchange rates, interest rates, and fishmeal and beef prices - were taken from World Bank files. GNP growth for the rest of the world was taken from WEFA projections. Trend values were used for fish wholesale price projections in the United States. World population was estimated at 5.1 billion in 1988 and is expected to increase to about 6.2 billion by the year 2000, representing an average annual growth rate of 1.6 %. During the same period, population growth is projected to be 0.8 % p.a. for the United States, 0.4 % p.a. for Japan, and 1.6 % p.a. for the rest of the world. Real GNP growth is projected to be 2.3 % p.a. for the United States, 4.0 % p.a. for Japan, and 3.2 % p.a. for the rest of the world. The MUV index is projected to increase at 3.5 % p.a. during the 1990-2000 period.

World production of shrimp is projected to increase from 2.98 billion lb. (head-off weight) in 1988 to 6.58 billion lb. in the year 2000, an average growth of 6.8 % p.a. This rapid growth can be mainly attributed to the rapid growth in cultured shrimp production, projected to grow at 13.6 % p.a. Production from landings is projected to increase at 2.6 % p.a. On the basis of these projections cultured shrimp production will surpass landings toward the end of the century. Details of the projections are shown in Table 2.

Real prices of shrimp are expected to decline substantially during the 1990's as a result of the faster growth in production due to the fast growth of cultured shrimp production. The model forecasts a decline of 4.6 % p.a. in the US market and 5.0 % p.a. in the Japanese market. Without the fall in prices, world consumption would have grown at 4.8 % annually during the projection period, as compared to the projected 6.8 % p.a. growth.

### *5.2 Sensitivity Analysis*

The cultured shrimp production variable can be used as a policy variable to look at the effects of various rates of growth in cultured shrimp production on prices. The model has been simulated with two rates of increase in cultured shrimp production -- 5 % p.a., and 10 % p.a. The simulated results are presented in Tables 3 and 4. The results from the simulation indicate that if cultured shrimp production increases by only 5 % per year then real shrimp price in 2000 would be 23 % higher than the 1988 level. If cultured shrimp production increases by 10 % per year the real shrimp price in 2000 would be 14 % lower than in 1988.

## REFERENCES

**Adams C.M., F.J. Prochaska and T. Spreen** (1987). "Price Determination in the U.S. Shrimp Market", *Southern Journal of Agricultural Economics,* December .

**Blomo V.J., J.P. Nechols, W.L. Griffin and W.E. Grant** (1992). "Dynamic Modeling of the Eastern Gulf of Mexico Shrimp Fishery", *American Journal of Agricultural Economics,* Vol. **64**, No. 3, August.

**Chauvin W.D.** (1990). "World Shrimp Aquaculture Status", presented at a World Bank seminar, February.

**Doll J.** (1971). "An Econometric Analysis of the U.S. Shrimp Market", US National Marine Fisheries Service Working Paper No. 79, February.

**FAO** (1976). *The International Market for Shrimp*, Manila.

**Henriquer D.S.** (ed.) (1986). *Shrimp World II*, proceedings, The Second World Shrimp Market Conference, Hawaii, March.

**International Trade Center** (1983). *Shrimp : A Survey of the World Market*, Geneva.

**Lea J.D.** (1988). *A Dynamic Econometric Model of the U.S. Shrimp Market*, Ph.D. dissertation,University of Florida.

*Proceedings of the Workshop on Shrimp and Prawn Markets* , sponsored by the International Institute of Fisheries Economics and Trade and the South Carolina Wildlife and Marine Resources Department, July 1984.

**Rackowe R.** (1983). *The International Market for Shrimp, ADB/FAO INFOFISH, Market Report* Vol. **3**, March.

**Shrimp World Inc.** (1990). *Shrimpology 2000 : A Report* , October.

**Timmer C.P.** (1968). "A Projection Model of the U. S. Shrimp Market", *Food Research Institute Studies*, Vol. **VIII**, No. 3.

**U.S. Department of Commerce** (1983). *The U.S. Shrimp Industry : An Economic Profile for Policy and Regulatory Analysis*, January.

**U.S. Department of Commerce** (1988). *Aquaculture and Captive Fisheries : Impacts in U.S. Seafood Markets*, April.

**U.S. Department of Commerce** (1991). "Chinese Shrimp Culture", IFR 91/43, June.

**World Bank** (1989). The Shrimp Industry : Global Subsector Study, *Industry and Energy Department Working Paper* No. 18, December.

**World Bank** (1989). *Asia-Wide Shrimp Agro-Industry Sector Study* , ASTIF, September.

**TABLE 1.**
**SUMMARY STATISTICS FOR EX-POST SIMULATION.**

| Variables | Mean of Actual | Mean Absolute Error | Root Mean Squared Error | Mean % Error | Root Mean Squared % Error | Theil Inequality Coefficient | Inequality Proportions | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Bias | Regression | Residual |
| Per Capita Consumption: | | | | | | | | | |
| SHCAUS | 2.11 | 0.09 | 0.12 | 4.11 | 5.50 | 0.03 | 0.01 | 0.01 | 0.99 |
| SHCAJAP | 3.20 | 0.13 | 0.15 | 4.68 | 6.33 | 0.02 | 0.00 | 0.00 | 1.00 |
| SHCARW | 0.30 | 0.01 | 0.02 | 4.27 | 5.11 | 0.03 | 0.00 | 0.00 | 1.00 |
| Total Consumption: | | | | | | | | | |
| SHCUS | 468.75 | 19.92 | 26.70 | 4.11 | 5.50 | 0.03 | 0.01 | 0.00 | 0.99 |
| SHCJAP | 365.90 | 14.32 | 16.78 | 4.68 | 6.33 | 0.02 | 0.00 | 0.00 | 1.00 |
| SHCRW | 1,207.69 | 52.92 | 68.42 | 4.27 | 5.11 | 0.03 | 0.00 | 0.00 | 1.00 |
| Production: | | | | | | | | | |
| SHLW | 1,894.25 | 56.32 | 70.77 | 2.83 | 3.40 | 0.02 | 0.01 | 0.01 | 0.98 |
| SHCUW | 148.10 | 18.18 | 29.72 | 11.61 | 15.20 | 0.06 | 0.03 | 0.06 | 0.91 |
| Prices: | | | | | | | | | |
| SHPW | 325.40 | 28.05 | 39.70 | 8.01 | 10.05 | 0.05 | 0.00 | 0.01 | 0.99 |
| SHPUS | 339.63 | 36.57 | 51.56 | 9.71 | 12.00 | 0.07 | 0.00 | 0.01 | 0.99 |
| SHPJAP | 738.69 | 66.17 | 79.54 | 8.70 | 9.87 | 0.05 | 0.00 | 0.00 | 1.00 |
| SHPDW | 420.72 | 34.29 | 44.44 | 8.01 | 10.05 | 0.05 | 0.00 | 0.12 | 0.88 |
| SHPDUS | 424.71 | 42.87 | 54.91 | 9.71 | 12.00 | 0.06 | 0.00 | 0.13 | 0.87 |
| SHPDJAP | 984.60 | 86.17 | 98.06 | 8.70 | 9.87 | 0.05 | 0.00 | 0.08 | 0.91 |

Source: World Bank, International Economics Department.

**TABLE 2.**
**SHRIMP PROJECTIONS.**

| | 1988 | 1991 | 1992 | 1993 | 1994 | 1995 | 2000 |
|---|---|---|---|---|---|---|---|
| Consumption | | | | | | | |
| Per Capita (lb headless): | | | | | | | |
| United States | 2.97 | 3.54 | 3.75 | 3.86 | 4.08 | 4.37 | 5.90 |
| Japan | 5.34 | 7.00 | 7.09 | 6.97 | 7.26 | 7.62 | 9.71 |
| Rest of World | 0.34 | 0.44 | 0.45 | 0.47 | 0.49 | 0.52 | 0.65 |
| Total (million lb headless): | | | | | | | |
| United States | 729.0 | 891.9 | 952.9 | 989.0 | 1,052.7 | 1,137.0 | 1,589.6 |
| Japan | 654.4 | 868.3 | 883.9 | 871.4 | 912.4 | 961.0 | 1,248.9 |
| Rest of World | 1,597.7 | 2,199.1 | 2,296.6 | 2,429.1 | 2,584.5 | 2,751.7 | 3,743 9 |
| Production (million lb headless): | | | | | | | |
| Landings | 2,204.6 | 2,639.6 | 2,610.8 | 2,625.7 | 2,694.5 | 2,756.1 | 2,984 6 |
| Cultured | 776.5 | 1,319.8 | 1,522.6 | 1,663.9 | 1,855.1 | 2,093.7 | 3,597.4 |
| Prices | | | | | | | |
| United States ($/lb): | | | | | | | |
| Current | 5.64 | 4.94 | 4.91 | 5.27 | 5.34 | 5.31 | 5.43 |
| Deflated | 4.76 | 3.43 | 3.31 | 3.45 | 3.39 | 3.27 | 2.71 |
| Japan (¥/lb): | | | | | | | |
| Current | 840.3 | 610.6 | 599.9 | 633.8 | 630.4 | 618.3 | 593.7 |
| Deflated | 974.8 | 618.0 | 600.6 | 623.8 | 612.8 | 592.1 | 523.9 |

Source: World Bank, International Trade Division.

**TABLE 3.**
**SHRIMP MARKET PROJECTIONS UNDER THE ASSUMPTION OF 5 % p.a. INCREASE IN CULTURED PRODUCTION.**

Table 3: Shrimp Market Projections Under the Assumption of 5% p.a. Increase in Cultured Production

| | 1988a/ | 1991 | 1992 | 1993 | 1994 | 1995 | 2000 |
|---|---|---|---|---|---|---|---|
| Consumption | | | | | | | |
| Per Capita (lb headless) | | | | | | | |
| United States | 2.97 | 3.18 | 3.31 | 3.42 | 3.51 | 3.66 | 4.40 |
| Japan | 5.34 | 6.35 | 6.33 | 6.24 | 6.32 | 6.49 | 7.43 |
| Rest of World | 0.34 | 0.44 | 0.45 | 0.47 | 0.49 | 0.52 | 0.65 |
| Total (million lb headless): | | | | | | | |
| United States | 729.0 | 802.6 | 841.8 | 876.4 | 905.4 | 953.3 | 1,186.6 |
| Japan | 654.4 | 788.4 | 789.1 | 780.2 | 794.9 | 817.9 | 955.7 |
| Rest of World | 1,597.7 | 2,199.1 | 2,296.6 | 2,429.1 | 2,584.5 | 2,751.7 | 3,743.9 |
| Production (million lb headless): | | | | | | | |
| Landings | 2,204.6 | 2,891.2 | 2,983.7 | 3,094.8 | 3,244.2 | 3,430.3 | 4,491.7 |
| Cultured | 776.5 | 898.9 | 943.8 | 991.0 | 1,040.5 | 1,092.6 | 1,394.4 |
| Prices | | | | | | | |
| United States ($/lb): | | | | | | | |
| Current | 5.64 | 6.53 | 6.81 | 7.25 | 7.94 | 8.44 | 11.73 |
| Deflated | 4.76 | 4.53 | 4.59 | 4.74 | 5.05 | 5.20 | 5.86 |
| Japan (¥/lb): | | | | | | | |
| Current | 840.3 | 798.4 | 821.9 | 861.7 | 924.5 | 967.5 | 1,248.2 |
| Deflated | 974.8 | 808.1 | 822.9 | 848.1 | 898.8 | 926.5 | 1,101.5 |

a/ Actual

Source: World Bank, International Trade Division.

**TABLE 4.**
**SHRIMP MARKET PROJECTIONS UNDER THE ASSUMPTION OF 10 % p.a. INCREASE IN CULTURED PRODUCTION.**

Table 4: Shrimp Market Projections Under the Assumption of 10% p.a. Increase in Cultured Production

| | 1988a/ | 1991 | 1992 | 1993 | 1994 | 1995 | 2000 |
|---|---|---|---|---|---|---|---|
| Consumption | | | | | | | |
| Per Capita (lb headless): | | | | | | | |
| United States | 2.97 | 3.29 | 3.45 | 3.61 | 3.73 | 3.94 | 5.05 |
| Japan | 5.34 | 6.55 | 6.58 | 6.55 | 6.70 | 6.93 | 8.42 |
| Rest of World | 0.34 | 0.44 | 0.45 | 0.47 | 0.49 | 0.52 | 0.65 |
| Total (million lb headless): | | | | | | | |
| United States | 729.0 | 829.6 | 878.1 | 924.1 | 964.3 | 1,025.3 | 1,360.1 |
| Japan | 654.4 | 812.6 | 820.2 | 818.9 | 842.0 | 874.3 | 1,082.8 |
| Rest of World | 1,597.7 | 2,199.1 | 2,296.6 | 2,429.1 | 2,584.5 | 2,751.7 | 3,743.9 |
| Production (million lb headless): | | | | | | | |
| Landings | 2,204.6 | 2,807.8 | 2,858.1 | 2,921.6 | 3,015.1 | 3,138.2 | 3,949.9 |
| Cultured | 776.5 | 1,033.5 | 1,136.8 | 1,250.5 | 1,375.6 | 1,513.1 | 2,436.9 |
| Prices | | | | | | | |
| United States ($/lb): | | | | | | | |
| Current | 5.64 | 5.98 | 6.09 | 6.31 | 6.73 | 6.96 | 8.19 |
| Deflated | 4.76 | 4.15 | 4.11 | 4.13 | 4.28 | 4.30 | 4.09 |
| Japan (¥/lb): | | | | | | | |
| Current | 840.3 | 734.1 | 738.3 | 753.2 | 787.8 | 804.0 | 882.5 |
| Deflated | 974.8 | 743.0 | 739.2 | 741.4 | 765.9 | 769.9 | 778.7 |

a/ Actual

Source: World Bank, International Trade Division.

# Changes in Poland's Foreign Trade Management and Impacts on the Foreign Trade of Fishery Products

**Halina Nakonieczna-Kiesiel[a] and Jolanta Zieziula[b]**

[a]Cathedral of Foreign Trade and International Economic Relations, University of Szczecin, ul Mickiewicza 64, 71-101 Szczecin, Poland

[b]Academy of Agriculture, ul Janosika 8, 70–965 Szczecin, Poland

ABSTRACT

*Since the end of the 1980s, the Polish economy has been changing towards a market-oriented system. Essential institutional changes have been undertaken by the Polish authorities in order to start to create a new basis for the economy - private ownership. The first step in that direction is the demonopolisation of state-owned enterprises.*

*The paper is organised into two main parts. First all newly-established regulations concerning Poland's foreign trade are presented, namely regulations on demonopolisation, tariff barriers and exchange rates.*

*Secondly the impact of the undertaken measures on Poland's fishery economy, especially on foreign trade, is presented. Finally, some conclusions are drawn.*

## 1. INTRODUCTION

Since the very end of 1989 Poland's centrally planned and managed economy started to transform to become market-oriented, based on principles of competition and private capital ownership. Transformation processes have been accompanied by structural and economic changes.

Poland's foreign trade is essentially affected by most of structural and economy changes. And it is obvious, that transformation processes can not be successfully carried off without a wide opening of economy for cooperation with foreign countries [1].

1. See : Polityka ekonomiczna i handlowa Polski w 1990 r. /Poland's Economic and Trade Policies in 1990/, Warszawa 1991, p.32 and the next ones.

## 2. NEW REGULATIONS CONCERNING POLAND'S FOREIGN TRADE

### *2.1 Demonopolization*

In fact, in 1989 a monopolistic position of state-owned enterprises in Poland's foreign trade was abolished. According to newly created regulations, all existing and new firms could deal with export-import transactions without the necessity to apply for a special concession, as it was before [2]. Regulations on demonopolization in the foreign trade sphere, together with previously imposed regulations on foreign investments in Poland, set up conditions of competition between firms involved in foreign trade transactions of any kind [3].

Additionally, all export and import quotas were gradually diminished. Fewer and fewer goods were on a list of products, permanently or temporarily restricted in Poland's foreign trade [4]. Generally, apart from some exceptions, any restrictions /such as import quotas/ in Poland's imports do not exist. However, there are some constraints in exports of strategically important goods or trade on intergovernmental agreements of Poland.

### *2.2 Exchange rate*

A substancial change of governmental currency exchange rate policy was the next step of transforming Poland's economy, especially the foreign trade management sphere. A principle of submarginal currency exchange rate policy accompanied with very ineffective mechanism of direct and indirect subsidies were replaced by policy of real exchange rate [5]. Initially, Poland's currency exchange rate was based on US dollar. On January 1st, 1990 the rate was worked out at 9,500 zl/1 USD. However, changing conditions of economic activities and fast growing rate of inflation in the country, made it necessary to get currency exchange rate into line. It was changed twice : in May 1991 for 11,000 zl/1 USD and in February 1992 for 13,400 zl/1 USD. Additionally, basis of currency exchange rate determination was changed. Since September 1991 the exchange rate of Poland's zloty has been based on five western currencies. It was also decided not to keep zloty at a stable level but let it gradually depreciate, according to rate of inflation, even week by week.

The real exchange rate of our currency made it possible to introduce internal exchangeability of Poland's zloty. It was the next step towards opening economy for cooperation with other countries.

Since 1991, all firms have been obliged to change all their foreing sales incomes in banks for zloties at a given rate of exchange. However, firms have been allowed to purchase foreign currencies, needed for realization of their imports, without any constraints. The new governmental policy on currency exchange rates have been accompanied by substancially restricted monetary and budget policies. Both moves limit financial flexibility of firms. According to a new requirement, firms are obliged to keep a deposit of 10 % of purchased foreign currency value in banks. This fact strengthens the tendency mentioned above.

Internal exchangeability of Poland's zloty was accompanied by a new-fixed exchange rate between US dollar and zloty, compared to transfer Rouble and zloty /it changed from 2,2 in 1988/1989 to over 4,5 in 1990/. However, it did not encourage Poland's firms to expand their exports to Western countries, instead of the Soviet Union block countries. Only, a new system of trade introduced in January 1991, first of all transaction settlements with former socialist countries - according to world prices and in exchangeable currencies - hold up firm's tendency to export mainly to former socialist countries [6].

### *2.3 Tariff barriers*

New customs regulations have been the next systemic change playing an important role in opening Poland's economy for cooperation with Western countries. Their characteristic feature was that unequal treatments of people and enterprises

2. Dziennik Ustaw No 72/89 pos 432 and No 116/91 pos. 505 .
3. More on foreign capital investments in Poland in nineteen-eighties see : Raport o systemie kierowania handlem zagranicznym Polski w 1988 r./Report on System of Poland's Foreign Trade Management in 1988/, Warszawa 1989, p.80-104.
4. Dziennik Ustaw No 19/90 pos. 114, No 47/90 pos. 282, No 61/90 pos. 385, No 140/90 pos. 280 and No 1/92 pos. 2.
5. Wider discussion on the problem see : U.Plowiec, Proeksportowa restrukturyzacja polskiej gospodarki /Export-oriented Restructurization of Poland's Economy/, Handel Zagraniczny /Foreign Trade/ No 1-2- 3/1991.
6. See : M. Oniszczuk, Handel Polska-ZSRR, Refleksje po czarnym polroczu /Trade Poland-USSR, Remarks after Black Half Year/, Rynki Zagraniczne /Foreign Markets/ No 85/1991.

were eliminated. Before, all state-owned enterprises were given privileges, such as tariff reductions. Apart from that, foreign trade transactions differentiated previously for trade ones and non-trade ones, become just transactions. People cannot import goods on their touristic trips without paying duties, any longer.

Construction of tariff duties has been changed. Only imported goods have been charged, according to new customs regulations, when before there were duties also on some exported goods. There is no preferential treatment of any country. Customs tariffs, introduced since August 1991, have been based on EEC customs tariff nomenclature [7]. They contain wide and more accurate lists of goods, subjects of tariff duties. According to EEC customs tariff names, foreign trade agreements as well as international comparisons are much easier.

However, successive modifications of Poland's customs tariffs since 1989 resulted in an increase of average tariff duties on imported goods. While in 1990 they consisted of less than 4 % of imported goods value and they were among the lowest ones in Europe, the new tariff construction caused an increase of average tariff duties up to 14 % of imported products value [8].

Another constraint in Poland's imports - playing a role against development of competition between firms - has been an increasing rate of import surcharge /so called border tax/. Since August 1990 it was fixed at 20 % of imported goods value and in the second half of the year at 15 % [9].

In the second part of the paper - considering all systemic changes of Poland's foreign trade management - their impact on foreign trade of fishery products is analysed.

## 3. IMPACT ON POLAND'S FISHERY ECONOMY

To open Poland's economy for cooperation with other countries, for fishery economy sphere meant abolishing foreign trade monopoly of "Rybex" - the state-owned company. Everybody could deal with export-import transactions, on condition to register the activity and to pay taxes.

At the begining, export activities started mainly private fishermen. They sold parts of their catches, mainly cod in Denmark /Bornholm Island/. Almost at the same time, private firms competing with the state-owned processing enterprises have appeared. They buy Baltic Sea fish and fresh-water fish in order to process them and to sell in Poland and/or abroad.

One of expanding private firms dealing with fish processing, exports and imports is Morawiak Corporation. It has developed since 1986 when it was small artisanal fish smoking firm. At present, Morawiak Corporation could afford to buy 81 % shares of a privatised state-owned processing firm /Centrala Rybna/ in Szczecin. They have expanded many trade contacts all over the country as well as abroad.

Other enterprises, for a long time involved in fishery activities of any kind, such as "Certa" in Szczecin, "Szkuner" in Wladyslawowo, as well as "Centrala Rybna" in Gdynia, even before 1990 - when only new state regulations on foreign capital investments in Poland came into power - then set up join ventures with foreign partners. According to mutual agreements, Polish partners most often provide raw materials for processing, location and labour. Foreign partnersusually give processing technologies and equipment as well as modern organization of work. In Poland, until 30.09.1989, the biggest joint venture company, with foreign capital share was "Schooner" Co Ltd., turned from "Szkuner" with one of US companies as a shareholder [10].

As a matter of fact, according to systemic solutions, all firms may deal with foreign trade of fish products, but all state-owned distant-water fishing firms - as it was before 1990 - still export their products by "Rybex". However, since

7. See : M.Nogaj, Przepisy prawne regulujace obrot towarowy z zagranica /Legal Regulations on Foreign Trade Markets/, Rynki Zagraniczne /Foreign Markets/ No 11/1990.
8. Warunki dzialania przedsiebiorstwa /Conditions for Firm's Economic Activities/, Rzeczpospolita No 276/1990, p.III and Nowa taryfa celna /New Customs Tariff/, Rynki Zagraniczne /Foreign Markets/, No 91/1991.
9. U.Plowiec, op.cit., p.11.
10. See · T.Malecka, Przedsiebiorstwa zagraniczne w Polsce /Foreign Companies in Poland/, Handel Zagraniczny /Foreign Trade/, No 12/1989 p. 7.

the second half of nineteen-eighties, a role of "Rybex" has changed, because distant-water fishing enterprises make export-import deals with foreign partners by themselves. They are known as "off board" transactions. Only formal documents are sent to "Rybex".

Shareholders of "Rybex" Co Ltd. /now undergoing privatization process/ are the state-owned distant-water fishing companies. They continue to keep formal monopoly of 'Rybex", because of their previous declarations and then obligations to maintain an integration of Poland's fishery economy as a whole. However, all changes in Poland's economy made "Rybex" to diminish its share in foreign trade of fish products - in 1991 to about 40 % [11].

According to data given in table 1, in the latest two years there was strong decreasing tendency in Poland's foreign trade of fish products. In fact, presented figures give only available information - the "Rybex" data, which makes the picture darker than it really is. Undoubtedly, in 1991 exports of fish products were much lower than they were in 1989. The similar tendency could be observed in imports. In the analized period, exports considerably exceeded imports.

A decrease of fish products exports /among them "off-board exports" were caused by growing difficulties in getting an access to world fish resources. Gradually diminishing opportunities of distant-water fishing [12] caused Poland's fishing fleet to be underutilized. As a result, some old fishing vessels were scrapped and some other have been sold abroad [13].

Fewer and fewer opportunities to fish brought not only problems of fishing vessels utilizations, but also some other problems. Profitability of fishery enterprises worsened and hence existing level of employment was found to be excessive. Deficit of fish raw material caused underutilization of processing equipment in many firms. Additionally, rigorous state monetary policy and high rate of interest on credits made it necessary reorganize or liquidate most of state-owned fishery enterprises [14].

As mentioned before, diminishing opportunity to fish negatively influenced exports. Exports of fish products only exist because fewer products are delivered on the domestic market. Higher prices of fish products abroad than in Poland are main stimula of exports.

Import liberalization, mainly very low tariff duties in 1989 did not result in an increase of fish imports. According to the figures in table 1 imports have been decreasing. In 1990 and in 1991 they were much lower than in 1989. There were some reasons of that. Higher prices abroad than in the country were one of them. The second one has been a deep recession, partly a result of an antiinflationary governmental policy and growing level of unemployment made domestic demand on fishery products to collapse, like it is for many other products.

Prior to Poland's association with EEC countries, since 1.08.1991, a new one column customs tariff on fish products - bringing it into line with EEC import regulations - has come into power [15]. According to the tariff, duties on imported fish products have been fixed at between 5 % and 55 % of their customs value.

However, fears of excessively rising costs of imports and decreasing quantities of imports caused that until 1.03.1992 customs duties were lowered for many fish products [16]. Mostly, they did not exceed 5 % or 10 % of products customs value. The highest duty rate was established at 25 %. Undoubtedly, increasing customs duty rates for fish products strengthened diminishing tendency in their imports to Poland.

Apart from the mentioned reasons, decreasing Poland's imports were caused by almost entirely stopped imports of canned fish from former USSR. It was strictly connected with expiries of inter-governmental economic agreements between both countries, as well as changing settlements of trade transactions, from transfer Roubles /clearing accounts in fact/ to convertible currencies.

11. See : A. Gwiazda, Niepomyslne perspektywy polskiego rybolowstwa /Bad Perspectives of Poland's Fishery/, Rynki Zagraniczne /Foreign Markets/, No 15/1992, p.7. A situation and problems of Poland's fish products foreign trade in nineteen-eighties has been presented in : J.Zieziula, Problems of Polish Foreign Trade in Fishery Products, 4th Biennial Conference, August 7-12, 1988, Esbjerg, Denmark, Seafood Trade, Fishing Industry Structure and Fish Stocks - The Economic Interaction, volume I, p. 456-469.
12. See : A. Gwiazda, Problemy polskiego rybolowstwa /Problems of Poland's Fishery/ Rynki Zagraniczne /Foreign Markets/ No 15/1992 p. 7.
13. Only one of the distant-water fishing big enterprises "Odra", since October 1991, sold 7 trawlers. Recently, 3 trawlers were sold to Greece and 1 to Germany. See : Ubyly kolejne 4 trawlery /The next 4 trawlers less/, Rynki Zagraniczne /Foreign Markets/ No 15/1992, p. 7.
14. See : Bogaty.. w dlugi, /Rich... in debts/, Gazeta Wyborcza /Election Newspaper/ No 54/1992, dodatek lokalny /local supplement/ p.1 and wider J.Dudzinski, J. Zieziula Poland's Fishery Economy under Changing Economic Conditions, Fisheries Economic Newsletter No 31 May 1991, p. 1-13.
15. See : Taryfa celna importowa /Customs Duty Tariff on Imported Goods/, Zalacznik do Dziennika Ustaw Rzeczpospolitej No 67 pos. 288 z 30.07.1991, Dzialy : 3, 11 i 16. On EEC Custom Duty Tariff construction see : J.Zieziula, Narzedzia polityki handlowej panstw jako bariery w swiatowym imporcie produktów rybnych /Trade Policy Measures of Governments as Barriers of World Fish Products Imports, Zeszyty Naukowe Akademii Rolniczej w Szczecinie /Scientific Papers of Szczecin Academy of Agriculture/ No 136/1989, p. 19-39.
16. That was until signing an agreement on trade and economic cooperation between Poland and EEC. The agreement is presented in Rynki Zagraniczne /Foreign Markets/ No 7/1992, p. 3 and 4.

Additionally, since 1988 Poland's fish imports "off board" have diminished [17] It has been caused by fewer and fewer fishing opportunities of Polish distant-water fleet. It means : smaller catches, less "off board" export and less "off board" import.

In analysed period, there existed surpluses in Poland's fish products foreign trade balance. Main reason of that was the existing high demand for fish products abroad as well as profitability of exports. The latest could be achieved because of : higher prices for fish products abroad than in Poland, especially for fillets and headed and gutted white fish /both were main items in exports/, relatively low costs of fish processing in Poland and Polish zloty devaluation.

However, a high rate of inflation in Poland without accompanying it officially changed Zloty rate of exchange until May 1991, lowered profitability of foreign trade. It made export transactions less profitable in 1991 than they were in 1990..

## 4. CONCLUSION

i) Poland's foreign trade of fish products was affected both by internal and external factors. Among them long-term cosequences of loosing access to the most valuable fishing grounds and substancially diminishing catches were of great importance. Less and less fish had to cause decreasing exports.

ii) Factors playing against above tendency were - for some time - exchange rate between zloty and US dollar, encouraging exports, as well as higher prices of fish products abroad than in Poland.

iii) Demonopolization of Poland's foreign trade enhanced mainly small and new established firms to export. However, an influence of systemic changes on exports were of less importance. Nevertheless conditions for competition among firms, some transformation processes and improvement of effectiveness in fishery economy sector have been started.

iv) Decreasing tendency of fish products imports was a result of deepening economic recession in Poland and rising level of import duties. Indirectly, diminishing distant-water catches strengthened the tendency.

17. See : Informacja o dzialalnosci morskiej gospodarki rybnej, /Information on Sea Fishery Economy Activities/, Morski Instytut Rybacki, Zaklad Ekonomiki i Statystyki Rybackiej, Gdynia, za lata 1989, 1990 i 1991.

REFERENCES

**Bogaty w dlugi.** (1992). Gazeta wyborcza No 54, Dodatek lokalny.

**Dudzinski J., Zieziula J.** (1991). Poland's Fishery Economy under Changing Economic Conditions of the Country, *Fisheries Economics Newsletter*, No **31**, May.

**Dewaluacja** (1991). Zycie Gospodarcze No 81.

**Dzienniki Ustaw.** No 72/89 pos. 432 ; No 19/90 pos. 114 ; No 47/90 pos.282 ; No 61/90 pos. 358 ; No 140/90 pos. 280.

**Gwiazda A.** (1992). Niepomyslne perspektywy polskiego rybolowstwa, *Rynki Zagraniczne* No 15.

**Gwiazda A.** (1992). Problemy polskiego rybolowstwa, *Rynki Zagraniczne* No. 3

**Informacja o dzialalnosci morskiej gospodarki rybnej,** Morski Instytut Rybacki, Zaklad Ekonomiki i Statystyki Rybackiej, Gdynia 1989, 1990, 1991.

**Malecka T.** (1989). Przedsiebiorstwa zagraniczne w Polsce, *Handel Zagraniczny* No **12.**

**Monitor Polski** (1989). No 44 pos. 362.

**Morski Instytut Rybacki, Gdynia** (1989). Morska Gospodarka Rybna PRL (1945-1985).

**Nogaj M.** (1990). Przepisy prawne regulujace obrot towarowy z zagranica, *Rynki Zagraniczne* No **11.**

**Oniszczuk M.** (1991). Handel Polska-ZSRR, Refleksje po czarnym polroczu, *Rynki Zagraniczne* No **85.**

**Plowiec U.** (1991). Proeksportowa restrukturyzacja polskiej gospodarki - instrumenty i wyniki w 1990 r., *Handel Zagraniczny* No 1-2-3.

**Polityka ekonomiczna i handlowa Polski w 1990 r., Warszawa (1991).**

**Polska-EFTA** (1992). Handel rybami i przetworami, *Rynki Zagraniczne* No **34.**

**Rynki zagraniczne** (1991), Nowa taryfa celna, No **91.**

**Rocznik Statystyczny Handlu Zagranicznego, GUS, Warszawa (1986 i 1989).**

**Taryfa celna importowa /2/ - dodatek do Rynkow Zagranicznych No 101 (1991).**

**Taryfa celna importowa /11/ - dodatek do Rynkow Zagranicznych No 131 (1991).**

**Umowa przejsciowa o handlu i wspolpracy gospodarczej z Polska,** *Rynki Zagraniczne* No **7** (1992).

**Warunki dzialania przedsiebiorstw, Rzeczpospolita No 276/1990.**

**Zieziula J.** (1989). Narzedzia polityki handlowej panstw jako bariery w swiatowym imporcie produktów rybnych, Zeszyty Naukowe Akademii Rolniczej w Szczecinie No 136.

**Zieziula J.** (1988). Problems of Polish Foreign Trade in Fishery Products, 4th Biennial Conference, August 7-12, Esbjerg, Denmark, Seafood Trade, Fishing Industry Structure and Fish Stocks - The Economic Interaction, volume I.

TABLE I
POLAND'S FOREIGN TRADE OF FISH PRODUCTS, MARINE CATCHES AND MARKET DELIVERIES (1985–1991)

| Specification | Measure | 1985 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|
| Export | mln USD | 100,1 | 170,8 | 241,9 | 149,7[a)] | 46,2[b)] |
| Import | mln USD | 55,4 | 100,2 | 135,8 | 30,3[a)] | 24,3[b)] |
| Export-Import | mln USD | 44,7 | 70,6 | 106,1 | 119,4 | 21,9 |
| Marine Catches | thou. t | 651,5 | 619,1 | 531,1 | 421,0 | 403,5 |
| - Distant-Water | thou. t | 172,7 | 492,6 | 412,4 | 320,3 | 306,5 |
| - Baltic Sea | thou. t | 178,8 | 126,5 | 118,7 | 100,7 | 97,0 |
| Market Deliveries | thou. t | 256,9 | 200,0 | 195,0 | 141,0 | 144,7 |

a) "Rybex" Co Ltd only
b) Apart from "Rybex Co Ltd also other firms but only trade with EFTA countries

Sources: Informacja o dzialalnosci morskiej gospodarki rybnej (Information on Seafish Economy Activity), Morski Instytut Rybacki, Zaklad Ekonomiki i Statystyki Rybackiej, Gdynia 1989, 1990 and 1991; Morska Gospodarka Rybna PRL 1945-1985 (Seafish Economy of Poland 1945-1985), Gdynia 1989; Polska - EFTA, Handel rybami i przetworami (Poland - EFTA, Trade of Fish Products), Rynki Zagraniczne No 34/1992

# Le commerce extérieur français des produits de la mer en 1991

**Joëlle Dari**

DPA (Direction des Produits Agro-Alimentaires), CFCE (Centre Français du Commerce Extérieur),
10, Avenue d'Iéna, 75783 PARIS, France

ABSTRACT

*(i) Some figures*

*French Trade in Fish Products in 1991*

| *billions FRF* | | *Change 91/90* |
|---|---|---|
| *Imports* | *16.3* | *+ 7.6 %* |
| *Exports* | *5.2* | *+ 2.8 %* |
| *Balance* | *- 11.1* | *- 2.1 %* |

*(ii) The French exchanges*

*The most important products are :* fish, fresh or chilled (especially saltwater fish), crustaceans and molluscs.

*French imports come from a lot of countries, but french exports are very concentrated on two countries : Spain and Italy, which represent 61.4 % of french exports.*

*(iii) Difficulties and leading factors*

*Main difficulties are* reduction of captures and most of exported products low value-added.

*Main leading factors are* a good location, a large range, especially in fine fish, a high market-share in some markets (Spain, Italy), a growing aquaculture.

## 1. INTRODUCTION

Quelques chiffres-clés

*1.1 Balance commerciale française en 1991 (cf figure 1).*

| | Milliards FRF | Evolution 1991/1990 |
|---|---|---|
| Import | 16.3 | + 7.6 % |
| Export | 5.2 | + 2.8 % |
| Solde | - 11.1 | - 2.1 % |

*1.2 Situation de la France sur le marché mondial en 1989*

- 3ème importateur mondial après le Japon et les Etats-Unis,
- 14ème exportateur mondial et 5ème exportateur européen,
- captures 1989 : 880.000 tonnes en poids vif, soit le 4ème producteur européen.

## 2. LES CARACTÉRISTIQUES DES ÉCHANGES FRANÇAIS

*2.1 Postes prédominants (cf figures 2 et 3)*

(i) les poissons frais et congelés :

1er poste des exportations (60 %),
1er poste des importations (30 %) avec une prépondérance des poissons de mer : 55 % des exportations françaises, 15 % des importations françaises.

(ii) les crustacés et mollusques : 2ème poste des exportations (21 %) et des importations (27 %).

*2.2 Les importations françaises*

Nos 5 premiers fournisseurs (Royaume-Uni, Norvège, Danemark, Islande, Pays-Bas) en produits de la mer - non compris les préparations et conserves - représentent 49,8 % de la valeur des importations.

*2.3 Inversement, les exportations sont très fortement concentrées,*

sur l'Espagne et l'Italie qui absorbent 61,4 % des ventes françaises. En outre, cette concentration s'accentue au fil des ans.

## 3. DEUX EXEMPLES FRANCAIS : LE COMMERCE EXTERIEUR FRANCAIS EN POISSONS DE MER ENTIERS, EN CRUSTACES ET MOLLUSQUES

*3.1 Poissons entiers de mer (cf figures 4 et 5)*

Devenu positif en 1988, le solde de ce poste ne cesse de progresser, mais plus en volume : + 25,6 % qu'en valeur : + 18,6 %.

Les exportations françaises concernent une gamme assez étendue d'espèces : ainsi les 5 premières espèces ne représentent que 44 % du total.

Elles sont marquées par une valorisation insuffisante. Les ventes s'accroissent en effet pour les espèces bon marché, ou dont les cours diminuent (thon, sardine, hareng) ; tandis que les exportations d'espèces à valeur ajoutée se réduisent (soles, anguilles, roussettes par exemple), ou progressent trop faiblement (baudroie, merlu).

Les importations, bien qu'en recul, restent dominées par des produits plus chers : cabillaud (15 %), sole (15 %), baudroie (9 %).

### *3.2 Crustacés et mollusques (cf figures 6 et 7)*

Ce poste accuse le déficit le plus élevé en 1991 : - 3,2 milliards FF, et le plus brutal : + 21,8 % ; après une année 1990 relativement favorable.

En effet, les importations sont en hausse sensible : + 13,5 % en valeur, et marquées par l'importance de produits à forte valeur ajoutée : langoustes, langoustines, homards, dont les prix sont stables ou en hausse. Les exportations, au contraire, portent davantage sur des produits peu chers : crevettes, seiches, calmars, huîtres, et dont les cours ont tendance à baisser (à l'exception des crabes et tourteaux).

## 4. DIFFICULTÉS ET ATOÛTS DE LA FRANCE

### *4.1 Principales difficultés*

(i) raréfaction de la ressource, d'où des difficultés à assurer un courant régulier d'exportations

(ii) forte atomisation de l'offre,

(iii) manque d'organisation logistique par rapport à nos concurrents d'Europe du Nord (Pays-Bas, Danemark, notamment).

(iv) faible valorisation des produits exportés.

### *4.2 Principaux atouts*

(i) position géographique privilégiée, vaste façade maritime.

(ii) variété de l'offre française notamment en poissons fins, ce qui lui confère une bonne image.

(iii) position dominante sur certains marchés (Italie, Espagne), rémunérateurs pour quelques espèces (merlu en Espagne, par exemple).

(iv) développement d'une aquaculture performante, qui facilite l'accès à certains marchés de part les garanties d'approvisionnement, et élargit la gamme française.

**TABLEAU 1.**
**PRIX A L'IMPORTATION (FRF/KG)**

| | 1990 | 1991 |
|---|---|---|
| Langoustes | 113,91 | 136,44 |
| Homards | 54,11 | 59,89 |
| Langoustines | 40,80 | 39,47 |

**TABLEAU 2.**
**PRIX A L'EXPORTATION (FRF/KG)**

| | 1990 | 1991 |
|---|---|---|
| Crevettes | 58,80 | 55,89 |
| Seiches | 12,97 | 11,41 |
| Crabes et tourteaux | 57,60 | 65,85 |
| Huîtres | 13,55 | 13,47 |
| Calmars | 23,03 | 22,52 |

FIGURE 1.
EVOLUTION DU SOLDE DES PRODUITS DE LA PECHE (ESCARGOTS, FARINES ET HUILES EXCLUS).

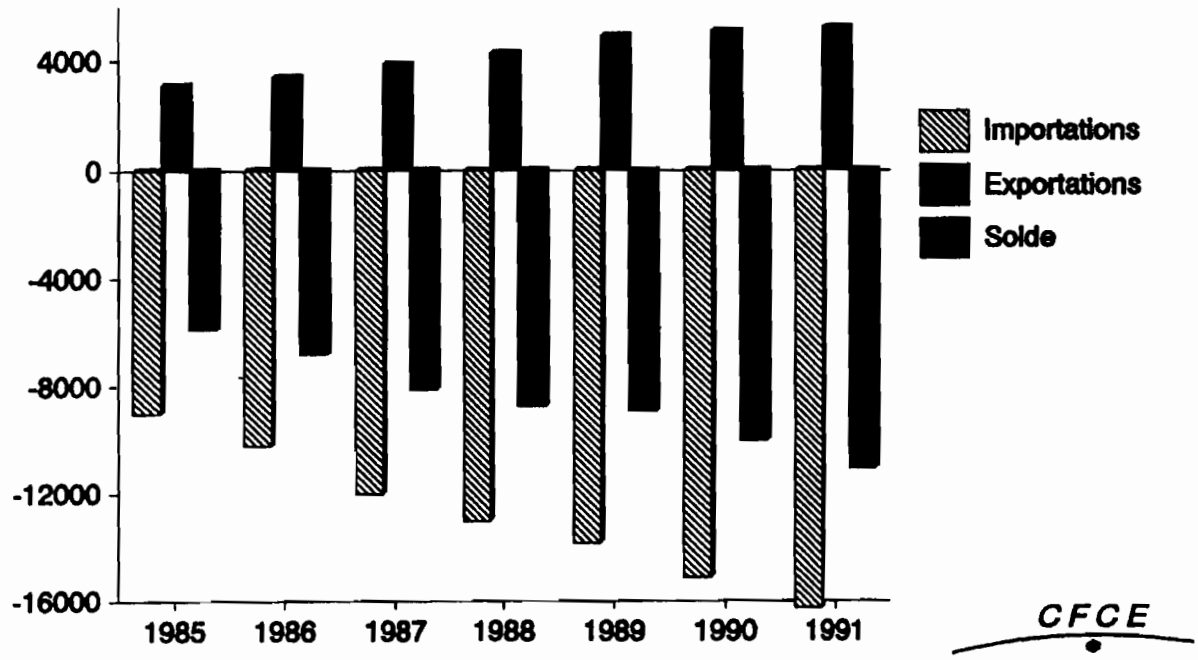



FIGURE 2.
REPARTITION DES IMPORTATIONS EN 1991 (EN VALEUR).

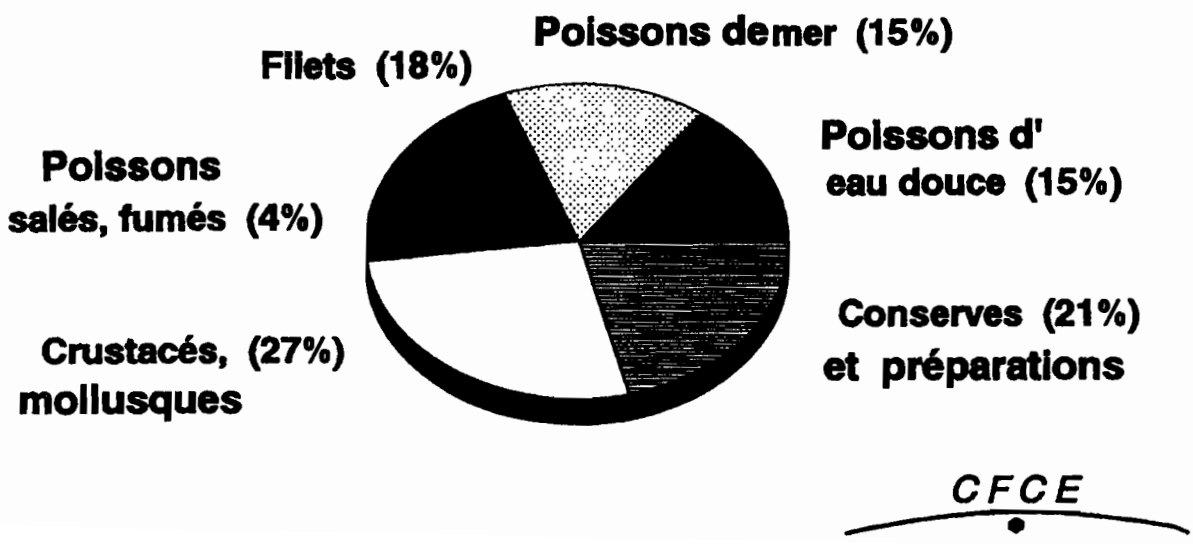


FIGURE 3.
REPARTITION DES IMPORTATIONS EN 1991 (EN VALEUR).

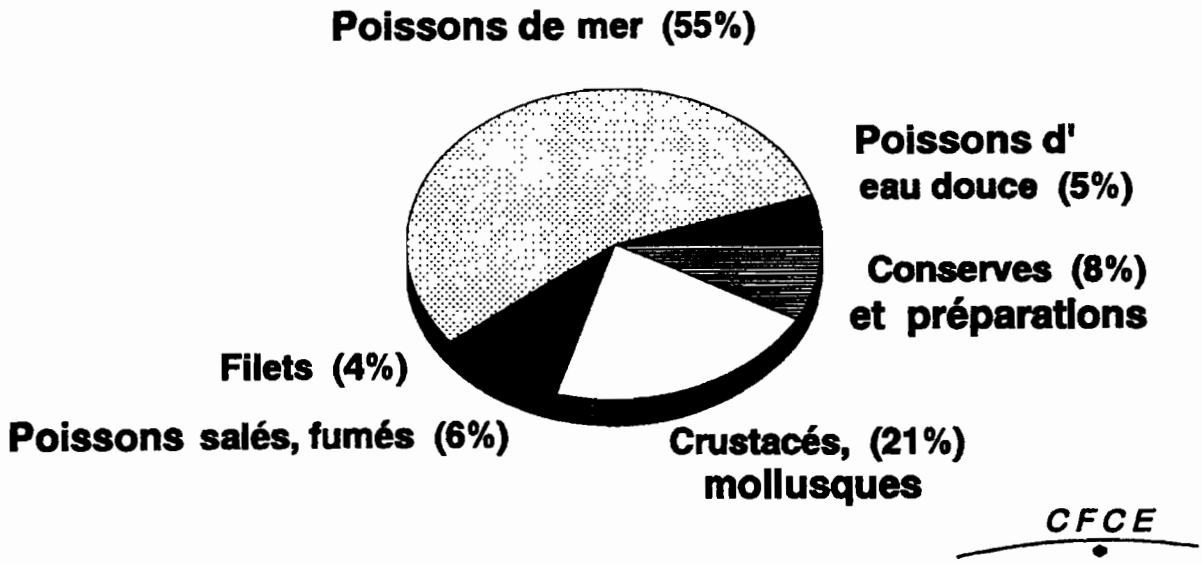



FIGURE 4.
IMPORTATIONS FRANCAISES DE POISSONS ENTIERS DE MER EN 1991 (EN VALEUR).

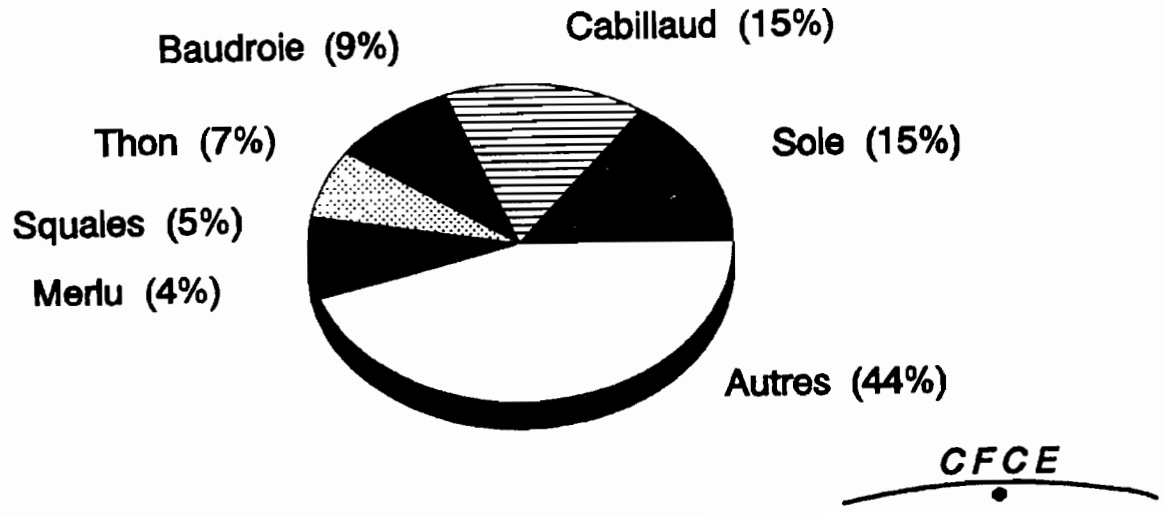


FIGURE 5.
EXPORTATIONS FRANCAISES DE POISSONS ENTIERS DE MER EN 1991 (EN VALEUR).

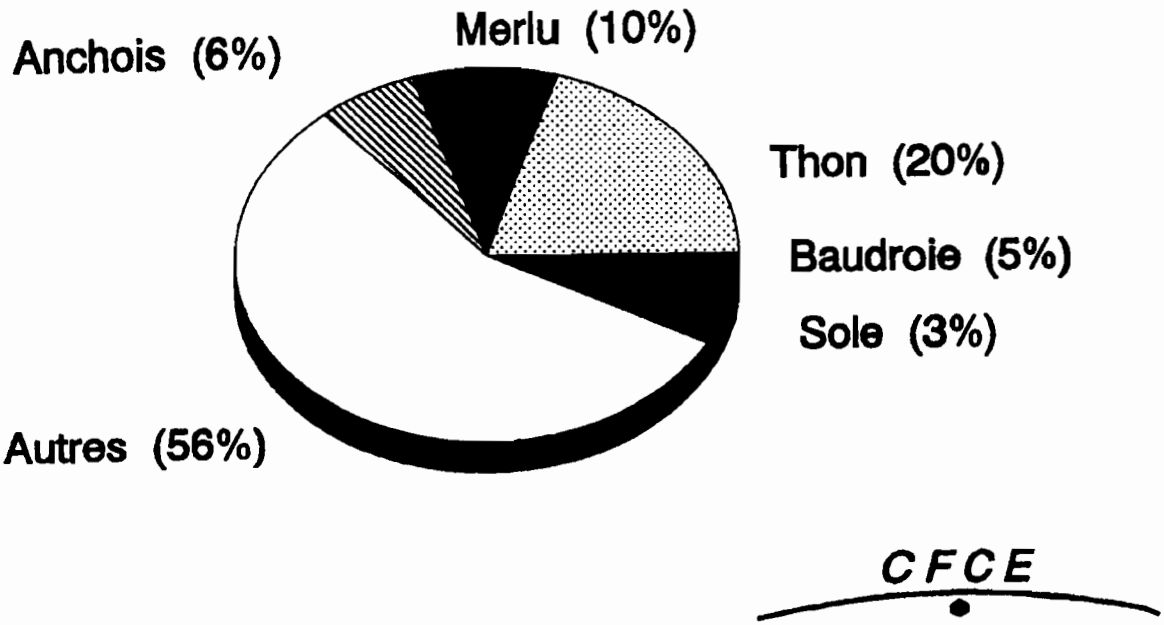



FIGURE 6.
CRUSTACES, MOLLUSQUES : REPARTITION DES IMPORTATIONS EN 1991 (EN VALEUR) ET PRINCIPAUX FOURNISSEURS.

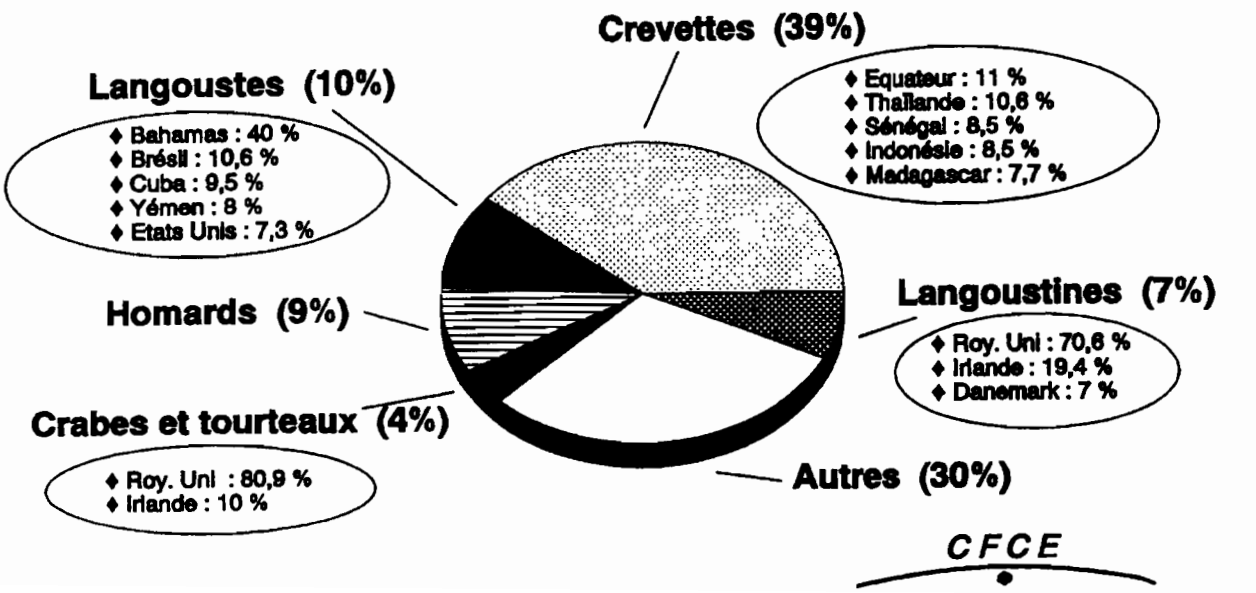
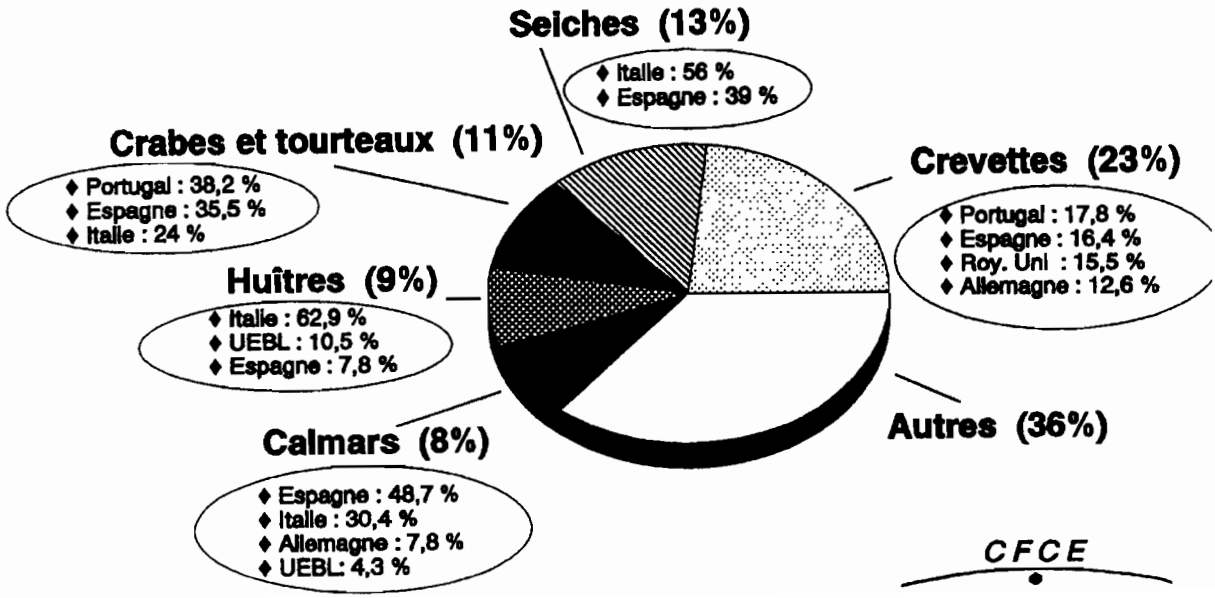


FIGURE 7.
CRUSTACES, MOLLUSQUES : REPARTITION DES EXPORTATIONS EN 1991 (EN VALEUR) ET PRINCIPAUX CLIENTS.



# Monopsony, Trade Restrictions and International Markets for Intermediate Seafood Products : The U.S.-Canada Herring Dispute

**Ali Emami[a], Lewis E. Queirolo[b] and Richard Johnston[a] ***

[a]Department of Agricultural and Resource Economics, Oregon State University, Ballard Extension Hall 213, Corvallis, Oregon 97331-3601

[b]Alaska Regional, NOAA — Alaska Fisheries Science Center, 7600 Sand Point Way NE, Bin C15700, Seattle, Washington 98115

ABSTRACT

*In much of the fisheries economics literature, it is assumed that seafood products are produced under conditions of perfect competition in both the raw fish and fish processing sectors and that free trade prevails in international markets. This paper analyzes international trade in value added products when free trade and perfect competition in the market for an intermediate product, such as raw fish, is the exception rather than the rule. The limited number of fish processors in the coastal regions of seafood exporting countries provides bases for the exercise of monopsony power by those processors vis-a-vis their raw fish suppliers. Current evidence from the GATT regarding disputes between countries such as the U.S. and Canada over trade in raw herring suggests that bilateral free trade in raw fish between major exporters of seafood products may not exist.*

*The study specifically presents analytical models showing the behavior of two rival seafood exporting countries competing in the same import market when monopsony exists in the processing sector of one of these countries, supported by export restrictions in the other.*

*The analysis illustrates how, under such conditions, trade disputes evolve. It further demonstrates how expansion of the demand for herring roe may, through trade reversal pressures, dilute the market power of the processor monopsony and make trade restriction policies irrelevant. There are lessons here for other markets as demand growth leads to trade liberalization.*

* The authors gratefully acknowledge the assistance of Clinton Atkinson, Peter Leitz, and Nilo Cachero. This paper reports on research supported, in part, by the OSU Sea Grant program and by the Cooperative State Research Service, U.S. Department of Agriculture, under Agreement No. 92-34276-7140.

## 1. INTRODUCTION

In much of the fisheries economics literature, it is assumed that seafood products are produced under condition of perfect competition in both the raw fish and fish processing sectors and that free trade prevails in international markets. This paper analyzes international trade in value added products when free trade and perfect competition in the market for an intermediate product, such as raw fish, is the exception rather than the rule. The limited number of fish processors in the coastal regions of seafood exporting countries provides a base for the exercise of monopsony power by those processors vis-a-vis their raw fish suppliers. Current evidence from the General Agreement on Tariffs and Trade (GATT) regarding disputes between countries such as, for example, the U.S. and Canada in the matter of trade in unprocessed herring suggest that bilateral free trade in raw fish between major exporters of seafood products may not be a reasonable analytical assumption. Reasons for this include both government restrictions and market structure constraints. Indeed understanding the mechanism of trade in unprocessed herring between these two countries may yield insights into bilateral trade issues involving other pairs of countries.

The study specifically draws on features of the U.S.-Canada market to develop analytical models showing the behavior of two rival seafood exporting countries competing in the same import market when monopsony exists in the processing sector of one of these countries, supported by export restrictions in the other. The analysis illustrates how, under such conditions, trade disputes evolve. It further demonstrates how expansion of the demand for the final product — in this case, herring roe (kazunoko) — may, through trade reversal pressures, dilute the market power of the processor monopsony and make trade restriction policies irrelevant. There are lessons here for other markets as demand growth leads to trade liberalization.

The remainder of this paper is organized as follow : the first section provides an overview of the dispute between Canada and the U.S. In the second section we abstract from the specific details of this dispute and present an analytical model of U.S.-Canada trade in which Canada exports raw fish to U.S. processors and both countries export the final product, herring roe, to the Japanese market. The third section shows the results of an export embargo on raw fish from Canada to the U.S. processors in the presence of collusive oligopsonistic behavior by U.S. fish processors with respect to their raw fish suppliers. It compares the economic impacts of both market conditions (the export embargo and oligopsony behavior) with the free trade situation of the second section. The fourth section illustrates how expansion of the Japanese demand for final product (herring roe), through trade reversal pressures, dilutes the market power of the processor monopsony in the U.S. and makes restrictive trade policies (the export embargo) by Canada irrelevant. The fifth section compares the U.S.-Canada free trade equilibriums after demand expansion in Japan with the results obtained in the previous section. The sixth section presents conclusions and draws policy implications.

## 2. AN OVERVIEW OF THE U.S.-CANADA RAW FISH TRADE DISPUTE

Japan is the principal country in the world in which there is a strong consumer demand for kazunoko, considered a food delicacy and made from herring roe. [1] Historically, the major source of supply of roe-bearing herring has been the waters off northern Japan. While landings from this area have declined since 1926 (the earliest date for which records are available) a significant and abrupt drop in production occurred in 1977, from which there has been no recovery (Atkinson and Katsuyama, 1981). This occurred at the same time that many nations, including the U.S., Canada and USSR, extended jurisdiction over their respective fisheries zones. The exclusion from (or significant restriction within) U.S. and USSR waters of Japan's distant water fleets added to the decline in Japanese landings in the late 1970s.

The continued strong demand for kazunoko in Japan and the sharp decline in domestic supply provided new export opportunities for both Canada and the U.S. The response to this new opportunity elicited rather different economic and

1. Herring roe (kazunoko) is a traditional food used, primarily, as a part of the New Year's celebration in Japan. Kazunoko is said to symbolize long life and prosperity, and obtains a very high price in the Japanese market. Pacific herring is the preferred source of kazunoko by the Japanese. As a result, virtually all the U.S. and Canadian harvest of Pacific roe-bearing herring and herring roe ultimately finds its way onto Japanese markets.

political strategies in the two countries, however. Within an economic environment characterized by increasing cross-border tension, these divergent trade strategies produced conditions which ultimately brought the U.S. and Canada into direct conflict.

Since the mid-1970s, Canada has prohibited the export of unprocessed Pacific herring (*Culpa havengus pallasi*), pink salmon (*Oncorhynchus gorbuscha*), and sockeye salmon (*O. nerka*). [2] In 1984-85, Canadian buyers for the first time began to purchase Pacific roe herring directly from U.S. fishermen in the Kah Shakes herring-roe fishery (and subsequently the Sitka Sound fishery) of S.E. Alaska. Prior to the entry of Canadian buyers, U.S. processors had enjoyed a market with many of the characteristics associated with a classic oligopsony : that is, a small number of buyers and many sellers. In this case many herring fishermen, competing to harvest a highly perishable product within an extremely short period, confronted a very small number of potential buyers for their catch. Price and landings data for the years immediately preceding the entry of Canadian buyers into these fisheries suggest that U.S. processors consistently paid less per metric ton to U.S. fishermen than Canadian processors paid Canadian fishermen. And when Canadian buyers entered the S.E. Alaska herring fishery, ex vessel prices were quickly bid up, by between 50 % and 100 %, over opening offerings by U.S. processors. Under these conditions, S.E. Alaska processors understandably perceived a threat to the economic status quo. In a coordinated effort to counter the effects of Canada's entry into their market, S.E. Alaska herring processors struck back with a series of political actions aimed at what they considered to be "unfair" trade practices.[3] They expressed significant concern, to the Alaska Governor and Legislature and to the U.S. administration, about the restrictive Canadian regulations, arguing that there were inherent inequities in an arrangement under which Canadian buyers could purchase unprocessed roe herring directly from U.S. fishermen but U.S. processors could not purchase directly from Canadian fishermen.

In 1986, the U.S. Trade Representative (USTR), principally on behalf of the S.E. Alaska fish processors, initiated an action against Canada, under provisions of the Trade Act of 1974, section 301. The USTR, in consultation with the petitioners, ultimately sought relief through arbitration provisions of the GATT. While the section 301 petition cited alleged violations by Canadians pertaining to restraint of trade of pink salmon, sockeye salmon and Pacific herring, and the list of petitioners ultimately included processors from both Alaska and Washington state, as suggested above, the initial source of the dispute centered on the lucrative Pacific herring roe fisheries in S.E. Alaska and northern British Columbia.[4]

In March, 1986, the GATT panel, hearing the dispute, ruled in favor of the U.S. Subsequently, Canada "officially" revoked the offending prohibitions on export of raw herring, pink and sockeye salmon. In their place, however, Canada imposed new regulations which require that Canadian fishermen "land" their catch in Canadian ports "for inspection" before export. The effective result was that the originally offending prohibition on direct export of raw fish from Canada had been reinstated, although the new regulations were extended to include all species of fish. These new export rules were immediately challenged by the U.S., under provisions of the U.S.-Canada Free Trade Agreement (FTA), which had been entered into by the two countries during the time the dispute was being adjudicated under GATT. Presumably this dispute will ultimately be resolved within that forum under the subject of nontariff trade barriers (NTB).[5] At the present time, the two nations are evaluating an interim agreement negotiated under FTA in February 1990 and assessing options to that agreement, which is scheduled to be revisited in 1993.

2. No equivalent regulations governed the export from Canada of other unprocessed species, however, including economically important species such as chinook salmon (*O.tshawytscha*), coho salmon (*O.kisutch*), or chum salmon (*O.keta* ). Despite the availability of, among others, these latter three species of Canadian-caught salmon, there appears to have been virtually no effort by U.S. processors, operating in S.E. Alaska (immediately adjacent to the British Columbia fisheries) to import Canadian-caught fish for processing ; this despite the fact that, in some years, chinook (and on occasion coho) were in relatively short supply in S.E. Alaska fisheries. On the other hand, historical records indicate that, in some years, when pink salmon were in particularly great supply in S.E. Alaska, raw pink salmon were shipped to British Columbia plants for processing, thus relieving the glut in the U.S. fisheries. Furthermore, the U.S. did not have equivalent reciprocal restrictions on the movement of unprocessed U.S. catches to Canadian processors.
3. It should be noted that Canada had, prior to this time, not been rigorously consistent in enforcement of its regulations against export of "unprocessed" herring. It was determined by National Marine Fisheries Service, Fisheries Trade Services Division that, as late as 1977 and 1978, Canadian processors were selling unprocessed Pacific herring to U.S. firms in the Seattle, Washington area for interim cold storage and refrigeration before shipping the product back to British Columbia, Canada, where the roe was then stripped (personal communication, Matteo Milazzo, 1986).
4. The harvest of roe-bearing herring progresses sequentially up the North American west coast, beginning in San Francisco Bay (in November), proceeding through Washington state (although poor stock conditions have virtually eliminated the herring fisheries there in recent years), then northward along the British Columbia coast, to the S.E. Alaska coast. The fishery then continues north and west along the Alaska coast, terminating in the Norton Sound area, near Nome (in June). In the early to mid-1980s, the period during which the dispute arose, the U.S. harvest accounted for between half and three-quarters of the total North American catch. The S.E. Alaska fisheries, however, represented only about 15 % of the U.S. total.
5. For additional discussion, see Leitz and Wright (undated a, undated b) and McDorman (1990).

In the next section we present a highly simplified partial equilibrium trade model which allows us to analyze this intra-industry trade dispute and the likely consequences of interventions in raw fish markets by either U.S. or Canada, or both, on their domestic fishermen and processors. We believe the analysis provides insights into how demand changes can affect the sustainability of market imperfections.

## 3. AN ANALYTICAL MODEL OF U.S.-CANADA INTRA-INDUSTRY TRADE IN ROE HERRING

In this section we present an elementary model of trade in an intermediate product (raw fish) between two countries, where both are exporting the finished product (processed fish) to a third country. The model follows and modifies previous analytical models on trade in both intermediate and final goods introduced in the literature by Corden [1971], and expanded by Houck [1986], Nakamoto, Halloran, and Martin [1990], Lindsey and Johnston [1989]. However, our model differs from previous ones in that (a) it allows for three countries, (b) employs the large country assumption, (c) admits the possibility of monopsony behavior by the processors of one of the participant exporting countries, and (d) allows the other exporting country to impose restrictions on exports.

As suggested, the model abstracts considerably from the facts of this particular, complex case. Our objective is not to restrict our analysis to the U.S.-Canada dispute but, rather, to illustrate how, in general, trade disputes may be resolved through changing, often predictably, economic conditions. Thus we are somewhat selective in which facts of the case we incorporate in the model and a bit cavalier in the assumptions we impose on biological and relative cost conditions. Nonetheless we have retained many of the essential features of this particular dispute. The assumptions underlying the markets for the final product — processed fish (F) in the U.S., Canada, and Japan, raw fish (R), and value-adding, nontradeable inputs (V) in the U.S. and Canada are stated next.

We assume the world consists of three countries U (U.S.A.), C (Canada), and J (Japan). Countries U and C both produce a homogenous tradeable final product F, by utilizing two inputs of production, R and V, that are also produced domestically. Production of F is characterized by fixed input-output ratios (i.e., F is produced via a Leontief-type production function) in U and C.[6] Input R is harvested by U and C from different stocks of fish. Input V is considered to be a composite input consisting of labor and capital. Input R is a tradeable input only between U and C while V is a nontraded input. There is no domestic demand for F in either U or C ; F is demanded only by J in the world market. The final product F is not traded between U and C, but is exported by both U and C to J. All countries are "large countries" in all markets. Finally, for analytical expediency we assume that all three countries have identical currencies and that transportation costs among the countries are zero.

In Figure 1 we assume, for graphic convenience, that one unit of R is combined with one unit of V to produce one unit of F. Panels (a), (b), and (c) of Figure 1, represent fish markets in U, C, and J, respectively. In panels (a) and (b), the upward sloping supplies of raw fish, and the value adding inputs are respectively labeled $S_R$ and $S_V$ for the U.S., $S_R^*$ and $S_V^*$ for Canada (henceforth, variables for Canada are marked with an asterisk). By assumption, the intercept (the set up cost) for $S_R$ is higher than the intercept for $S_R^*$ due to the U.S. fishermen's higher access cost associated with remoteness, but the slope of $S_R$ is lower than the slope of $S_R^*$ since labor costs, landings taxes and capital costs are higher in Canada than the U.S. The supply curve of V in Canada is higher and flatter than its corresponding curve in the U.S. That is, while Canada is the more costly supplier of V at low levels of processing, at higher levels the average cost declines such that it falls below that of the U.S. for similar processing levels in part because of stricter regulations on waste from processing facilities in the U.S. This may result from higher capital costs in Canada but larger plant sizes and fewer size diseconomies in that country.[7] These curves slope upward because higher prices result in increased demand for inputs and, thus, higher input prices (for example, labor must be imported from increasingly distant locations). In panel (b), the curve labeled $S_F^*$ is the vertical summation of the curves $S_R^*$ and $S_V^*$ in that panel. In panel (c), the demand in Japan for the imports of processed fish (in this case kazunoko) is labeled $D_F^J$. In that same panel, the curve labeled $SS_R$ is the horizontal summation of the supplies of R in panels (a) and (b), and the curve labeled $SS_V$ is the horizontal summations of supplies of V in panels (a) and (b). The curve labeled $SS_F$ in panel (c) is the vertical summation of the $SS_R$ and $SS_V$ curves in that panel.

6. This assumption is made for analytical convenience only. Relaxing it would not materially affect the results.
7. Alternatively, one may consider the situation where the supply of V in Canada is everywhere above that of the U.S., largely as a consequence of higher Canadian wage rates and the private costs of social services assessed on Canadian firms. The results of this study do not change.

**U.S.-Canada Free Trade in R**

Suppose there is free trade in R between U and C, and free trade in F between U and J and between C and J. The equilibriums in each sector are found by equating $SS_F$ with J's demand $D^J_F$ at point $E^F$ in panel (c), (henceforth the superscript "F" denotes the values of variables under free trade).

In equilibrium, J imports $Q^F_{R,V,F}$ of processed fish. The aggregate production of $Q^F_{R,V,F}$ by U and C requires a total of $Q^F_{R,V,F}$ units of each input R and V in panel (c), with corresponding prices of $P^F_R$ and $P^F_V$, respectively. At equalized factor V prices of $P^F_V = P^{*F}_V$, U allocates $q^F_{V,F}$ units of V to produce $q^F_{V,F}$ units of F, and C allocates $q^{*F}_{V,F}$ units of V to produce $q^{*F}_{V,F}$ units of F. With free trade factor R prices are equalized at $P^F_R = P^{*F}_R$, U's fishermen supply $q^F_R$ units of R, and C's fishermen supply $q^{*F}_R$ units of R, of which $q^{*F}_{V,F}$ goes to domestic processors (utilization from domestic supplies of R) and the rest is exported in the round to U. To produce $q^F_{V,F}$ units of F in U requires $q^F_{V,F}$ units of R to be combined with $q^F_{V,F}$ units of V. Thus, with free trade in R, U imports $(q^F_{V,F} - q^F_R)$ units of R from C, which is equal to the $(q^{*F}_R - q^{*F}_{V,F})$ units of R exported from C.

## 4. CANADIAN EXPORT EMBARGO ON R AND THE EXERCISE OF MONOPSONY POWER BY THE U.S. PROCESSORS

In section 3 above, it was shown that, under free trade, Canada would, apparently, be an exporter of raw herring to the U.S. In fact this situation never arose. This is because Canada prevented such trade by imposing an embargo on the export of unprocessed herring to the U.S., presumably to protect its fish processing industry under the "infant industry" protection argument. This is considered next.

Let U.S. fishermen have the choice of selling their U.S.-harvested raw fish in the U.S., Canada, or both. Assume further, that Canada imposes an embargo on exports of raw herring and that, simultaneously, U.S. processors arrange a collusive oligopsony[8] in buying raw fish from U.S. fishermen (henceforth we treat this oligopsony as if it were a monopsony). Under these conditions, the new equilibrium values are indicated with superscript "M" in Figure 1, and are determined as follows.

First, we construct the residual demand for F facing the U.S. processors (labeled as $D_r$ in panel (a)) by horizontally subtracting $S^*_F$ from $D^J_F$ at all price levels. Second, we construct the U.S. processors "derived demand" for raw fish ($DD_R$) from their fishermen by vertically subtracting $S_V$ from $D_r$ at each quantity. Third, we construct the curve $MFC_R$ as the marginal factor cost of raw fish to U.S. processors. Then, the U.S. processors impose a monopsony price of $P^M_R$ (the price on $S_R$ corresponding to the quantity $q^M_{RVF}$, determined by the intersections of $DD_R$ and $MFC_R$) on their fishermen. The resulting final product is supplied to the Japanese market, in competition with final product from Canada's market. Note that this monopsony position can be sustained as long as the Canadian price ($P^{*M}_R$) is lower than that in the U.S. since, at those price levels, U.S. fishermen would have no economic incentive to ship to Canadian processors. This discrepancy, in turn, follows from Canada's preventing exports of raw fish, leading to higher utilization of domestic supplies than in free trade ($q^{*M}_{R,V,F} > q^{*F}_{V,F}$), but lower utilization in total, of Canada's raw fish ($q^{*M}_{RVF} < q^{*F}_R$) and corresponding lower ex-vessel prices.

A comparison of the value of the model's variables under a Canadian export embargo on raw fish and monopsony behavior by U.S. processors with the values of the model's variables under free trade indicates that for prices :

$$P^M_R > P^F_R > P^{*M}_R, P^M_V < P^M_V = P^{*F}_V < P^{*M}_V, P^M_F = P^{*M}_F \geq P^F_F,$$

and for quantities of V and F :

$$q^M_{R,V,F} < q^F_{V,F}, \text{ and } q^{*M}_{R,V,F} > q^{*F}_{V,F}.$$

Under these new conditions Canadian processors utilize the entire domestic catch of raw fish ($q^{*M}_{R,V,F}$) and thus export a higher volume of processed fish to Japan than the volume they were supplying under free trade. The U.S. processors are

8. The assumption that U.S. processors enter into a "collusive oligopsony" is an analytical construct and is not intended to suggest that U.S. processors actually undertook this action.

unable to import any R from Canada and utilize only their own domestically caught R ($q^{M}_{R,V,F}$), which is purchased at monopsony prices. These prices, however, are higher than what is paid to Canadian fishermen by Canadian processors and higher than the "free trade" prices to U.S. fishermen because of removal of competition from Canadian supplies. These particular price relationships follow from the assumption made here about the supply functions in the two countries. They appear to be reasonable approximations of the actual situation, however : because of the higher U.S. price, Canadian fishermen have an incentive to export R to the U.S. and, thus, to prevent this, Canada keeps in place its export embargo on R. This is consistent with a situation in which two market imperfections (monopsony in the U.S., and an export embargo by Canada) can effectively coexist and sustain.[9]

## 5. DEMAND EXPANSION IN JAPAN AND TRADE REVERSAL

This section illustrates that how an expansion of demand in the import market for the final product, i.e. the Japanese demand, can mitigate the market imperfection in both the U.S. and Canada. In fact the Japanese import demand for herring roe has increased considerably in recent years. Reasons for this include :

i) An increase in the value of the Japanese yen relative to both the U.S. and Canadian dollars.

ii) The imposition of extended fisheries jurisdiction by both the U.S. and Canada, cutting off Japanese access to the waters of these countries. This reduced Japan's domestic supply of kazunoko and hence increased its demand for imports ($D^{J}_{F}$ may also be treated as Japan's excess demand curve).

iii) An increase in personal incomes in Japan.

iv) An increase in the Japanese population.

v) An increase in the price of substitute fish products in Japan, because of (ii), above.[10]

As $D^{J}_{F}$ increases to $D^{J'}_{F}$, $D_r$ and $DD_R$ shift up to $D'_r$ and $DD'_R$, respectively. In the presence of monopsony in the U.S., and a continued export embargo on R in Canada, the new equilibrium values of the model's price and quantity variables are indicated with a superscript ('). The new levels of prices in the U.S. and Canada for raw fish indicate that $P^{*M'}_{R} > P^{M'}_{R}$. Thus, Canada's export embargo is no longer relevant since Canada shifts from having an incentive to export raw fish to being an importer of raw fish. The increased demand in Japan has made the trade restriction unnecessary and led to trade reversal. In the U.S. the processors can no longer maintain their monopsony position because the U.S. fishermen now can sell at higher prices to Canadian buyers. In summary, demand expansion has reduced the incidence of market imperfections in the U.S. and Canada and has led to trade reversal in a traded intermediate product.

Note that, the trade reversal in this model is neither because of changes in factor intensities due to the changes in the factor prices, nor due to direct domestic demand expansion in any of the exporting countries (demand based trade reversal). These are the usual explanations for trade reversal (see, for example, Ethier, pp. 134-6). With regard to the former case, our production technologies in both exporting countries are characterized by fixed proportions ; thus, any changes in the factor prices due to the existence of monopsony or the export embargo do not change the factor intensities. In the latter case, trade reversal happens because the domestic demand in an exporting country expands to such an extent that its domestic price is higher than the price in its importing partner and thus the exporting country becomes an importing country. In our model, after demand expansion in Japan, the U.S. and Canada still hold their positions as exporters of the final product, yet their pattern of trade in the intermediate product is reversed. One may label this kind of trade reversal as "foreign demand based trade reversal."

The results, once again, follow from the relationships among supply curves. Specifically, at relatively low levels of demand in Japan, and in the absence of either monopsony pricing or export controls, Canada is the low-cost producer of raw fish but the high cost processing country. Thus, Canada, with a comparative advantage in raw fish harvesting, exports to the higher cost country. At the higher level of demand in Japan, Canada's comparative advantage switches

9. Actual price relationships did not mirror those discussed here. This may be a consequence of asymmetrically-held information, a hypothesis we are currently exploring.

10. In the more general case, other factors, such as an import subsidy could also lead to increased demand facing the exporting countries.

from raw fish production to processing. At higher levels of production of the final product, average harvesting costs in the U.S. are so much lower than those in Canada and U.S. processing costs so much higher, per unit, that it pays the U.S. to export raw fish to Canadian processors.

It is not clear that these are in fact the circumstances that prevail in the two countries but the model does seem to reproduce, in broad terms, what has actually occurred. More important, perhaps, it suggests that analysis of trade patterns involving both intermediate and final goods may require examination of costs relationships beyond those associated with current production levels. For example, where cost disparities are a consequence of differences in external economies and diseconomies — certainly a strong possibility where trade is in products having a natural resource base (so that real externalities are significant) and where the exploitation of that natural resource represents a significant economic sector in a region (so that pecuniary externalities play a large role) — the results suggested here seem quite reasonable. At least, in our judgment, they merit more attention than they have received to date.

## 6. DEMAND EXPANSION IN JAPAN AND FREE TRADE IN R

In the absence of imperfections in the U.S. and Canadian R markets, as $D_F^j$ increases to $D_F^{J'}$ the equilibrium in each sector is found by equating $SS_F$ and $D_F^{J'}$ at point $E^{F'}$, and the new equilibrium values are indicated with a superscript (F'). At equalized factor V prices of $P_V^{F'} = P_V^{*F'}$, U allocates $q_{V,F}^{F'}$ units of V to produce $q_{V,F}^{F}$ units of F, and C allocates $q_{V,F}^{*F'}$ units of V to produce $q_{V,F}^{*F'}$ units of F. With free trade factor R prices are equalized at the new level of $P_R^{F'} = P_R^{*F'}$, at which U's fishermen harvest $q_R^{F'}$ units of R, in total, of which $(q_R^{F'} - {}^{F'}_{V,F}$ are exported to Canada. C's fishermen supply $q_R^{*F'}$ units of R to their domestic processors. To produce $q_{V,F}^{*F'}$ units of F in C requires $q_{V,F}^{*F'}$ units of R to be combined with $q_{V,F}^{*F'}$ units of V. Thus, with free trade in R and the absence of market imperfections, C imports $(q_{V,F}^{*F'} - q_R^{*F'})$ units of R from U, which is equal to the $(q_R^{F'} - q_{V,F}^{F'})$ units of R exported from U.

## 7. CONCLUSION

These findings are highly dependent on the relative positions of the supply curves — of both R and V — in Canada and the United States although they can be generated under a variety of assumptions about that relationship. In the above discussion, as output increases, Canada changes from having a cost advantage in fishing to having a cost advantage in processing vis-a-vis the U.S.

Suppose the R supply curves in the two countries are identical. Suppose, further, that the supply curve of V in Canada is higher and flatter than its corresponding curve in the U.S., as shown in Figure 1. In this case the results of this paper re-emerge. This means that before the demand in Japan expands, Canada, in free trade, would have an incentive to export R to the U.S. due to higher processing costs in Canada. However, as the Japanese demand increases, Canada experiences cost advantages. This leads to trade reversal, as in the example above.

Now suppose that processing costs are equal in the two countries but that the supply curve of R in Canada is lower — at low harvesting levels — than that in the U.S., as is shown in Figure 1. Further suppose, however, that this cost advantage disappears at higher harvesting levels — perhaps due to locational advantages for the Canadian fleet but higher fuel and labor costs in Canada — so that the Canadian supply curve intersects (from below) its U.S. counterpart. Again, the results of this model re-appear. In this case the explanation is that Canada, being the less costly harvester at low fishing levels, ships raw fish to the U.S. — or, at least, under free trade would have an incentive to do so. As Japanese demand expands, the U.S. emerges as the less costly fishing nation and, thus, trade reversal occurs once again.

Other configurations could be considered. The point is that this model is useful not only in understanding events underlying the U.S.-Canada trade dispute over roe herring but may also provide insights into bilateral trade patterns in intermediate products among a large number of pairs of trading partners. It demonstrates that existing trade patterns, existing market structures and existing trade policies may change significantly, not only in response to explicit government action but also in response to changing supply and demand conditions. Perhaps, then, concern about unfair trade practices could more effectively be addressed by awaiting — or even promoting — changes in market conditions than by issuing calls for retaliation.

## REFERENCES

**Atkinson, Clinton E. and Yoshio Katsuyama** (1981). "The Marketing of Herring and Herring Products in Japan." Report prepared for the Alaska Native Foundation, Anchorage, Alaska.

**Corden W.M.** (1971). *The Theory of Protection*. Oxford : Oxford University Press.

**Ethier W.J.** (1988). *Modern International Economics* . Second edition. New York : W.W. Norton & Co.

**Houck J.P.** (1986). *Elements of Agricultural Trade Policies*. New York : MacMillan.

**Johnston R.S. and L.E. Queirolo** (1990). "The U.S.-Canada Free Trade Agreement and Fisheries." A paper presented at the 1990 meetings of WRCC-70—The U.S.-Canada Free Trade Agreement : Impacts on the Economy of the Pacific Northwest. Portland, Oregon, January 11, 1990. Unpublished.

**Leitz P. and S. Wright** (Undated a). "Economic and Management Implications of Removing Canadian Restrictions on the Export of Unprocessed Sockeye and Pink Salmon and Roe Herring."

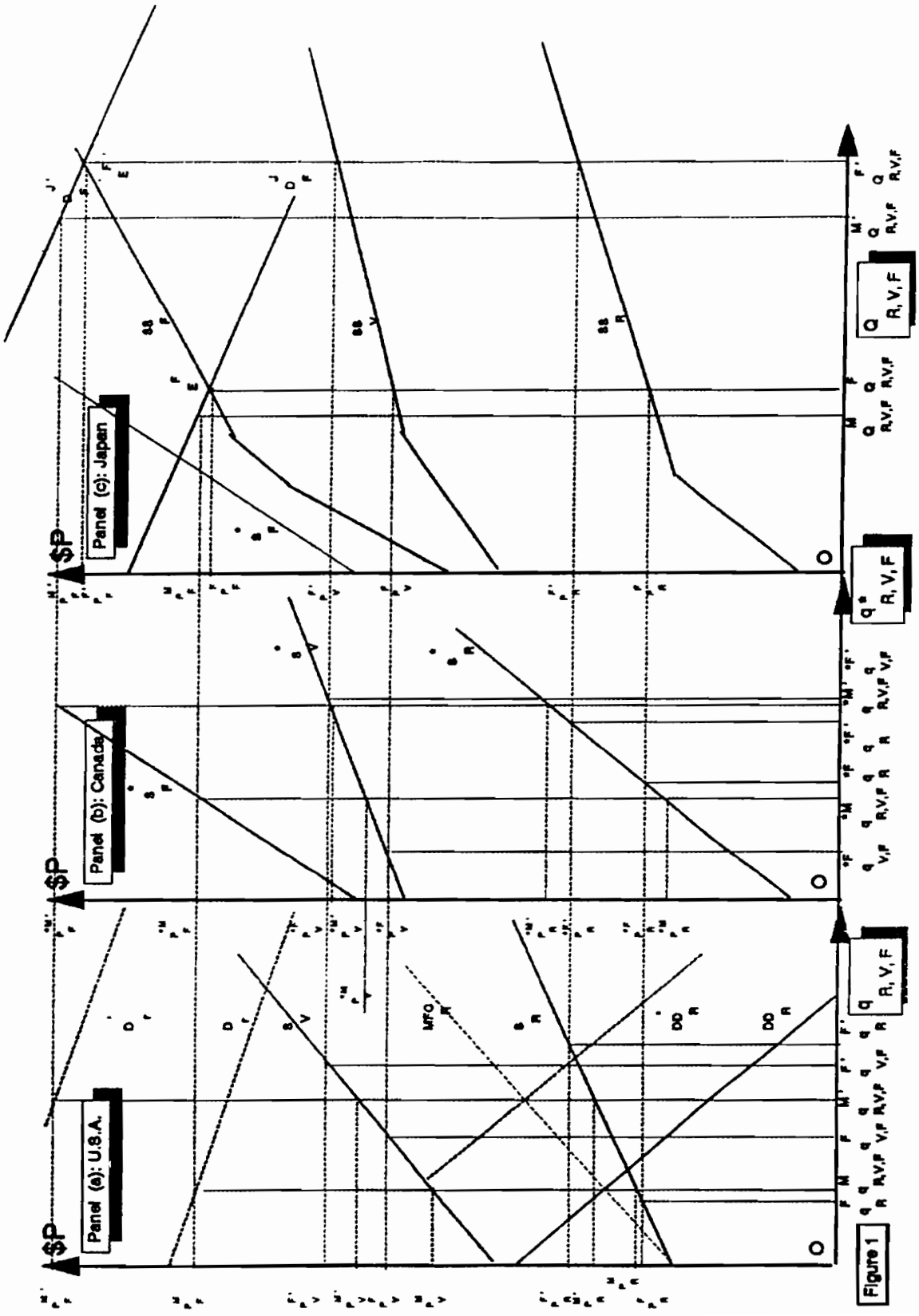
**Leitz P. and S. Wright** (Undated b). "Economic Impacts of Free Trade in Salmon and Herring Between Canada and U.S.A."

**Lindsey P. and R.S. Johnston** (1989). "Implications of the Free Trade Agreement for U.S. Food and Agriculture : A Western Perspective." Presented at the 1989 Annual Meetings of the Western Agricultural Economics Association, Coeur d'Alene, Idaho. Unpublished.

**McDorman and L. Ted** (1990). "International Trade Law Meets International Fisheries Law : The Canada-US Salmon and Herring Dispute." *Journal of International Arbitration* **7** (4) : 107-121.

**Nakamoto S., J. Halloran and M. Martin** (1990). "Trade Liberalization Policy Reform and the U.S. Sugar Industry." *Journal of International Food and Agribusiness Marketing*, Vol. **2** (1) : 21-35.

**FIGURE 1**



# Price Linkages between Japanese and United States Markets for Sablefish and Thornyheads

**James D. Hastie[a], Dale Squires[b] and Julie A .Elston[c] ***

[a]National Marine Fisheries Service, Northwest and Alaska Fisheries Center, 7600 Sand Point Way, Seattle, Washington 98115, USA

[b]National Marine Fisheries Service, Southwest Fisheries Center, P.O. Box 271, La Jolla, California 92103, USA

[c]Department of Economics, DK-30, University of Washington, Seattle, Washington 98195, USA

ABSTRACT

*Many fishery markets are becoming increasingly globalized, and with the extension of exclusive economic zones to 200 miles, growing international trade is coupled with the replacement of foreign harvesting by domestic production. These trends raise questions concerning the nature of market integration and price linkages and the implications for export, market, and management policies. When domestic ex-vessel and export markets are linked by prices as well as commodity flows to central foreign markets, then domestic production, marketing, and management must consider, at least in part, developments outside of the traditional autarkic market boundaries. This paper assesses the price linkages between the United States and Japan for two species whose exports have risen considerably over the past decade : sablefish and thornyheads. The empirical results indicate segmentation of price linkages for sablefish but probable price linkages for some thornyhead markets. The findings suggest that U.S. ex-vessel markets for these species may be less sensitive to price changes in Japan than would be expected, based on commodity flows.*

## 1. INTRODUCTION

Many fisheries in the past decade have experienced increased globalization of their markets and growing international trade, as foreign harvesting has been replaced by domestic production. These changes raise issues regarding the nature of market integration and price linkages and the implications for fisheries management.

* Discussions with Jim Anderson, Clint Atkinson, Larry Jacobson, Trina Wellman, and Dick Young are gratefully acknowledged. The authors, however, are responsible for any remaining errors.

When domestic ex-vessel and export markets are linked by prices as well as commodity flows to central foreign markets, then domestic production and marketing decisions cannot be separated from events in the central foreign markets. Where strong price linkages exist, domestic fisheries management should be formulated with an awareness of developments in foreign markets, consumer taste and preferences, trade policies, and even foreign fisheries policies. In short, domestic production, marketing, and management must weigh developments outside of the traditional market boundaries.

Following the Magnuson Fishery Conservation and Management Act of 1977, United States harvesters replaced foreign producers of sablefish (*Anoplopoma fimbria*). U.S. harvesters rapidly expanded production and exports of sablefish to Japan. These factors have combined to increase the ex-vessel sablefish revenue received by Pacific coast and Alaskan groundfish fishermen to a level surpassed by only pollock and halibut. Unlike pollock which undergoes considerable processing--into surimi and fillets--soon after harvest, sablefish normally remains in a headed-and-gutted form throughout much of the market chain. Halibut seasons have typically been very short in most areas, creating time series problems for comparative market analysis. Since a very high percentage of sablefish is exported to Japan, it offers an excellent opportunity to compare prices of equivalent products in U.S. ex-vessel and foreign Japanese markets.

The nature of this market integration for sablefish was previously examined by Squires, Herrick, and Hastie (1988). This study examined the integration by prices of Alaska and Pacific ex-vessel markets for sablefish and the **Tsukiji** or Tokyo central wholesale market for 1981-1986. The study considered the pot and longline (hereafter fixed gear) sector of the sablefish fleet, because these vessels produce the higher quality sablefish desired by Japanese consumers. This study found that the Alaskan and Tsukiji markets had a form of price integration. In contrast, the Pacific coast and Tsukiji markets were segmented, so that changes in the Tsukiji market had no effect, immediate or lagged, on the prices of the Pacific coast market.

In this previous study, the Tsukiji market role was assessed as the center of a radial market for sablefish. Price was first formed in the Tsukiji market, with the Alaskan market price responding to it. Hence, the central market prices are expected to be causal to some non-central market prices, but other non-central market prices would not be causal to each other or to the central market. This previous study of sablefish markets utilized "real" rather than nominal prices, i.e. prices were adjusted for inflation. There are no theoretical reasons for the use of either real or nominal prices in testing price linkages. However, different inflation rates between two markets can create (temporary) real profit differentials in the central market. In turn, central market demand shifts and prices in the radial market are pushed up, other things being equal. Because the use of real prices may mask some of these effects, the current study uses nominal prices. Adjusting prices using the yen-dollar exchange rate fluctuations is used to account for differential inflationary variations.

The previous study also specified lag lengths up to six months based upon an assessment of the price formation process. The true lag structure may nonetheless differ, which in turn could affect the results. Hence, the present study evaluates market integration for lag lengths up to two, three, four, five, and six months. Robust results for the different lag lengths will strengthen conclusions.

The purpose of this study is fourfold. First, since 1986 the Pacific coast and Alaskan ex-vessel sablefish markets appear more closely linked to the Tsukiji market, at least by commodity flows, with possibly a form of price linkage for even the Pacific coast market. Hence, this relationship will be reexamined in the light of conditions through 1989. Second, the causal price linkages between the Tsukiji market and the ex-vessel Alaskan and Pacific coast sablefish markets for fixed gear will be assessed, thereby allowing for a more complex form of market structure than the previous study. In addition, previously unexamined causal price linkages between the Tsukiji market and the Pacific coast and Alaska ex-vessel markets for thornyheads (*Sebastolobus altivelis* and *Sebastolobus alascanus*) caught with all gear (combined fixed and groundfish trawl gears) will be evaluated. Third, recent advances in evaluating Granger causality, that surmount limitations to previous approaches, will be applied and compared to the original methodology. And fourth, the study will incorporate the use of varying lag lengths and nominal rather than real prices.

The study is organized as follows. The next section provides a background to the fisheries and markets. The third section considers causal relationships, price linkages, and presents the empirical model. The fourth section discusses the data. The fifth section examines the empirical results. The final section offers policy implications and concluding remarks.

## 2. BACKGROUND TO THE FISHERIES AND MARKETS

Domestic Alaskan fixed-gear landings of sablefish increased from 800 mt in the early 1980s to more than 13,000 mt by the end of the decade. Pacific coast fixed-gear landings fluctuated between 4,500 and 8,100 mt during this period. Coastwide landings of thornyheads increased from 3,200 mt 1981 to more than 11,000 mt throughout the 1980s, largely in response to the development of Japanese export markets, and the lure of higher ex-vessel prices. The bulk of the thornyheads landed in each year are taken off northern California and Oregon by bottom trawlers. Shortspine thornyheads (*S. alascanus*) predominate in landings, although the proportion of longspine thornyheads (*S. altivelis*) has increased during recent years.

Alaskan ex-vessel prices for fixed-gear sablefish (adjusted for inflation and measured in 1989 dollars) increased from \$0.40/lb to more than \$1.00/lb in 1988. Pacific coast ex-vessel prices for thornyheads (also in 1989 dollars) rose from \$0.17 per pound in 1981 to \$0.40 in 1990 (Jacobson, 1991). Alaskan and Pacific coast ex-vessel prices tend to be competitively formed, although short-term fluctuations in Pacific coast trawl prices are moderated to some extent by agreements between processors and fishermen. Seattle dominates as the port of export. Many of the prices received by Alaskan sablefish vessels are formed in a Seattle auction, where several processors or brokers will bid for deliveries from vessels, while other ex-vessel prices are formed directly when a vessel lands its catch at a processor. Formation of fixed prices and informal contracting occur between some processors and harvesters, but flexibility nonetheless exists in the fixed price negotiated prior to harvesting so that stochastic fluctuations in the size, quality, and composition of landings are accommodated. While wholesalers can be strung out along the coast, seemingly in a strong position to offer noncompetitive prices to vessels, competition is nonetheless stronger than initially appears among wholesalers and processors, and harvesters always have the option to land in different ports, though this may result in higher costs. In Alaska, approximately five to seven processors handle the bulk of the Alaskan product, although there are at least fifty processors in total.

We consider the Tsukiji market for reasons of data availability and because it plays an influential and increasing role in the handling of sablefish and thornyheads in Japan. Before the imposition of foreign harvest restrictions, when the Japanese fishing fleet was responsible for providing most of the sablefish consumed in Japan, the centralized market in Tokyo played a less important part in the distribution of sablefish ; it may have handled less than fifty percent of that consumed. As Japan was forced to rely increasingly on imports of sablefish and thornyheads, the clearinghouse in Tokyo has become more prominent, by providing a conduit for the imported product. Throughout most of the 1980's, the Tokyo market has generally handled an estimated 60-70 % of the sablefish sold in Japan (Hastie, 1989).

## 3. CAUSAL RELATIONSHIPS IN PRICE LINKAGES

This section defines market integration and presents the formal model used to empirically assess the causal structure of price linkages.

### *3.1 Market integration and price linkages*

Markets are integrated by prices if there is an interdependence in price movements at different spatially separate markets (Monke and Petzel, 1984). In market economies, market information to the different participating economic agents is largely transmitted by prices, so that an understanding of the manner in which markets are linked by prices can contribute to the general process of policy formulation.

Markets may be integrated by prices to different degrees and along some dimensions but not others. Geographical links or interregional trade are among the most important. Market boundaries are defined by the geographical limit of spatial price linkages. If buyers and sellers are subject to the same demand or supply conditions, they are deemed to be part of the same market (Cochrane, 1957). Hence, this study is aimed, in part, at defining the boundaries of the Tsukiji markets for sablefish and thornyheads.

### *3.2 Causal relationships*

Granger (1977) defined causality among a set of variables based upon predictability and the fact that the effect of a change in an exogenous variable upon an endogenous variable requires time. A variable X is said to cause another variable Y, with respect to a given information set that includes X and Y, if present Y can be better predicted by using past values of X than by not doing so, given all other relevant information. If the relationship is linear, this implies that in a regression context $X_{t-i}$ $(i > 0)$ and $Y_t$ are correlated. Causality from Y to X is defined in the same manner. Feedback occurs if X causes Y and Y causes X. A causal relationship between X and Y does not exist if causality does not run from X to Y or from Y to X [1].

A direct bivariate Granger test of causality is based upon the following general linear models (Holmes and Hutton, 1990) :

$$g(Y_t) = \alpha_0 + \sum_{i=1}^{k1} \beta_i\, g(Y_{t-i}) + \sum_{i=1}^{k2} \tau_i h(x_{t-i}) + \varepsilon_t + \sum_{j=2}^{4} \Omega_j D_j + \pi LT \qquad (1)$$

$$h(X_t) = \delta_0 + \sum_{i=1}^{k1} \theta_i\, h(X_{t-i}) + \sum_{i=1}^{k2} \phi_i\, g(Y_{t-i}) + \mu_t + \sum_{j=2}^{4} \Omega_j D_j + \pi LT \qquad (2)$$

where $\epsilon_t$ and $\mu_t$ are stochastic, white noise residuals, g(Y) and h(X) are strictly monotonic transformations of Y and X respectively, k1 and k2 are lag lengths (which may differ in equations (1) and (2)), LT refers to a linear time trend, and $D_j$ is the zero-one (dummy) variable for quarter j. The presence of lagged dependent variables is counted on to remove serial correlation from the estimated residuals.

The test of the null hypothesis that X does not cause Y is a test that $\tau_1 = \tau_2 = \ldots = \tau_{k2} = 0$. The test of the null hypothesis that Y does not cause X is a test that $\phi_1 = \phi_2 = \ldots = \phi_{k2}$ . Conventional parametric analysis involves least squares estimation of each of the full and null models and, assuming that $\epsilon_t$ and $\mu_t$ are generated from a normal distribution with constant variance, $N(0, \varsigma_i^2)$, subsequent calculation of F statistics with k2 and N-K (K = k1 + k2 + 4) degrees of freedom (Holmes and Hutton).

Tests for Granger causality conventionally rely on parametric analysis. The results of these statistical tests are limited by the augmenting hypotheses of a specific functional form of the variables and the homoscedasticity and normality of the errors, $\epsilon_t$ and $\mu_t$. However, an alternative to parametric testing of Granger causality employs the multiple rank transformation procedure (Holmes and Hutton 1988, 1990). The results of the multiple rank F test are invariant to monotonic transformations of all variables (and hence functional form) and are robust over alternative distributions of the errors (Conover and Iman, 1982 and Iman and Conover, 1979).

A multiple rank F test of the causal relationship between X and Y involves the variables measured in ranks, $g(Y_{t-i}) = R(Y_{t-i})$ and $h(X_{t-i}) = R(X_{t-i})$, all i, where R is the rank transformation, a strictly monotonic transformation (Holmes and Hutton). Equations (1) and (2) are then estimated by ordinary least squares for both the full and null models, and calculation of the standard F statistic based upon the residual variances from these rank regressions.

Lag lengths k1 and k2 must be selected [2]. Lagged effects in the model are likely to arise from sluggishness in price adjustment, delays in transportation, cold storage inventory holdings, and expectations formation under price uncertainty. Following Squires, et. al., a six month lag length was selected. This relatively long lag length allows for the Tsukiji market's fall prices to influence Alaska's spring prices and ex-vessel markets after Alaska harvesting has tapered off over

1. If the information set contained all the information available in the universe at time t, then $Y_t$ could be said to cause $X_{t+1}$. In practice, the information set contains considerably less information and so the phrase "prima facie" causality is used. The name is chosen to include the unstated assumption that possible causation is not considered for any arbitrarily selected group of variables, but only for variables for which the researcher has some prior belief that causation is, in some sense, likely (Granger 1988, page 201). Hence, the causality examined in this paper is prima facie causality.
2. While multicollinearity from current price and six lagged prices could present a problem in estimates and tests of significance for individual regression coefficients, the hypothesis tests in this paper are for the joint effects, requiring tests on the joint confidence region, so that multicollinearity presents far less of problem than it ostensibly might appear.

the winter months. Moreover, this lag length accommodates any possible effects of commodity flows from Alaska's spring harvests on price formation in the Tsukiji market. However, as noted above, while the preferred lag length is six months, the hypothesis test results might vary by lag length. Hence, the models were assessed for equal lag lengths in all markets up to two, three, four, five, as well as six months.

The influence of seasonality is accounted for by quarterly dummy variables for winter, spring, summer, and fall. Finally, the possibility of long-term effects from increasing United States exports are captured by a linear time trend.

## 4. DATA

Monthly price data for thornyheads and Alaskan sablefish were available from 1984 through 1989. Pacific coast and Tsukiji market sablefish prices were available from 1981 through 1989. Average monthly market price data for the Tsukiji market were obtained from the Tokyo Central Wholesale Market Yearbook. These are implicit prices formed by dividing monthly total revenues by comparable quantities. Most of the sablefish sold in this market are not homogeneous, and hence movements in average prices may reflect changes in the composition of the product form and quality. The thornyheads price includes both longspine and shortspine, and thus represents an average of the two. Since the use of averages (grouped data) can induce heteroscedasticity, the multiple rank F test rather than the standard parametric F test for Granger causality is particularly appropriate. In addition, these prices implicitly assume that different product forms and grades are perfect substitutes for each, i.e. linear aggregation is assumed. The data are in raw form, without any prior seasonal adjustments or smoothing. As noted by Sims (1974), prior seasonal adjustments or smoothing would confound the distributed lag relationships of Equations (1) and (2). Moreover, because these prices are average implicit prices, they may not be equilibrium prices. Even though spot prices are available for different size classes of sablefish, they are less suitable because corresponding quantities are not available, and because the transactions sampled may not be indicative of the entire month.

For the parametric comparisons, Japanese prices were converted to U.S. dollars per pound after adjusting for the yen-dollar exchange rate. Japanese prices were for eastern dressed weights while U.S. prices corresponded to round weight equivalent price for fish that are usually landed dressed. This difference should not affect empirical results, because the recovery rate between the two product forms is very stable.

For the rank comparisons, price series were created in both dollars and yen for each market. Transformation of these series was obtained by replacing the observations of each series with their respective ranks from 1 to N, where N is the number of observations. Ranks were generated using price values in both currencies, because application of the exchange rate to a price series can alter the rank ordering of its elements. Analyzing both sets of data allowed for an assessment of the significance of selecting a particular currency for the analysis. The dummy variables and linear time trend were unaffected by the rank transformation.

## 5. EMPIRICAL RESULTS

The full models, equations (1) and (2), for both rank data and actual (nominal) prices were estimated by ordinary least squares. The residuals were analyzed for serial correlation, the absence of which was verified with the Ljung-Box portmanteau test, or modified Q-statistic [3]. The autocorrelations were run for twenty lags [4]. Autocorrelation plots of the residuals for twenty lags were also visually inspected, and auxiliary regressions upon the residuals using various lags were also performed as informal checks on the presence of serial correlation.

The regressions using actual (nominal) prices did not exhibit serial correlation due to the lagged variables. The regressions using ranks exhibited serious serial correlation with fairly complex autocorrelated error structures. Moreover,

3. The modified Q-statistics are distributed independently as chi-squared random variables with degrees of freedom equal to the number of autocorrelations. The null hypothesis is that all longer lagged autocorrelations of the residuals are zero. See Greene (1990) for further discussion.
4. Autocorrelations are the correlation of the series, here residuals, with its own values lagged once, lagged twice, and so forth. Partial autocorrelations are the correlations measured with the series residual after all the prior lags have been removed. That is, the second partial autocorrelation is the correlation of the series lagged twice with the part of the series which is orthogonal to the first lag.

multicollinearity sufficiently serious to prohibit estimation for longer lag lengths was also experienced with the rank data. First-differencing the data and then calculating the ranks of current and lagged values of the differenced series (treating each as a separate variable) corrected for both the serial correlation and problems with multicollinearity.

The statistical significance of the linear trend and seasonal dummy variables was subsequently assessed for each unrestricted model for the a priori preferred lag structure, six months. The linear trend variable was statistically significant and retained only for the parametric regression of Pacific coast prices upon Alaskan prices for sablefish. The seasonal dummy variables were not statistically significant, and not retained, in any of the models.

The multiple rank F test is more robust over alternative error specifications than the parametric F test. Nonetheless, heteroscedasticity of the residuals remains a possibility, and the Breusch-Pagan (1979) test for heteroscedasticity was applied. If the chi-square test statistic was statistically significant for conventional levels of significance, heteroscedasticity was corrected by White's (1980) general procedure. In general, heteroscedasticity was found for most regressions, so that heteroscedastic-consistent estimates were applied when appropriate [5].

The Granger causality tests for sablefish using ranks, reported in Table 1a, uniformly indicate that the Tokyo Tsukiji and Pacific coast and Alaska ex-vessel markets were not integrated with one another by prices through 1989. These results were robust across the lag lengths examined. The Granger causality tests using actual (nominal) prices, reported in Table 1b, provided similar results, except for the model testing the influence of Alaska price on that of the Tsukiji market. Given the superior robustness of the multiple rank F test over the parametric F test, it is likely that a strong link between these markets was not present over the time period examined. Hence, despite the direct linkage known to exist for commodity flows between both U.S. fixed-gear sablefish markets and the Tsukiji market, there do not appear to be strong linkages between the prices in these markets.

These results for sablefish contradict the findings of Squires, et. al, that the Alaskan ex-vessel market was integrated by price as a radial market to the central Tokyo market. Several factors may have contributed to the difference in results. Nominal rather than real prices were used in the current study, although accounting for exchange rate fluctuations should have dampened the impact of this change. Another factor, which is largely undocumented, is the extent to which intermediaries, such as processors and brokers may be insulating each of the markets from price changes in the others.

Also, the rise in Japanese interest rates in recent years has shifted Japanese buying patterns from relatively infrequent but substantial purchases--utilizing cold storage holdings--to smaller but more frequent purchases (Dore, 1991). If this recent purchasing pattern is fairly stable and somewhat independent of Tsukiji market price fluctuations (to minimize inventory holding costs), then price changes in the Tsukiji market may not transmit to the ex-vessel level. However, a dummy variable for the months of 1988 and 1989 in the unrestricted model was not statistically significant, for each of the different lag lengths, as indicated by its t-ratio or a Lagrange multiplier test for heteroscedastic-consistent estimates. Hence, this statistical evidence suggests that significant structural change of this type did not occur. Finally, the previous study did not assess the robustness of results across lag lengths.

The Granger causality tests for thornyheads using ranks, reported in Table 2a, provide somewhat conflicting evidence that Tsukiji prices may follow Pacific coast ex-vessel prices. When the ranks were computed using prices expressed in yen, rejection of the null hypothesis was indicated for all lag lengths at the 5 %-level of significance, or better. The highest levels of significance were observed for lags of from 2 to 4 months. However, when the ranks were based on prices expressed in dollars, no significant price linkage was observed. This finding raises questions regarding the sensitivity of the rank test to the currency which is used in comparing markets within different countries. Intuitively, it may seem more appropriate to place greater weight on the results that are based on the currency of the market which is being tested for price dependence, but a solution to this problem is beyond the scope of this paper. The Granger causality tests for nominal prices, reported in Table 2b, provide some support for this interpretation, at least in this particular case. Pacific coast price was, again, observed to influence Tsukiji price, albeit with somewhat less statistical significance and over a smaller range of lags.

5. Heteroscedasticity gives a biased estimator of the variance. There is no well-established best way to test for heteroscedasticity (Greene, 1990). The most powerful tests specify a particular form of heteroscedastic process while more general but less powerful tests specify less restrictive forms of the heteroscedastic process. This study uses the more general approach of testing and correcting for heteroscedasticity. Finally, the empirical results and conclusions of this study are not changed by the heteroscedasticity correction. Finally, the relatively large number of observations are counted upon to give normally distributed residuals.

The tests using ranked data also provided moderate evidence of price integration among some of the other thornyhead market connections. Both of the models testing the influence of the Tsukiji market on Alaskan price had one lag specification for which the null hypothesis was rejected at the 10 %-level of significance. The significant lag period was 4 months for the ranks based on dollars and 5 months for those based on yen. Also, the 2- and 3-month lags were significant at the 5 %-level in the model assessing the influence of Alaskan price on that of the Pacific coast. Neither of these less robust linkages, nor any additional linkages, were indicated in the tests using nominal prices.

## 6. CONCLUSIONS

This study examined the Tokyo central wholesale (Tsukiji) sablefish market and the Pacific coast and Alaska ex-vessel fixed gear sablefish markets for the possibility and direction of price linkages between all markets. The study also assessed thornyhead price linkages between the Tsukiji market and the Alaskan and Pacific coast ex-vessel markets for all gears.

We found little evidence for market integration between the Pacific coast and Alaskan fixed gear ex-vessel and Tsukiji markets for sablefish. Price changes in any of these markets appear to have no predictable effect over a period of 6 months on the prices the other two. That U.S. prices were not found to be responsive to Japanese price changes may mean that U.S. fishermen may be better insulated from changes in foreign sablefish demand than would be expected from the magnitude of commodity flows. The Tsukiji price may not respond to supply-induced price changes as a result of the price inter-relationships with available substitutes, such as salmon. Another possible explanation for market segmentation is that processors or export brokers of sablefish may be absorbing much of fluctuation between prices in the Tsukiji and U.S. markets. If this is the case, the extent to which U.S. prices are affected by Japanese demand in the future may depend upon how far the profit margins of these intermediaries are squeezed.

As one example of the implications of these findings, Japanese policy makers might feel that sablefish imports threaten the well-being of Japanese producers domestically culturing or harvesting fish (e.g. chum salmon, a consumption substitute in Japan). In this case, because U.S. ex-vessel markets do not respond to the information in Japanese price changes, a tariff on imported sablefish from U.S. would not effectively reduce the price received by the U.S. producers and a Japanese import tariff would not impact commodity flow at the ex-vessel level. Alternatively, a Japanese import quota on sablefish would directly restrict the commodity flow, so that import quotas may be a more effective Japanese policy option to insure that commodity flows are restricted.

The Pacific coast thornyhead fishery appears to be linked by prices to the Tsukiji market. Furthermore, the evidence suggests that the Tsukiji price is likely to be influenced by changes in Pacific coast price, and not the reverse. Although some evidence was found of linkages acting from the Tsukiji market to Alaska, and from Alaska to the west coast, the strength of these linkages appeared to be weaker than that between the Pacific coast and the Tsukiji market. Since the Pacific coast is the larger producer of thornyheads, this finding indicates that the most important domestic ex-vessel markets for thornyheads may also be insulated from price changes in Japan.

Finally, another form of vulnerability theoretically facing U.S. harvesters involves a trade parameter under less direct policy control : changes in the currency exchange rate between Japan and the U.S. All prices used in this analysis are converted to U.S. dollars so that fluctuations in the exchange rate will tend to move prices of a traded good in opposite directions within the producing and consuming countries. Since the ex-vessel fixed gear sablefish markets are apparently not linked by price to the Tokyo market, exchange rate fluctuations should not impact production at the vessel level, although perhaps profit margins of processors or export brokers might be impacted. Since the Tsukiji price for thornyheads appears to follow that of the Pacific coast, much of any thornyhead price differentials caused exchange rate fluctuations may be expected to be absorbed by intermediaries or the by the Japanese market, itself.

## REFERENCES

**Atkinson C.E.** Undated. Japanese markets for groundfish. Memo, Seattle, Wash.

**Breusch T.S. and A.R. Pagan** (1979). A simple test for hetero-scedasticity and random coefficient variation. *Econometrica* **47 :** 1287-1294.

**Cochrane W.W.** (1957). The market as a unit of inquiry in agricultural economics research. *Journal of Farm Economics* **39** (1) : 21-39.

**Conover W.J. and R.L. Iman** (1982). Analysis of covariance using the rank transformation. *Biometrics* **38 :** 715-724.

**Dore I.** (1991). Cresting or crashing : West coast dependency on Japanese imports. *Pacific Fishing, 1991 Yearbook.* Seattle, Washington.

**Granger C.W.J.** (1977). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* **37 :** 424-438.

**Granger C.W.J.** (1988). Some recent develops in a concept of causality. *Journal of Econometrics* **39 :** 199-211.

**Greene W.** (1990). *Econometric Analysis.* Macmillan, New York.

**Hastie J.** (1989) An economic analysis of markets for Pacific sablefish. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-171, 71p.

**Holmes J. and P. Hutton** (1988). A functional-form distribution-free alternative to parametric analysis of Granger causal models. *Advances in Econometrics* **7 :** 211-225.

**Holmes J. and P. Hutton** (1990). On the causal relationship between government expenditures and national income. *Review of Economics and Statistics* **72 :** 87-95.

**Iman R.L. and W.J. Conover** (1979). The use of the rank transformation in regression. *Technometrics* **21** (4) : 499-509.

**Jacobson L.D.** (1991). Thornyheads — stock assessment for 1991. Memo, National Marine Fisheries Service, La Jolla.

**Judge G.G., W.E. Griffiths, R.C. Hill and T.C. Lee** (1980). *The Theory and Practice of Econometrics.* John Wiley & Sons, New York.

**Monke E. and T. Petzel** (1984). Testing market integration. *American Journal of Agricultural Economics* **68** (1) : 102-109.

**Sims C.** (1974). Distributed lags. In : M.D. Intriligator and D.A. Kendricks (Editors), *Frontiers of Quantitative Economics*, Vol. II, Amsterdam : North-Holland Publ. Co., pp. 289-336.

**Squires D.** (1986). Ex-vessel price linkages in the New England fishing industry. *Fishery Bulletin* **84 :** 437-442.

**Squires D., S. Herrick, Jr., and J. Hastie** (1988). Integration of Japanese and United States sablefish markets. *Fishery Bulletin* **87 :** 341-351.

**White H.** (1980). A heteroscedasticity-consistent covariance matrix estimator and a direct test for heteroscedasticity. *Econometrica* **48 :** 817-838.

TABLE 1a.
MULTIPLE RANK F TESTS FOR SABLEFISH.

| Causation Hypothesis | Currency | Number of Lags 2 | 3 | 4 | 5 | 6 | Causation Finding |
|---|---|---|---|---|---|---|---|
| A -----> J | $ | 0.341 | 0.376 | 0.718 | 0.934 | 1.131 | A --/--> J |
| A -----> J | Y | 0.630 | 1.172 | 1.280 | 1.031 | 1.011 | A --/--> J |
| J -----> A | $ | 0.825 | 0.597 | 0.920 | 0.710 | 0.701 | J --/--> A |
| J -----> A | Y | 0.857 | 0.436 | 1.501 | 1.219 | 1.056 | J --/--> A |
| J -----> A | Y/$ | 0.773 | 0.506 | 1.754 | 1.584 | 1.340 | J --/--> A |
| P -----> J | $ | 0.044 | 0.051 | 0.061 | 0.063 | 0.940 | P --/--> J |
| P -----> J | Y | 0.832 | 0.687 | 0.506 | 0.544 | 1.077 | P --/--> J |
| J -----> P | $ | 0.531 | 0.625 | 0.968 | 0.769 | 0.631 | J --/--> P |
| J -----> P | Y | 0.668 | 1.020 | 0.904 | 0.808 | 0.694 | J --/--> P |
| A -----> P | $ | 0.001 | 0.806 | 1.029 | 0.996 | 0.863 | A --/--> P |
| P -----> A | $ | 0.955 | 0.626 | 0.393 | 0.452 | 0.712 | P --/--> A |

NOTE: Ranks of first-differenced nominal prices. Heteroscedastic-consistent estimates.

TABLE 1b.
PARAMETRIC F TESTS FOR SABLEFISH.

| Causation Hypothesis | Currency | Number of Lags 2 | 3 | 4 | 5 | 6 | Causation Finding |
|---|---|---|---|---|---|---|---|
| P ------> J | $ | 1.778 | 1.564 | 1.221 | 0.794 | 0.650 | P --/--> J |
| J ------> P | $ | 0.059 | 0.019 | 0.016 | 0.014 | 0.014 | J --/--> P |
| A ------> J | $ | 8.023[1] | 5.586[1] | 3.673[1] | 2.677[2] | 2.532[2] | A -----> J |
| J ------> A | $ | 0.056 | 0.008 | 0.009 | 0.013 | 0.012 | J --/--> A |
| A ------> P | $ | 0.018 | 0.005 | 0.003 | 0.007 | 0.005 | A --/--> P |
| P ------> A | $ | 0.018 | 0.008 | 0.009 | 0.013 | 0.005 | P --/--> A |

NOTE: Nominal prices. Heteroscedastic-consistent estimates. Currency: $: dollars, Y: yen.
Variable definitions are: A: (Alaska) , P: (Pacific coast), J: (Japan).
Statistical significance of F-test parameters - 1: 1%, 2: 5%, 3: 10%.
Causation findings: A ---> B = A causes B, A -?-> B = A may cause B,
A -/-> B = A does not cause B.

TABLE 2a.
MULTIPLE RANK F TESTS FOR THORNYHEADS.

| Causation Hypothesis | Currency | Number of Lags 2 | 3 | 4 | 5 | 6 | Causation Finding |
|---|---|---|---|---|---|---|---|
| A -----> J | $ | 0.297 | 0.240 | 0.174 | 0.570 | 0.448 | A --/--> J |
| A -----> J | Y | 0.021 | 0.276 | 0.335 | 0.284 | 0.247 | A --/--> J |
| J -----> A | $ | 1.378 | 2.178 | 2.082[3] | 1.750 | 1.466 | J --?--> A |
| J -----> A | Y | 0.881 | 0.987 | 1.874 | 2.060[3] | 1.707 | J --?--> A |
| P -----> J | $ | 1.171 | 1.132 | 0.784 | 0.717 | 0.607 | P --/--> J |
| P -----> J | Y | 7.225[1] | 4.826[1] | 3.557[1] | 2.746[2] | 2.223[2] | P -----> J |
| J -----> P | $ | 0.216 | 0.811 | 1.440 | 1.417 | 1.277 | J --/--> P |
| J -----> P | Y | 0.367 | 0.047 | 0.284 | 0.457 | 0.467 | J --/--> P |
| A -----> P | $ | 2.641[2] | 2.416[2] | 1.843 | 1.459 | 1.706 | A --?--> P |
| P -----> A | $ | 0.531 | 0.334 | 0.360 | 0.417 | 0.324 | P --/--> A |

NOTE: Ranks of first-differenced nominal prices. Heteroscedastic-consistent estimates.

TABLE 2b.
PARAMETRIC F TESTS FOR THORNYHEADS.

| Causation Hypothesis | Currency | Number of Lags 2 | 3 | 4 | 5 | 6 | Causation Finding |
|---|---|---|---|---|---|---|---|
| A -----> J | $ | 1.246 | 0.855 | 0.595 | 0.408 | 0.826 | A --/--> J |
| J -----> A | $ | 0.367 | 2.060 | 1.835 | 1.697 | 1.408 | J --/--> A |
| P -----> J | $ | 3.331[2] | 2.211[3] | 1.439 | 1.028 | 0.868 | P --?--> J |
| J -----> P | $ | 1.087 | 0.712 | 0.578 | 0.490 | 0.807 | J --/--> P |
| A -----> P | $ | 0.454 | 0.282 | 0.216 | 0.363 | 0.407 | A --/--> P |
| P -----> A | $ | 0.593 | 0.544 | 0.616 | 0.825 | 0.673 | P --/--> A |

NOTE: Nominal prices. Heteroscedastic-consistent estimates. Currency: $: dollars, Y: yen.
Variable definitions are: A: (Alaska) , P: (Pacific coast), J: (Japan).
Statistical significance of F-test parameters - 1: 1%, 2: 5%, 3: 10%.
Causation findings: A ---> B = A causes B, A -?-> B = A may cause B,
A -/-> B = A does not cause B.

# The Alaskan King Crab Industry - An Industry in Transition

**Joshua A. Greenberg[a], Scott C. Matulich[b] and Mark Herrmann[c] ***

[a]Department of Resources Management, University of Alaska Fairbanks, Alaska, 99775, USA

[b]Washington State University, Pullman, Washington, 99164, USA

[c]Department of Economics, University of Alaska Fairbanks, Alaska, 99775, USA

ABSTRACT

*The Alaskan king crab industry has historically been one of the most lucrative fishing industries in the U.S. Last year the industry was staggered by low exvessel prices. An international marketing model of the Alaskan king crab industry is developed in this paper to provide insight into potential causes of price movements. Wholesale price formation and allocation for the two largest markets, Japan and the U.S., are explicitly modelled. Specific market conditions are shown to have resulted in an unusual structure to processor's price formation and product allocation. Recent events, including the deterioration of the U.S. wholesale king crab market and economic liberalizations in Russia, may have a profound impact on this industry. Model results are used to discuss the potential ramifications of these events to industry participants.*

## 1. INTRODUCTION

The Alaska fishing industry plays an integral role in the Alaskan economy. It is the state's largest employer, as well as the state's second largest private source of revenue. The fisheries have provided a steady, and even lucrative, source of income to fishery participants. However, in the past year, two of Alaska's most lucrative fisheries, sockeye salmon and Alaskan king crab, have experienced severely depressed exvessel prices. The low exvessel prices have been a cause of

* This report is the result of research sponsored by Alaska Sea Grant with Funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, under grant no. NA90AA-D-SG066, project # M/81-01, and with funds from the University of Alaska with funds appropriated by the state

great concern to fishery participants. In general, an understanding of the international markets for Alaskan fishery products is necessary if fishery participants are to gain insight into potential causes of past and future price movements, and for prudent investment decisions.

This paper examines the international Alaskan king crab market. An econometric model of historical product allocation and wholesale price formation for the two largest markets, Japan and the U.S., is developed. The detailed market structure is shown to contain unusual characteristics which have, in part, developed on the basis of Alaska being a dominant world supplier of king crab. This market structure has in the past helped support high prices to U.S. fishery participants.

The paper concludes with a discussion of how changing conditions, both within the market and in Russia, may be altering the basic market structure. These changes threaten the future stability of the Alaskan king crab industry.

## 2. BACKGROUND

Alaskan king crab are harvested during early fall in the western coastal areas of Alaska. The dominant harvest region is located in Bristol Bay. The crab fishery is managed by the State of Alaska through its Board of Fisheries and the Alaska Department of Fish and Game (ADF&). Commercial harvest of Alaskan king crab dates back to 1930, when Japanese fishers began harvesting red king crab (*Paralithodes camtschaticus*) in the Eastern Bering Sea. The domestic U.S. commercial fishery was not initiated until 1947.

The foreign fleet (comprised of vessels from Japan and Russia) were displaced through a series of Bilateral Agreements between the U.S. and both Japan and the USSR. The agreements resulted in declining annual harvests for both the Japanese and USSR fleets, beginning in 1966. The Soviet fleet had exited the king crab fisheries in U.S. territorial waters by 1972, and the Japanese fleet was completely displaced by 1976.

Harvests of Alaskan king crab by foreign (non-U.S.) vessels was further restricted with U.S. Congressional passage of the Magnuson Fisheries Management Conservation Act of 1975. Among its other provisions, the Magnuson Act extended U.S. territorial jurisdiction over all living marine resources to the 200 mile limit. Thus, the Magnuson Act, in conjunction with the earlier bilateral agreements, vastly reduced the harvest of king crab by the Japanese fleet. Since the mid 1970s, Japan's harvest of king crab has been limited to minor domestic fisheries.

Japan was a minor market for Alaskan king crab prior to 1973. However, as the Japanese harvest of king crab decreased, Japan became increasingly reliant on king crab imported from the U.S. The importance of the Japanese market increased rapidly in the 1970s. Japan's market share of U.S. harvested product was less than one percent in 1974 and 1975. By 1978, Japan accounted for one-third of U.S. king crab sales. Since that time, its market share has fluctuated between 10 percent and 50 percent, stabilizing in the late 1980s at around 44 percent. Japanese consumption of the highest valued species, red king crab, recently exceeded 90 percent of harvest.

The harvested Alaskan king crab is delivered live to either shore-based or floating processors. The processing procedure, and the subsequent market channel for the product, depends on the designated destination for the product. Crab destined for the U.S. market is brine (cooked) frozen in whole, or section and claws product forms. The frozen product is subsequently shipped to Seattle were it is reprocessed and placed in cold storage. Inventoried crab is shipped to brokers for distribution to the year-long U.S. wholesale market. The primary retail outlets in the U.S. differ by species, but include upscale restaurants (referred to as the white tablecloth trade), fish markets, supermarkets, and specialized catering. In addition, a portion of the Seattle inventoried crab is shipped to other export markets and a small portion is shipped to Japan.

Alaskan king crab destined for the Japanese market is processed in Alaska primarily in the raw (uncooked) frozen product form. It is shipped directly from Alaska to Japan. The raw frozen product form allows for secondary reprocessing to occur in Japan, where the product is subsequently processed into numerous different product forms which fill a variety of specific demand niches. It also allows the Japanese to control quality of the final products.

The Japanese retail market for king crab appears to be targeted primarily for the end-of-year holiday season. Alaskan king crab is a prestigious year-end gift item. Consequently, most of the Japanese purchases occur in the fourth quarter of the calendar year.

Thus, characteristics of both the U.S. and Japanese markets require that processors allocate live crab between the two markets early in the harvest season. Consumer preferences in Japan and the U.S. dictate that the king crab be processed in different product forms. Additionally, Japanese buyers must secure their supply of king crab early in the autumn harvest season if there is to be sufficient time for secondary reprocessing and distribution to retail outlets prior to commencement of the end-of-year holiday season.

Several market characteristics provide insight into processors product allocation behavior between the U.S. and Japanese markets. The early season designation of product to Japan allows processors to avoid shrinkage associated with holding the perishable raw frozen processed product in inventory. Second, shipment of the crab directly from Alaska to Japan allows processors to avoid transshipment costs to Seattle cold storage facilities, and also to avoid the capital costs of holding processed product in inventory. Third, early season sales to Japan firms up U.S. price by lowering available supplies throughout the remaining year. Finally, and most importantly, the Japanese pay cash at the time of sale. This provides processors with an early season cash flow that can be used to offset the cost of unprocessed crab purchases and subsequent reprocessing, holding and marketing costs. It also lowers processor risk by avoiding possible seasonal wholesale price declines.

## 3. MARKET MODELS

A model of allocation and demand for Alaskan king crab sections provides insight into how current changes in the world may impact the future health of the Alaskan king crab industry. The model represents a portion of a complete bioeconomic model of the Alaskan king crab industry (see Greenberg 1990, Matulich et al. 1991). The time periods in all models refer to the ADF&G seasonal year, July 1-June 30. The terminal time period in all models of 1987 (corresponding to July 1, 1987-June 30, 1988) was dictated by data availability.

### *3.1 Allocation*

A conventional economic treatment of allocative behavior and price formation involves arbitraging the alternative markets, where inventories buffer current and expected future prices. One would expect processors to simultaneously evaluate the price in each market and adjust allocation toward the market that has the higher net price, thereby extracting maximum profits across markets and time. Adjustments would continue until processors are indifferent between the market prices.

This arbitraging scenario involves modelling the processors' price offer to a particular market as a function of quantity allocated to that market, total available supplies, processing costs, the opportunity costs of holding inventories for future sale, and the alternative market price. However, processor behavior appears to deviate from this conventional paradigm because of the distinct market characteristics. Japanese buyers' early entry in the market, coupled with the advantages of Japanese market sales, have led to processors segmenting their price formation between the two markets [1].

Market segmentation became more formal following the fishery collapse of 1983, which severely disrupted product flow to Japan. Many of the processing firms were purchased wholly or partially by Japanese firms in the mid 1980s. This arrangement further assured Japanese access to product at a "fair" price, where fair refers ostensibly to a margin above exvessel price--the principal cost to processors. This notion of "fair" price was articulated in personal communication by many of the processors.

Equation (1) represents an unusual, simple relationship that exists in the Japanese market.

$$\underset{}{PSECTJ_t} = \underset{(2.57)}{0.40322} + \underset{(25.16)}{1.98705}\ AVEXVP_t \qquad (1)$$

$R^2 = 0.980$ df = 13

1. Conventional price arbitraging models were investigated. Estimation results were unsatisfactory, e.g. low t-values and incorrect parameter signs.

Japanese wholesale price of Alaskan king crab sections, $PSECTJ_t$ (\$/lb, FOB Alaska) is represented as function of the primary variable costs to processors, average Alaskan king crab exvessel price, $AVEXVP_t$ (\$/lb). The price offer function was estimated for the 1973-87 time period using ordinary least squares (OLS). This simple margin relationship accounts for 98 percent of all variation in the Japanese wholesale section price (t-values are reported in parentheses).

Processors' price offer was found not to be quantity responsive. Instead allocation to the Japanese market is implicitly determined by the Japanese demand at the price determined in equation (1). This suggests that the Japanese buyers may be more concerned with gaining access to a high quality product than with specific price. And that they are willing to support a price level that assures processors a fair return, in order to secure an early season supply.

One should not infer that this specification is a literal representation of the market behavior. Some brine frozen product is exported from Seattle to Japan later in the marketing year, indicating that limited arbitraging does occur. However, the influence of these sales is minor and statistically indiscernible.

In contrast to wholesale price formation captured by equation (1), the U.S. allocation equation corresponds to a more conventional market analysis, where supply and demand are determined simultaneously. The preferred log specification of U.S. section supply is given in equation (2).

$$\begin{aligned} \ln SECTUS_t = {} & -2.27711 + 1.35942 \ln PSECTUS_t - 0.78218 \ln AVEXVP_t \\ & (-2.28) \quad (3.11) \quad (-2.71)) \\ & + 0.83286 \ln(HARV_t - SECTEXPJ_t) + 0.33826 \ln(SECTHOLD_{t-1} + SECTIMP_t) \\ & (8.63) \quad (6.17) \\ & - 0.42519 \, IND83 \\ & (-3.30) \end{aligned} \tag{2}$$

$R^2 = 0.973 \quad df = 9$

where

$SECTUS_t$ is the section supply to the U.S. wholesale market (million lbs),
$PSECTUS_t$ is the New York Fulton Market frozen section wholesale price (\$/lb),
$SECTHOLD_t$ is quantity of frozen inventoried sections (million lbs),
$SECTIMP_t$ is the quantity of Russian crab imported to the U.S. (million lbs)[2],
IND83 is an indicator variable marking the year of fishery closure.
The quantity ($SECTHOLD_{t-1} + SECTIMP_t$) is treated as a separate supply variable. Russian imports did not begin until 1982, and neither variable is inventoried more than a single year.

Equation (2) was estimated for the 1973-87 time period using two stage least squares (2SLS). The model accurately estimates U.S. wholesale section supply, as indicated by the reported $R^2$ of 0.973.

The absence of the Japanese wholesale price in equation (2) highlights the recursive nature of the Japanese and U.S. wholesale markets. The Japanese wholesale market intratemporally impacts the U.S. market by reducing supply availability of king crab in the U.S. market, thereby firming U.S. wholesale price.

### *3.2 Demand*

The other side of wholesale product allocation and price formation is determined by consumer response to the wholesale price offers. According to the previously specified Japanese price offer function, processors set price on a margin basis with exvessel price. Japanese buyers then equilibrate the Japanese market by adjusting the quantity purchased according to Japanese consumer response to the price offer. Thus, price is an exogenous factor to Japanese consumers.

The Japanese demand function specified in equation (3) was estimated for the time period 1975-87. 1975 corresponds to the year that Japan ceased fishing in U.S. waters. The equation was estimated using nonlinear OLS, reflecting that price is exogenous. $SECTCONJ_t$ is set equal to $SECTEXPJ_t$ in a definitional identity. The model based on real income and prices outperformed its nominal counterpart.

2 Limited U.S. imports of Russian king crab began in 1982 under a special barter arrangement.

$$SECTCONJ_t = PSECTJ_t^{-2.01785} PCEJ_t^{2.73523} EXCHJ_t^{-2.37477} (IMPR_t + JHAR_t)^{-0.58745} SECTCONJ_{t-1}^{0.27327} \quad (3)$$
$$(-3.87) \qquad (7.25) \qquad (-6.90) \qquad (-5.00) \qquad (2.03)$$

$$\exp(-1.02920\ IND8287)$$
$$(-2.43)$$

$R^2 = 0.991 \qquad df = 7$

$SECTCONJ_t$ is expressed as a function of Japanese wholesale price and 6 demand shifters :

Japanese personal consumption expenditures, $PCEJ_t$ ($1,000) ;
the Japanese-U.S. exchange rate, $EXCHJ_t$ (¥/$, third quarter) ;
Quantity of substitute sources of king crab from Japanese harvest, $JHAR_t$ (million lbs), and
Russian imports, $IMPR_t$ (million lbs) ;[3] [4]
a measure of Japanese consumer habit formation for king crab sections ($SECTCONJ_{t-1}$).
In addition, an indictor variable, IND8287, was found to be significant, suggesting a structural break in demand beginning in 1982. In that year price more than doubled from the 1981 level. IND8287 equalled one for the 1982-87 period, and zero otherwise.

The fit is good, with 99 percent of the variation in price explained by variation in the explanatory variables. All parameters conform to a priori expectations and are significant at the 0.08 level.

The Cobb-Douglas functional form is characterized by estimated parameters representing constant elasticities. Several of the elasticities deserve examination. As would be expected for this high priced product, Japanese demand for king crab sections was found to be very responsive to changes in Japanese income. Section exports to Japan are estimated to rise (fall) 2.74 percent for a 1.0 percent increase (decrease) in personal consumption expenditures.

The elasticity associated with exchange rates is of special interest because this represents the most volatile explanatory variable in the demand function. A change in the exchange rate not only alters the effective yen price that the Japanese pay for king crab (price effect), but it also raises or lowers Japanese purchasing power in foreign markets (income effect).

The composite demand elasticity associated with these two effects can be derived from equation (3). Extracting the portion of the exchange parameter that converts $PCEJ_t$ to yen values (i.e., holding per capita consumption expenditures, measured in yen, constant), yields the cumulative price and income exchange rate elasticity. The resulting combined elasticity of -5.11 shows Japanese demand to be highly sensitive to exchange rate changes. The volatility of exchange rates in recent years translates into swings in Japanese demand, and potentially, substantial movements in the dollar price Japanese are willing to pay.

The responsiveness of the Japanese demand to both the exchange rate and income is particularly troubling to the U.S. industry given recent indications that the Japanese economy is slipping into a recession. The yen has recently weakened against the dollar, and declines in personal consumption expenditures are anticipated. These events could substantially depress Japanese demand for Alaskan king crab.

Finally, the Japanese harvest and Russian import elasticity of (-0.587) show these products to be substitutes for U.S. produced crab. Japanese imports of Russian product are of particular concern to the Alaskan king crab industry. There have been indications that Russian king crab exports to Japan have increased substantially in recent years. Time series data on Russian exports to Japan are not available. However, Russian export trends can be inferred from available data on Russian exports of all crab species to Japan. According to trade statistics reported by the Japanese Marine Product Importers Association, Russian exports between 1984 and 1988 of all crab species increased almost threefold. This trend of increasing Russian-Japan trade has continued through 1990. Russian exports of all crab species increased by 180 percent between 1988 and 1990.

U.S. demand for Alaskan king crab sections completes the market models. The demand function models the relationship between U.S. section price, $PSECTUS_t$ ($/lb) and U.S. section consumption, $SECTCON_t$ (million lbs), and demand shifters. $SECTCON_t$ is set equal to domestic supply in a definitional identity.

3. Price series were not available for either Japanese domestic king crab production or king crab imported from Russia. Instead quantities were used.
4. Historical time series data for Japanese imports from Russia were not available. The quantities used in estimation represent the quantity imported by one of Japan's largest importers.

The demand shifters fall within the same general categories as those in the Japanese demand model. U.S. personal consumption expenditures, $PCE_t$ ($1,000), are included as the measure of U.S. income. American lobster is included as a substitute for Alaskan king crab. A retail price series for lobster is unavailable. The lobster price, $PLOB_t$ ($/lb), represents an exvessel price index for lobster compiled by the National Marine Fisheries Service. It is assumed that exvessel price is linearly correlated with retail lobster price. Lagged U.S. section consumption, $SECTCON_{t-1}$, provides a measure of consumer habit formation. The indicator variable IND83 marks the year in which the Bristol Bay Fishery was closed.

Quantity and price dependent demand functions were estimated in both linear and nonlinear functional forms. The inverse demand function given in equation (4) provided the best results. Models in which income and prices were included in nominal terms consistently outperformed the real term counterparts. Simultaneity between $PSECTUS_t$ and $SECTCON_t$ required the use of 2SLS in model estimation. The linear specification of the inverse demand function provided the best results.

$$\begin{aligned} PSECTUS_t = {} & \underset{(-2.41)}{-2.06135} - \underset{(-4.46)}{0.04361}\, SECTCON_t + \underset{(1.72)}{0.00152}\, PCE_t + \underset{(2.35)}{2.15540}\, PLOB_t \\ & + \underset{(1.73)}{0.01501}\, SECTCON_{t-1} + \underset{(1.84)}{1.25166}\, IND83 \end{aligned} \tag{4}$$

$R^2 = 0.972 \qquad df = 12$

U.S. demand was modelled for the 1970-87 period. All parameters conformed to a priori sign expectations. The ability of the model to estimate wholesale price changes is reflected by the reported $R^2$.

The results from the estimated model show that U.S. consumers are highly responsive in their purchasing behavior to price changes. And that price was nearing the choke price. The estimated mean price flexibility coefficient for section consumption of -0.359 suggests that even small increases in U.S. price will severely depress consumption. This in fact occurred in 1991, one year after the model was completed. An industry report indicated that the domestic market all but vanished, in large part due to high prices (Murphy 1991).

## 4. DISCUSSION

Development of the Japanese market provided great benefits to the Alaskan king crab industry and was the primary reason why prices, both wholesale and exvessel, achieved record levels in 1990. Processors focused attention on Japan, virtually ignoring the domestic market. By entering the market early and "pulse buying" before U.S. buyers enter the market, by assuring U.S. processors a "fair" margin above exvessel price, and by paying cash, Japan has effectively segmented the market, leaving the U.S. market as a residual market. Discussions with industry representatives indicate that the U.S. market has been neglected and become perilously thin in recent years. A recent industry report stated that "... distributors (seafood) expressed a strong conviction that Alaskan king crab processors were in the process of abandoning the American market for a more profitable Japanese market (Murphy 1991)." The report further stated that recent high prices and changing consumer tastes have led to Alaskan king crab losing its position in the U.S. white tablecloth, fine dining segment. The industry will have difficulty recovering this lost market segment.

This suggests that in the near term the financial well-being of the industry is dependent on the Japanese market, and a market structure based on the U.S. being the dominant supplier of king crab. However, a structural break in the industry may be likely in the near future due to increased king crab trade between Japan and Russia.

Little is known (outside of Russia) about the Russian king crab industry. The center of the industry is Vladivistok, which is only a few hundred miles from Japan. Russian fisheries are believed to contain immense king crab stocks. This is reflected by the 1990 Russian harvest of approximately 92 million pounds (FAO 1990). In comparison, the 1990 U.S. harvest was approximately 33.4 million pounds (ADF&G 1990). Most of the harvested crab from Russia has been canned and exported to Europe. Canning of Russian product is a consequence of two dominant factors. First, the Russians lack modern freezing technology. They do process limited quantities of "blast frozen" product, but quality appears to be problematic. The Russian product suffers from "over-cooking," salt penetration and improper freezing. Thus, Russian

processed king crab is viewed by Japanese buyers as being an inferior product to Alaskan king crab. Moreover, the Russia Far East has virtually no cold storage facilities to support rigorous expansion into either the Japanese or U.S. markets. Limited technology, capital, and marketing skills have in the past restricted the Russian king crab industry, resulting in production of an unnecessarily low valued product that has not been able to fully penetrate the Japanese market. Correction of these deficiencies will greatly enhance the value of the Russian product, and permit Russian king crab to compete in markets which have been traditionally dominated by the U.S. king crab industry.

There are several reasons why this development should be expected to occur. Russia is in desperate need of hard currency. Development of the king crab industry would lead to the production of a high valued product that can be exported to the wealthy, enormous Japanese market (and potentially the U.S. market). Additionally, unlike terrestrial resources (e.g. timber and minerals), development of the king crab industry would not require costly capital investment in infrastructure.

Joint ventures between the U.S. and Russia, and Japan and Russia could provide necessary capital, technology, and marketing skills, which Russia lacks. Currently, limited joint ventures between the U.S. and Russia exist. The proximity of the Russian fishery, and the strong consumer demand for high valued king crab, provides a strong impetus for Japanese investment in the Russian king crab fishery. Increased trade linkages between capital poor but resource rich Russia, and capital rich but resource poor Japan could provide significant benefits to both countries.

We can speculate as to the consequences to the U.S. king crab industry of increased Russian production of high quality king crab. The development of an alternative king crab supply source can be expected to lead to a structural break in the Japanese purchasing behavior. Japanese buyers will be able to arbitrage across the U.S. and Russian processed product markets. The resulting equilibrium price in Japan should be substantially below the current Japanese price for Alaskan king crab, and above the current Japanese price for Russian king crab.

Increased Russian exports to Japan will result in U.S. product, previously allocated to the Japanese market, entering the U.S. marketing channel. This would depress U.S. wholesale price. Additionally, Russian product may be exported to the U.S., further depressing U.S. price. Reductions in U.S. and Japanese wholesale prices will be passed along to U.S. fishers in the form of substantially lower exvessel prices.

The 1991 U.S. fishery season may have provided a preview of future structural changes in the Alaskan king crab industry. Japanese purchasing behavior in 1991 deviated from past behavior. In the past, Japanese buyers have reached agreements with U.S. processors early in the harvest season. The agreements specified both price and quantity. As noted in the development of the market model, this price was based on exvessel price. However, in 1991, agreements between U.S. processors and Japanese buyers were delayed. This resulted in a portion of the processed product being shipped to Japan without a firm price offer. Exvessel price in Alaska dipped severely from the 1990 price of $5.00 per pound, to $3.25 per pound.

The cause of these changes in Japanese behavior can not be determined without additional information. One possible explanation is that the Japanese buyers, aware of the demise of the U.S. wholesale market, exerted increased market power--Japanese buyers took a more aggressive role in setting price.

Alternatively, the depressed market prices may have resulted from increased Japanese imports of Russian crab. There were unconfirmed reports of extremely large shipments of Russian king crab to Japan immediately preceding the opening of the 1991 Bristol Bay red crab fishery.

The emergence of Russian fisheries has implications extending beyond the king crab fishery. For example, Russia may emerge as an important source of Tanner crab and sockeye salmon. As with king crab, Alaskan fisheries have been the primary supply source of these species, and Japan has been the dominant market. Thus, gaining additional information on Russian fisheries and incorporating this information in future market models is critical to gaining insight into future performance of Alaskan fisheries. Efforts, funded by Alaska Sea-Grant, are currently underway at the University of Alaska Fairbanks toward achieving these objectives.

So what does the future hold for the Alaskan king crab industry ? The results of this analysis suggest that the outlook is less than rosy. A weakening yen, coupled with prospects of a recession in Japan, will put tremendous pressure on price. Continued growth in trade between the Russian Far-East and Japan will further exaggerate any price slippage. But the real wild card is whether processors can recapture the domestic market at a price that keeps the fleet fishing. The 40 percent drop in exvessel price last year sets the stage for a major restructuring of this fishery.

## REFERENCES

**Alaska Department of Fish and Game** (1991). "Westward Region Shellfish report to the Alaska Board of Fisheries." Division of Commercial Fisheries, Kodiak, Alaska, March .

**FAO** (1990). "Yearbook of Fishery Statistics Catches and Landings." Food and Agriculture Organization of the U.N., Rome, V.70.

**Greenberg J.A.** (1990). "An Econometric Analysis of the Alaska King Crab Industry : A Bioeconomic Perspective." Ph.D. Dissertation. Washington State University, December.

**Japanese Marine Product Importers Association** (1991). "Japanese Imports of Marine Products (Statistics)." Tokyo, Japan.

**Matulich S.C., J.A. Greenberg and R.C. Mittlehammer** (1991). "The Prominence of Japan in the Alaska King Crab Fishery." Chap. 13 in *In Understanding the Multifaceted Japanese Market.* Ed. D. O'Rourke, Hayworth Press Inc..

**Murphy J.R.** (1991). "Alaskan King Crab Foodservice Attitude and Use Distributor and Operator Focus Group." The Qume Group LTD, July 1991.

# Java Sea Purse Seiners : the Impact of Innovation on Performance

**James Kevin McElroy [a] and Wijopriono [b] ***

[a]Landell Mills Management Consultants, Jl. Plaju 6, Jakarta 10230 Indonesia

[b]Marine Fisheries Research Institute, Jl. Pasir Putih 1, Ancol Timur, Jakarta Utara 11001 Indonesia.

ABSTRACT

*Given the significance of the purse seine fleet to fish supplies in Java, an island in Indonesian with a population approaching 100 million, the paper analyses the relative importance of several interactive factors on Javanese purse seine vessel catch and economic performance, including the effects of vessel size, age, speed, net size, use of fish aggregating devices (FADs) and fishing lights, lunar period, season, oceanographic and weather characteristics, distance to and location of the fishing ground, the impact of navigation, fish location and communication aids, 'fleet cooperation' and 'fleet congestion', time/distance to port auction, auction size and purchasing power, general fish supply and demand conditions, etc.*

*The importance of vessel size on fishing pattern and preservation method(s) used is highlighted, as is the importance of lunar period and brightness of artificial fishing lights.*

## 1. INTRODUCTION

The Java Sea small pelagics fishery has immense biological, social and economic importance (McElroy, 1991a ; 1992a). This fishery yields over 400,000 tons/year, with an ex-vessel value in 1991 estimated at over US$ 220 million.

* The author wishes to thank the two Project Co-Directors, Thiery Boely and Johannes Widodo, the counterparts Abdull Sari and their counterpart organizations. Special thanks go to the Landell Mills Ltd. team members, Naval Architect Chris Temple and Post-harvest Specialist Ivor Clucas and to ORSTOM's Biologist Michel Potier for their advice and open discussion. Responsibility for any misconceptions and omissions remains with the author.

This work is being funded by the European Community under the 'Java Sea Pelagic Fishery Assessment Project', ALA/INS/87/17. This paper reports on 'work in progress' on vessel economics.

The Java Sea small pelagics resource base is being heavily exploited throughout its range and for many stocks throughout much of their life cycle by a variety of fishing gears, including *bagan* (lift net), gill net, *payang* and purse seine. A large subsistence economy (using small-scale gears and vessels) plus commercial enterprises (using medium-scale vessels) depend upon these resources for their own nutrition and as a source of income. Indeed, currently, the Java Sea small pelagics fishery is the single most productive fishery in Indonesia.

No empiracle study on the techno-economic performance of the Java Sea purse seine fleet has been carried out to date. Pre-1980 studies on the economic performance of both small and large Java Sea purse seine vessels have recently been reviewed (Bailey et al, 1987). These studies suffered from covering only one season, or the sample being very small. A few aggregate studies were carried out in the second half of the 1980s (see RMC/PMO, 1987 ; Bandjono et al, 1989 ; McElroy, 1991a, 1992a).

This paper chronicles changes in the fleet size, and the main technical innovations that have taken place since the introduction of the purse seine vessel to the Java Sea about 1970. The present-day vessels have evolved gradually. They remain technologically simple, with none of the current fleet of inboard purse seiners being engaged in 'active' fishing, neither using sonar in 'open water' to locate fish schools, nor power block to haul the net[1].

The fishery, today, is a 'passive' one, more closely allied to mobile 'light fishing', such as *bagan* or 'lift net' fishing operations, than the activities generally associated with modern purse seine fishing involving the hunting for and setting on schools of pelagic fish in 'open water'. However, such concepts as 'active' and 'passive' fishing are misleading in a mobile light fishery where vessels shift grounds according to the latest fleet information on the location of good fishing areas, concentrate or disperse according to the pattern of distribution of the fish, and 'filter' large volumes of water with the use of lights and *rumpon*, a fish aggregating device. The success of this fishing technique probably reflects the particular distribution patterns and behavioural characteristics of these small pelagic fish. As such, it may well be the most techno-economically appropriate.

## 2. MATERIALS AND METHODS

Primary data on vessel characteristics was collected in February/March 1992 by undertaking a 'frame survey' of nearly 40 purse seine vessels, large and small, at the two major fishing harbours of Pekalongan and Juwana (Bajomulyo). Trip data for a sample of vessels was collected at the same time, and supplemented with trip data collected by the project's permanent staff. The data covers : date of departure, date of return, main fishing ground, number of sets made, number of holds filled - sometimes with the split between fresh and salted fish given, date(s) of unloading at the auction, and volume and value of the fish auctioned for the period January 1990-March 1992. In addition, data was collected on queuing times, species composition, quality grade and unit price for a sample of vessels.

Cost and earnings data for a sample of twelve large purse seiners (over 20 m keel length) and five small purse seiners (below 20 m keel length) was collected from vessel owners, and verified/supplemented with data collected by the harbour administrations, etc. This data covers the same period, namely January 1990 - March 1992, although data for some (new) vessels is of a shorter duration. This data analysis is not yet complete. Consequently, the results reported here should be taken as indicative rather than definitive.

Where secondary data is used, the source is indicated.

### *2.1 Catch and Economic Performance*

A number of factors affect both the catch and economic performance of any small pelagic purse seiner fleet 'light fishing'. The principle factors affecting catch performance of a vessel are likely to be : vessel size (grt or hold size), age, power

1. Active fishing', using sonar and power block, have been tried in the Java Sea. Indeed, a State-owned fishing company, PT. Tirta Raya Mina, was set up with the purpose of introducing this technology into the Java Sea in the 1970s. Whilst catches were reported to be satisfactory, the economics of this method of fishing were unfavourable for this company at that time. Since then, at least one private company has attempted to introduce purse seine fishing using sonar and power block, on traditional wooden vessels. This attempt was abandoned after two years, again reportedly due to unfavourable economics compared to the traditional 'passive' fishing method, using large crews to haul the net. These vessels may still be using sonar, however, to select suitable locations to fish using fish aggregating devices, notably rumpon and artificial lights.

(Hp) and speed ; number and size (or fishing power) of Fish Aggregating Devices (FADs), namely rumpon, and fishing lights used ; net and mesh size ; other fishing equipment and communication systems used ; crew size and skill ; abundance and distribution of the fish stock(s) ; lunar period ; season ; oceanographic factors (current and wind, direction and strength) ; weather ; location of and distance to the fishing ground ; 'fleet cooperation' and 'fleet congestion'. These factors are interrelated, some being more important than others under specific circumstances.

The principle factors affecting the economic performance of the vessel include all of the above, as each affects catch performance, while factors related to fish quality and fish price need to be added. These factors include : preservation method used (ice, salt) ; the effect of trip duration (including time spent in port waiting to unload) on fish quality and remaining 'shelf life' ; insulation ; quantity, application and quality of ice and/or salt used ; time/distance to port auction ; auction size and purchasing power, etc.

### *2.2 Technical Innovation*

According to Cunningham et al (1985), technical innovations are concerned with improvements in the technique of fishing or in attempts to find the optimum combination of gear, equipment and operating procedure. They are essentially directed at maximizing vessel profitability, either by increasing catch and/or revenue or reducing the cost of fishing. However, technological change in fisheries is a two-edged sword (Bell, 1978). That is to say it may have a favorable or detrimental effect on economic performance, depending on the circumstances. Essentially, while a particular innovation may be of benefit to the innovating vessel, if adopted by a significant proportion of the fleet, it may increase the catch efficiency of the total nominal effort, which in a normal fishery of limited productive capacity may have one of two outcomes :

i) total catch increases, or

ii) total catch is reduced.

In the measurement of fishing effort, nominal fishing effort (number of vessels, total fleet horsepower, total days at sea, total time spent searching) is related to effective fishing effort by the catchability coefficient, or the measure of how much fish can be caught per unit of nominal effort. We can measure the impact of technological change by measuring changes in the catchability coefficient. However, whether output goes up or down as a result of technological change depends upon the level of exploitation of the fish stock(s).

### *2.3 Measures of Fishing Effort*

To date in the Java Sea purse seine fishery, all authors have suggested or used the single parameter 'days spent at sea' as a practical measure of fishing effort. This measure has also been converted to 'standard effort units' by adjusting for changes in the propulsive power of the fleet (i.e. total main engine horse power) (Potier and Suherman, 1991). At best, this adjustment may be considered a proxy for changes in vessel size. But, given that the method of fishing is essentially 'passive', relying on the power of attraction of rumpon and fishing lights, the best measure of fishing effort in this fishery remains to be found.

The number and size of vessels, fishing technology and fishing techniques employed, have all changed since the early 1980s, and the measure 'days spent at sea' may no longer be, if it ever was, the most appropriate.

This paper attempts to analyse the impact of changes in fishing technology and technique upon catch efficiency (catchability coefficient) over the past 12 years, which incidentally coincides with the rapid expansion of the Java Sea small pelagic fish catch.

As Figure 1 illustrates, the measure 'days spent at sea' has been fairly insensitive to large changes in light fishing power, which may have increased between 2 to 4 fold over this period on average.

## 3. HISTORICAL DEVELOPMENT OF THE FLEET

Four phases in the development of the Java Sea purse seine fleet can be distinguished to date (information based largely on Atmadja and Sadhotomo, 1985 ; Nurhakim et al., 1987 ; Potier and Suherman, 1991 ; and Potier and Boely, 1991).

*Phase 1 (1970-1975).* The *introduction and widespread adoption along the north coast of Java of purse seine vessels,* with a variety of different engine (inboard, outboard) and gear arrangements, size of nets and fishing methods, including active daytime searching. The inboard powered vessels mostly operated from bases along the north coast of Central Java province. Trip lengths were 1-5 days long, extending to 3 - 6 days by the end of this period, with fishing grounds between 3-16 hours from port. The vessels, mostly between 5 - 20 grt, were active for about 8 months each year, with night-time fishing concentrated in the new moon period. Other purse seine vessels, particularly in East Java province, were powered by outboard engine. No 'assist boat' is used.

*Phase 2 (1976-1981).* This period is characterized by a *second pulse of new vessels* , with conformity in the size of new vessel (20-30 grt), engine (120 or 160 Hp) and net (typically 400m x 60 m) ; the shift to 'passive' rumpon fishing, with Petromax lights being used at night. The fishing grounds remained within 1 day's journey time, and trip lengths averaged 3-7 days. The number of new vessels and the average vessel size in the fleet increased dramatically in 1978 and 1979 as a result of the new additions. In 1981, some of these vessels were venturing further from Java, which resulted in some fish being preserved at sea in an ice-brine mix.

*Phase 3 (1982-1986). Expansion of fishing area to cover the whole Java Sea followed by a third pulse of new, larger vessels, particularly in 1985 and 1986,* resulting in a further expansion in fleet capacity. The trawl ban came into effect in the Java Sea in January 1981 and had spread throughout the area by the end of 1982. Grants were provided to change to other fishing methods, and purse seine fishing was promoted as a suitable method as the small pelagic fish stocks were underutilized in areas far from the north Java coast and offshore islands. As more vessels entered the fleet between 1983 - 1987 to take advantage of the higher catch rates available, they got progressively bigger in size, and fished further from Java, by the end of this period operating throughout the Java Sea proper, and extending into the South China Sea (Pejantan) and Makassar Strait (e.g. Lari-larian) at certain times of the year, in their search for productive year-round resources to fish. Besides the continuing expansion in vessel size and fleet capacity (though not vessel numbers), this period is also characterized by the widespread adoption of wet salted fish preservation at sea, introduction of the first electric-powered lights (about 1983/84) and SSB radios (about 1985/86). Trip durations had also risen, by the end of this period of up to 40 days during trips to fishing grounds four to five days one-way journey time away.

*Phase 4 (1987-present). Increased emphasis on technical innovation, widespread adoption of electric fishing lights and SSB radio, the consolidation of vessel numbers over the period, with a fourth pulse of new vessels, particularly in 1991 and 1992, to take advantage of the better port facilities.* This period is characterized by the consolidation of vessel numbers as old vessels are withdrawn and new vessels added, the dramatic increase since 1988 in the number of 'fresh fish' purse seine vessels, making shorter trips of 7 to 12 days at sea, a general increase in vessel engine power (ranging from 250 - 360 Hp for the largest, new vessels of 100 - 130 grt), the growth in size of the mixed fresh/salt fish purse seiners as port facilities (water depth, length of unloading wharf, size of auction area, etc) improve. Technical innovations and adoption have also become more important, with the widespread use of radio, an increasing emphasis on the use of more powerful electric lights and generators, the introduction of halogen lights, the decreasing reliance on *total numbers* of rumpon for fishing, the increasing use of polyurethane for improved fish hold insulation in place of polystyrene, etc.

## 4. VESSEL OPERATING PATTERN

### *4.1 Large purse seiner*

#### 4.1.1 Preparing for Departure

A large purse seiner normally spends *two days* to load fuel, water, ice, salt, rumpon, food. One of these two days is set aside to take ice onboard. Fifty tonnes of ice represents 1,000 50 kg blocks, each of which is, in part, man-handled into the vessel's holds. Time spent preparing for departure ranges from 1 - 2 days in the peak season, to 2 - 5 days in the low season. Total port turnaround times, after waiting-to-unload and unloading the catch which can take between 2 - 5 days, is normally less than 7 days.

### 4.1.2 Selecting fishing ground

Selection of the target fishing ground commences before the vessel leaves port and is largely based upon information received by radio from vessels of the same company (or, on the 'open waveband' radios, from other vessels) which are still at sea fishing. In general, though, the seasonal distribution of small pelagic fish in the Java Sea is nowadays well known, so the target fishing ground or grounds for a particular period will normally be the same from year to year. During the journey, regular updates of success on different fishing grounds is received, particular attention being paid to the good fishing grounds, as the location of these within a general area may change over a short period.

### 4.1.3 Outward Journey

The vessel normally sets off on a rising tide, and at night. Typically, fishing grounds are 1.5 - 4 or 5 days journey time for these vessels, which have speeds of 6 - 7.5 knots (laden). Navigation is by compass bearing and time, making use of the many island groups and peaks for waypoints. Normally, no chart is used. The Nakhoda (captain) and boswain remember the course bearings to the different grounds. Indeed, less than half the vessels appear to carry charts with them. None use position fixing equipment such as radar or Global Satellite Positioning (GSP), the other feasible options. Almost all vessels today have 'open band' Single Side Band (SSB) (mostly ICOM) radio for communication between vessels and with home port/company. Although not a legal requirement for vessels officially registered as below 100 grt (which basically covers over 90 percent of the present fleet), the use of radio has been officially encouraged as an important safety feature.

### 4.1.4 Locating good fishing grounds

Once the vessel arrives at the fishing ground, she will normally use rumpon of vessels from the same company for setting upon the first night. Alternatively, she may use rumpon she placed on the previous trip. If the area is good, she will place about 5 rumpon of her own the next morning. A number of features are considered in setting the rumpon. Water depth of between 40-80 m, ideally between 50-65 m is chosen. Water colour is also used. Areas with turbid or murky water are avoided as they have low water transparency for light fishing and are not good fishing grounds ; areas of clear, transparent water are chosen, where the rumpon show a good fish presence. The presence of fish schools in the early morning and mid to late afternoon is another indicator. The presence of small pelagic fish is thought to be related to different water masses which move into and out of an area seasonally. But within a given water mass, current streams and particularly their interfaces are good indicators. Areas of upwelling, close to islands, underwater features, and especially near the edge of the continental slope are often favourable.

### 4.1.5 Fishing Operation

The fishing operation has been described recently (Wijopriono et al, 1991 ; Dremiere and George, 1991 ; and Temple, 1992)

The 'fishing operation' starts in the afternoon by checking individual rumpon, using a handline with about 12 small, unbaited, hooks (*brandil*). From those which indicate a good school of fish near the surface, one or two are chosen for setting upon that night. New rumpon will normally have a school of fish after 3-4 days of setting out. Sometimes, if a good fishing ground is found, newly set rumpon can be used immediately (the same night) because fish are already schooling nearby.

After checking wind and current direction, the vessel manoeuvers into position, and drops its anchor, drifting back to within 10-20 m of the rumpon, normally positioned either to starboard or to stern of the vessel. (The actual position changes over the tidal cycle). A line is normally attached to the rumpon to 'hold' the vessels position near that of the rumpon.

The electric lamps are switched on towards nightfall (at sunset). The spotlights are directed to the area of the rumpon, the objective being

(i) to concentrate the fish already schooling around the rumpon into a tight group, and to bring them near to the surface, and

(ii) to attract other fish, passing in the current within visual distance of the vessel during the next several - to ten -hours, to the vessel's lights.

Normally only one set is made a night, and this is carried out in the early morning, commencing at between 03.30-04.30 h., to allow the maximum time for light fishing. But sometimes two sets and, occasionally, three sets per night may be made, each on a different rumpon, especially if the fishing ground is poor or over the full moon period when catches can be more erratic. One strategy here is to fish over deeper water to help offset the high background illumination of the moon. If two sets are made, the first set is normally commenced between 20.00 - 22.30 h. for the large purse seiner, with the second set still being made between 04.00-04.30 h (Wijopriono et al., 1991).

As no 'light vessel' is used, the purse seine vessel's lights must be switched off before the net is set. Also, the *rumpon*'s anchor must be lifted across the vessel before the purse rings are closed. Yet at the same time, as far as possible, the fish attracted to the light and *rumpon* should not be disturbed !

The procedure currently in use is as follows. Before the electric lights are switched off in turn, they are replaced using a floating raft holding a bank of kerosene lamps, attached to the *rumpon* by a line, and held in place by a swimmer. Next, the *rumpon*'s anchor line is lifted on deck. The anchor section of the line is untied. A stone used to weight the floating coconut leaf section is tied on, before this end of the line is returned to the water. The *rumpon*'s bamboo float is now held in position by two swimmers wearing inflated rubber inner tubes, with the float-mounted kerosene fishing lamps attached. The vessel moves off and manoeuvres into position, with the '*juruarus*' (literally, current specialist) in the water signaling updates to the skipper on the position, and if moving off, the direction the school of fish is swimming in. Only then is the net set.

Setting the net depends upon its size, and the vessel's maximum speed ; for one large purse seiners it took on average just under 4 minutes, while for a mini purse seiner two minutes was sufficient. Next, the rumpon and floating lamps are pulled to the side of the net furthest away from the vessel as the purse rings are being closed by winching in the purse line. This is to avoid fish being attracted by any lights on the vessel and escaping through the open net under the vessel. After the bottom of the net is closed and the bunt formed (which took on average 13.5 minutes on the large purse seiner) the lamps and rumpon are brought to the side of the vessel and hauled on deck. The headrope and body of the net are hauled on deck by the large crew, totalling 35 - 40 men. Later, two derricks, one forward, one aft, are used to lift the headrope out of the water and towards the vessel's side, while a scoop net is attached to a third aft derrick for scooping up the catch in the net, before bringing it over the side, and tipping its contents into a fish hold.

Typically, catches range from 0 - 10 tonnes per set, though average catches are generally less than three tonnes per set.

### 4.1.6 Catch rate

To date, only a small amount of catch rate data per set, per night, per lunar day or quarter, per month and season has been collected for individual vessels, although considerably more effort in this area is planned (Figure 2). Currently, more extensive data is available for vessel catch rates/trip, where the number of days at sea, main fishing area and reported total number of sets is recorded, allowing the average catch per set and per night to be calculated (McElroy, 1992b).

To date, the most intensively studied trip data covers a 23 day trip made by KM Mustika Sakti, a large purse seiner, between mid-September to early October 1988, in the eastern part of the Java Sea in the peak fishing season (Wijopriono et al., 1991). The following data was calculated :

| No. of sets | No. of Zero Set | Total catch (tonnes | Average (catch/set) (ton/set) | No.of nights fishing | Average catch/night fishing (tonnes/night) |
|---|---|---|---|---|---|
| 23 | 1 | 26.96 | 1.17 | 19 | 1.42 |

Figure 3 presents a cumulative distribution of this small sample of data. The narrow range in both catch/set and catch/night is noteworthy, respectively 0 - 3.5 t/set and 0 - 3.5 t/night. Both the median (50 percentile) catch/set and catch/night was just 800 kgs, indicating the weighted distribution towards below average catches. However, too much should not be read into this particular distribution, as most fishing took place in the second and third lunar quarters (i.e. with the full moon period occurring in the middle of the trip). Nevertheless, it does indicate this period coincides with the period of lowest catches, even is the main fishing season.

*4.2 Mini purse seiner*

The main differences between the operating pattern of the mini purse seiner and the large purse seiner relate to their different product targets. While the large purse seiner generally will remain at sea until its fish holds are full (with most of the fish normally heavily salted, and only the last 3-5 fish holds retained for 'fresh' fish) or until supplies such as food and ice are nearly used up, the mini purse seiner aims to bring back fish of 'fresh' quality only. Its maximum trip length is fixed by the keeping characteristics of the small pelagic fish species in ice. This is put at between 9 to 12 days, after which they are suitable for the production of salted dried fish up to a maximum limit of 16 days (Clucas and Reilly, 1992). As fresh fish achieves a considerable price premium, depending upon its quality grade, trip lengths for mini purse seiners are normally restricted to a maximum of 10-12 days at sea, with trips of 7-10 days being normal.

For most of the year, the most productive fishing grounds in the Java Sea are too distant for the mini purse seine vessels to fish. With catches likely to be lower/set and more erratic, mini purse seine vessels attempt to overcome this shortfall by generally fishing two rumpon per night, with a maximum of three being fished. They also favour grounds which, on a seasonal basis, yield a higher proportion of the higher value small pelagics, such as mackerel, trevally and little eastern tuna (tongkol).

Interestingly, as a general rule the mini purse seiners have been slower to adopt useful innovations adopted quickly by the large purse seine fleet, such as electric lights to replace kerosene lamps and radio. This is at least in part a result of the difference in their ownership, they being owned typically by small family businesses, with limited capital resources of their own. Some of the large company groups operate a fleet comprising both fresh fish and mixed fresh/salt fish purse seiners. Their vessels tend to be better equipped.

## 5. CATCH PERFORMANCE

Catch performance is affected by both endogenous and exogenous factors.

*5.1 Exogenous or 'non-controllable' factors*

The main exogenous factors in this fishery are environmental, namely :

(i) weather

(ii) oceanographic factors

(iii) lunar cycl

### 5.1.1 Seasonal factors

Rainfall and salinity are probably the main environmental factors affecting seasonal fluctuations in small pelagic fish distribution and abundance in the Java Sea (refer Potier and Boely, 1990). These are affected in turn by the general movement of air currents across the Java Sea and of sea masses into and out of it, which has a definite seasonal pattern.

The peak fishing seasons in the Java Sea occurs between September, October and November in the eastern part, around Masalembo and Matasiri. A second, smaller peak normally occurs around June and July, off the north coast of Central Java and its offshore islands of Karimunjawa.

Between December and April in recent years, most large vessels have fished off south-east Kalimantan, around Lumu-lumu and Lari-larian. Between May and June, some vessels venture to the islands near Pejantan, west of Kalimantan, in the South China Sea. Generally, it is uneconomic for the smaller vessels to make these longer trips. Even for the larger vessels, the lower catch rates result in long trips with a larger portion of the catch being preserved in salt, generating lower incomes and higher costs for the vessels.

### 5.1.2 Lunar cycle

The lunar cycle affects the 'local' behaviour of small pelagic fish, with higher catches associated with the use of fishing lights during the two lunar quarters centred on the new moon, and lower catches during the two lunar quarters centred on the full moon, irrespective of the season.

## *5.2 Endogenous or 'controllable' factors*

The most important 'controllable' factors on the catch performance of the Java Sea purse seiners 'passive' method of night-fishing are the number and size (or fishing power) of Fish Aggregating Devices (FADs), namely *rumpon*, and fishing lights used.

During the 1980s, the method of purse seine fishing has shifted from relying on fixed physical fish aggregating devices (FADs), with kerosene lamps when fishing at night, to the increasing, even total, reliance on 'fishing with light', which, traditionally, probably accounted for the greater of the catch taken by most purse seiners. Today, in Indonesia, some vessels have dispensed with FADs in good fishing areas, relying solely on the power of attraction of high illumination artificial lights. Normally, though, both FADs and light attraction techniques are still used in combination.

### 5.2.1 Fish Aggregating Devices

These devices are designed to exploit the behaviour of small pelagic fish. The use of bamboo and coconut FADs as a method of fishing small pelagic fish dates back at least to the 19th century (Zerner, 1991).

Today, the *rumpon* FAD typically consists of a bamboo float and weighted anchor line, into the top part of which is interwoven branches of coconut leaves every 0.2 - 0.3 metres, forming a structure resembling an underwater 'christmas tree', somewhat bent by the current near the surface. Fish are attracted to such fixed structures in the sea. No-one is sure exactly why.

Between 10 - 20 *rumpon* are taken on board each trip, depending upon season, and whether the vessel is returning to a ground it recently fished. More rumpon are taken during poor fishing periods.

### 5.2.2 Light Fishing

But probably the most important innovation during this decade was the introduction of ever-more-powerful electric-powered lights to replace pressurized kerosene wick lamps, and, thereby, increase catch per night.

As one observer recently stated, "at night the area of sea around a vessel is lit up like a floodlit playing field, which from a distance, with vessels strung out in a line, resembles an illuminated section of highway out at sea !"

While a fishing lamp, which can be seen miles away in air, will be visible at a distance, at most, of a few tens of metres underwater because of the high extinction of light in water, nevertheless, brighter fishing lights have a greater fishing efficiency because of their increased radius, and hence volume, of attraction. In the sea, which is subject to currents, brighter lights translate into a greater volume of water 'sieved' for fish.

Fish are attracted to light. The effectiveness of an artificial light source is greater (1) the lower the background light, and (2) the brighter the artificial light source. Thus a given artificial light source is most effective attracting small pelagic fish at night during the new moon (dark) phase compared to the full moon phase (when background illumination is relatively high). Lift net (*bagan*) fishermen, using kerosene wick lamps at night, have exploited this characteristic behaviour of fish to catch anchovy and sardine for many years.

Electric lamps, apparently first introduced about 1983-84 by Pekalongan vessels, were adopted quickly as standard equipment. Virtually all the large purse seine vessels based at Pekalongan employed electric lights (standard or mercury lamps) by the end of 1987, although smaller purse seine vessels have been slower to adopt this technology.

The lamps are powered by an auxiliary diesel engine and generator. Since their introduction, both the size of generator and total power input of the lamps has continued to increase. Generators producing 10 Kw of power have been in use

on some vessels since 1986. Typically, by 1992, the total power input of the banks of electric lamps located port, starboard, and sometimes aft, of the wheelhouse and on the forward mast of the large purse seine vessels ranged from about 6.0 - 12.0 kilowatts, with individual lamps ranging between 250 - 1,500 watts. This compares to 200 - 300 watts for the standard Petromax kerosene lamp, amounting in total to about 1,500 watts per float with 6 units.

Also, there has been a shift, since 1990, towards using some 'Galaxy' halogen lamps, which are enclosed in sealed units, have better reflectors and a more focussed beam, with a higher power rating, and possibly emit a better frequency spectrum for attracting fish.

Normally four to six halogen lamps are fitted, located high up on both port and starboard sides of the forward part of the wheelhouse and forward mast, from where they can be directed to the area of the *rumpon* and passing shoals of fish. Indeed, by the start of 1992, in apparent recognition of their greater effectiveness, several of the newest vessels were fitted with 'all halogen' lamps. Some older vessels had also been converted.

Such 'all halogen' lamp purse seine vessels are understood to be common now in Malaysia and Philippines also.

### *5.3 Net and mesh size*

Based on a small sample of vessels, there does not appear to be a marked relationship between net size (length, depth) and catch performance. Net size is not considered a critical determinant of catch efficiency. Indeed, in most setting situations the nets are considered to be 'oversized'. Typical sizes are : large purse seiner 450 m x 100 m ; small purse seiner 350 m x 75 m.

Mesh size, which is 3/4" (19.05 mms) only in the two net pieces which make up the bunt and 1" (25.4 mm) in the main body and wings (Barus et al, 1991), is sufficiently large to allow many juvenile fish to escape.

### *5.4 Crew size and skill*

The number of crew on a purse seiner is determined by the skipper, but essentially depends upon the net size, as the function of most of the crew is as labour to haul the net. Crews range in size from 25 for a small purse seiner to 40 for a large purse seiner.

Fishing skill is notoriously difficult concept to assess objectively. Ultimately the skipper is responsible for selecting his crew. Certain skippers have 'good reputations', and their vessels tend consistently to land 'above average' catches from 'below average' trip lengths. As a result good skippers tend to complete a high number of trips per year and achieve high earnings.

It is not surprising, therefore, that the top skipper(s) within a company are given command of the new vessels ; it is often their ideas that are incorporated into the new vessels (more lights, halogen bulbs, larger generators, etc). Also, the owner is keen to see a good return on his latest investment.

### *5.5 Communications, fleet cooperation and coordination*

While of obvious relevance for the analysis of fishing effort, nevertheless it is difficult to evaluate the importance of improved radio communications on fleet catch performance. It undoubtedly reduces 'searching time', but to what extent is not known.

If the activities (location, catch last night) of a large part of the fleet covering a wide area are provided freely over the radio for all to hear, and this information is reasonably accurate, then we can presuppose that with two thirds of the fleet at sea at any time, the fleet follows the drift or migration of the small pelagic fish in a relatively informed and concentrated way. For example, as the stocks concentrate, the fleet has the capacity also to concentrate on them. And as the fish disperse, the fleet also will disperse over a wide area, searching out the next concentration to form or pass through the area.

The standard SSB radio in use, Icom 700 series, is an 'open channel' radio telephone system, with individual companies or groups allotted a single frequency, into which anyone else can tune if they wish (and they do). The radio is on continuously, and up-to-date information is, in principle, available to all.

Obviously, within the one company using the same radio frequency and having fixed call-up times, information on the location and performance of each vessel is available to all the others in the company at least twice a day.

An analysis of the pattern of fishing of one company with eight large vessels active over the course of one year did not show a marked difference to the distribution of the general fleet. However, there was a tendency to have a minimum of two company vessels operating on the same fishing ground at any one time. However, the vessels did not show a strong pairing or teaming up from one trip to the next. The best fished alongside the worst and on one trip and with the mediocre on the next. It was noted that when the general fleet was spread out between several fishing grounds, the company vessels were also. Further, some would switch grounds, from ground A to B, then back to A again on successive trips, while others would spend their three trips over the same period on the same gounds. While a small company has the ability to coordinate its fleet's activities with information generated internally, it would appear in general to benefit more by 'cooperating' with the larger group of non-company vessels in determining the best grounds to fish at any point in time.

## 6. DISCUSSION

The paper is concerned primarily with determining the technical and operating characteristics of the Java Sea purse seine fishing system. In other words, the factors affecting catch per trip and those which underlie vessel income and cost. It is necessary to understand these well before undertaking an economic analysis.

The essential parameters are catch/trip and earnings/trip. Surprisingly, the two often show little obvious relation-the same level of earnings being achieved for widely differing catches. The difference in value is attributable largely to

(i) differing species composition of the landings, and

(ii) differing fish quality, generally the latter being the more important. (Obviously, other factors, such as total fish landings that day and where the fish is landed, the fasting month, etc play an important part too).

This analysis has proved necessary because little reliable published information exists on the characteristics of the current fleet of Java Sea purse seine vessels and their fishing technology, their method of fishing, their operating pattern, factors affecting catch performance, etc, at a level of detail sufficient for operational analysis. In other words, all the factors which determine production cost and income. The European Community funded 'Java Sea Pelagic Fishery Assessment Project' clearly appreciates the value of this information, as much of the relevant information is recorded on a routine basis and efforts are being made to obtain other necessary data, e.g. trip log book data using independent observers onboard.

Nevertheless, it does appear that the essential point about this fishery has been largely overlooked in the literature to date.

The Java Sea fishery for small pelagics, as elsewhere in SE Asia, is essentially a *'light fishery'*, and this light fishery makes use of the most effective means of catching fish using light, which is purse seining.

In principle, the fishing method relies upon the *visual attraction of small pelagic fish*, passing in the current, *to a fixed point* (actually a large number of fixed points) *in the sea*

(i) using *rumpon* , an anchored coconut leaf fish aggregating device or FAD, for daylight attraction and

(ii) artificial light from an anchored light vessel (purse seiner) for attraction in the dark (at night or at depth, if using underwater lamps).

Having attracted a passing 'school' (which may actually have been passing as dispersed fish), next the attractant must work to keep them there. A rumpon tends to work better in seawater when it has been colonized by filamentous algae and other micro-organisms, a process which takes several days and is called 'ageing'. These micro-organisms attract small (juvenile) fish which in turn attract larger fish. But the food available at the rumpon is insufficient on its own to sustain the fish (whether grazers or predators) for as long as they may stay at the rumpon (which can be several days). Other factors obviously play a part, too.

The second attractant, and generally more important for achieving good catches, is artificial light. Different animal species show different reactions to light. Ben Yami (1976) has characterized four behavioral patterns or behaviour 'types' for the dominant component small pelagic fish. But even within the same fish species, its reaction to light may change with age, prior to spawning, just after feeding, when its gut is full, etc.

Current strength (which changes on a seasonal basis, also its direction) and the impact on it of tidal ebb and flow (which is highest just after new moon/full moon and at the equinoxes) also play an important part in determining (a) the volume of water (and hence fish) passing the light beam and so 'filtered' by it and (b) the length of time the fish can swim against the current, and still stay in the light or at its edge.

The effectiveness of artificial light works best in the dark. (Also important for the transmission of light through water is its transparency : the water should have a high transparency). As noted above, this can be at depth or at night. The main efficiency factor is the level of background illumination. Low background illumination boosts the range over which an artificial light source attracts ; high background illumination reduces its effective range dramatically. Hence, the phase of the moon and the time it rises and sets during the night affect fishing success and, hence, the timing of fishing trips, and fishing strategy once on the fishing ground.

For example, most fishing vessels fish one rumpon per night, setting the net about 04.00 h, some ten hours after they start light fishing. But during the full moon phase, they will make a first set (if possible) before the moon rises, and a second, at a different rumpon site, also about 04.00 h (i.e before first light). The longer the lights are left on before setting, the higher the potential catch per night. Fishing two rumpons per night cuts down the light fishing time and, generally, the catch.

This demonstrates that it is the volume of water fished on a dark night that has the greater impact on the catch size, rather than the initial population 'resident' at the rumpon site.

Variations in other fishing technology factors, such as net size (length, depth, mesh size), hauling system, vessel size and speed, etc, are of marginal significance relative to the brightness of the vessel's lights used for fishing.

Vessel size (i.e. fish hold capacity) is important in determining the duration of a fishing trip. Carrier or freezer/carrier vessels have not been adopted up to now.

Maximum vessel speed is important in determining journey times for getting to and from the fishing ground. It is important in determining the time it takes to set the net, although this is considered generally of marginal importance in determining catch size. Of much more importance here is the speed at which the purse line and rings are brought onboard after setting the net, thereby cutting off the main escape route for the fish inside the net. While this operation is being carried out, the escape route is under the vessel. Hence, between the time the vessel has switched off its fishing lights until the purse line is onboard it is important that no vessel lights are used to attract the fish away from the Petromax lights, which if the current allows are normally held by line near the far end of the net from the vessel during this operation.

These are some of the main 'endogenous' or controllable factors affecting catch performance in this fishery.

### *6.1 Price formation at the auction*

The main factors affecting price formation at the auction are briefly reviewed here. This system has two components ; the supply of fish and factors which affect this ; and the demand for fish and factors which affect that. The present concern is with factors affecting price formation at the auction.

In principle, there are two types of purse seine fishing vessel supplying the market, (i) fresh fish only and (ii) mixed fresh and wet salted fish (*gereh*). The price of fresh fish is determined by quality and species. There are three quality grades in current use for fresh fish. These grades are based on physical appearance.

The price achieved for first grade fish is typically between 2-3 times the price of third grade. Second grade lies between the two. Apart from appearance, these price differences reflect remaining shelf-life of the fish (if it is to be sold as fresh fish). Comparing first and second grade fish at Pekalongan auction, first grade fish, which achieves the highest price, is dispatched to Jakarta and a few other major cities in Java.

Meanwhile, second grade fish marketed fresh is sold within the local area and province. (However, most is processed into 'pindang', a light to heavily salted product before sale). This fish distribution pattern reflects income distribution and the concentration of high earners within a few major cities. The 'ability to pay' a higher price and the price competitiveness of small pelagic fish compared to other 'white' fish, meat and chicken ensures a good demand. Only first quality fish (and shrimp) is on display in supermarket fresh fish counters in Jakarta (and, presumably, Java's other major cities).

### *6.2 Future Technical Innovations*

The following list of technical innovations are likely to be economically justified and so are likely to be introduced before the end of this decade.

Navigation Aids. GPS, and possibly radar, for steering a straight course, avoiding obstructions and relocating FADs.

Improved light fishing technology and techniques, such as using underwater lamps from a series of small 'light vessels' which the purse seiner sets on in the course of the night. This would vastly increase fishing effort.

Improved onboard insulation which retains its water tightness and hence its insulation properties better.

Freezer and refrigerated carrier vessels serving groups of purse seiners for improving fish quality and for supplying the fresh fish market and, possibly, canneries in times of low supplies

## 7. SUMMARY AND CONCLUSIONS

The two most significant developments of the last decade in the Java Sea purse seine fishery for small pelagics were :

i) locating new, more productive, distant fishing grounds which allow a vessel to be operated year-round ; and

ii) the use of more powerful electric lights to attract and concentrate small pelagic fish at night near the sea surface around a vessel, which improves the catch rate per night, even during the full moon period.

The Java Sea purse seine fishery has seen steady step-by-step technical advances introduced in recent years, the most significant of which has been the introduction of powerful electric fishing lamps, followed by the use of radio telephones which allow up-to-the-minute fishing conditions in this fishery to be transmitted around the fleet on its open airways.

However, the impact of these significant increases in fishing power are masked out by the standard measure of 'days spent at sea' used in this fishery to measure nominal changes in fishing effort.

The major technological advances predicted over the next decade will concentrate on improvements in light fishing and fish quality.

## REFERENCES

**Atmadja S.B. and B. Sadhotomo** (1985). Operational aspects of the purse seine fisheries in the Java Sea (Aspek operasional perikanan pukat cincin di Laut Jawa). *Journal of Marine Fisheries Research*, No **32** : 65-71. (In Indonesian).

**Bailey C., A. Dwiponggo and F. Marahudin** (1987). 'Indonesian marine capture fisheries'. *ICLARM Studies and Reviews* 10, International Centre for Living Aquatic Marine Resources Management, Manila, Philippines, 196 p.

**Bandjono et al.** (1989). 'Field study report on NFP Pekalongan, Project Monitoring Evaluation/Appraisal', *Directorate General of Fisheries - Institute of Management, Faculty of Economics,* University of Indonesia, Jakarta.

**Bell F.** (1978). 'Food from the sea : the economics and politics of ocean fisheries'. Westview Press, Boulder, Colorado.

**Clucas I.J. and P.J.A. Reilly** (1992). 'Small pelagics post harvest studies'. Technical Report 04/92. ALA/INS/17. Rep. Mission, April 1992.

**Cunningham S., M.R. Dunn and D.Whitmarch** (1985). 'Fisheries Economics : an introduction ; Mansell Publishing Ltd., London, St Martine Press, New York.

**Dremiere P.Y. and J.P. George** (1991). Fish Technology (Technologie des peches). IFREMER, ALA/INS/87/17, Rep. Mission, July 1991, 36 p., 5 Table., 40 Fig. (Original in French).

**McElroy J.K.** (1991a). 'The Java Sea purse seine fishery - a modern day 'tragedy of the commons' ?' *Marine Policy* , Vol **15** No. 4, July 1991 : 255-271.

**McElroy J.K.** (1991b). 'Managing the Indonesian small pelagic fishery', *Marine Policy*, Vol **15**, No 6, November 1991 : 462-464.

**McElroy J.K., J.Rogers and C.Temple** (1991). 'Proposed project programme incorporating report of field visit to project area' *Landell Mills Ltd* , First Technical Report 01/91. ALA/INS/87/17 Rep.Mission, July 1991, 42 p., 13 Tabl., 8 Fig., 3 Ann.

**McElroy J.K.** (1992a). 'Java Sea purse seine fishery : resources, production methods and product markets - a case study'. In : *Pelagic Fish : the resource and its exploitation'.*

**Eds. Burt J.R., R.Hardy and K.J. Whittle** (1992). *Fishing News Books,* Blackwell Scientific Publications Ltd, Oxford, February 1992, pp 336-357.

**McElroy J.K.** (1992b). 'Purse seine vessel economic performance' *Landell Mills Ltd,* Technical Report, 06/92. ALA/INS/87/17 Rep.Mission, May 1992.

**Nurhakim S., M.S. Banon, Potier and T. Boely** (1987). Study on the big purse seiners fishery in the Java Sea. III. Evolution and structure of the Javanese big purse seiners fleet. *Journal of Marine Fisheries Research*, No **40**, 1987 : 65-76.

**Potier M. and T. Boely** (1990). Influence de parametres de I' environnement sur la peche a la senne tournante et coulissante en mer de Java. *Aquat Living Resources*, **3** : 193-205.

**Potier M., T. Boely and S. Nurhakim** (1990). Study on the big purse seiners fishery in the Java Sea. V. Estimation of the effort. *Journal of Marine Fisheries Research*, No **54**, 1990 : 79-95.

**Potier M. and Suherman** (1991). Main results of the previous studies of the small pelagic fishery in the Java Sea. Seminar on 'The pelagic fishery assessment in the Java Sea', ALA/INS/87/17, Jakarta, 21 March 1991.

**Potier M. and T. Boely** (1991). Purse seiner technology.Seminar on 'The pelagic fishery assessment in the Java Sea', ALA/INS/87/17, Jakarta, 21 March 1991.

**RMC/PMO** (1987). 'Feasibility study on NFP Pekalongan', Fisheries Infrastructure Sector Project, Directorate of Infrastructure, DGF, Jakarta, May 1987.

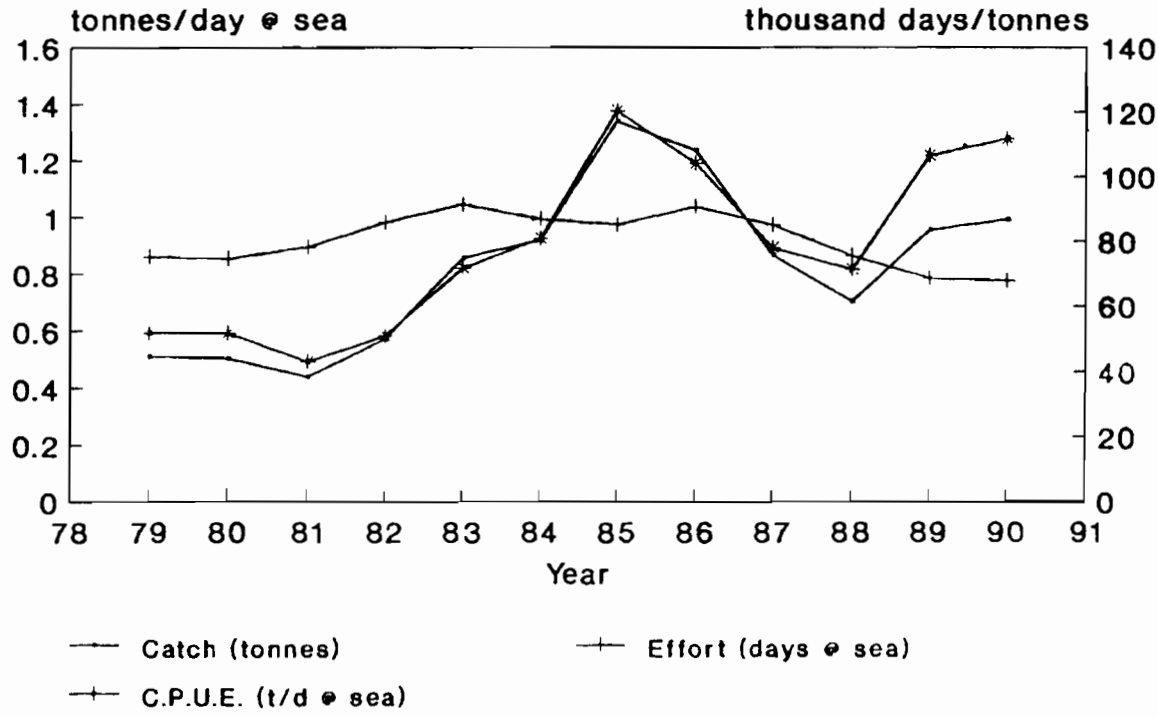
**Temple C.R.** (1992). Purse seiner performance and capacity trials. Technical Report 05/92. ALA/INS/17. Rep. Mission, April 1992.

**Wijopriono M.L., Linting and Mahiswara** (1991). 'Observations on several fishing aspects of big purse seiners in the Java Sea' (Pengamatan terhadap beberapa aspek penangkapan dengan pukat cincin besar di laut Jawa), *Journal of Marine Fisheries Research*, No **61**, 1991 : 13-22. (In Indonesian).

**Yami B.** (1976). Fishing with light. Fishing News Books Ltd.

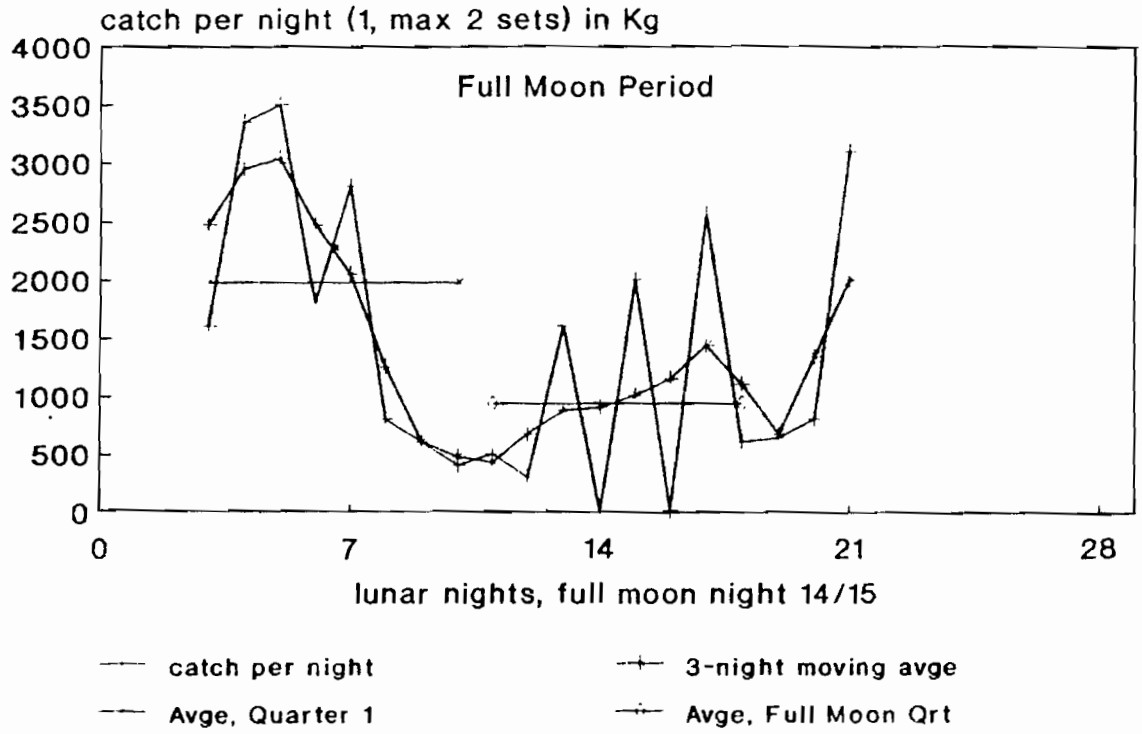
**Zerner C.** (1991). 'Sharing the catch in Mandar : changes in an Indonesian raft fishery (1970-1989)'. In eds. J.J. Poggie and R.B. Pollnac. *Small-scale fishery development : socio-cultural perspectives'*, International Centre for Marine Resource Development, The University of Rhode Island, Kingston, R.I., USA, pp 42-70.

FIG. 1.
DEVELOPMENT OF CATCH (TONNES), NOMINAL FISHING EFFORT (TOTAL DAYS SPENT AT SEA), AND CATCH PER UNIT EFFORT (C.P.U.E.) FOR THE JAVA SEA PURSE SEINER FLEET, 1979 - 1990.



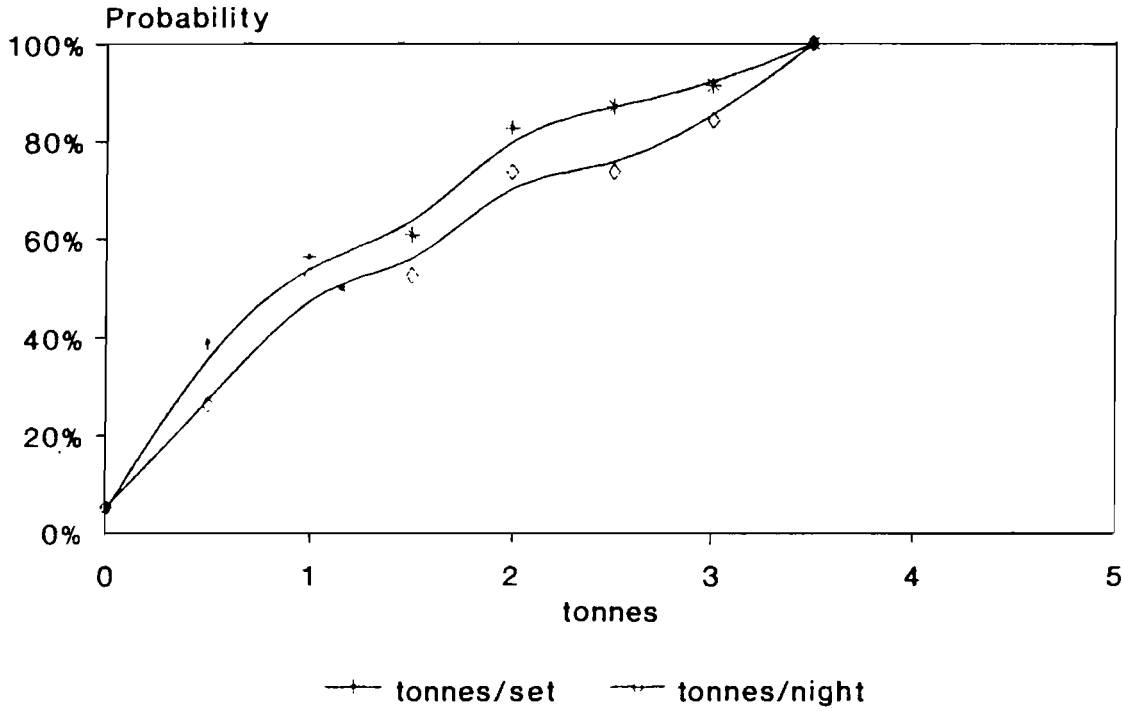

Sources: Project Reports

FIG. 2.
RELATIONSHIP BETWEEN PURSE SEINE CATCH LIGHT FISHING AND LUNAR PERIOD.




Source. based on Wijopriono et al, 1991
note x-axis shows nights after new moon

FIG. 3.
CUMULATIVE FREQUENCY DISTRIBUTION OF CATCH SIZE FOR ONE JAVA SEA PURSE SEINER LIGHT FISHING IN THE MAIN FISHING SEASON (PERIOD COVERED 19 DAYS OF THE LUNAR CYCLE ONLY).




Source: data from Wijopriono, 1991.
Note : small samples sets=23, nights=19

# Fishing Enterprise Management
# by
# S. Cunningham

Une grande partie de la littérature concernant la gestion des pêches porte sur les questions principales de détermination de tailles optimales de stocks et de flottilles. Toutefois il y a une prise de conscience croissante du fait que pour résoudre ces questions d'ajustement, les autorités responsables de la gestion ne doivent pas considérer seulement leurs propres tactiques, stratégies et objectifs mais également ceux des pêcheurs. Autrement il faudra faire face à un nombre important de problèmes. En premier lieu il est difficile de prévoir la réaction des pêcheurs aux différentes mesures de gestion et en conséquence il est difficile d'assurer que les bonnes mesures sont engagées. En second lieu, les stratégies de gestion qui s'opposent à des stratégies des pêcheurs peuvent avoir des effets inattendus et rencontrent aisément des résistances.

Les textes présentés dans cette session se focalisent sur ces questions. La plupart traitent des pêcheurs eux-mêmes, alors que certains considèrent les questions qui se posent au niveau industriel, et d'autres enfin discutent des problèmes qui apparaissent face aux autorités de gestion.

McElroy et Wijopriono abordent un des effets importants au niveau des pêcheurs : l'impact de l'innovation sur les performances en pêche dans le cas des pêcheries pélagiques de la mer de Java. Comme ailleurs dans le monde l'innovation technologique augmente l'efficacité d'un niveau donné ou d'une définition donnée de « l'effort de pêche » – dans ce cas, les jours de mer. Dans les pêcheries de la mer de Java, les changements dans la distribution spatiale de l'effort (exploitation de zone plus distante des côtes) et l'introduction de puissances d'éclairage plus grandes (comme technique d'attraction des poissons) sont les principaux facteurs qui agissent sur F pour un niveau donné de f. Squires considère le même problème sous l'angle de la mesure de la productivité pour les pêcheries chalutières côtières du Pacifique. Il trouve que les estimations d'amélioration de productivité sont biaisées sauf si la capacité d'utilisation, l'abondance des ressources et le coefficient de capturabilité sont pris en compte. L'estimation exacte de l'accroissement de la

Much of the literature concerned with fisheries management concentrates on the key issues of identifying optimal stock and fleet sizes. There is increasing recognition however that in resolving these issues, the management authority must consider not only its own tactics, strategy and objectives but also those of the fishermen. Otherwise, a number of problems will have to be faced. First, it may be difficult to predict the reaction of fishermen to different management measures and hence difficult to ensure that the correct measures are implemented. Second, management strategies that cut across fishermen's strategies may have unintended consequences and are likely to meet resistance.

The papers presented in this session concentrate on these issues. Most focus on the fishermen themselves, although some consider industry-level issues, whilst others discuss the problems facing the management authority.

McElroy and Wijopriono discuss one important effect at the fisherman level: the impact of innovation on fishing performance in the case of Java Sea Pelagics. As elsewhere around the world, technological innovation increases the effectiveness of a given level, or a given definition, of "fishing effort" – in this cas, days spent at sea. In the Java Sea Fishery, changes in the spatial distribution of effort (the exploitation of more distant grounds) and the introduction of more powerful lights (as fish attractors) are the main factors increasing F for a given level of f. Squires considers the same problem from the point of view of productivity measurement in the Pacific Coast trawl fishery. He finds that estimates of productivity improvement are biased unless capacity utilisation, resource abundance and the catchability coefficient are taken into account. Accurate estimation of productivity growth is especially important in licence limitation programmes that limit the number of vessels.

A number of papers discuss the behaviour of fishermen and the way in which this may impinge upon management. Rey applies the concept of hysteresis to fishermen behaviour, arguing that investments do not depend simply on the state of fish stocks and the exploitation rate of

productivité est particulièrement importante dans des programmes de limitation par licence qui tendent à contraindre uniquement le nombre de bateaux.

Certains textes évoquent le comportement des pêcheurs et les voies par lesquelles ils peuvent se heurter aux systèmes de gestion. Rey applique le concept d'hysteresis aux comportements des pêcheurs montrant en quoi l'investissement ne dépend pas seulement de l'état des ressources et du taux d'exploitation de celles-ci mais également d'autres variables comportementales. Hillis et Whelan considèrent le rôle d'escompte dans la réhabilitation de stocks surexploités. Au travers d'une enquête, ils ont tenté d'approcher le taux d'escompte utilisé ou implicite entrant dans le processus de décision des pêcheurs. Ils constatent ainsi qu'un taux très élevé semble le plus courant. En conséquence directe de cela, les programmes de réhabilitation de stocks qui se fondent sur des pertes de court terme en retour de gains de long terme ont peu de chance de satisfaire les pêcheurs. Résultant de cela, les autorités de gestion auront à mettre en place des méthodes qui garantissent que le pêcheur pourra être amené à accepter de tels programmes. Roy *et al.* prennent en compte quant à eux l'impact d'une prime de chômage et la durée de la saison de pêche dans les pêcheries du Newfoundland. Ils développent un modèle de revenu des pêcheurs et considèrent alors l'effet de l'introduction d'une assurance chômage. Il n'y pas de relation simple entre les deux ; les résultats dépendent du nombre de semaines travaillées avant même l'introduction des bénéfices et des bénéfices particuliers de la régulation (nombre de semaines à prendre en compte). La conclusion principale est que rien ne peut être déduit de l'utilisation de la moyenne du nombre de semaines travaillées mais que l'assurance chômage est propice à réduire la variance autour de la moyenne.

D'autres textes traitent des stratégies des pêcheurs. Campbell *et al.* s'intéressent au thon comme cas d'étude de stratégies de gestion multi-espèces. Ils trouvent que l'aptitude du pêcheur à cibler différentes espèces est une clef caractéristique des pêches. S'il est impossible de cibler sur une espèce, alors le contrôle de n'importe quelle espèce peut causer une chute inacceptable des captures associées à cette espèce. Des conclusions identiques sont obtenues par Hanna, et Lantz *et al.* Hanna considère le comportement des pêcheurs en terme de portfolio présentant une sélection de stratégies de pêche. Elle montre que les pêcheurs privilégient volontairement une stratégie pluri-espèce pour réduire le risque. Le résultat est que la gestion d'un stock unique est généralement inappropriée puisqu'elle ne prendra pas en compte les effets induits sur les stocks liés. En fait l'unité de gestion a besoin d'être définie en intégrant les comportements de ciblage. Lantz *et al.* analysent également la ressource, mais aussi les variables comportementales. Hillis et Whelan considèrent le rôle d'escompte dans la réhabilitation de stocks surexploités. Au travers d'une enquête, ils ont tenté d'approcher le taux d'escompte utilisé ou implicite entrant dans le processus de décision des pêcheurs. Ils constatent ainsi qu'un taux très élevé semble le plus courant. En conséquence directe de cela, les programmes de réhabilitation de stocks qui se fondent sur des pertes de court terme en retour de gains de long terme ont peu de chance de satisfaire les pêcheurs. Résultant de cela, les autorités de gestion auront à mettre en place des méthodes qui garantissent que le pêcheur pourra être amené à accepter de tels programmes. Roy *et al.* prennent en compte quant à eux l'impact d'une prime de chômage et la durée de la saison de pêche dans les pêcheries du Newfoundland. Ils développent un modèle de revenu des pêcheurs et considèrent alors l'effet de l'introduction d'une assurance chômage. Il n'y pas de relation simple entre les deux ; les résultats dépendent du nombre de semaines travaillées avant même l'introduction des bénéfices et des bénéfices particuliers de la régulation (nombre de semaines à prendre en compte). La conclusion principale est que rien ne peut être déduit de l'utilisation de la moyenne du nombre de semaines travaillées mais que l'assurance chômage est propice à réduire la variance autour de la moyenne.

A number of papers looked at fishing strategy. Campbell *et al.* discuss tuna as a case study of multi-species management. They find that the ability of fishermen to target different species is a key feature of the fishery. If targeting is not possible, then the control of any one species may cause unacceptable declines in catches of associated species. Similar conclusions are reached by Hanna and Lantz *et al.* Hanna considers fishermen behaviour in terms of portfolio selection of fishing strategies. She argues that fishermen deliberately target a diverse range of species as a way of reducing risk. As a results single stock management is generally inappropriate since it will have unintended side effects. Instead management units need to be defined taking account of targeting behaviour. Lantz *et al.* also look at fishing strategies. They discuss the concept of the "metier": a combination of area, species and gear. They show that although a fleet catches many species and uses many gears, it is possible to identify metiers based upon 1 or 2 gears and at most 4 species. They conclude that management needs to consider the impact of regulation on sub-sectors of the fleet as well as the inter-relationships between different sub-sectors.

These papers indicate the need for the fishery management authorities to take into consideration at least the following issues when developing management plans:

(i) the relationship between fishing mortality and fishing effort;

(ii) the response of fishermen to behaviourial and institutional variables;

ment les stratégies de pêche. Ils mettent en avant le concept de « métier » : combinaison d'une zone d'activité, d'espèces cibles, d'engins utilisés pour leur capture. Ils montrent bien qu'alors qu'une flottille de pêche capture plusieurs espèces et emploie plusieurs types d'engins, il est possible d'identifier des « métiers » en fonction d'un ou deux engins et au plus quatre espèces. Ils en concluent que pour la gestion, il convient de considérer l'impact de la régulation sur les autres aires d'actions de ces flottilles ainsi que les interactions entre les différentes sous zones.

Ces textes mettent en avant le besoin pour les autorités de gestion de prendre en compte pour le développement de plans de gestion au minimum les questions suivantes :

(i) les relations entre la mortalité par pêche et l'effort de pêche ;

(ii) la réponse des pêcheurs aux variables comportementales et institutionnelles ;

(iii) les stratégies d'exploitation des ressources qui ont été mises en œuvre par les pêcheurs.

Dans tous les cas il est nécessaire de surveiller la façon dont les variables changent au fil du temps ainsi que le chemin par lequel les pêcheurs réagissent. Le fait de ne pas prendre en compte ces variables conduit communément à une stratégie de gestion défectueuse avec des effets imprévisibles et pervers.

Au niveau industriel, Wilson *et al.* développent un modèle bioéconomique de réensemencement des stocks de coquilles Saint-Jacques au Québec. Ils mettent en exergue la nécessité d'arrangements institutionnels appropriés si de telles initiatives veulent être couronnées de succès. Dreyer et Vassdal proposent un modèle prédictif portant sur la probabilité de faillite par anticipation jusqu'à cinq ans. Des modèles similaires sont développés pour être appliqués aux entreprises norvégiennes de transformation de poissons.

Deux textes portent sur les stratégies de gestion au niveau même des institutions responsables. Mickwitz et Hilden analysent l'emploi d'incitations dans le cadre de la théorie des jeux. Ils démontrent que quelques catégories d'incitations peuvent encourager les collusions entre pêcheurs qui n'auraient pu exister sans cela. Avec Whitmarsh nous nous sommes intéressés à la question de savoir si oui ou non un Etat côtier devrait développer sa propre flottille ou compter plutôt sur des flottilles de longue distance. On constate que plusieurs pays ont privilégié trop vite la première option sans considérer pleinement l'impact que pouvait avoir une telle politique surtout sur la rente générée par les ressources et l'échange au niveau des services attachés à l'activité de pêche.

(iii) the resource exploitation strategies that have been developed by the fishermen.

In all cases there is a need to monitor the way in which variables change over time and the way in which the fishermen respond. Failure to consider these variables is likely to lead to a flawed management strategy with unpredictable and perverse effects.

At the industry level, Wilson *et al.* develop a bioeconomic model of stock enhancement of giant scallop in Quebec. They stress the need for appropriate institutional arrangements if such activities are to be successful. Dreyer and Vassdal develop models to predict the likelihood of bankruptcy up to 5 years before the event. Reliable models are developed which are applied to the Norwegian fish processing industry.

Two papers consider strategic issues at the level of the management authority itself. Mickwitz and Hilden analyze the use of subsidies in a game theoretic context. They demonstrate that some types of subsidy may encourage collusion between fishermen that would not other wise have existed. Cunningham and Whitmarsh consider the issue of whether a coastal state should develop its own fleet or rely upon distant water fleets. It is argued that many nations have opted too quickly for the first alternative without fully considering the impact of such a policy especially on resource rents and trade in fishing services.

# Coastal State Fisheries Management : Fleet Development Versus Trade in Fisheries Services

**Stephen Cunningham and David Whitmarsh**

Centre for the Economics and Management of Aquatic Resources, University of Portsmouth, Locksway Road, Portsmouth, PO4 8JF, U.K.

ABSTRACT

*The problem of deciding what proportion of available catches should be allocated to Distant Water fishing fleets is one which continues to pre-occupy many Coastal States. The paper suggests that much of the debate surrounding this issue is misplaced, since it draws attention away from the more important question of how exploitation rights should be allocated in order to ensure that resource rents are maximised. The paper highlights the drawbacks inherent in the essentially 'administrative' approach to fisheries management adopted by most Coastal States, and suggests that a market approach would help avoid many of the distortions and contradictions which typically arise.*

## 1. INTRODUCTION

Following the extension of fisheries limits worldwide, many Coastal States (CSs) face the difficult problem of deciding what, if any, proportion of available catches should be allocated to Distant Water (DW) fleets. A fair amount of economic research has been directed towards resolving this problem, and this Conference Paper is intended to be a contribution to that debate. Our aim is to explore the extent to which the catch allocation problem arises due to management failure following extended fisheries jurisdiction (EFJ) rather than due to any inherent feature of EFJ itself.

The paper is organised as follows. In the first section we assess the effects of EFJ and examine how far it has generated benefits to CSs. We next consider the problems of CS fisheries management, focussing on the bioeconomic aspects of attempting to regulate a fishery which is exploited jointly by a domestic and a foreign fishing fleet. This leads onto a discussion of the distortions and conflicts which may arise when a CS loses sight of what is arguably the principal source of benefit from the fisheries, namely the rent which the natural resource is capable of generating. It is suggested that because CSs have tended to take decisions that favour their domestic fleet, some quite complicated administrative decisions are required. The nature of such decisions is outlined and their impact on key variables such as the trade in services, employment and income is discussed.

## 2. THE AFTERMATH OF EXTENDED FISHERIES JURSIDICTION

### *2.1 Assessing the effects of EFJ*

It is now 15 years since the majority of the World's coastal states declared EFJ, and a clearer picture is beginning to emerge of the impact which this has had on World fisheries. In some areas of economic activity, such as trade in fisheries products, the effects of EFJ became apparent within a fairly short time. For example, Copes (1982) highlighted the increasing internationalisation of fisheries markets and showed that between 1976 and 1979 the World volume of fish exports increased by over 22 % compared with a much more modest increase in global catch of only 2 % over the same period. Other effects have taken longer to identify, and this in part is due to the difficulty in isolating the specific influences of EFJ from other factors. An illustration of this is given by Garrod (1990) who argues that EFJ has had a destabilising effect on international markets, and this has been reflected in greater year-to-year volatility in fishery product prices since 1977.

The one area in which it has been especially difficult to establish the effects of EFJ concerns the net economic gains to different countries, and such evidence as we have is far from conclusive. Pontecorvo (1988) selects 9 of the leading fishing nations and compares their annual catches in the period 1970-72 with those in 1983-5. The change in the capitalised value of gross revenue is then used as an approximate indicator of the economic gains to the CS resulting from the annexation of what had formerly been 'marine commons.' With the exception of Japan and Peru, all countries selected were shown to have gained substantially from EFJ. A recent paper by Juda (1991) looks in more specific detail at the distribution of world marine fish catches since EFJ, and in particular the partition of catches between developed and less developed countries. The paper concludes that while developing CSs as a group have probably benefitted from EFJ in terms of increased catches, these have tended to be concentrated in a sub-set of states and that for many other developing coastal nations EFJ has not resulted in particularly large absolute increases in the volume of landings.

This begs the question of how economic gains to the CS ought appropriately to be measured. Juda's study focusses on national catches, but it is admitted that these may not be fully reflective of the benefits attributable to EFJ. While Juda makes no attempt to evaluate rents (associated with access fees, etc) he acknowledges that these "may be quite significant." (p.17). Evidence from other sources suggests that such rents may indeed be very important to a CS, which on crude indicators (e.g the weight of fish harvested by the domestic fleet) may not appear to have gained much from EFJ. In this paper we take it as axiomatic that economic rent is the *principal* source of benefit which may accrue to a CS who can be assumed to be the de facto owner of the marine resource. In the next section we briefly consider the way in which EFJ has created the opportunity for capturing resource rent and the reasons why in practice CSs have not always taken full advantage of such opportunities.

### *2.2 Coastal State benefits from EFJ*

As Queirolo and Johnston (1989) have pointed out, a CS which has declared EFJ enjoys two sources of increased production. On the one hand, expanded oceanic dominion increases the production possibilities open to it by virtue of its ownership of a valuable natural resource. On the other, the CS now has the opportunity to manage these resources more effectively and to deal with the open-access problem which had been a feature of the pre-EFJ era. Most economists would argue that a CS which takes advantage of both these opportunities will, in theory, enjoy higher real national income. This improvement has its counterpart in the rents which the natural resource should be capable of generating under the new regime and which will necessarily accrue to the CS as resource owner. It may well contended that a third source of potential gain to the CS stems from its ability to displace foreign effort from its newly created EFZ and to increase its share of whatever the total harvest might be. Such a benefit would, however, be at the expense of the DW fleet ; and, as many observers have pointed out, such a strategy may not be to the advantage of the CS in the long run. We return to this point later.

Though EFJ creates opportunities for resource rent capture by the CS, experience suggests that in practice many CSs fail to capitalise on such opportunities. Firstly, it may the case that a CS chooses to trade off rent for some other 'benefit'. This appears to have happened in Newfoundland, for example, where economic efficiency in resource management has deliberately been sacrificed in favour of employment creation within its fishing communities. Secondly, even in situations where the CS attempts to maximise economic benefits from its fish resources, this may not be achieved because of

weaknesses in the fisheries management regime itself. Robb (1984) estimates that in the early 1980s the Pacific Islands were receiving only about 2 % of the value of the resources in their fishing zones. This was attributable to a failure of compliance by foreign fleets, stemming in turn from an inability by CSs to exercise full control over their proprietory rights. Another kind of problem is illustrated by the EEC where, despite the declaration of a 200 m EEZ in 1977, the potential gains have been largely negated by the inability to restructure the fleet and to control over-capitalisation.

It is clear therefore that management is essential if a CS is to reap the full benefits of its newly acquired marine resources. Experience suggests, however, that this is far from easily achieved. In the next section we discuss some of the particular difficulties associated with managing a fishery which is exploited by both a domestic and foreign fleet.

## 3. MANAGEMENT PROBLEMS

### *3.1 Bioeconomic issues*

Figure 1 illustrates some of the bio-economic interdependencies. The CS management authority is assumed to wish to earn a certain level of rent from its EEZ, which can be a source of funds for use either outside the fisheries sector or in developing domestic fleet capacity. The fishery may be exploited either by domestic or foreign vessels, and we can anticipate that in any given time period the amount of effort from each will be dependent on profitability. This is unlikely to be the same for both fleets, however, if only because of differences in technical efficiency. If profitability should differ between the two fleets, this will have major implications for the development trajectory of the resource since what will tend to happen is that over time the more efficient vessels will drive out the less efficient. For the sake of argument let us suppose that the foreign fleet enjoys lower costs than the domestic fleet, and that they jointly exploit a fishery which is unregulated. The tendency will be for the fish stock to be reduced to a level at which the least cost vessels make only a normal profit. At this stock size, however, the domestic vessels will not be able to operate profitably and will exit from the fishery.

A less dramatic version of this scenario may occur in a situation where the CS adopts the 'surplus' principle proposed by the Draft Convention of UNCLOS III. Under this principle a CS is entitled to set a TAC for a fishery within its 200 mile EEZ, but is then expected to allow a DW fleet access to any fish which are surplus to its own domestic harvesting and processing needs. The fundamental flaw in this whole arrangement, as Garcia et al (1986) have pointed out, is that it is bioeconomically unrealistic. Unless each fleet is limited in the absolute amount it can remove from the jointly-exploited resource, stock depletion will occur and the less efficient of the two fleets - which we are assuming will be that of the CS - will gradually be expropriated from the fishery. Essentially what happens is that the harvesting capacity of the domestic fleet will become increasingly uncompetitive as stock depletion causes catch rates to fall and unit harvesting costs to rise. Where this uncompetitiveness results in a cutback in catching capacity and a drop in total CS catches, it implies that the amount that the DW state is permitted to catch automatically increases. Clearly, the 'surplus' principle may become the thin end of potentially very large wedge by which a foreign fleet gains entry into a coastal fishery. What is likely to happen, of course, is that the CS management authority will feel obliged to alter the terms of the access agreement or else introduce financial support measures for its domestic vessels.

For this reason a CS management authority may choose to employ a number of other regulatory instruments besides TACs and quotas. Of these, possibly the most important are royalties which may be levied on the quantity of fish landed. Differential royalty rates may be imposed, and indeed it is not uncommon for a CS to levy a low (or even negative) royalty rate on its indigenous fleet and a considerably higher one on foreign vessels. It is important to understand that, within the context of CS fisheries management, royalties serve two distinct but complementary functions. Firstly, they can be used to regulate the flow of effort to the fishery by altering the absolute and relative profitability of the two fleets. If we continue to assume that domestic vessels have the higher operating costs, the management may, if it chooses, attempt to offset this cost disadvantage by the imposition of lower royalty rate on the indigenous fleet. In this way royalties may be used as an instrument for curtailing the expansion of one fleet relative to another. The other purpose of imposing royalties is, of course, to act as a vehicle for capturing the rent from the resource. However, setting a royalty rate for each fleet which will maximise total rent is a particularly complicated task for the management authority. This

is because the harvests which generate the rents, and on which the royalties have to be paid, are themselves a function of past and present royalty rates. The information requirements involved in setting the optimum royalty rate are thus quite formidable.

### *3.2 Administrative versus market approaches to the management problem*

It is suggested therefore that a CS that is intent on maintaining some sort of balance between its domestic and foreign fleet capacity - and specifically where it is trying to support and develop the indigenous fleet in the face of competition from foreign vessels - faces a very difficult management task. The difficulty is compounded where an administrative rather than a market approach is being pursued. Quite complex decisions must be made by the Fisheries Ministry in relation to the number of domestic vessels to allow into the fishery, how much investment is required in such vessels, as well as the key issue of what royalty rates to impose on each fleet.

We would contend, however, that to see the management problem in these terms is to misunderstand what is required. The question to ask should not be : 'what is the appropriate balance between domestic and foreign vessels ?' but rather : 'how should exploitation rights be allocated to ensure that rents to the CS are maximised ?' If this is accepted, it immediately follows that there should be no presumption in favour of either the domestic or the foreign fleet, since the relevant consideration becomes one of employing factors of production with the lowest opportunity cost. Subject to an explicit statement that the CS retains ownership of the resource, exploitation rights (e.g. in the form of ITQs) should be allocated to those who will bid most for them.

In practice, most CSs have not chosen to follow a strict economic maximization approach but instead have used EFJ to opt for a long-run policy aiming either to exclude foreign vessels or at the very least to maintain a domestic fleet presence. The reasons for doing this are largely political and/or socio-economic. Charles & Yang (1991, p.292) state that " coastal state objectives go beyond strict optimization of royalty revenues, to include the desire to create employment and shore-based economic activity through domestic fleet development". This statement probably commands widespread support, certainly among policy makers. However, we argue that even if such objectives are considered legitimate, they do not necessarily imply that domestic fishermen should be favoured. In particular, the implication that an inefficient domestic fleet should be developed at the expense of an efficient foreign one in the name of employment creation seems misguided. Policy makers who argue that the development of the domestic fleet is necessary in order to create jobs for CS fishermen and onshore workers - jobs which would not have existed had the competitive activities of the foreign fleet not been curtailed - are in danger of confusing economic *impact* with economic *value*. The impact of CS fisheries development, measured by its multiplier effects, may indeed be very great. The net economic value will be negative, however, if the resources tied up in the fishing sector could have been put to better use elsewhere in the economy. If the comparative advantage lies with the foreign fleet, then it would be in the interests of the CS to employ the services of DW vessels. The real economic benefit can then be taken in the form of resource rent, which the CS can use in whatever way it wishes.

As well as this general issue about confusing economic impact with economic value, we can also point to more specific problems which arise from trying to favour domestic fishermen using an administrative approach to fisheries management.

## 4. DISTORTIONS, CONTRADICTIONS AND CONFLICTS

Where a CS management authority is not prepared to allow the market to decide the allocation of exploitation rights, perverse effects may arise in a number of specific areas.

### *4.1 Effects on trade in fishing services*

At the level of the fishery, two effects, at least, can be discerned. First, joint ventures tend to proliferate. This occurs to the extent that comparative advantage lies, for reasons explored in Munro (1985), with the DW fleet. If the more efficient

foreign fleet is excluded and exploitation rights are granted to domestic fishermen, then it is to be expected that such fishermen will try to charter foreign effort as a way of minimizing their costs. Hence many joint ventures probably represent disguised trade in fishing services between CS and DW states. Second, CS companies are likely to be very keen to acquire the managerial expertise of foreign skippers. Trade in individual labour services may also be expected to flourish therefore. Such trade is likely to be difficult to detect in balance of payments data.

If the effort level of the domestic industry is not controlled, the quantity of trade is likely to be higher than in the case where it is controlled. In part this is simply due to the fact that the effort level will be greater. Partly however it will result from the intensity of competition between domestic companies to obtain the best inputs, be they foreign or domestic. Ironically, therefore, the immediate consequence of a regime intended to favour CS fishing interests is likely to be increased purchases of fishing services supplied by the DW state.

### *4.2 Effects on investment in domestic capacity*

Another interesting issue is the assumption that resource rent should be re-invested in the fishery, hence building up domestic capacity. However, the payoff to the CS of such a strategy is likely to be zero if domestic capacity simply displaces foreign capacity. In such circumstances there would be no capacity increase and therefore no increase in resource rents ; in fact, since by hypothesis efficient fleets are being displaced, there is good reason to believe that rents will be lowered. The question has to be asked : why should the CS invest in its domestic fleet ? Surely the fact that rents are generated from fishing does not mean that they have to be reinvested in it. Where capital is so severely rationed that the industry can only obtain investment funds from rents generated from the fishery, one would have thought that the country would have many potential projects awaiting funding. The idea of using resource rents merely to displace foreign fishing effort seems somewhat profligate in such a situation.

### *4.3 Effects on employment*

The issue of employment is also important. Frequently the idea is to ensure that employment exists for domestic fishermen. A number of points must be made. First if rights are initially allocated to domestic fishermen then the problem might be resolved although at the cost of giving away much rent. If rights are granted to domestic companies we have already argued above that this is likely to generate trade in fishing services rather than protecting local employment. One way of protecting such employment would be to attack the problem directly - eg by making it a condition that all vessels having an exploitation right should employ a minimum number of nationals. Of course, if such employees are less efficient, then their extra costs will have to be met by reduced rent receipts by the CS as fish stock owner. This may nevertheless be regarded as a legitimate use of rental income. An alternative, and perhaps ultimately more profitable, approach would be to consider supply-side policies for the domestic industry. If domestic fishermen are less efficient due to a lack of experience or a lack of qualification, then the CS might use some rent to establish training programmes so that domestic fishermen might become as efficient as their foreign competitors.

### *4.4 Effects on income*

Another frequent management goal that is cited in support of management measures that discriminate in favour of domestic fishermen is to increase incomes and welfare of fishermen and their regions, especially where the regions are disadvantaged in some way (eg locationally). This argument relies on a view that fishermen's incomes are determined from within the fishery. We would deny that this is the case. This is not the place to develop a detailed argument but we would hold as a general principle that the incomes of fishermen depend on the opportunity cost of labour in the relevant region. An increase in anticipated incomes from fishing is likely just to increase the number of fishermen, thereby depressing incomes again. An increase in opportunity costs on the other hand is likely to reduce the number of fishermen thereby inducing a permanent rise in incomes. A property rights system will certainly affect the wealth of fishermen but it seems most unlikely of itself to alter their incomes.

Once more we come to the conclusion that meeting the objective does not depend on eliminating foreign fishermen. Moreover, eliminating such fishermen reduces resource rents and therefore represents a disguised subsidy given to the domestic fishing industry by society in general, usually without anyone explicitly taking such a decision.

*4.5 Effects on wealth distribution*

Part of the debate concerning domestic versus foreign fleets seems to relate to the issue of wealth distribution. For instance, suppose freely transferable exploitation rights were initially to be given to (by hypothesis) less efficient domestic fishermen. It is to be expected that more efficient foreign producers would purchase the rights, so that the fishery would end up being exploited by the least cost producers, who happen to be foreign. Domestic fishermen could be counted upon to support such a scheme since the resource rents would accrue to them rather than to the CS itself.

Wealth effects may also materialise in the form of a power struggle between the management authorities representing society (the resource owner) and domestic fishermen (politically-important resource exploiters). It is to be presumed that the owner of the resource should wish to capture the rent, but rent-seeking behaviour on the part of the exploiters is also to be expected. The policy to exclude foreign fishermen comes about perhaps as a result of political pressure exerted by domestic fishermen as part of this power struggle and as an illustration of Cushing's famous dictum that the best policy from the point of view of the individual fisherman is 'to sink all vessels but mine'. In this case foreign fishermen are selected precisely because they represent an easy target since generally they lack political power in the CS.

The point is, therefore, that so long as an administrative solution is sought, the management authority is likely to find itself in an impossible position. Foreigners are usually sacrificed partly in a misguided attempt to achieve non-economic objectives but also as a way of buying off domestic fishermen. However, much of the problem has been created by the CS management authorities themselves. A market-based management system would provide them with the flexibility to favour domestic fishermen (eg in the allocation of rights) without having explicitly to exclude more efficient fishermen simply on nationality grounds.

## 5. CONCLUSION

This paper has argued that much of the debate about whether a coastal state should develop its own fleet or use foreign vessels is misplaced. It arises from a series of confusions, most notably a failure of management authorities to understand (or at least to act as if they understood) the difference between the economic value of a fishery and its impact. The economics profession seems to have some work left to do if the message is to be brought home. Another difficulty concerns the fact that the resource, though publically owned, is exploited by private companies or individuals. Many of the problems of fisheries management stem from a confusion between ownership rights and exploitation rights. It needs to be stressed that, except where specific laws state otherwise, fishing firms do not *own* the resource ; what is granted to them is the right to *exploit* it. Fishermen's exploitation rights are awarded by public authorities, whose role should be to manage the resource for the benefit of society as a whole ; and that, in the first instance, requires the explicit recognition that it is rent which gives the resource its value. In this context we would draw a parallel between fishing industry and the oil industry. Few, if any, commentators now propose that foreign oil companies should be excluded and that domestic capacity should be built up. Countries which followed such strategies in the 1970s (eg Algeria, Libya) are now inviting the foreign oil majors to return as a way of obtaining least cost inputs. They have learnt the hard way that it is extracting resource rent rather than oil that matters for the country. As economists it is our role to help CSs learn the same concerning their fisheries without facing the difficulties currently being experienced by some OPEC countries.

## REFERENCES

**Charles A.T. and C.W. Yang** (1991). 'A Strategic Planning Model for Fisheries Development.' *Fisheries Research*, **10** : 287-307.

**Copes P.** (1982). 'Extended Fisheries Jursisdiction and Its Effect on World Trade in Seafood.' in : *Proceedings of the International Seafood Trade Conference*, Alaska, pp 27-41.

**Garcia, S., J.A. Gulland and E. Miles** (1986). 'The New Law of the Sea, and the Access to Surplus Fish Resources.' *Marine Policy*, **10** (3) : 192-200.

**Garrod B.** (1990). 'EFJ and Price Instability - a Current Cause for Concern ?' *Marine Policy*, **14** (1) : 86-88.

**Juda L.** (1991). 'World Marine Fish Catch in the Age of Exclusive Economic Zones and Exclusive Fishery Zones.' *Ocean Development and International Law*, **22** (1) : 1-32.

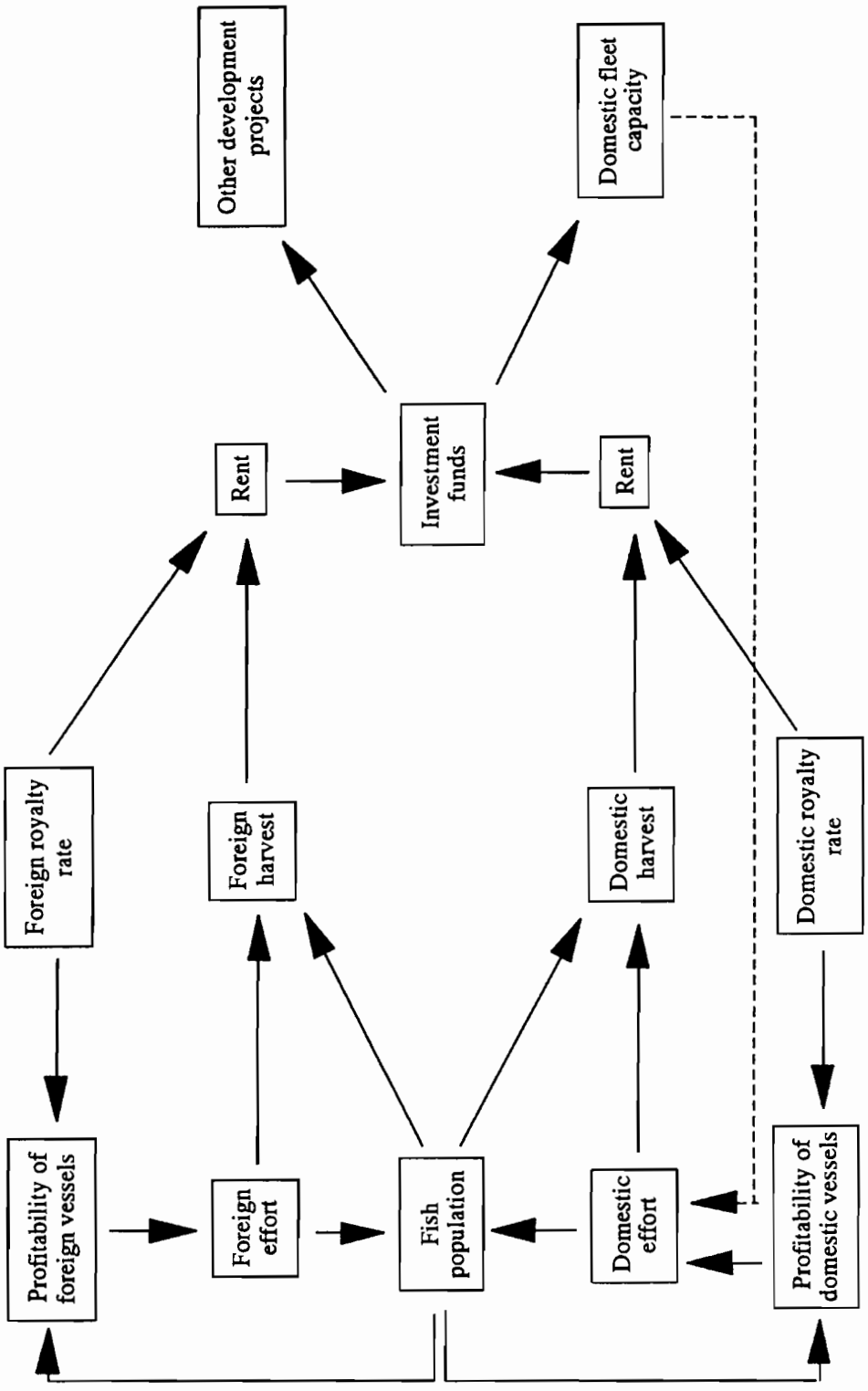
**Munro G.R.** (1985). 'Coastal States, Distant Water States and EFJ : Some Long Run Considerations.' *Marine Policy*, **9** (1) : 361-372.

**Pontecorvo G.** (1988). 'The Enclosure of the Marine Commons : Adjustment and Distribution in World Fisheries.' *Marine Policy*, **12** (4) : 361-372.

**Queirolo L.E. and R.S. Johnston** (1989). 'Distant Water Fishing Nations and Extended Fisheries Jurisdiction.' *Marine Policy*, **13** (1) : 16-21.

**Robb D.H.** (1984). 'Foreign Fishing Access Regimes in the Pacific Basin.' in : Gopalakrishnan (Ed) *The Emerging Marine Economy of the Pacific,* pp 107-119.

**FIGURE 1.**
**COASTAL STATE FISHERIES MANAGEMENT : SOME INTER-DEPENDENCIES.**



# La théorie économique de l'investissement dans le rétablissement des ressources naturelles renouvelables, avec référence spéciale au cas de la pêche du pétoncle géant aux Iles-de-la-Madeleine, Québec (Canada)

**James R. Wilson[a], Fernando Mendez[b] et Marcel Fréchette[c] ***

[a] Département Economie et Gestion, Université du Québec à Rimouski, UQAR, 300 Allée des Ursulines, Rimouski, Québec, G5L 3A1 Canada

[b] Programme en Gestion des Ressources Maritimes, UQAR, Rimouski, G5L 3A1 Canada

[c] Projet REPERE, Institut Maurice-Lamontagne, Ministère des Pêches et Océans, Canada

ABSTRACT

*A question which is becoming pertinent in fisheries management is how species might be saved from extinction in a manner which is consistent with economic rationality, by in situ management of the natural production process. How to do this seems straightforward ; in effect, the "how" part of the problem has been addressed in places like Japan, Alaska, and Norway, where there are already attempts at the enhancement of coastal fisheries. However, management which is "consistent with economic rationality" poses a more difficult problem. The conditions for the optimal extinction of a species in an extractive industry has already been demonstrated in the economic dynamics literature. However, the motivations for investment in renewable resource stocks, apart from issues concerning comparative rates of return on capital stocks, have been less thoroughly explored. The conditions for the optimal public or private investment in stocks*

* Cette étude est financée par le Ministère des Pêches et Océans.
Nous remercions les étudiants du cours Micro-économie des ressources maritimes (automne 91), et en particulier Eduardo Klein Salas et Thomas Noël du Payrat, pour leurs commentaires. Contacter les auteurs avant de citer.

*and habitat in situ (as opposed to aquaculture) seems to be an important intermediary link between those cases where hunters exploit naturally occurring processes, and those cases where this natural process is altered within a well-defined ownership context.*

*The optimal investment in the enhancement of the Sea Scallop fishery in Québec, Canada is explored using dynamic analysis with multiple controls. One control is the level of effort expended in the fishery, and the other controls are the levels of investment in the stock and in the habitat. This problem is then changed to one where the fishery is in open access, where enhancement of stock or habitat is a collective endeavor, but harvest takes place by individual entrepreneurs. Finally, the question of overinvestment in natural processes is addressed. Density-dependence (including depensation effects and self-thinning) is identified as an important factor which exacerbates investment errors, if habitat is a binding constraint. At extreme levels of stocking with habitat constraints, chaotic stock behavior obviates potential benefits to the investment.*

## 1. INTRODUCTION

Bien qu'il existe des études concernant l'extraction optimale des ressources maritimes, très peu a été écrit sur les conditions optimales qui guident l'investissement dans la récupération des ressources vivantes en mer. Les études actuelles font principalement référence aux techniques de récolte optimale et aux problèmes de rotation optimale en forêt.

L'ensemencement de certaines ressources aquatiques est déjà une réalité sur le globe. Les techniques aquicoles développées profitent du comportement migratoire de certaines espèces. Ces techniques consistent à lâcher des juvéniles en milieu naturel et à recapturer les adultes en mer ou lors de leur migration de retour pour le frai. Les pays où l'on retrouve une importante industrie d'ensemencement sont le Japon, l'ex-URSS, les États-Unis (en particulier l'Alaska) et le Canada. Cependant, un débat subsiste concernant la rentabilité de ces activités du fait que les espèces en question sont en pleine mer, et donc hors contrôle des investisseurs, pendant une grande partie de leur vie.

Les premiers essais réalisés en Amérique du Nord remontent aux années 1930, lorsque le Secrétariat au Trésor des États-Unis a tenté de mettre en place un programme d'ensemencement du saumon en Alaska financé par des investissements privés (Orth et al., 1980). Durant les années 1970, lors de la crise dans la pêcherie de saumon, l'Alaska a développé le programme "Fisheries Rehabilitation Enhancement and Development Program" (FRED) qui visait le rétablissement des stocks de saumon. Les résultats de ces investissements ont été prétendument très favorables, malgré les questions qui se posent concernant les évolutions à long terme de la productivité des océans. L'État d'Orégon possède également des programmes visant à l'ensemencement d'espèces aquatiques et l'amélioration des habitats de certaines ressources perturbées par les activités de pêche. Ces programmes sont largement supportés par des contributions volontaires.

En ce qui a trait aux études économiques sur les programmes de repeuplement des espèces en mer, les travaux sont très limités. Clark et al. (1979) abordent le problème d'irréversibilité dans l'investissement du capital et ses conséquences sur les politiques d'exploitation des stocks de pêche. Whoriskey (1991) et Wilson (1991) décrivent les projets publics qui touchent les aspects de repeuplement des stocks ainsi que les conditions socio-économiques nécessaires pour réaliser un ensemencement. Chaudhuri (1988), Bjorndal (1988) et Polovina (1991) ont réalisé des évaluations économiques des programmes publiques d'ensemencement en utilisant une approche de modélisation mathématique.

Les expériences réalisées dans l'île de Man au Royaume-Uni suggèrent que la gestion des stocks de pétoncle, en combinant les activités de repeuplement dans des zones fermées à la pêche et sous un système de rotation, produisent des résultats très positifs (Brand et al., 1991). Les résultats indiquent aussi que le repeuplement doit se réaliser à des tailles comprises entre 60 et 70 mm pour éviter la prédation par d'autres animaux (en particulier le crabe).

Les études qui traitent des effets des activités de repeuplement ou de l'aménagement de l'habitat sur la croissance d'une population semblent inexistantes. Les conséquences d'un sur-investissement dans la croissance des stocks contrôlés ainsi que les problèmes de "densité-dépendance" et de "self-thinning" sont rarement discutés en dehors du contexte de l'agriculture et de l'aquiculture. Ces derniers points devraient être traités lors de l'élaboration des politiques concernant les activités d'ensemencement d'espèces en milieu aquatique et naturel.

L'objectif de notre communication est de développer un modèle bioéconomique pour dériver le niveau optimal d'investissement dans une activité d'ensemencement. Les résultats de cette étude seront utilisés dans une étude empirique

sur l'économie de l'ensemencement de pétoncle géant (*Placopecten magellanicus*) aux Iles-de-la-Madeleine (Québec) afin de déterminer la valeur optimale des captures des adultes obtenues grâce à l'ensemencement. L'objectif ici est de fournir les fondements mathématiques permettant de réaliser l'évaluation économique de l'activité de rétablissement des stocks de pétoncle dans des conditions institutionnelles bien définies. L'objectif principal du projet REPERE (Recherche sur le Pétoncle à des fins d'Elevage et de Repeuplement) vise à développer une source stable d'approvisionnement en juvéniles de pétoncles aux Iles-de-la-Madeleine par le développement de technologies d'élevage rentables dans le contexte québécois. La réalisation d'un projet pilote permettant l'exploitation de l'espèce à l'échelle commerciale constitue un des principaux buts de ce programme.

## 2. LA PÊCHE DU PÉTONCLE AU QUÉBEC

L'exploitation commerciale du pétoncle au Québec a débuté dans les années 1960. Les pêcheries ont été développées principalement dans cinq secteurs maritimes. Les Iles-de-la-Madeleine occupent le second rang en termes de contribution aux captures totales de la Province.

D'après les statistiques du Ministère des Pêches et des Océans (MPO), les débarquements de pétoncles provenant des Iles-de-la-Madeleine ont subi une réduction significative depuis 1971. La cause de cette diminution est principalement la sur-exploitation des stocks naturels. Selon le MPO, les stocks semblent réduits et difficiles d'accès avec les techniques conventionnelles de dragage. Par ailleurs, les observations de Giguère et Legaré (1989) suggèrent que la présence de pré-recrues dans la zone est variable mais plutôt à la baisse. Les méthodes de gestion des pêches ne sont pas suffisantes pour rétablir les faibles rendements de la pêche. Pour ces raisons, une nouvelle stratégie basée sur le repeuplement des stocks épuisés a été adoptée.

Depuis les années quatre-vingts, des essais de capture de naissains sauvages et d'élevage de juvéniles ont été entrepris au Québec. Bien qu'il existe actuellement une expansion du marché du pétoncle, les travaux de Gilbert et Leblanc (1991) démontrent que la culture de cette espèce peut dans certains cas ne pas être rentable. Mais en regardant les technologies proposées, ce résultat n'est pas étonnant. Ils proposent la capture de juvéniles sauvages et l'élevage pendant une période de cinq ans jusqu'à la taille commerciale, en utilisant des techniques de culture différentes. Ces résultats incitent à une réflexion sur les modes de cultures autres que l'aquiculture proprement dite. Une stratégie de rentabilisation des opérations de culture peut être dans l'ensemencement d'une espèce, soit par la capture de juvéniles, soit par l'aquiculture de naissains. Ces produits d'une entreprise aquicole peuvent être ensuite utilisés pour l'ensemencement du fond. L'utilisation du fond par l'ensemble des pêcheurs est un contexte institutionnel de propriété qui n'est ni strictement privé ni d'accès libre.

Le pétoncle est une espèce attrayante pour l'ensemencement en milieu naturel car le problème de la mobilité est largement restreint. De plus, c'est une espèce de haute valeur commerciale. Enfin, grâce à sa mobilité limitée, l'espèce semble adaptée à des institutions d'ensemencement collectives dans le cadre d'une pêcherie en propriété commune. Ceci est spécialement vrai lorsque le terrain utilisé pour la production (dans ce cas le fond de la mer) est la propriété exclusive de la collectivité. Dans ce cas, la question de l'investissement en ensemencement pour le pétoncle s'avère plus pertinente que l'investissement dans l'ensemencement du saumon atlantique par exemple. Cependant, parce que ceci est un problème d'investissement collectif dans une ressource vivante, le problème est de trouver la combinaison des niveaux annuels de captures et d'ensemencement qui maximisera la valeur présente nette au fil du temps. Ceci est donc un problème dynamique à deux variables de contrôle. La détermination de la valeur optimale de l'investissement dans l'ensemencement de pré-recrues ($E_t$) de pétoncle géant et de la récolte postérieure des adultes (Yt) dans la pêche commerciale permettent de répondre à la question suivante : existe-t-il une stratégie permettant de rentabiliser les opérations de pêche par l'intermédiaire d'activités telles l'aquiculture, tout en sachant qu'un *sur-investissement* est possible ?

## 3. MÉTHODE

L'investissement optimal pour l'ensemencement de pétoncle est analysé à la lumière de la théorie du contrôle optimal en cas discret. L'application de ces principes et théories permet de trouver, pour un intervalle de temps défini, le contrôle

optimal pour chaque période de temps qui maximisera une fonction objectif. Le principe maximal donne les conditions nécessaires qui doivent être satisfaites pour l'application optimale des variables de contrôle. Pour des exemples pratiques de l'application de ces principes en économie, le lecteur pourra consulter Kamien et Schwartz (1981) et pour des applications économiques à la pêche et aux problèmes forestiers, Clark (1976).

Nous présenterons d'abord un modèle général et analytique concernant le problème de l'ensemencement et de la récolte. Pour une application empirique en cas discret avec deux variables de contrôle, on peut se référer à Bjorndal et Conrad (1989) sur la capture du phoque de l'Atlantique Nord dans les stades juvénile et adulte. Nous en dérivons le résultat dynamique, sans prendre explicitement en compte les effets de la densité sur la dynamique de la population (i.e. self-thinning). Cependant le sur-investissement comme phénomène économique n'est pas lié nécessairement à l'observation de self-thinning ou de dépendance lié à la densité, mais surtout à la forme de la fonction objectif, qui dépent du signe et de la valeur des paramètres estimés.

## 4. LE MODÈLE BIOÉCONOMIQUE

Les décisions de repeuplement dépendent étroitement de la dynamique de la population en question et des facteurs qui contrôlent sa taille. Les mécanismes associés aux limitations de la présence de recrues sont généralement le manque de nourriture, le manque d'espace, ou la modification de l'habitat naturel de l'espèce. La présence des adultes est plutôt limitée par le manque de ressources alimentaires dans une population.

Le modèle bioéconomique ici proposé suppose une population simple, composée d'individus de taille inférieure à 30 mm que nous appelons pré-recrues. Par recrutement à 30 mm, nous entendons l'entrée dans la population des individus qui ont atteint la maturité sexuelle. L'ensemencement sur le fond est le déversement en milieu naturel des individus qui sont matures sexuellement. Le recrutement à la pêcherie s'opère deux ans après. L'élevage des pré-recrues est fait dans des collecteurs pendant deux ans. Après déversement il faut que les pré-recrues croissent encore pendant deux ans avant de rentrer dans la pêcherie. Pour explorer le modèle en toute simplicité, on suppose que le déversement est fait d'une manière aléatoire et que le recrutement à la pêcherie est en "lame de couteau" (c'est-à-dire que le recrutement partiel est nul).

Le revenu net d'une association de pêcheurs qui ensemence à l'année t est fonction de l'amplitude de l'ensemencement en pré-recrues ($E_t$), de la récolte des adultes ($Y_t$) et du stock ($X_t$). Pour une description purement théorique, il suffit de décrire les propriétés fonctionnelles de la forme en considération. Cependant notre objectif est de décrire des relations qui pourront ensuite faire l'objet d'une estimation économétrique avec les données réelles. La relation considérée est une fonction de revenu net séparable de la forme :

$$N(E_t, Y_t, X_t) = pY_t - cE_t^{\alpha} - eY_t^{\beta} X_t^{\phi}; \qquad \alpha > 1; \quad \beta > 1; \quad \phi < 0.$$

Dans cette expression, $Y_t$ représente la capture à l'année t ; $E_t$ le nombre de juvéniles de 30 mm déversés sur le fond à l'instant t ; $X_t$ est le stock adulte à l'instant t. Le premier terme est le revenu brut provenant de la capture et p est le prix au débarquement. Le deuxième terme est la fonction de coûts totaux d'élevage des individus jusqu'à 30 mm. On suppose explicitement que l'entreprise confronte des coûts croissants pour l'ensemencement ainsi que pour l'activité de récolte. Le premier terme est une fonction linéaire, le second terme est toujours croissant avec l'argument $E_t$. Le dernier terme est une fonction de coûts qui est croissante en captures ($Y_t$) et décroissante en stock ($X_t$).

Il faut souligner que dans la formulation proposée, le prix est considéré comme un paramètre plutôt que comme une variable. La raison est que l'analyse est basée sur des données annuelles, dans un contexte où les pêcheurs des Iles sont considérés comme "price takers". Une condition plus restreinte serait de supposer que l'association confronte une demande à pente négative. À noter aussi que l'existence d'une solution unique repose sur l'hypothèse de concavité de la fonction objectif, qui implique des fonctions de coûts croissants si le revenu brut est considéré linéaire et croissant.

## 5. DÉRIVATION ANALYTIQUE

Pour le problème d'optimisation abordé ici, nous supposons deux activités différentes : l'ensemencement de pré-recrues de 30 mm ($E_t$) et la récolte des adultes ($Y_t$) à un âge supérieur à 4 ans. L'ensemencement est traduit par une augmnentation au taux intrinsèque de croissance de la population ($r_{30}$ : nombre d'individus survivants générés par un couple de pétoncles et qui atteignent une taille de 30 mm). Pour cette analyse, nous utilisons deux cohortes : les pré-recrues ($R_t$) dont la taille est comprise entre 30 et 70 mm et les adultes ($X_t$) qui possèdent déjà une taille commerciale c'est-à-dire 70 mm. Il est nécessaire de souligner que les pré-recrues sont des individus qui ont déjà atteint la maturité sexuelle, tout en n'étant pas encore recrutés à la pêche.

La maximisation de la valeur présente du revenu net s'exprime mathématiquement par la fonction suivante :

$$Max\ J = \rho^t N(E_t, Y_t, X_t)\ ;\quad \text{où}\quad \frac{\partial N}{\partial E_t} \leq 0\ ;\quad \frac{\partial N}{\partial Y_t} > 0 \tag{1}$$

Dans cette équation, $\rho = 1 / (1 + i)$ représente la fonction d'actualisation (i : taux d'actualisation). La fonction de revenu net est linéaire quant à la récolte $Y_t$. L'ensemencement $E_t$ s'apparente à des coûts de la période courante effectués dans l'espérance d'un remboursement ultérieur sous forme de récoltes des adultes.

Les contraintes biologiques qui s'imposent sont les suivantes :

$$X_{t+1} = (1 - M_0) R_t + (1 - M)(X_t - Y_t) \tag{2}$$

$$R_{t-1} = r_{30}\left(X_t + R_t - \frac{(X_t + R_t)^2}{k}\right) + E_{t+1} - (1 - M_0) R_t \tag{3}$$

Les termes $M_0$ et M sont les taux de mortalité respectifs des juvéniles et des adultes. La capacité de charge du système est exprimée par k.

Le Lagrangien s'écrit :

$$\begin{aligned}\mathcal{L} = \sum \rho^t N(E_t, Y_t, X_t) + \\ + \rho^{t+1}\lambda_{t+1}\left(r_{30}\left(X_t + R_t - \frac{(X_t + R_t)^2}{k}\right) + E_{t+1} - (1 - M_0) R_t - R_{t-1}\right) + \\ + \rho^{t+1}\mu_{t+1}((1 - M_0) R_t + (1 - M)(X_t - Y_t) - X_{t-1})\end{aligned} \tag{4}$$

La formulation précédente représente un problème d'optimisation dynamique avec deux variables d'état ($R_t$ et $X_t$ ) et deux variables de contrôle ($E_t$ et $Y_t$ ).

Les conditions de premier ordre nécessaires pour le maximum sont :

$$\frac{\partial \mathcal{L}}{\partial E_t} = -\rho^t[c\alpha E_t^{(\alpha-1)} + \rho\lambda_t] = 0 \tag{5}$$

$$\frac{\partial \mathcal{L}}{\partial Y_t} = \rho^t[p - \beta e Y_t^{(\beta-1)} X_t^{\theta} - \rho\mu_{t+1}(1 - M)] = 0 \tag{6}$$

Les deux équations adjointes sont :

$$\mu_{t+1} = \frac{p - \beta e Y_t^{(\beta-1)} X_t^{\theta}}{\rho(1 - M)} \tag{7}$$

$$\lambda_t = \frac{c\alpha E_t^{(\alpha-1)}}{\rho} \tag{8}$$

Les dérivées partielles par rapport aux variables d'état pour les adultes sont exprimées comme :

$$\frac{\partial \mathscr{L}}{\partial X_t} = \rho^t\left[-\theta e Y_t^{\beta} X_t^{(\theta-1)} + \rho\lambda_{t+1} r_{30}\left(1 - \frac{2(X_t + R_t)}{k}\right) + \rho\mu_{t+1}(1+M) - \rho\mu_t\right] \tag{9}$$

Celles pour les pré-recrues sont exprimées comme :

$$\frac{\partial \mathscr{L}}{\partial R_t} = \rho^t\left[\rho\lambda_{t+1} r_{30}\left(1 - \frac{2(X_t + R_t)}{k}\right) - \rho\lambda_{t+1}(1-M_0) - \rho\lambda_t + \rho\mu_{t+1}(1-M_0)\right] \tag{10}$$

Pour garantir une trajectoire optimum, les ensemencements et les récoltes seront faits ensemble, en respectant la condition :

$$\begin{aligned}\lambda_{t-1} - \lambda_t &= -\frac{\partial \mathscr{L}}{\partial R_t} \\ &= -\rho^{(t+1)}\left[\lambda_{t-1} r_{30}\left(1 - \frac{2(X_t + R_t)}{k}\right) - \lambda_{t+1}(1-M_0) - \lambda_t + \mu_{t-1}(1-M_0)\right]\end{aligned} \tag{11}$$

Il est à noter que les conditions dérivées de cette manière prennent compte des ajustements vers l'équilibre dynamique et donc englobent cette solution et les ajustements. La substitution des termes $\lambda_t$ et $\mu_t$ exprimés en (9) et (10) et la résolution postérieure du système d'équations permettent de trouver l'expression optimale pour l'ensemencement $E_{t+1}$ :

$$E_{t-1} = \left[\frac{E_t^{\alpha-1}(1+\rho^{-(t+1)}) - c\alpha^{-1}\left(\frac{1-M_0}{1-M}\right)(P - \beta e Y_t^{(\beta-1)} X_t^{\theta})}{1 + \rho^{-(t+1)} + r_{30}\left[1 - \frac{2(X_t + R_t)}{k}\right] + M_0}\right]^{\frac{1}{\alpha-1}} \tag{12}$$

Dans cette équation, l'activité d'ensemencement $E_{t+1}$, est liée de façon positive avec la valeur future du coût marginal de l'ensemencement. Ce n'est pas surprenant de noter que le profit marginal des récoltes aura un effet négatif sur la décision d'ensemencer. Par ailleurs, avec un taux de survie plus élevé des jeunes, par rapport aux adultes, les effets négatifs seront plus prononcés. Par contre, lorsque le taux de mortalité des juvéniles augmente, $E_{t+1}$ diminuera. Les effets négatifs sont aussi évidents lorsque la croissance naturel du stock est à la hausse. Enfin, en regardant le terme $\rho^{-(t+1)} = (1+i)^{(t-1)}$, il est évident que la hausse du taux d'escompte diminuera l'ensemencement aux périodes futures. Mais cet effet est minime par rapport aux effets de la valeur future et des coûts de l'ensemencement sur l'ensemencement en période t+1.

Une application similaire du principe maximum dans le cas discret permet de dériver les récoltes optimales à travers le temps, $(Y_t)$ :

$$\begin{aligned}\mu_{t-1} - \mu_t &= -\frac{\partial \mathscr{L}}{\partial X_t} \\ &= -\rho^t\left[-e\theta Y_t^{\beta} X_t^{(\theta-1)} + \rho\lambda_{t+1} r_{30}\left[1 - 2\frac{(X_t + R_t)}{k}\right] + \rho\mu_{t-1}(1+M) - \rho\mu_t\right]\end{aligned} \tag{14}$$

Cette équation n'a pas une solution unique pour $Y_t$, sauf dans le cas où $\beta = 2(\beta\text{-}1)$. Dans ce cas, et en faisant la substitution des termes $\lambda_t$ et $\mu_t$ et la simplification de l'équation (14), $Y_t$ peut être exprimé comme :

$$Y_t = \left[ \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \right]^{\frac{1}{\beta - 1}} \tag{15}$$

avec

$$A = e\theta X_t^{\theta - 1} \qquad (<0)$$

$$B = [1 + (1 + i)^{t+1}(1 - M)^{-1}]\,\beta e X_t^{\theta} \qquad (>0)$$

$$C = c\alpha E_{t-1}^{\alpha - 1} r_{30}\left[1 - \frac{2(X_t + R_t)}{k}\right] + P\left(1 - \frac{1}{1 - M}\right) + \beta e Y_{t-1}^{\beta - 1} X_{t-1}^{\theta}(1 + (1 + i)^{t+1})$$

La racine négative à été sélectionnée pour notre analyse car les valeurs provenant de cette racine sont positives. Il est à noter que le terme A (les effets du stock) est négatif à cause du signe du paramètre θ. Mais dans la racine négative de l'équation (15) ces effets sont directs et positifs. Le terme B est toujours positif, avec une relation inverse entre sa valeur et le stock. La valeur future de ces stocks pondérée par le taux de survie est évidente. Lorsque le taux d'intérêt augmente, $Y_t$ augmente aussi. Lorsque le taux de survie est important, il y a moins d'incitation à effectuer la récolte immédiatement. Le terme le plus complexe est C. Le premier terme de C suggère que les captures à la période t sont directement liées aux coûts marginaux de l'ensemencement planifié en période t+1 et au taux de croissance de la biomasse. Le deuxième terme est le prix pondéré par le taux de survie. En effet, on voit que le prix, s'il varie, affectera les captures directement, mais cet effet est diminué par la valeur de $1\text{-}(1\text{-}M)^{-1}$, toujours négative. Si le prix augmente, la façon de maintenir la trajectoire qui maximise le flux de profits est de réduire les captures. La valeur future du coût marginal des captures affecte les captures courantes de manière positive. Pour les taux d'escompte très petits et les taux de survie très élevés l'effet du prix peut devenir négatif. Le troisième terme de C suggère que les décisions de capture en t sont déterminées par la valeur future à t des coûts marginaux des captures en t-1 et la valeur du coût marginal en t-1 escomptée, le tout pondéré par le taux de survie. Ce terme est positif.

La racine négative de l'équation donne des valeurs positives pour $Y_t$ et la forme de la fonction quadratique préserve les interprétations de B et C. Cependant, il est à noter que la signification du terme A est ambiguë. Au dénominateur, une grande population d'adultes dans une période donnée entraînera nécessairement une augmentation des captures. Le numérateur suggère une certaine minimisation des effets directs de C et une importance de l'existence du stock sur les décisions sur $Y_t$ . Une interprétation plus exacte de cette fonction n'est possible que par les méthodes numériques avec des données réelles. La prochaine étape de cette recherche vise l'estimation des fonctions des coûts de captures et des coûts d'ensemencement dans un effort de démontrer plus clairement ces effets et d'expérimenter avec les autres formes fonctionnelles.

Il existe un niveau d'ensemencement qui permet le rétablissement de la population à long terme, avec les objectifs fonctionnels en profit qui sont concaves. D'autre part, la solution suggère aussi que l'ensemencement optimal est sensible aux variations dans l'état des stocks, aux coûts de l'ensemencement, et aux valeurs futures du profit provenant des captures.

## 6. EXTENSIONS POSSIBLES

Le modèle décrit ci-dessus, bien qu'il semble complexe, est très simple en termes de construction et d'hypothèses de base. Parce que le modèle est conçu avec seulement deux cohortes limitées par k (la capacité du système), la compétition intra-spécifique n'est pas prise en compte. De plus, le modèle suppose que les pêcheurs sont capables de se regrouper en association et ont des droits d'usage exclusifs concernant le fond autour des Iles-de-la-Madeleine. On suppose que l'association distribue les juvéniles de 30 mm de la même manière que la production naturelle ; une situation qui n'est pas tout à fait raisonnable sur le plan réel. Enfin, les auteurs ont supposé que le recrutement à la pêche est "en lame de couteau" ; le recrutement partiel n'est pas considéré. Malgré l'utilité des approches analytiques, le vrai projet

d'ensemencement aura à prendre en compte ces éléments. Les auteurs proposent un agenda de recherche pour étendre les résultats présentés. Un premier groupe d'extensions doit traiter les problèmes duaux de densité et self-thinning d'une manière plus réaliste. Le deuxième groupe d'extensions doit traiter des stratégies possibles d'ensemencement et des implications institutionnelles de ces stratégies. Cependant, la prise en considération d'une technologie dans un contexte institutionnel spécifique risque de rendre impossible l'utilisation des approches analytiques pour la modélisation.

### *6.1 Ensemencement, densité, et self-thinning*

Il est bien connu que la densité, exprimée en biomasse par unité de surface, affectera le taux de croissance de la biomasse. Aussi la densité dans un contexte aquicole est une variable de contrôle qui peut entraîner des réductions par une augmentation du taux naturel de mortalité.

D'après la formulation du modèle, une augmentation très forte de la densité de la population ensemencée engendrera une baisse de rentabilité des opérations de récolte. Le travail de Mallet et Carver (1991) indique qu'une forte concentration des individus ensemencés engendre une compétition pour la nourriture et pour l'espace. Les densités élevées entraînent aussi une diminution dans la capacité de fixation des juvéniles et par conséquent une augmentation de la mortalité. Watanabe (1986) indique que les opérations de repeuplement introduisent des changements au plan de la stabilité de la population. Une augmentation du taux de reproduction de l'espèce peut occasionner de grandes fluctuations de densité et par conséquent provoquer un effondrement de la population. Il insiste sur la nécessité de développer des études sur la reproduction des espèces avant de s'engager dans des activités de repeuplement.

Berryman (1991) souligne que des cycles chaotiques pour certains crustacés, en particulier le crabe, sont occasionnés par l'interaction entre la dynamique de la population et la pêche. Selon cette hypothèse, la population de crabe oscille autour d'une densité d'équilibre qui est sensible à l'augmentation de l'effort de pêche. De ce fait, l'accroissement des captures entraîne une diminution de la population. Si la pression de la pêche est maintenue longtemps, le crabe peut subir des périodes de très faible abondance et "éclater".

Conséquence des limitations d'espace ou de nourriture ainsi que de la nature compétitive des animaux, les individus ensemencés peuvent subir des effets comme le "self-thinning", où la taille ou biomasse moyenne de l'individu montre une relation négative avec la densité. Les individus restant dans la population continueront à croître, en remplaçant la biomasse perdue par la mort des autres individus (Begon et al 1986). D'après les observations de Hugues et Griffiths (1988) et de Fréchette et Lefaivre (1990), les effets de "self-thinning" sont observés dans différentes populations de mollusques dont la densité atteint des niveaux très élevés.

D'après la littérature, on peut souligner que la densité initiale d'ensemencement aura un effet sur la vitesse de croissance des individus. Ces effets se font sentir à travers les processus de mortalité naturelle, provenants de la dynamique entre l'environnement et la population, mais aussi à travers les effets directs et indirects de la compétition intra-spécifique. Il est assez clair que l'investissement en ensemencement ne doit pas dépasser la capacité de charge du système sous peine d'entraîner une situation non-rentable voire de détruire le stock complet. Cependant, la taille et la gestion de la taille des individus devient une considération importante car le prix varie souvent avec la taille. Ces considérations soulignent l'importance d'une connaissance de la mortalité naturelle ainsi que des dynamiques de compétition, dans un système fermé et également dans un système ouvert.

### *6.2 Institutions et stratégies de repeuplement*

Pour bien gérer les opérations d'ensemencement-récolte et maximiser les bénéfices des participants, la nature des institutions de gestion doit être considérée. Quelques États et provinces utilisent un système de location du fond aux particuliers. Un excellent exemple de ce type d'institution existe dans la Baie Chesapeake parmi les producteurs d'huîtres. En Alaska, les associations régionales de pêcheurs commerciaux de saumon engagent des gestionnaires pour des projets d'ensemencement dans la région qui sont auto-financés par la production des saumons qui reviennent aux rivières après leur migration. Ceci est possible car les pêcheurs régionaux ont des droits exclusifs de pêche dans la région.

Un point de discussion très important est alors le type d'institution de propriété qui accompagnera les activités d'ensemencement aux Iles-de-la-Madeleine. Cette institution, soit une coopérative des pêcheurs soit une formule

individualiste, doit tenir compte des activités de pêche et d'élevage autant que des réalités de la gestion publique des pêches en vigueur. Il semble qu'il n'y a pas au Canada d'infrastructure en place permettant l'octroi de droits pour exploiter le fond de l'océan. Cependant, les coûts et l'échelle de l'élevage d'espèces peuvent devenir intéressant pour la coalition des pêcheurs. Une innovation de ce système serait la passation de contrats entre le secteur public et l'industrie pour exploiter certaines parcelles de l'océan. Ces contrats peuvent être passés avec des individus ou avec les membres d'une coopérative ou d'une association, en utilisant les méthodes de culture adaptées au milieu.

Les études réalisées au Japon ont démontré l'importance des coopératives de pêche dans les activités de rétablissement des stocks épuisés par la pêche. D'après Mahmoud et Masuda (1991), plusieurs coopératives de pêcheurs sont directement responsables des activités de déversement et de capture du saumon. Une partie des fonds provenant de l'activité de récolte est utilisée pour couvrir les coûts de repeuplement. Il est important de remarquer que les niveaux de remontées de saumons au Japon semblent étroitement liés avec les nombres de poissons relâchés dans les années précédentes.

La gestion de la population de pétoncles avec ensemencement et captures est prometteuse parce que la culture de pêcheur est préservée et les pratiques de l'aquiculture sont utilisées en conjonction avec les processus naturels. Par contre, l'adoption des techniques de la mariculture nécessite une vision d'aquaculteur. La possibilité de sur-investissement en ensemencement est toujours à craindre lorsque les contraintes, que l'on regroupe sous le terme générique "k", sont fixes. D'une part la population s'accroît par le déversement d'individus, mais cet acte peut générer des problèmes de compétition, de limitation d'espace et de nourriture et donc une augmentation du taux de mortalité. Ceci n'est rien que le principe économique des rendements décroissants. D'autre part, la pêche des adultes enlève une partie de la population ce qui peut avoir des effets nuisibles selon l'effort appliqué. La combinaison de ces deux facteurs peut très bien entraîner une situation de chaos écologique et subséquemment la non-rentabilité du projet.

## REFERENCES

**Begon M., L. Firbank et R. Wall** (1986). "Is there a self-thinning rule for animal populations ?" in *Oikos* **46** (1) : 122-124.

**Berryman A.A.** (1991). "Can economic forces cause ecological chaos ? The case of the Northern California Dugeness crab fishery." in *Oikos* **62** (1) : 106-109.

**Bjorndal T.** (1988). "Optimal harvesting of farmed fish." in *Mar. Res. Econ.*, **5 :** 139-159.

**Botsford L.W. et R.C. Hobbs** (1984). "Optimal fishery policy with enhancement through stocking : california's white sturgeon as an example." in *Ecological modelling*, **23** : 293-312.

**Brand A.R., A.W. Wilson, S.J. Hawkins, E.H. Allison et N. Duggan** (1991). "Pectinid fisheries, spat collection, and the potential for stock enhancement in the Isle of Man." *ICES mar. Symp.*, **192 :** 79-86.

**Clark C.W.** (1976). *Mathematical bioeconomics : the optimal management of renewable resources.* $2_e$ éd., Wiley-Intersciences publication.

**Clark C., F.H. Clarke et G. Munro** (1979). "The optimal exploitation of renewable resource stocks : problems of irreversible investment." in *Econometrica* **47 :** 25-49.

**Conrad J.M. et T. Bjorndal** (1989). *A Bioeconomic Model of the Harp Seal in the Northwest Atlantic.* Dept of Agr. and Resource Economics, Cornell University, Doc. trav.

**D'Amours D. et S. Pilote** (1982). *Données biologiques sur le pétoncle d'Islande (Chlamys islandica) et le pétoncle géant (Placopecten magellanicus) de la Basse-Côte-Nord du Québec.* MAPAQ, DRST. No. 99.

**Fréchette, M. et D. Lefaivre** (1990). "Discriminating between food and space limitation in benthic suspension feeders using self-thinning relationships." in *Marine Ecology Progress Series* **65 :** 15-23.

**Giguere M. et B. Legare** (1989). *Exploitation du pétoncle aux Iles-de-la-Madeleine en 1988.* MPO, IML, CAFSAC. Res. Doc. 89/14.

**Gilbert E. et Y. Leblanc** (1991). *La culture du pétoncle géant : état de la situation et analyse bioéconomique de différents scénarios d'élevage.* MAPAQ, DRST. Doc. trav. 91/01.

**Holliday J.E., G.B. Maguire et J.A. Nell** (1991). "Optimum stocking density for nursery culture of Sydney rock oysters (*Saccostrea commercialis*)." in *Aquaculture*, **96 :** 7-16.

**Hughes R. et C.L. Griffiths** (1988). "Self-thinning in barnacles and mussels : the geometry of packing." in *Am. Nat.* **132 :** 484-491.

**Kamien M.I. et N.L. Schwartz** (1981). *Dynamic Optimization : The Calculus of Variations and Optimal Control in Economics and Management.* North-Holland

**MacDonald B.A. et R.J. Thompson** (1986). "Production, dynamics and energy partitioning in two populations of the giant scallop *Placopecten magellanicus*." in *J. Exp. Bio. Ecol.* 285-299.

**Mahmoud M. A. et H. Masuda** (1991). "An economic review of artificial salmon propagation and management operations in Japan." in *Bull. Fac. Fish. Hokkaido Univ.* **42** (2) : 58-79.

**Mallet A.L. et C. E. Carver** (1991). "An assessment of strategies for growing mussels in suspended culture." in *Journal of Shellfish Research.* **10** (2) : 471-477.

**Orth F.L., J.R. Wilson, J.A. Richarson et S. Pidde** (1980). *Market structure of the Alaska sea food processing industry.* University of alaska, Sea Grant Report 78-14 mars 1991.

**Polovina J.J.** (1991). "Evaluation of hatchery releases of juveniles to enhance rockfish stocks, with application to Pacific Ocean Perch *Sebastes alutus*." in *Fish. Bull.* **89 :** 129-136.

**Ridler N.B. et W. Roderick** (1991). "Financial feasibility and farm systems in cultivating *Ostrea edilus* Linn." in *Jour. Shellfish Res.* **10** (2) : 395-398.

**Whoriakey F.H.** (1991). "Politiques et programmes d'ensemencement aux États-Unis." in *Colloque sur l'ensemencement*. Conseil de l'aquiculture et des pêches du Québec, MAPAQ, MLCP. 1-2-3 mars 1991, Ste Foy. 99-102.

**Wilson J. R.** (1991). "The public finance of salmon enhancement : two others perspectives" in *Colloque sur l'ensemencement.* 167-173.

**Watanabe S.** (1987). "Restocking effects on the single species population obeying difference equation" in *Nippon Suisan Gakkaishi* **53** (3) : 363-366.

# Fishermen's Time Discounting Rates and other Factors to be Considered in Planning the Rehabilitation of Depleted Fisheries

**John P. Hillis[a] and Brendan J. Whelan[b]**

[a]Department of the Marine, Fisheries Research Centre, Abbotstown, Castleknock, Dublin 15, IRELAND

[b]Economic and Social Research Institute, Burlington Road, Dublin 4, IRELAND

ABSTRACT

*All programmes to rehabilitate run-down fisheries by enhanced conservation measures incur immediate losses to allow increased fish survival, and the pattern of immediate losses and long-term gains is routinely modelled by biologists using inputs of growth-rate, mortality and recruitment. This paper discusses the effects of including in the model fishermen's time discounting rates, price elasticity and price-size effects (price per unit weight being generally higher in large fish than in small) in influencing the predicted outcome and reports on the results of a questionnaire survey in the Irish Sea Irish fishery undertaken among other things inter alia to establish the fishermen's time discount rates applicable in rehabilitation calculations.*

## 1. INTRODUCTION

The run-down state of most technologically well developed fisheries close to large markets is by now well-known, and in the case of the north-western Irish Sea, as in many other areas, the situation has been deteriorating progressively for many years, despite the efforts of national governments and since 1983 the European Communities to conserve them so as to stabilise yield at maximum sustainable level.

In this area, the three most important species traditionally are *Nephrops* (Dublin Bay or Scampi prawn), cod and whiting, which are exploited by Republic of Ireland and Northern Ireland boats, and plaice and sole, fisheries for which are largely confined to the Republic whose fishery is the subject of this paper. The composition by value of the Irish catch in 1991 (IR#m) was as follows : Nephrops 2.97 (56.5 %) ; Sole 0.52 (9.9 %) ; Cod 0.46 (8.8 %) ; plaice 0.45 (8.5) ; whiting 0.44

(8.4 %) ; all other species 0.42 (7.9), giving a value of IR#5.26m. All five main species are known to be overfished to varying extents, and in recent times there has been some evidence of the situation changing as boats diversify to avoid constraints imposed by EC quotas, catching monkfish, while catches of hake may be increasing due to gradual warming of the climate. There is also a very small herring fishery between the Mourne coast and the Isle of Man. The area of the main fisheries is shown in Figure 1. The amount of effort to which a fish species should be subject to yield maximum profit has been discussed by many, including Hillis (1989) and is indicated in Figure 2, which shows the zone of fishing mortality (F) values within which profit is maximised, i.e. between the values of F where profit is maximised with nil costs (i.e. Fmax where yield is maximised) and that where it is maximised with costs equal to 100 % of revenue at current F value (i.e. nil profit), also the F values at which profit is maximised using typical variable and fixed costs at current F values, and deeming all costs to be variable (as is the case where fleet size is reducible).

Profit Maximising Fvalues - which are dependent on the amount of fishing effort deployed - can be shown from the Reports of the ICES Irish Sea and Bristol Channel and Nephrops Working Group (Anon. 1991a, 1991b, 1992) to fall short of current Fvalues for the main NW Irish Sea species shown in Table 1. The extent to which Fe is exceeded by Fcurrent has increased in recent years, particularly for cod.

Due to the fact that the Irish Sea was a relatively discrete area fished by relatively few countries and with, as far as could be ascertained, relatively sedentary fish stocks, it was selected by the authors' institutes, together with the Sea Fish Industrial Authority, Fishery Economics Research Unit, Edinburgh, and the Irish Sea Fisheries Board, Dun Laoghaire, for a joint bioeconomic study, which was chosen for funding by the Commission of the European Communities under the Fisheries and Aquaculture Research (FAR) Programme. In discussing the issues involved in attempting to rehabilitate fisheries run-down by overfishing, this paper reports on the findings of a questionnaire survey carried out in the Republic of Ireland to establish the time discounting rates held by the fishermen and underlying their business thinking and decision-making. This is probably the most important of the factors influencing cost benefit analysis of any programme of improved fishery management through stock rehabilitation.

## 2. EFFECTS OF REHABILITATING FISH STOCKS BY REDUCING EFFORT

Typically, recovery of catches after reduction of fishing effort (and hence fishing mortality) is preceded by initial losses which persist until the extra fish spared realise enough growth to raise volumes caught with the reduced effort beyond their initial level. This effect, which is modelled routinely in fisheries biology, is shown in Figure. Also shown is the effect of gradual, stepwise reduction, which reduces the severity of the initial losses, but by spreading them at a lighter level over a longer period delays the onset of long-term gains.

Several biological and economic effects exist which may influence the modelling of effort reduction ; these are as follows :

i) Density-dependent growth. As a stock increases in numbers, competition for food will tend to reduce individual growth rates, slightly reducing the level of returns expected from an improved conservation programme.

ii) Multi-species effects. For fish preyed on by other species, reduction of fishing all round may well expose the prey species to increased natural mortality,a s survival of the predator increases. This is a very laborious topic to quantify, normally requiring sampling of predator stomachs ; it also depresses level of expected gains.

iii) Price-size effect. During most of a fish's life its value per unit weight increases, so increased fish age at capture will cause an increase in catch value greater than that in catch weight. This effect raises the levels of expected gains. (It reverses in extreme old age but the numbers of individuals involved are very small).

iv) Price elasticity. This tends to reduce slightly expected changes in both initial losses and long-term gains. However effects may be negligible where initial losses and long-term gains are confined to a pilot area fishery small in extent compared to all fisheries in the same market.

v) As will be shown, a most important effect, since it may strongly influence decisions on conservation measure is that of future (time) discounting. The effect of future discounting on effort reduction calculations is to reduce expected gains since expected immediate losses being close to the present, are less reduced by this effect than the long-term gains.

## 3. QUESTIONNAIRE SURVEY

To assess the fishermen's views on the state of the Irish fishery and examine its amenability to rehabilitation by conservation measures, an interview survey was undertaken during 1991. Its main aim was the acquisition of information on the Irish fleet and its operating expenses in the north-western Irish Sea fishery. Views of skippers on the state of the stocks and as to which measures could best improve catches were also sought as well as the future discounting rates held by them and their attitudes to certain specific Conservation measures, notably individual boat quotas, non-transferable and transferable.

The population surveyed was that of all boats of over 12 metres overall length registered as belonging to owners with addresses on the NW Irish Sea coastline. Of 107 boats on the register, 21 had ceased working in the area, 21 owners could not be located and 10 declined to participate, leaving a sample of 55 respondents. These comprised 39 boats, mainly fishing for Nephrops fourteen mainly fishing for Whitefish (Cod, Whiting etc.) mostly with a minority component of *Nephrops* activity, and two boats beam trawling for sole (Table 2). As these last were so very different from all others (Brake Horse Power of 1260 and 2000 respectively, whereas the other 53 boats lay in range 90-700 BHP range), it was felt that they would distort any size-category in which they were included with others and that since they on their own form a small category, their data should only be reported for non-contentious subjects. In some other cases sample size is slightly reduced by inability or reluctance of respondents to answer specific questions. Mean profitability of most boats is given in Table 3 which suggests positive correlation with size and better levels for nephrops fleet than for the whitefish fleet. Some preliminary results of the survey have already been reported (Hillis and Whelan, *in the press*). The skippers' views on the degree to which the main species were overfished are shown in Table 4, showing responses in respect of the five main species plus the next two in importance in 1991. Replies, which omit the very few "don't knows", show that a majority of all respondents ranging from 62 % for "plaice and other flatfish" and for ray/skate to 91 % for cod thought each species to be overfished. From 7 % (for cod) to 36 % (for plaice and for ray/skate) thought the species involved to be about optimally fished, whilst from 2 % to 6 % of respondents were optimistic enough actually to consider each species underfished. Interestingly whitefish respondents were considerably (10-31 %) more pessimistic about whitefish (except for ray/skate) than were nephrops respondents, who in turn - despite 8 % who thought nephrops underfished - were on balance more pessimistic about nephrops than were the whitefish respondents, i.e. (apart from the two sole beamer respondents) each fleet thought its own species in worse condition than those of the other fleets.

Further responses noted by Hillis and Whelan (*op.cit* ) very strongly indicate that the fishermen are under no illusion but that the NW Irish Sea is severely overfished ; 88.9 % of respondents think present policy inadequate to ensure survival of overfished species and 72.7 % think regulations should be enforced more strictly. 72.7 % also responded to the effect that a reduction in total catch for a few years would lead to a permanent increase in future profits, with the reasons given by the dissenting 27.3 % ("I could not survive the few years' reduction" and "It could not be implemented/cheating could not be eliminated") showing that they were not, in fact responding to the question as put, but to an implicit question on practicality of such a course perceived as underlying the question put.

## 4. TIME DISCOUNTING RATES

### *4.1 Money*

To investigate the question of the perceived importance amongst skippers of events and values int he non-immediate future compared to their importance in the immediate future, respondents were asked whether they would prefer to receive IR# 1000 now, or sums of IR# 1050, IR# 1100, IR# 1200, IR# 1500, IR# 2000, IR# 2500, IR# 3000 or IR# 5000 after elapsed periods of 1 year, 2 years and 5 years. This gave ranges within which respondents' time discounting rates could be assumed to lie, and composite values were obtained from means of the three lengths of period arbitrarily weighted by 3,2 and 1 for 1,2 and 5 years to account for a slight decrease in consistency of results observed with increasing period length.

The resultant values were very variable, ranging from under 2 % to over 60 %. Table 5 shows that their distribution related to engine BHP indicated an inverse relationship of values to engine size with a marked bimodality of distribution

of values clearly apparent with the smaller boats, implying a minority element, nearly all with boats of under 400BHP with values of over 40 % in contrast to the majority with values of under 40 %. The distributions by port area show three out of the four areas - those with the greatest quantities of small boats -to exhibit the same bimodal distribution. This is important as it indicates the possibile existence of two rather contrasting attitudes towards fishery management to be catered for in these ports. The mean values by port and by degree of profitability are given in Table 6. Ports A, B and C which are almost completely dedicated to nephrops fishing and have smaller boats than port D, have somewhat higher mean values, but the differences are not significant. As is to be expected, low profitability boats including lossmakers quote higher values than medium profitability boats, but it is of interest to note that the most highly profitable boats also a mean have value slightly higher than those of medium profitability.

### *4.2 Fish*

To test the applicability of the reasonable hypothesis to which a large majority have been shown to assent, to the effect that reduced catches in the immediately future could lead to permanently improved catches later, respondents were presented with the diagram in Figure 4, simplified to indicate two years of reduced profits, followed by two years of profits at their current level followed by profits at a permanently increased level ; they were asked to specify how much of a reduction in catch they would agree to if the permanent increase (B in the diagram) were respectively : 100 % ; 50 % ; 25 % and 10 %. In theory, the 'rational' respondent would calculate the relative value of two income streams :

(a) continuation of present average catch levels

(b) a reduction in periods 1 and 2, followed by a permanent increase of the specified amount in periods 5 to infinity.

The discounted present value of the latter income stream for a fisherman presently catching on average of 100 units is :

$$100 \sum_{i=0}^{i=3} 1/(1+r)^i - (A + A/(1+r)) + (100 + B) \sum_{i=4}^{i=\infty} 1/(1+r)^i$$

On this basis, Table 7 shows the percentage reduction that a 'rational' individual should be willing to make in his catch to obtain the benefit specified. The calculation is carried out for various hypothetical discount rates from 5 per cent to 50 per cent. The last column but one of the table shows the actual average reduction that respondents said they would be willing to make to achieve the gains specified. Thus, when promised a doubling of catch from year 5 on, respondents said they would be willing to reduce catch by 10.8 per cent in periods 1 and 2. If the expected increase were 10 per cent, then the average reduction would only be 1.4 per cent. The last column gives the implicit actual discount rates, obtained by extrapolating rational reduction rates on Gaussian paper to the actual average level. Results were very close, at 52-54 % except for those corresponding to 100 % anticipated eventual increase, which were 60 %. An approximate average value of about 55 % would appear to be applicable.

The actual values of the reductions which respondents said they would be prepared to make have been average for the four levels used in the question and the results appear in Table 6 together with the percentages of people willing to make any reduction at all. Sorted by port, they show port A to have a much greater willingness to reduce than ports B, C and D and a correspondingly higher mean value of percentage reduction contemplated. Sorted by profitability category the contrast is less (i.e. values are less influenced by profitability than by inherent inter-areal differences in outlook). However, as with discount rates for money, the least profitable are the least inclined to short-term sacrifice, with however the moderately profitable more strongly inclined thereto than the highly profitable.

To demonstrate the effect of fishermen's discounting rates, they were applied to an example of predicted recovery levels of a fish stock after an improvement in conservation (nephrops after an increase in mesh size, Anon 1985). The two plots show predicted recovery assuming natural (non-fishery-related) mortality rates of M = 0.2 and M = 0.3 ; the value of this difficult-to-assess parameter is believed to lie in the region of M = 0.26. In both cases an immediate fall in yield of 22.8 % from which recovery is quite rapid leads to a permanent increase above former status quo of 18.4 % assuming M = 0.3 and 4.1 % assuming M = 0.2. The worthwhileness of the conservation operation being dependent on the

costs/losses quantified as the space below zero and down to the line of the plot on the left-hand part of the graph being less than by the benefits, the space above zero and up to the plot line in the right hand area. The use of time discounting reduces values below and above zero to an increasing extent with the passage of time and hence reduces the gains to a greater extent than the losses ; the higher the rate of time discounting the stronger this effect is bound to be.

In addition to zero discount rate, the rates shown are 12 %, approximately real rate of interest in Ireland applicable to normal commercial cost benefit analyses, 25 %, the approximate time discounting rate of fishermen applied to money, and 55 %, the time discounting rate of fishermen implicit in their views on accepting immediate catch reductions to achieve long-term benefits.

Figure 5 and Table 8 demonstrate graphically how apparent gains in conservation are whittled away by application of time discounting due to the downgrading of long-term gains to a much greater extent than short term losses ; using M = 0.2 the commercial 12 % rate reduces 20 year gains at 0 % discount rate by about 80 %, and with M = 0.3, 12 % discounting turns the small gain at 0 % into a loss about 3.5 times greater. At 25 % discount rate the M = 0.2 result is approximately a break-even, while for M = 0.3 it is a loss, as is the case for both values of M at the 55 % fishermens 'fish' discount rate.

## 5. DISCUSSION

The depressing conclusion is that from the fishermen's standpoint, reducing catches now to allow the stock to recover is simply unacceptable, as even with the fishermen's 'money' discount rate, future gains are far enough away to fall below the level of short-term losses. A point that may possibly have some significance is that while the unwilling to contemplate reduction of catches as they feel they cannot afford it, the high profitability boats are slightly less willing to reduce catches, possibly because they feel that for them personally, the problem of dwindling catches is not serious to warrant acceptance of any constraints. Looking over the coast however, there are signs of considerable variation, and it is possible that by investigating different attitudes and their bases some way forward might become apparent. Otherwise the only way to make such stock rehabilitation measures acceptable would appear to involve some form of grant/subsidy program to mitigate the effects of initial losses ; if it were certain that implementation would take place, such mitigation of initial losses would become a sensible subject for commercial style loans from financial institutions. However, many responses displayed confidence with present management measures and the strictness of their enforcement, hence there are indications that such loans could be highly risky. However, if conservation can be made more effective, if funds can be found to mitigate initial losses and if such a recovery programme can be implemented in a cheat-proof fashion, the chances are that the Irish fishery in the north-west Irish Sea, as well as many others, can be made reasonably profitable.

## REFERENCES

**Anon** (1990). Report of the Irish Sea and Bristol Channel Working Group Copenhagen, 5-14 September 1990. ICES, C.M., 1990, Assess : 1.

**Anon** (1991). Report of the Working Group on Nephrops stocks, Aberdeen, 28 Febuary-6 March *ICES, C.M. 1991,* Assess : II.

**Anon** (1992). Report of the Irish Sea and Bristol Channel Working Group, Copenhagen, 3-12 September 1991. *ICES,* C.M. 1992, Assess : 1.

**Hillis J.P.** (1989). Effects of considerations of value fish stock assessments. *ICES,* C.M. 1989, G : 57.

**Hillis J.P. and B.J. Whelan** (1992). The optimisation of profitability in Irish Sea Fisheries. Some Preliminary Results. *Proceedings of 4th conference of EAFE, Salerno April.*

**TABLE 1.**
**FISHING MORTALITY VALUES AT WHICH PROFIT IS MAXIMIMISED AS PERCENTAGE OF CURRENT FISHING MORTALITY VALUES, AND PERCENTAGE BY WHICH MAXIMUM PROFIT EXCEEDS CURRENT PROFIT, 1990–'91.**

Fe1,P1=Fishing mortality, Profit maxmimised where costs /revenue at current F = 23% fixed, 32% variable.

Fe2,P2=Fishing mortality, Profit, maxmimised where costs /revenue at current F = zero fixed, 55% variable

| | Fe1/Fe% | Fe2/Fe% | (Pe1-Pc)/Pc% | (Pe2-Pc)/Pc% |
|---|---|---|---|---|
| Nephrops | 54 | 47 | 27 | 52 |
| Cod | 34 | 29 | 81 | 115 |
| Whiting | 14 | 13 | 121 | 166 |
| Plaice | 49 | 41 | 27 | 67 |
| Sole | 48 | 39 | 21 | 47 |

**TABLE 2.**
**NUMBERS, MEAN ENGINE POWER, CREW SIZE OF VESSEL AND CATCH VALUE IN SAMPLE BY FISHING METHOD AND MEAN VALUES OF MAIN SPECIES IN CATCH.**

| | Fishing type | | | |
|---|---|---|---|---|
| | Nephrops | Whitefish | Sole | Total |
| Number of boats | 39 | 14 | 2 | 55 |
| Mean B.H.P. | 289.8 | 390.5 | 1630.0 | 364.2 |
| Mean crew numbers | 4.7 | 4.0 | 7.5 | 4.6 |
| Mean catch | 86.0 | 103.8 | * | * |
| | | | | Overall |
| ** | | | | |
| Nephrops | 80.0 | 14.4 | 0.0 | 56.5 |
| Sole | 1.3 | 5.3 | 72.2 | 9.9 |
| Plaice*** | 4.6 | 21.9 | 5.6 | 8.8 |
| Cod | 4.8 | 22.9 | 5.6 | 8.5 |
| Whiting | 6.5 | 11.2 | 16.1 | 8.4 |
| Other species | 2.8 | 24.3 | 0.0 | 7.9 |

* Information excluded for confidentiality reasons
** Percentage main species in catch
*** Questions were put in respect of "Plaice and other Flatfish

**TABLE 3.**
**PROFITABILITY OF BOATS, BY SIZE CATEGORY AND GEAR**

| Value of Catch | Value of Catch | Total Costs* | Net Profit* | Profit % of costs |
|---|---|---|---|---|
| Total | 95.6 | 73.1 | 22.5 | 30.8 |
| By length**:<18m | 55.0 | 42.2 | 12.8 | 30.3 |
| 18-24m | 105.2 | 67.3 | 37.9 | 56.3 |
| By gear***:Nephrops | 86.0 | 55.9 | 30.1 | 53.8 |
| Whitefish | 103.7 | 72.6 | 31.1 | 42.5 |

* Profit here includes crew pay based on share system
** Five larger boats in two categories are excluded for confidentiality reasons
*** Two beam trawlers are excluded for confidentiality reason

**TABLE 4.**
**PERCENTAGES OF SKIPPERS WHO BELIEVE MAIN SPECIES TO BE (A) OVERFISHED, (B) ABOUT OPTIMALLY FISHED & (C) UNDERFISHED, BY FISHERY TYPE.**

| | Nephrops(34-39) Vessel | | | Whitefish(13-14) Vessel | | | All Vessel | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | AA | B | C | A | B | C |
| Nephrops | 71 | 21 | 8 | 43 | 57 | 0 | 65 | 30 | 6 |
| Sole* | 61 | 36 | 3 | 92(50) | 8(50) | 0(0) | 69 | 29 | 2 |
| Cod | 87 | 10 | 3 | 100 | 0 | 0 | 91 | 7 | 2 |
| Plaice** | 57 | 40 | 3 | 71 | 29 | 0 | 62 | 36 | 2 |
| Whiting | 75 | 22 | 3 | 85 | 15 | 0 | 76 | 22 | 2 |
| Monk | 63 | 32 | 5 | 77 | 23 | 0 | 66 | 30 | 4 |
| Ray/Skate | 66 | 34 | 0 | 54 | 38 | 8 | 62 | 36 | 2 |

* Includes two sole beam-trawlers, whose views on sole are indicated in brackets.
** Questions were put in respect of "plaice and other flatfish"

**TABLE 5.**
**NUMBERS OF BOATS BY PERCENTAGE VALUE OF TIME DISCOUNTING RATE (MONEY) BY ENGINE BRAKE HORSE POWER CATEGORY.**

| Time discounting rate | Engine B.H.P. of Vessel <200 | 200 -299 | 300 -399 | 400 -499 | 500+ | Total |
|---|---|---|---|---|---|---|
| 60-69 | 1 | 1 | 1 | - | - | 3 |
| 50-59 | 1 | 2 | 2 | - | - | 5 |
| 40-49 | - | 4 | 1 | - | 1 | 6 |
| 30-39 | - | 1 | 2 | 2 | 1 | 6 |
| 20-29 | 2 | 6 | 1 | 3 | 2 | 14 |
| 10-19 | 1 | 2 | 2 | 3 | 2 | 10 |
| 0-9 | 1 | 1 | 2 | 2 | 1 | 7 |
| Total | 6 | 17 | 11 | 10 | 7 | 51 |

**TABLE 6.**
**MEAN TIME DISCOUNTING RATES FOR MONEY AND MEAN ACCEPTANCE PERCENTAGE TWO YEAR REDUCTION IN PROFITS, WITH PERCENTAGE WILLING TO MAKE SUCH A REDUCTION, BY PORT AND PROFITABILITY.**

| | Time discounting rate, money % | | | Acceptable reduction % | | | Boats willing to reduce % |
|---|---|---|---|---|---|---|---|
| | Mn | SD | N | Mn | SD | N | |
| By port: | | | | | | | |
| A | 30.7 | 17.9 | 20 | 9.3 | 8.5 | 20 | 65 |
| B,C | 32.3 | 20.0 | 16 | 1.9 | 5.3 | 18 | 22 |
| D | 22.3 | 12.5 | 15 | 2.5 | 4.3 | 15 | 33 |
| By Profitability Level: | | | | | | | |
| Low* | 31.2 | 18.6 | 15 | 3.5 | 8.5 | 17 | 18 |
| Medium | 27.5 | 17.8 | 20 | 6.0 | 6.5 | 20 | 55 |
| High | 27.7 | 16.2 | 16 | 5.0 | 7.2 | 16 | 50 |
| Total | 28.7 | 17.0 | 51 | 4.9 | 7.3 | 53 | 42 |

* Includes lossmakers

**TABLE 7.**
**THEORETICALLY 'RATIONAL' REDUCTIONS IN CACTH IN YEARS 1 & 2 CLASSIFIED BY LEVEL OF FUTURE INCREASE AND TIME DISCOUNT RATE TOGETHER WITH ACTUAL AVERAGE REDUCTION AGREED, AND IMPLICIT ACTUAL TIME DISCOUNT RATE.**

| Future Increase | Discount Rate 5% | 10% | 20% | 30% | 50% | Actual Average Reduction | Actual Discount Rate % |
|---|---|---|---|---|---|---|---|
| 100% | >100 | >100 | >100 | 50.74 | 15.80 | 10.83 | 60 |
| 50% | >100 | >100 | 54.80 | 25.37 | 7.90 | 7.13 | 52 |
| 25% | >100 | 81.3 | 27.40 | 12.69 | 3.96 | 3.22 | 54 |
| 10% | 79.52 | 32.52 | 10.96 | 5.07 | 1.58 | 1.41 | 52 |

**TABLE 8.**
**EXAMPLES OF NEPHROPS YIELD RECOVERY SUBSEQUENT TO INTRODUCTION OF IMPROVED CONSERVATION OVER 20 YEARS AND IMMEDIATE LOSSES, LONG TERM GAINS AND OVERALL NET GAIN/LOSS CALCULATED USING NO TIME DISCOUNTING (= 0 %), AND DISCOUNT RATES OF 12 %, 25 % AND 55 %.**

| Natural Mortality | Discount Rate | Accumulated Losses | Accumulated Gains | Accumulated Net Gains/Losses |
|---|---|---|---|---|
| 0.2 | 0% | 19.1 | 236.9 | 217.8 |
| | 12% | 18.2 | 60.5 | 42.3 |
| | 25% | 17.2 | 17.1 | (0.1) |
| | 55% | 14.9 | 1.3 | (13.6) |
| 0.3 | 0% | 37.0 | 43.6 | 6.6 |
| | 12% | 32.3 | 8.7 | (23.6) |
| | 25% | 27.6 | 1.6 | (26.0) |
| | 55% | 19.3 | 0.03 | (19.3) |

**FIG. 1.**
**THE IRISH SEA, SHOWING THE NORTH-WESTERN AREA CONTAINING THE IRISH FISHERY UNDER DISCUSSION (BASED ON HOWTH, SKERIES, BALBRIGGAN AND CLOGHERHEAD), THE EXTENT OF THE ICES DIVISION VLLA AND THE NUMBERS OF ADJOINING ICES DIVISIONS.**

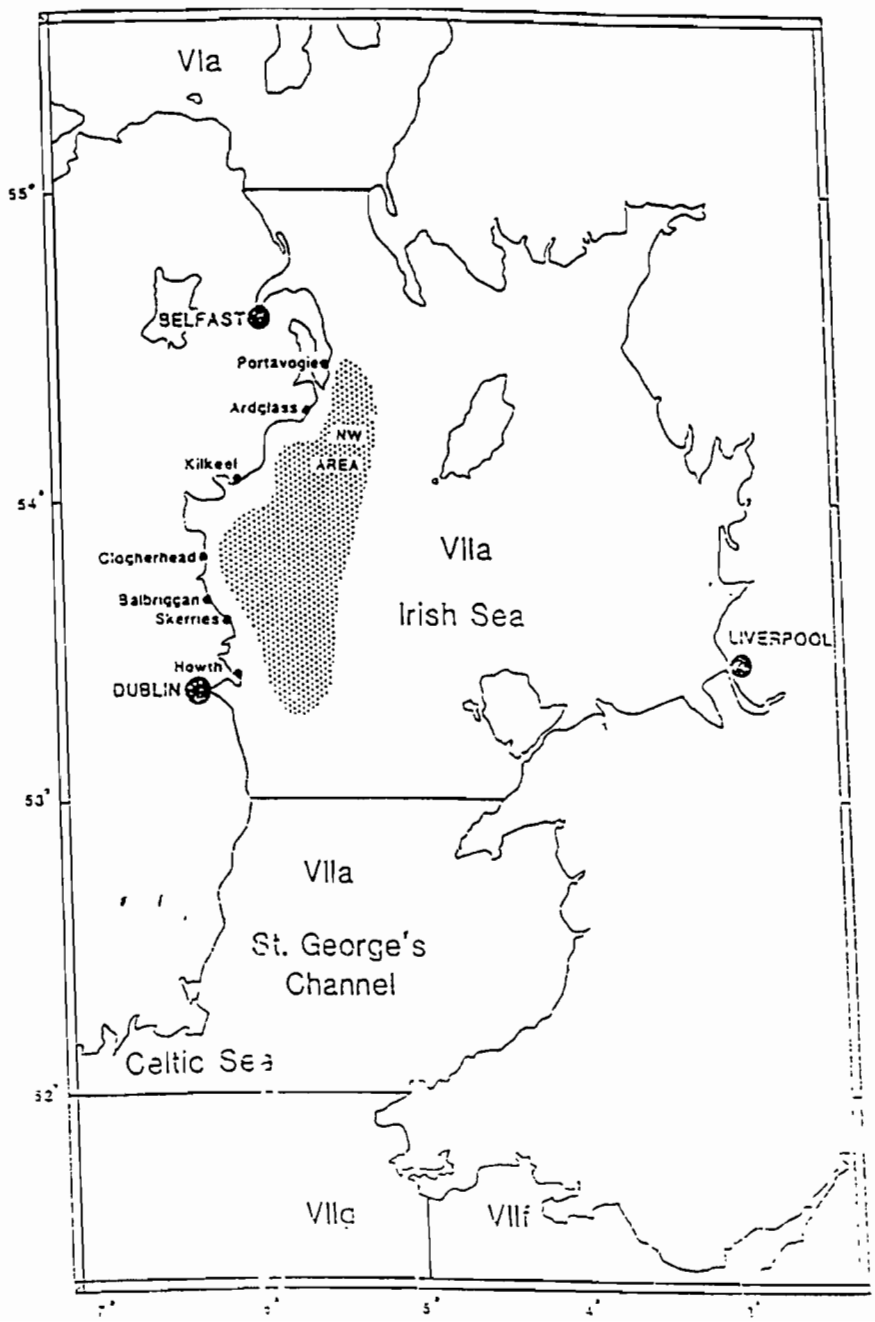


**FIG. 2.**
**CALCULATION OF PROFIT-MAXIMISING VALUES OF F (FE) FROM REVENUE-PER-RECUIT CURVE AND COSTS AT CURRENT F VALUE (F = 1.0). A : ZONE WITHIN WHICH FE MUST LIE (BETWEEN VALUES OF 0 % AND 100 % FOR TOTAL (= VARIABLE) COSTS. B : FE FOR VARIABLE COSTS OF 32 % AND FIXED COSTS OF 23 %. C : FE FOR FLEET SIZE CHANGEABILITY, HENCE TOTAL COSTS = VARIABLE COSTS, @ 55 %.**

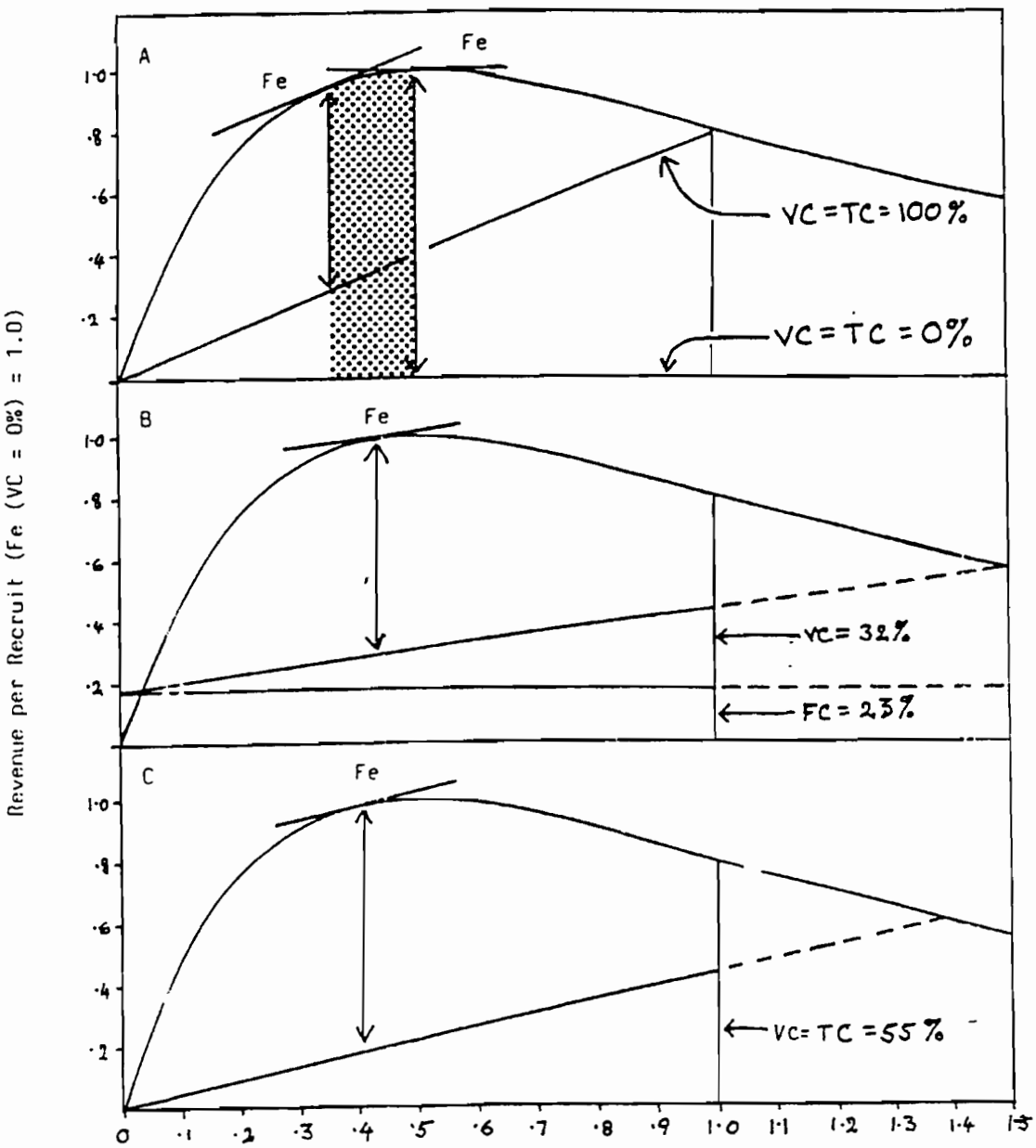


**FIG. 3.**
**STANDARD CURVE OF FISHERY RECOVERED AFTER APPLICATION OF IMPROVED CONSERVATION MEASURES (SOLID LINE) (A) WITH GRADUAL CONSERVATION RECOVERY CURVE, AND SHOWING EFFECTS OF (B) DENSITY DEPENDENT GROWTH, (C) PRICE SIZE RELATIONSHIP, (D) PRICE ELASTICITY AND (E) TIME DISCOUNTING.**

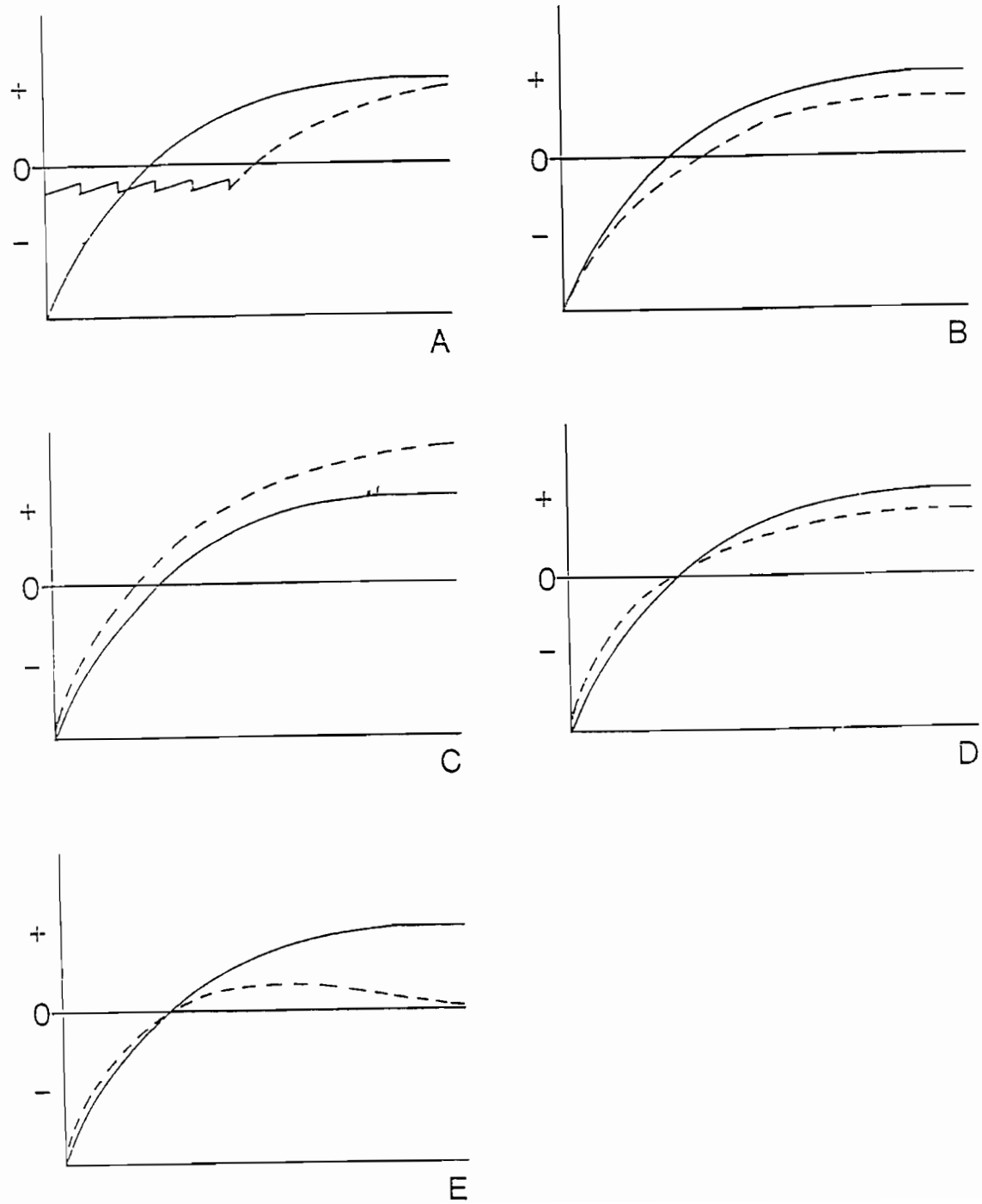


**FIG. 4.**
**DIAGRAM SHOWN TO RESPONDENTS TO ILLUSTRATE THE REDUCTION IN CATH (A) WHICH THEY WOULD BE WILLING TO ACCEPT TO ACHIEVE A PERMANENT INCREASE (B) IN EACH YAR FROM YEAR 5 ON.**

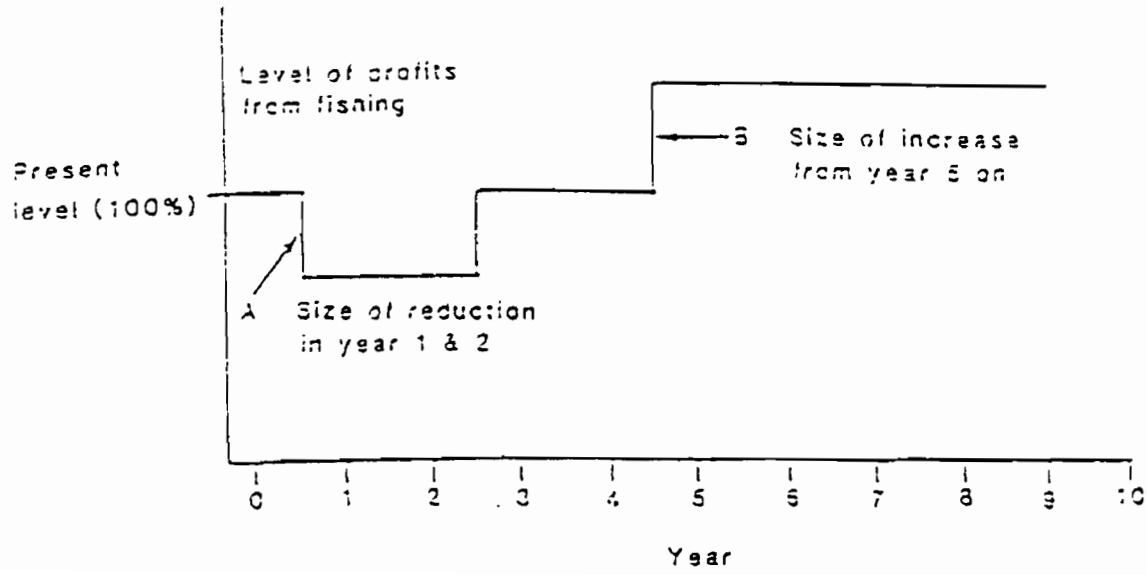
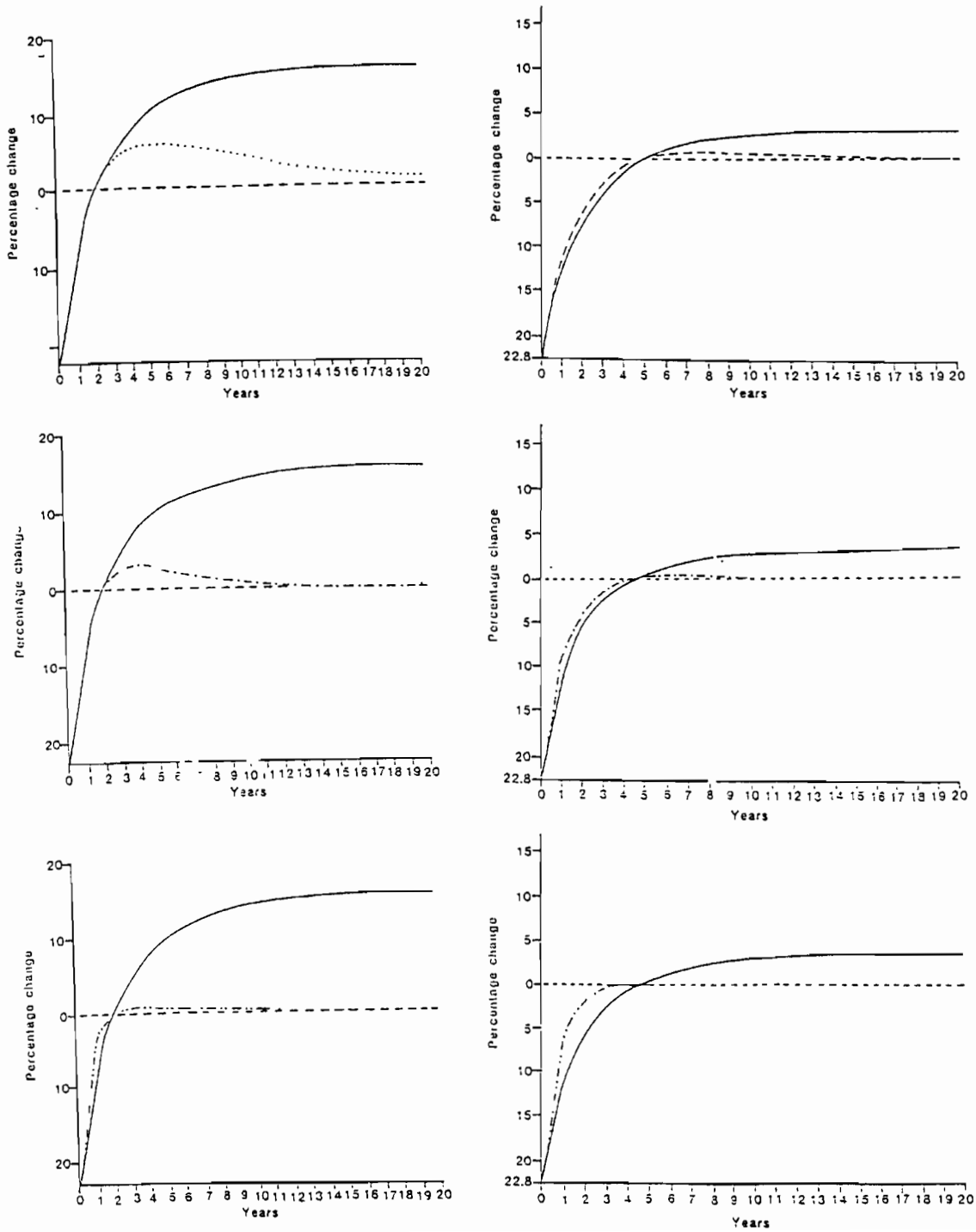


**FIG. 5.**
**EXAMPLES OF RECOVERY OF NEPHROPS YIELD AFTER IMPROVED CONSERVATION FOR M – 0.2 (LEFT) AND M - 03 (RIGHT) SOLID LINE - ZERO TIME DISCOUNT RATE, BROKEN LINES – 12 % (TOP), 25 % (MIDDLE) AND 55 % (BOTTOM).**



# Hysteresis et comportements adaptatifs des pêcheurs artisanaux

**Hélène Rey**

IFREMER 155, rue J.J. Rousseau 92138 Issy les Moulineaux Cedex, France

RÉSUMÉ

*The concept of hysteresis, originally used in the field of physics, has been introduced into social sciences. It helps explaining some of the adjustment gaps in the economy not only as a delay effect between variables, but also as a memory effect of the system. As a new step in our research about economic and social flexibility, adaptative processes in response to "shocks" are questioned here. Flexibility is generally studied as a process of adaptation to changes, for which the memory effects plays an important role. Are considered as "shocks", changes in the system that take place within unexpectable, because unexperienced previously, time frame and variability range. As complex systems are concerned here, the response is highly depending on the initial position of the system at the time of the impulse. Under these conditions, the degree of vulnerability of a fishery facing a shock might depend upon such variables as its life time or the length of the exploitation cycle.*

*The concept of foreseeability of uncertainty is introduced and the main determinants of the expectation ability are discussed. The introduction of effort mobility, depending on entry/exit costs, helps us to consider the succession of factor allocation decisions and thus to improve the deterministic perception of time. The analysis shows that investment decisions depend as much on the actors behaviour as on the steps in the evolution of the fishery or the very impact of the shock, that on the state of stocks, the level of pressure on the stock,...*

## 1. INTRODUCTION

Avec la crise économique la notion d'adaptabilité est devenue une préoccupation majeure des économistes. L'instabilité de la demande et l'allongement de la durée de réversibilité des décisions de production conduisent à une réflexion sur l'introduction de l'incertitude dans le processus de décision et sur la flexibilité des unités de production (Cohendet et Llerena, 1989 Guerrien, 1989 ; Walliser, 1985). Parallèlement les halieutes et les océanographes envisagent les conséquences de l'instabilité de la ressource en montrant le caractère "chaotique" de la dynamique des systèmes

halieutiques (Cury et Roy, 1991). Confrontées à la non applicabilité des modèles traditionnels, les recherches se réorientent vers des modélisations systémiques et pluridisciplinaires qui ne se limitent plus à la dynamique ressource-investissement mais qui tentent d'appréhender l'ensemble des interactions entre les systèmes naturels et les systèmes sociaux. Il en découle un changement de représentation théorique. Contrairement aux modèles déterministes prédateurs-proies, où les variables pertinentes sont définies *a priori*, les modèles systémiques mettent en jeu des interactions multiples où le temps et l'espace sont des variables à la fois spécificatives et explicatives (Chaboud et Fontana, 1991 ; Quensiere, 1992).

Ces approches nécessitent non seulement de nouveaux outils mais aussi de nouveaux concepts. L'intégration des phénomènes de mémoire (Atlan, 1979) et la multidimensionnalité des échelles de temps et d'espace (Lestienne, 1990) font référence à une propriété physique : l'hystérésis. Celle-ci offre un cadre conceptuel de réflexion sur le rôle du temps dans le processus de décision au sein d'un système complexe et ouvert. Il ne s'agit plus seulement d'analyser des effets retard entre variables, mais d'appréhender un effet mémoire du système.

Prolongeant une réflexion sur la flexibilité des unités de pêche artisanale (Dabat *et al.*, 1990 ; Rey, 1991-b), l'objectif de cette communication est d'analyser si la flexibilité est liée à une échelle de temps donnée qui serait le court terme. Le changement d'échelle de temps modifie le niveau d'interrogation : il ne s'agit plus d'aborder la flexibilité du point de vue productif comme la propriété d'un système mais plutôt la flexibilité décisionnelle comme processus d'adaptation dans le cadre d'une transformation du système.

## 2. L'ANALYSE DE LA FLEXIBILITE DES UNITES ARTISANALES RENCONTRE DES LIMITES

(i) Le caractère dispersé des débarquements, la multiplicité des techniques le plus souvent individuelles, la multispécificité des stocks exploités, l'hétérogénéité des niveaux d'activités, font des pêcheries artisanales un objet d'étude qui se caractérise par sa complexité et qui est doté de ce fait d'une propriété d'autorégulation (Atlan, 1979) permettant une adaptation à la variabilité de l'environnement. Ainsi ces pêcheries longtemps considérées comme archaïques, sont à présent étudiées sous l'angle de la flexibilité. Celle-ci induit des spécificités dans les fonctions de production qui relèvent d'une stratégie d'adaptation à un environnement incertain. Sans détailler les formes d'organisation que peut recouvrer cette recherche de flexibilité, on peut noter le caractère familial de la main d'oeuvre, l'existence de formes particulières d'embauche et de rémunération, la pluriactivité et la diversification des techniques et des espèces cibles (Rey, 1991-b). Fréquemment, la flexibilité est assimilée à la diversification de l'appareil productif. Ainsi en Languedoc-Roussillon 13 % seulement des unités de pêche aux petits métiers sont spécialisées tandis que certains pêcheurs pratiquent jusqu'à 15 techniques différentes au cours de l'année. De même 40 % des unités ont une activité complémentaire extérieure au secteur halieutique (Rey, 1989). D'un point de vue dynamique cependant, une fois définie une composition dite flexible des facteurs de production, on observe une stabilité du mode de production dans le temps et dans l'espace. Ainsi 76 % des pêcheurs petits métiers de Méditerranée n'ont pas modifié leur stratégie depuis qu'ils ont débuté leur activité et 72 % n'ont jamais changé de zone de pêche (Rey, 1989).

(ii) Le manque de mobilité constatée à moyen terme ne signifie pas pour autant absence d'innovation. Au contraire la pratique de la pêche s'effectue dans un contexte d'innovation technique continue. L'absence de changement concerne la nature des métiers pratiqués, elle n'exclut pas des modifications tactiques ou technologiques au sein de ces métiers. De même lorsque nous parlons de stabilité des zones de pêche nous faisons référence aux territoires des juridictions prud'homales de Méditerranée. S'il est vrai que peu de pêcheurs dépassent ces limites, cela ne doit pas obérer le fait qu'à l'intérieur de ces espaces, leurs terrains de pêche sont très diversifiés (hormis pour les pêcheries fixes). Dans de nombreuses pêcheries l'exploitation est structurée par les migrations. Cependant là encore il convient de caractériser ces déplacements selon qu'ils s'accompagnent ou non d'une stabilité des lieux concernés. Dans le Delta central du Niger, la réduction des superficies en eaux consécutive à la sécheresse s'est traduite par un déplacement des terrains de pêche qui a conduit certains pêcheurs à s'installer une partie de l'année, dans des campements proches de leurs agglomérations d'origine. Dans d'autres cas, on observe des migrations traditionnelles liées aux comportements de certaines espèces. Là encore, on note une stabilité des zones d'accueil : les campements, dont certains ont tendance à devenir permanents, sont organisés selon des affinités villageoises ou familiales souvent stables d'une année sur l'autre. La variabilité de la crue se traduit plutôt par un ajustement du temps passé dans les campements que par une modification des sites. De même en Côte d'Ivoire Delaunay (1990) observe des flux réguliers et organisés de pêcheurs ghanéens. Dans sa typologie des migrations de pêcheurs en Afrique de l'Ouest, Diaw (1992) montre qu'il s'agit pour la plupart de mouvements régulés.

## 3. L'APPROCHE DE LA FLEXIBILITE COMME PROCESSUS

(i) Les stratégies de flexibilité précédemment décrites relèvent de l'adaptation à une variabilité intra ou inter-annuelle de la ressource dans le cadre d'horizons temporels et d'amplitudes de variation attendus. Cette notion de variation attendue, bien qu'incertaine, nous oblige à nous interroger sur la prévisibilité de l'incertitude. Le concept de risque fait référence à des situations aléatoires mais dont la répétition permet des probabilités conditionnelles *a priori*. Par opposition toute situation où l'on ne dispose pas de statistiques relève de l'incertitude. Selon les cas on distinguera la flexibilité statique et dynamique (Cohendet et Llerena, 1990). La flexibilité statique relève d'une stratégie de diversification qui se traduit par des surcapacités productives mais qui permet une adaptation au risque. La flexibilité dynamique se définit comme la capacité de réagir continûment dans le temps aux incertitudes liées à l'environnement. Cette flexibilité repose sur les notions de délais de réaction (Cohendet et Llerena, 1990) et de capacité d'anticipation.

(ii) Face à l'incertitude, la capacité d'anticipation de l'individu est commandée par sa faculté de mémorisation. On se réfère ici à la notion de flèche du temps qui conduit à une perception du présent comme prolongement du passé et comme racine du futur : *"si les événements accomplis ont laissé des traces, il est vraisemblable d'imaginer que les événements à venir ont leur racine"* (Balzac). Une perception de l'incertitude peut être proposée selon le cadre introduit par Jankelevitch (1974) à propos de l'irréversibilité. Cet auteur distingue en effet quatre niveaux d'approche selon que la mémorisation ou non du passé est associée à une anticipation prospective ou non du futur. La capacité d'anticipation de l'incertitude ne peut intervenir que dans le cas d'une conscience à la fois rétrospective et prospective où il y a pressentiment intuitif du futur en fonction du ressentiment du passé (Jankelevitch, 1974). La théorie économique distingue deux mécanismes. Dans un contexte de stabilité, les anticipations extrapolatives appréhendent l'avenir par une simple projection des tendances passées. Les anticipations adaptatives sont quant à elles censées résoudre le problème de l'appréhension du futur dans un contexte instable. Elles relèvent d'un processus procédural qui raisonne sur une décomposition séquentielle de la décision. L'intégration des observations présentes permet une révision continue de ces anticipations. Dans tous les cas cependant on raisonne hors rupture majeure de l'évolution économique (Malinvaud, 1991). La flexibilité, même dynamique, est conditionnée par la perception des limites du système en fonction de la mémorisation de ses transformations passées et ne peut donc permettre une adaptation instantanée à des chocs.

(iii) La flexibilité se définit donc par rapport à une période (périodisation et historicité liée à la faculté de mémorisation) et par rapport à un cadre spatial (territorialisation liée au caractère déterminant du milieu et aux contraintes d'accessibilité (réglementation, savoir faire...)). Au delà de ces limites, (Cury (1991) parle de frontières) il se produit un changement de dimension du système qui est assimilable à un choc. Le processus d'adaptation doit alors faire intervenir d'autres paramètres et conduit, selon les principes de la dynamique des systèmes vivants, à la transformation du système (Atlan, 1979). Il y a une succession de systèmes dont les paramètres se transforment dans le temps selon les contraintes du milieu.

(iv) Notre définition des chocs fait référence à des faits de nature diverse, tant écologique qu'économique, aussi bien positifs (nouvelles opportunités) que négatifs. Leur origine peut être endogène ou exogène puisque le système pêche est appréhendé ici comme un système ouvert. Le dénominateur commun à tous ces facteurs est que leur impact suffise à engendrer une transformation du système. Cependant, s'agissant de systèmes complexes, les chocs ont des origines multiples. Ainsi la crise de la pêcherie péruvienne en 1973 (la production passe de 13 millions de tonnes en 1970 à 3,8 millions en 1974) est généralement attribuée à un changement hydrologique. Chaboud (1991) montre qu'elle s'explique aussi par des décisions de politique sectorielle. De même, les difficultés rencontrées dans le Delta central du Niger ne sont qu'en partie dues à la sécheresse de 1973. Le changement de réglementation qui attribue à l'Etat en 1963 une souveraineté sur les eaux jusqu'alors régulées de façon coutumière, a aussi eut un rôle perturbateur. De même la construction de barrages sur le fleuve Niger s'est traduite par une réduction des prises évaluée à 5000 tonnes, soit 10 % des captures annuelles (Lae, 1992). Par ailleurs certains chocs génèrent des processus d'autorégulation. Ainsi les phénomènes de malaïgue dans les étangs languedociens se traduisent par d'importantes mortalités et un arrêt temporaire de la pêche. Cependant les comportements grégaires des poissons quelques jours avant permettent des pêches miraculeuses. De même lors du réchauffement de l'upwelling péruvien, on a observé dans un premier temps des prises importantes (170 000 tonnes journalières) liées à des rassemblements d'anchois près des côtes (Chaboud, 1991). Dans ces cas, la possibilité de compenser les pertes futures dépend de la capacité de pêche des unités. On peut supposer que celle-ci, bien que difficile à définir, soit proportionnelle à l'investissement. En l'absence de contingentement, ces pics conjoncturels de capture bénéficient donc aux unités qui ont le plus investi et leur permet une réduction partielle des coûts de sortie de la pêcherie.

(v) Face à un choc, le concept d'adaptation doit être appréhendé de façon particulière. S'agissant de systèmes complexes, il est montré que les réponses dépendent de la position du système au moment de l'impulsion (Cury, 1991). La vulnérabilité d'une pêcherie pourrait donc être fonction de sa durée d'existence et de la phase du cycle d'exploitation auquel elle est soumise. La flexibilité n'offrant pas un cadre suffisant pour appréhender les stratégies d'adaptation à des chocs il convient de rechercher un cadre d'approche plus approprié.

## 4. TRANSFERABILITE DU CONCEPT D'HYSTERESIS A L'HALIEUTIQUE

(i) A l'origine le concept d'hystérésis est utilisé pour l'étude des phénomènes de ferromagnétisme (Bertin, Faroux et Renault, 1984). Après une aimantation portée à saturation, on observe des écarts des courbes de désaimantation qui définissent une aimantation résiduelle : le système ne revient pas à son point de départ et ne retrouve sa valeur originelle qu'après un certain délai. L'importance du phénomène est fonction de la vitesse de variation.

(ii) Dans le domaine des sciences sociales, la transposition de ce concept a permis d'éclairer les écarts d'ajustement observés dans les relations entre l'emploi et les salaires (Cotis et Mihoubi, 1990 ; Le Page, 1991) et entre le taux de change et le solde de la balance commerciale (Ducos et Lecointe, 1991). Dans les deux cas il s'agissait d'expliquer la persistance d'un déséquilibre. En effet au plan théorique, l'hystérésis réfute le postulat classique d'unicité et de stabilité de l'équilibre : Le Page (1991) parle d'analyse des équilibres fragiles. Le concept d'équilibre est au coeur de la science économique. Dans un premier temps, il est abordé de façon statique : on parlera successivement d'équilibre (Walras), d'équilibre général (Marshall), d'équilibre de sous emploi (Keynes). Dans tous les cas il s'agit de systèmes fermés, souvent bidimensionnels. Par la suite, l'introduction d'une dimension temporelle donne naissance au concept d'équilibre intertemporel appréhendé comme une suite d'équilibres temporaires. Là encore cependant, l'hypothèse implicite sous jacente est celle d'une régularité des phénomènes (Malinvaud, 1991).

(iii) L'hypothèse de phénomènes d'hystérésis rompt avec les modèles traditionnels de type récursif, pour lesquels chaque équilibre temporaire dépend des valeurs des équilibres temporaires précédents. Elle ne remet pas cependant totalement en cause le concept d'équilibre mais montre qu'il existe de multiples équilibres et qu'ils dépendent de l'ampleur de la variation, c'est à dire du chemin temporel qui mène à l'équilibre. L'hystérésis met en évidence une dérive qui s'incrémente à chaque période et qui tient compte de phénomènes dont les effets perdurent alors que leur cause originelle est dissipée (Amable *et al.*, 1990 ; Cotis et Mihoubi, 1990). Analyser le processus d'adaptation d'un système complexe et ouvert revient à étudier la dynamique d'un système par rapport à un environnement qui est lui-même en évolution. Selon les auteurs, de multiples images sont évoquées. Cury (1991) fait référence à une pièce de théâtre où le jeu des acteurs et les décors se modifieraient au fil des représentations. Le Page (1991) cite l'exemple d'une balle sur une surface accidentée développé par Blanchard et Summers (1988). Le point d'équilibre dépend de la forme de la surface, avec deux situations extrêmes : s'il s'agit d'un bol, il n'existe qu'un point d'équilibre ; si au contraire la surface est extrêmement plate, la position dépend du choc imprimé à la balle.

(iv) Tester l'hypothèse d'un effet d'hystérésis dans le domaine des systèmes halieutiques, revient à s'interroger sur l'existence d'une dérive temporelle des pêcheries qui résulterait de modifications structurelles liées aux chocs reçus. L'étude de la dynamique de l'investissement paraît être une entrée pertinente. Les observations témoignent généralement d'un trend orienté à la hausse. Il s'agit donc d'affiner l'analyse en envisageant comment cette augmentation peut être fonction des chocs reçus et de la situation de la pêcherie au moment où ils interviennent. Pour ce faire, nous envisagerons tout d'abord les délais de réaction aux chocs au niveau des unités, puis, en fonction des différentes phases d'investissement, les mécanismes de réaction du système dans son ensemble.

## 5. TYPOLOGIE DES DELAIS DE REACTION AUX CHOCS DANS LES SYSTEMES HALIEUTIQUES ET MOBILITE DE L'EFFORT

(i) L'introduction du temps dans les modèles bio-économiques ne s'effectue que par la prise en compte d'un taux d'actualisation qui pondère les valeurs futures du profit. On retrouve ici la même limite que dans les modèles économétriques où le temps est appréhendé d'un coup jusqu'à l'horizon temporel (Malinvaud, 1991). Il s'agit donc d'une

perception déterministe du temps où l'enchaînement des conséquences des décisions d'allocation des facteurs de production n'est pas considéré (Gilly, 1989).

(ii) La mobilité de l'effort est supposée immédiate, parce que gouvernée par le principe de maximisation du profit sous tendu par la rationalité néo-classique des modèles. Le mécanisme de stabilisation est conditionné par cette hypothèse de mobilité totale. Or la prise en compte des coûts d'entrée et de sortie peut expliquer des écarts d'ajustement. Une mesure de la mobilité peut être proposée en fonction de l'amortissement ou non des coûts d'entrée et de la décomposition des alternatives de sortie selon des critères spatiaux-sectoriels. En effet, les possibilités de reconversion externe à la sphère halieutique sont limitées par la spécificité de l'appareil productif qui tend à privilégier une mobilité intrasectorielle dépendant du marché d'occasion. Cependant, pour les pêcheries artisanales, des degrés de mobilité partielle peuvent être introduits avec le redéploiement d'une partie de l'effort sur d'autres pêcheries, ou avec la réaffectation du facteur travail au profit d'une activité complémentaire.

(iii) Le centrage de l'analyse ici sur le concept de coût d'entrée et de sortie relève de notre volonté de nous situer dans un cadre formel en fonction du temps et de l'histoire de la pêcherie Néanmoins il convient, en raison de la faiblesse des investissements initiaux, de relativiser ce concept pour certaines composantes de la pêche artisanale. L'hétérogénéïté des situations ne permet pas une définition universelle de la pêche artisanale. Sa délimitation est contingente à des situations, des espaces, voire des périodes. Elle se définit généralement de façon négative par rapport à la pêche industrielle (Chauveau et Weber, 1989). En France la discrimination s'effectue à partir d'une taille maximum fixée à 25 m. Sous le vocable pêche artisanale sont donc regroupés par exemple les pêcheurs artisans boulonnais dotés de bateaux de 20 à 25 m équipés de matériel de navigation perfectionné et les petits métiers méditerranéens dont l'actif brut est pour les trois quarts d'entre eux inférieur à 50000 F. De même le raisonnement en terme d'optimalité bute sur la pluralité des finalités poursuivies par les unités de pêche artisanales, notamment lorsqu'elles sont familiales. Parmi ces objectifs on relève la valorisation du statut social dans la communauté, la recherche d'autonomie, la minimisation du temps de travail, le désir d'un maintien dans la communauté et la région d'origine. (Rey, 1991-a).

(iv) Le croisement des degrés de mobilité dans le temps et dans l'espace peut être synthétisé par un tableau à double entrée (cf. tableau 1). Il existe un éventail de situations entre la mobilité et la fixité totale de l'effort qui correspondent à la possibilité de sortie immédiate ou au contraire à une obligation de maintien dans la pêcherie. Lorsque les coûts d'entrée ont été amortis, la mobilité est décomposable en fonction des opportunités. Ainsi on parlera de mobilité d'innovation lorsque l'unité de pêche recherche des opportunités d'exploitation de nouvelles espèces ou de nouvelles zones de pêche tout en continuant à titre complémentaire l'exploitation initiale. Cette continuité peut avoir pour objectif de maintenir des droits historiques, de profiter d'acquis technologiques ou de savoir faire ou résulter de l'impossibilité de réaliser les immobilisations correspondantes. Inversement la contrainte peut venir de ce que les alternatives de reconversion ne permettent pas à elles seules la rentabilisation des facteurs de production, ou, s'il s'agit d'activités nouvelles, du désir de minimiser les risques avec une autre activité maîtrisée. De la même façon la mobilité partielle peut concerner le facteur travail. On parlera alors de mobilité de diversification. A l'extrême la fixité de patrimoine correspond à la situation courante en zone défavorisée ou en situation de crise, où la valeur de revente des investissements se détériore. L'absence de possibilité de reprise oblige alors au maintien de l'activité même dans des conditions de rentabilité défavorables.

Le non amortissement des coûts d'entrée sous entend l'existence de coûts de sortie. Plusieurs possibilités peuvent aussi être distinguées. S'il existe des possibilités de reconversion, la sortie peut intervenir après un délai qui réduit les coûts de sortie. La durée de celui-ci résulte des arbitrages entre les pertes relatives attendues et la rentabilité escomptée des opportunités envisagées. Comme précédemment les alternatives peuvent être partielles et ne concerner que le capital ou le travail. Ainsi la mobilité partielle spatiale ou spécifique correspond au cas d'exploitation partagée entre plusieurs stocks ou plusieurs zones de pêche. Elle suppose par rapport à la mobilité d'innovation de pouvoir s'effectuer sans transformation importante des facteurs de production, ceux-ci n'étant pas amortis. La mobilité partielle temporaire correspond à une réaffectation d'une partie du travail à d'autres activités sans que, à la différence de la mobilité de diversification, cela remette en cause la continuité de l'exploitation initiale.

## 6. CONSEQUENCES SUR LA DYNAMIQUE DE L'INVESTISSEMENT

(i) En premier lieu, il convient de préciser le processus d'investissement. Les facteurs déterminants sont multiples mais les résultats antérieurs et l'accès au financement sont bien évidemment déterminants. En Languedoc Roussillon le niveau

d'investissement varie selon les zones et les types de pêche. Il est corrélé avec le mode de financement et l'existence d'un travail extérieur de l'épouse qui apparaît comme la possibilité d'une caution bancaire et d'un revenu minimum fixe (Rey, 1989).

(ii) L'analyse des comportements des pêcheurs en matière d'investissement nous conduit à distinguer plusieurs situations correspondant à des rationalités différentes. Nous retiendrons quatre catégories principales : des investissements de productivité, de modernisation ou d'opportunité, de flexibilité et de mimétisme (cf. tableau 2).

(1) Les investissements de productivité permettent d'adapter les conditions de rentabilité à l'évolution technologique ou économique du secteur. De ce fait, ils relèvent sauf cas particuliers de l'autofinancement ou du financement bancaire.

(2) Les investissements de flexibilité offrent une souplesse de réponse à des variations anticipables (cf. infra). Ces investissements sont donc dimensionnés en fonction des frontières maximales préssenties du système. Les analyses économiques s'accordent à montrer qu'ils se traduisent par des surcoûts (Cohendet et Llerena, 1990 ; Boussard, 1990). Une mesure de ces investissements peut être tentée en confrontant le matériel de pêche possédé avec le niveau habituellement utilisé et les besoins de rotation. Ainsi en Languedoc-Roussillon les pêcheurs calent en moyenne seulement 27 % de leurs capéchades, 30 % de leurs filets maillants et 32 % de leurs trémails (Rey, 1989).

(3) L'accès aux investissements de modernisation ou d'opportunité dépend fréquemment de l'attribution de crédits ou de subventions et relève souvent des acteurs leaders. Ceux-ci se démarquent souvent par un meilleur savoir faire, lié à une tradition de la pratique de la pêche ou à une plus grande aptitude. Dans certains cas ils peuvent avoir des droits particuliers sur la ressource. Il en est ainsi des maîtres des eaux dans le Delta central du Niger qui reçoivent un tiers des prises des pêcheurs allochtones. Les leaders ont une influence sur l'attribution des subventions voire sur l'orientation des mesures de réglementation édictées par les pouvoirs publics. Moricet et Reveret (1989) pour le Canada et Feral et Berger (1987) en Méditerranée mettent en évidence de tels phénomènes de lobbying où les pêcheurs dynamiques deviennent les interlocuteurs privilégiés de la puissance publique dont ils inspirent la politique d'intervention souvent à leur bénéfice. De même les règles de fonctionnement des prud'homies témoignent d'un corporatisme lui aussi inducteur de discriminations : ainsi dans les étangs languedociens, il faut disposer d'un équipement minimum pour postuler à l'attribution des postes de pêche fixe (Feral, 1976). L'existence de leaders génère une croissance de l'investissement qui se diffuse par mimétisme.

(4) Les investissements de mimétisme se font généralement à la suite de bonnes pêches. Comparativement au niveau d'équipement moyen, ils relèvent jusqu'à un certain seuil d'une rationalité ostentatoire. Par la suite lorsque leur diffusion à l'ensemble du secteur engendre un différentiel de compétitivité, ils deviennent des investissements de productivité pour les unités qui les réalisent tardivement. Les décisions d'investissement de mimétisme étant sensibles au concept de "bonne pêche", c'est moins le niveau global des résultats passés qui est déterminant que sa dispersion dans le temps. Ainsi en Languedoc-Roussillon les achats de matériel de pêche ne sont pas programmés en fonction des besoins mais des résultats (Rey, 1989).

(iii) L'hypothèse d'existence d'un effet d'hystérésis suppose que le taux de croissance de l'investissement est influencé par les successions de chocs et la nature des réactions d'adaptation qu'ils ont entraînées. L'intégration des phénomènes de lobbying et de mimétisme conduit à une approche de type insiders-outsiders où le niveau d'investissement qui est directeur est déterminé par les acteurs qui sont au coeur du système. Il se diffuse ensuite par mimétisme selon un rythme aléatoire lié à la réalisation de "bonnes pêches". La figure n° 1 tente de synthétiser ce processus. On observe la succession de phases d'investissement de modernisation et de productivité chez le groupe des leaders et de mimétisme et productivité pour les non leaders. La diffusion par mimétisme étant aléatoire, les paliers d'investissement et la durée de diffusion (symbolisée par les flèches entre les groupes sur le schéma) sont irréguliers.

Que se passe t-il lors d'un choc ? En cas de persistance d'une crise le nombre d'unités qui va quitter la pêcherie sera fonction des différentiels de coût marginaux, donc des phases d'investissement. Le moment où intervient la crise est déterminant des réactions. Quatre éventualités (cas n° 1 à n° 4 sur la figure) sont possibles quant à l'articulation des situations des deux groupes, leaders et non leaders (cf fig. 1). Selon les phases d'investissement, c'est à dire selon l'histoire de la pêcherie au moment où intervient la crise, les unités relèveront d'une des catégories de mobilité de l'effort et auront donc des réponses différenciées en terme de délais et de degré. Hormis si la crise paraît sans issue (cas où les leaders vont profiter de leur situation pour négocier au mieux leurs conditions de départ), on peut supposer que les acteurs leaders auront une propension plus forte à se maintenir dans la pêcherie (stratégie de confortation de leur avantage liée à leur position d'insiders). L'effort sera donc globalement réduit mais son niveau moyen unitaire s'élèvera du fait du

maintien des leaders. La dynamique des investissements de mimétisme se fondant sur une différenciation de statut l'accroissement du niveau moyen de l'effort unitaire lié à l'augmentation du poids relatif des leaders va accélérer la croissance de l'investissement, et ceci d'autant plus s'il y a attribution de subventions compensatoires, celles-ci étant généralement octroyées proportionnellement au niveau d'investissement.

## 7. CONCLUSION

L'analyse de ces différents mécanismes montre que la décision d'investissement relève autant des comportements d'acteurs, des phases d'évolution de la pêcherie et de la date d'apparition d'un choc que de l'état des stocks et du taux de prélèvement de la ressource. Les quelques éléments développés ici semblent attester d'un effet d'hystérésis. Néanmoins ils reposent pour l'instant sur de nombreuses hypothèses simplificatrices et n'ont pour prétention que d'offrir des orientations de recherche. Ainsi il conviendrait d'établir un modèle pour tester ces hypothèses. De même une exploration systématique du champ des comportements possibles est nécessaire à la généralisation des mécanismes présentés ici qui se basent sur des pêcheries particulières (Méditerranée, Delta central du Niger). Ainsi si les leaders quittent la pêcherie de façon préférentielle (Gates, 1990), les conséquences des chocs seront différentes. Par ailleurs, s'agissant de systèmes complexes, l'attention devra être portée sur les interactions en introduisant par exemple des différentiels d'effets selon les cadres réglementaires et l'impact des processus de substitution capital-travail.

## REFERENCES

**Amable B., J. Henry, F. Lordon et R. Topol** (1990). Une tentative d'élucidation d'un concept flou : l'hystérésis. La méthodologie de l'économie théorique et appliquée aujourd'hui. *Colloque annuel de l'AFSE* 1990. Nathan, Paris : 135-146

**Atlan H.** *Entre le cristal et la fumée ; Essai sur l'organisation du vivant.* Seuil, Paris, 288 p.

**Bertin M., J.P. Faroux et J. Renault** (1984). *Cours de physique ; Electromagnétisme IV : Milieux diélectriques et milieux aimantés.* Dunod, Paris, 261 p.

**Blanchard et Summers** (1988). Beyond the natural rate hypothesis. In *American Economic Review,* papers and proceedings, vol **78** : 182-187

**Boussard J.M.** (1990). Les stratégies anti-risque des producteurs limitent-elles leur productivité ? In *Sém. Int. L'avenir de l'agriculture des pays du Sahel ;* enseignements et perspectives économiques. Montpellier 12-14 septembre 1990, 101-110.

**Chaboud C.** (1991). La pêcherie d'anchois du Pérou. la crise de 1972-73 ; une étude de cas. Communication au séminaire *"recherches interdisciplinaires et gestion des pêcheries".* CIEO Casablanca 27 mai -14 juin 1991, 179-198.

**Chaboud C. et A. Fontana** (1991). L'approche système dans les pêches. Communication au séminaire *"recherches interdisciplinaires et gestion des pêcheries".* CIEO Casablanca 27 mai - 14 juin 1991, 111-146.

**Chauveau J.P. et J. Weber** (1989). L'apport des synthèses régionales. Perspectives historiques et institutionnelles sur la recherche interdisciplinaire dans le domaine des pêches artisanales. In symposium international IFREMER/ORSTOM *"la recherche face à la pêche artisanale"* Montpellier du 3 au 7 juillet 1989, Durand J.R., Lemoalle J ; et Weber J. Eds. Sci. Collection colloques et séminaires ORSTOM Ed. Tome 1 : 51-62.

**Cohendet P. et P. Llerena** (1989). Flexibilités, risque et incertitude dans la théorie de la firme : un survey. In *Flexibilité, information et décision* Cohendet P. et Llerena P. Eds Sci. Economica, Paris : 7-71

**Cohendet P. et P. Llerena** (1990). Nature de l'information, évaluation et organisation de l'entreprise. *Revue d'Economie d'Industrielle* n° **51** : 141-165

**Cotis J.P. et F. Mihoubi** (1990). L'hystérésis du taux de chomage en Europe. *Economie et Prévision* n° **92-93** : 127 -143

**Cury P. et C. Roy** (1991). *Pêcheries ouest africaines ; Variabilité, instabilité et changement.* ORSTOM Ed., 525 p.

**Cury P.** (1991). Une approche théorique de l'impact de l'environnement sur la pêche. In Cury P. et Roy C. *Pêcheries ouest africaines ; Variabilité, instabilité et changement.* ORSTOM Ed. : 368-376.

**Dabat M.H., M. Garrabé et H. Rey** (1990). Risk and internal and external flexibility in fishing and aquatic farming activities. Communication à la deuxième rencontre de l'Association Européenne des Economistes des Pêches. Lisbonne 5-7 mars 1990, in *Pesca e Navegaçäo* n° **101-102** : 22-25.

**Delaunay K.** (1990). Les pêcheurs ghanéens Fanti et Ewe sur le littoral ivoirien ; problématique de recherche. Table ronde ORSTOM Montpellier 7 Juin 1990 multigr. 17 p.

**Diaw C.** (1992). Aspects sociologiques des migrations de pêcheurs. Communication au colloque interrégional : *Les pêcheries artisanales en Afrique de l'Ouest.* Centre National de Recherche Océanographiques et des pêches de Nouadhibou. Mauritanie. 25-30 Avril 1992, 15 p.

**Ducos P. et F. Lecointe** (1991). Les apports de l'économie industrielle à l'analyse des effets d'hystérésis sur le commerce extérieur américain. *Problèmes Economiques* N° **2243** : 11-18.

**Féral F.** (1976). *La prud'homie des pêcheurs de Palavas.* Thèse de Droit, Univ. Montpellier 1, Novembre 1976.

**Féral F. et A. Berger** (1987). Problématique de l'interventionnisme de la puissance publique dans le domaine des ressources marines vivantes : les secteurs du poisson bleu et de l'aquaculture nouvelle en Méditerranée. In *Acuicultura y Economia* Esteve (R.), Narvaez (A.), Ruiz G. y Ruiz A. Eds. Sci. Ministerio de Agricultura, Pesca y Alimentacion. Universidad de Malaga Departamento de economia applicada : 451-488.

**Gates J.M.** (1990). - La régulation du taux d'exploitation dans les pêcheries commerciales. In *L'Homme et les ressources halieutiques ; essai sur l'usage d'une ressource renouvelable. Troadec J.P. Ed. Sci. IFREMER Ed, Paris : 498-524.*

**Gilly B.** (1989). Les modèles bio-économiques en halieutique : démarche et limites. *Cah. Sci. Hum. ORSTOM* 25 (**1-2**) : 23-33.

**Guerrien B.** (1989). *Concurrence, flexibilité et stabilité ; des fondements théoriques de la notion de flexibilité.* Economica, Paris, 303 p.

**Jankéléwich V.** (1974). *L'irréversibilité et la nostalgie.* Flammarion, Paris, Coll. Champ, 392 p.

**Laë R.** (1992). Modification of natural systems by man ; the impact of dams on small-scale fisheries of the central delta of the Niger. Soumis à *Aquatic living resources,* 14 p. + figures

**Lepage J.M.** (1991). L'hypothèse d'hystérésis dans la théorie économique du chômage : pertinence et implications. *Rev. Econ. Pol. 101* (**2**) : 281-299

**Lestienne R.** (1990). *Les fils du temps ; causalité, entropie, devenir.* Les presses du CNRS, Paris, 291 p.

**Malinvaud E.** (1991). *Voies de la recherche macroéconomique.* Ed. Odile Jacob, Paris, 507 p.

**Moricet M. et J.P. Rèveret.** Gestion par quotas individuels dans l'agriculture et la pêche ; une analyse critique. *Cah. Sci. Hum. ORSTOM* 25 (**1-2**) : 35-47.

**Quensière J.** (1992). Application de l'approche système à l'étude des pêcheries artisanales : l'exemple du projet d'études halieutiques du Delta central du Niger. Communication au colloque interrégional : *Les pêcheries artisanales en Afrique de l'Ouest.* Centre National de Recherche Océanographiques et des pêches de Nouadhibou. Mauritanie. 25-30 Avril 1992, 18 p.

**Rey H.** (1989). Etude économique de la pêche aux petits métiers en Languedoc-Roussillon. Rapport Centre d'Etudes de Projets, Montpellier, 211 p.

**Rey H.** (1991a). Economic rationality and variability ; somes milestones for an approach to the strategies of artisanal fishing units. Communication à la troisième rencontre de l'Association Européenne des economistes des Pêches. Dublin 9-12 avril 1991, 10 p.

**Rey H.** (1991b). Les unités de pêche artisanales : de la clarification sémantique à la construction d'un cadre d'approche. Document de travail multigr. OROTOM, 15 p.

**Walliser B.** (1985). *Anticipations, équilibres et rationalité économique.* Calman Lévy, Paris 252 p.

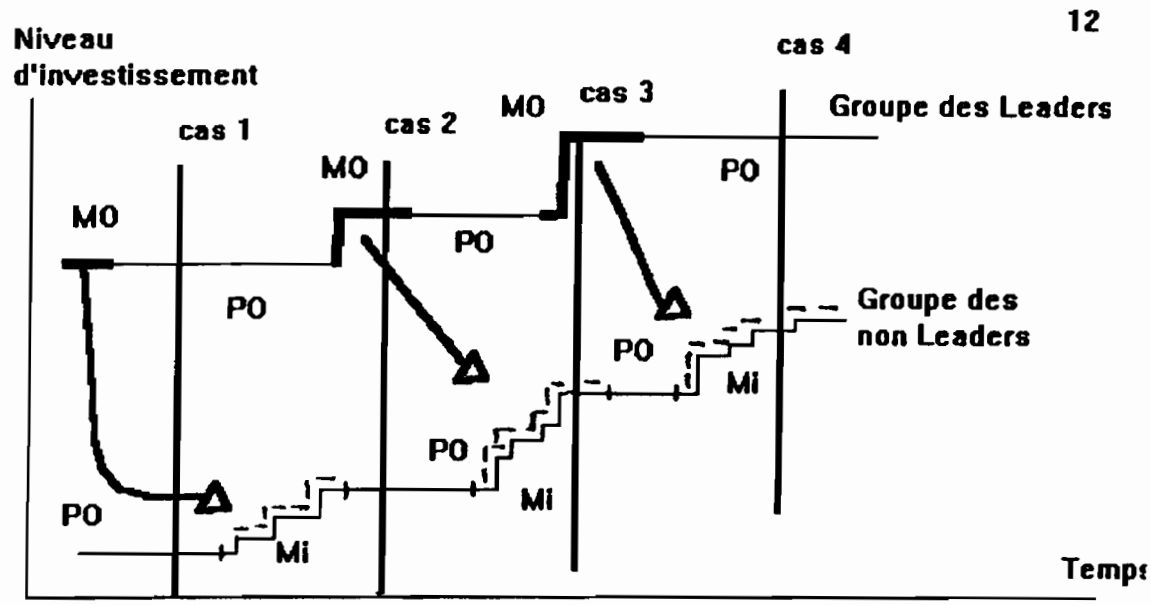
TABLEAU 1.
COEFFICIENT DE MOBILITE DE L'EFFORT.

| | Coûts entrée amortis | Coûts d'entrée non amortis |
|---|---|---|
| Possibilité de reconversion totale | Mobilité totale de l'effort (temps et espace) | Mobilité sous délais |
| Possibilité de reconversion d'une partie du capital technique | Mobilité d'innovation | Mobilité partielle spatiale ou spécifique |
| Possibilité de reconversion d'une partie du capital travail | Mobilité de diversification | Mobilité partielle temporaire |
| Aucune reconversion possible | Fixité de patrimoine | Fixité totale de l'effort |

TABLEAU 2.
TYPOLOGIE DES DECISIONS D'INVESTISSEMENT.

| Types d'investissement | Objectifs | Mode de financement |
|---|---|---|
| de productivité | adapter les conditions de rentabilité à l'évolution technologique ou économique du secteur | autofinancement ou financement bancaire |
| de modernisation ou d'opportunité | développer les capacités productives | dépendant de l'attribution de crédit ou de subventions |
| de flexibilité | offrir une souplesse de réponse pour des amplitudes et des situations anticipables | autofinancement ou financement bancaire |
| de mimétisme | rationalité ostentatoire jusqu'à un certain seuil<br>---<br>lorsque leur diffusion à l'ensemble du secteur engendre un différentiel de compétitivité, ils relèvent, pour les unités qui les réalisent tardivement, d'une rationalité de productivité. | en deça d'un seuil de diffusion : recettes exceptionnelles<br>---<br>au delà d'un seuil de diffusion autofinancement ou financement bancaire |

FIG. 1.
APPLICATION DES ANALYSES INSIDERS/OUTSIDERS : ARTICULATION DES PHASES D'INVESTISSEMENT DANS LE TEMPS.




| | Cas 1 | Cas 2 | Cas 3 | Cas 4 |
|---|---|---|---|---|
| Leaders | PO | MO | MO | PO |
| Non Leaders | PO | PO | Mi | Mi |

Légende :

Investissements de productivité [PO]
Investissements de modernisme [MO]
Investissements de mimétisme [Mi]

# Prediction of Financial Distress in the Norwegian Fish Processing Industry

**Bent Dreyer[a] and Terje Vassdal[b]**

[a]Norwegian Institute of Fisheries and Aquaculture LTD., Centre of Economics and Marketing, P.O.Box 2511, N-9002 Tromsø, Norway

[b]The Norwegian College of Fishery Science, University of Troms, N-9000 Tromsø, Norway

ABSTRACT

*Reliable prediction of financial distress is of great value to both shareholders and lenders. By "financial distress" we will in this paper mean bankruptcy. Nine models have been constructed consisting of various combinations of financial key ratios. These models are tested for their power to predict banckruptcy from one to five years before actual bankruptcy take place. Two statistical methods are used and compared ; the linear discriminant method and the probit method. For all the models the predictive power is significant up to three years before bankruptcy. Two of the models have the ability to predict significantly up to five years before bankruptcy.*

## 1. INTRODUCTION

During the period 1977 to 1990 the North Norwegian fish processing industry experienced a dramatic and turbulent time. The total number of companies declined from about 520 to 240. At the same time the landings of fish decreased from nearly 400 000 tons to 185 000 tons in this area. The main reason for the more than 50 % decline in the total population of processing companies, is financial distress, caused by insufficient capacity utilization, fluctuating marked prices and low productivity.

A few companies were able to rewind their operations in an orderly fashion. A Government scheme have been in operation, allowing a selected few to pay the creditors in full and still have some equity intact. Various conditions have been linked to this Government support program, which main aim has been to reduce overall capacity.

However, for most of the companies that have retreated from business the creditors and the owners have had to bear a loss.

We have divided the companies in this study into two groups : one group of companies consisting of those in good financial shape, and the other group consisting of companies under financial distress. As there are no accepted criteria for what should be considered a "good" or a "bad" financial position, we have decided on the following operational dichotomous definition : the companies that went bankrupt during our study period have been grouped as "bad", the rest are "good". Some problems with this definition will be discussed later in the paper.

The purposes of the paper are three-fold. First we will study methods to make prognoses of whether a company will end up as a "good" or as a "bad" company. The linear discriminant model and the probit method will be used to develop testable prediction models. The models are based on published data for the companies from one to five years before bankruptcy. Second, financial key ratios are chosen that best predict bankruptcy. Third, from these results policy concideration are drawn.

Perhaps the seminal article dealing with the problems covered in our paper is Beaver (1966). Beaver studied data bases with annual accounts from a large number of companies for many years. The companies were grouped into two subgroups ; bankrupt companies and non-bankrupt companies. He constructed a model based on the exact year of bankruptcy and calculated financial key ratios from several years before bankruptcy for the two groups. He developed profile analysis based on the financial ratios, and he also developed a method of classification based on the ratios. He demonstrated that substantial differences existed between the two groups regarding values of the individual key ratios many years before bankruptcy. Missing from his study was a formal method (statistical or other) to test the predictive strength of his selected ratios.

David Altman (1968) introduced the discriminant method to bankruptcy prediction problems. From 1968 to present a large number of articles have been published using discriminant prediction models based on financial ratios. The articles focus on statistical problems with discriminant methods, see Eisenbeis (1977), as well as the methods predictive ability. Prominent among the latter articles seems to be Edmister (1972), Altman and Eisenbeis (1978), Joy and Tollefson (1978), Collins and Green (1982), Richardson and Davidson (1983) and Inman (1988).

Another, and perhaps somewhat dissenting line of view, has focused on the methods lack of foundation in theory. Articles in line with this are Wilcox (1971), Scott (1981), Mensah (1984) and Barnes (1987).

Discriminant analysis has been compared with other methods. Lo (1986) and Press and Wilson (1978) compared discriminant analysis with logit regression. Rubin (1990) compared linear programming approaches with linear discriminant and quadratic discriminant models. Our study has compared the linear discriminant function with the probit method. As is well known, the probit method and the logit method will give very similar results when used to discriminate between two groups, and our results from using the probit method could easily be transferred to the logit method.

The rest of the paper will unfold as follows. In section two the data will be presented, and the results will follow in section three. Finally, conclusions and discussions will end the paper in section four.

Statistical methods used in the study are documented in Dreyer and Vassdal (1991), Dreyer (1991) and Vassdal (1991).

## 2. THE DATA

The data used in the study originates from "Driftsunderskelsen i Fiskeindustrien", a yearly, ongoing study of fish processing plants in Norway, see Bendiksen and Dreyer (1989). The companies taking part in this study are a sample of 86 companies from the total population of firms mentioned in the introduction. The sample size have been kept stable even if the total population has decreased. The companies in the sample are situated from mid Norway ("Nord-Mre") in the south, and continuing north to the Russian border. The processors are mainly producing white fish. Thus many of the producers of herring, capelin and shrimp are excluded from this study, as are all types of aquaculture. Some producers with mixed production have remained in the sample.

The part of the norwegian industry we are analysing in this study have their main activity in processing fish.

The same sample of 86 companies are studied each year. Being the same cross-section of companies each year for many years, the data is a so called "panel data" set. From the panel data we have extracted a sub-set of data used particularly for the bankruptcy study. This sample consists of a group of companies which went bankrupt in the periode, and a control group consisting of companies which remained in financial good shape the same period.

The table 1 shows the number of bankrupt companies and the number of companies in the control group for year one until year five before bankruptcy in our study.

Each company, both bankrupt and non-bankrupt (the control group), have been followed five consecutive years. This has been fully possible for the control group. As the data started in 1977, we have not been able to follow all the bankrupt companies up to five years before bankruptcy. As a consequence, of the 24 bankrupt companies in our study, only 13 have a full five years data set, increasing to 23 two years before bankruptcy.

We have excluded from the control group companies that have been refinanced with loss to the creditors or have undertaken other reorganizations with similar economic effects, like a composition or a private arrangement with the creditors. The control group is therefore intended to consist of financially sound companies.

## 3. THE RESULTS

### *3.1 Results from the probit model*

Detailed results from the probit study are reported in Vassdal (1991). This section is a brief summary of the results therefrom. The results from the discriminant study are presented and discussed (in Norwegian) in Dreyer (1991). Those papers are available from the authors.

In the probit part of the study, six different financial ratio models are tested for predictive power. The models originate from various sources. Combinations of financial key ratios suggested from other published studies have been tested. We have constructed ratios which take into account that we are dealing with a spesific industry.

The models are named "Model A" to "Model F" in what follows. The definition of the models are [1] :

Model A :

- Changes in stocks/Gross revenues ($X_1$)
- Interest charges/value added ($X_2$)
- Gross Revenues/Insurance value of assets ($X_3$)
- Profit before year-end adjustment/production value ($X_4$)

Model B :

- Total liabilities/Insurance value of assets ($X_1$)
- Gross Revenues/Insurance value of assets ($X_2$)
- Total indirect costs/Costs of Raw material ($X_3$)

Model C :

- Total liabilities/Insurance value of assets ($X_1$)
- Operating profit/Value of production ($X_2$)
- Contribution margin/Total direct wages ($X_3$)
- New investments/Insurance value of assets ($X_4$)

1. Detailed definitions of the variables are available (in Norwegian) from the authors on request

Model D :

- Current assets/current liabilities (Current ratio) ($X_1$)
- Total debt/total assets ($X_2$)
- Profit before extraordinary Items + Financial expences/Financial expences ($X_3$)

Model E :

- Operating revenues/Total assets ($X_1$)
- Changes in stocks/Sales revenues ($X_2$)
- New investments/Insurance value of assets ($X_3$)
- Financial expences/Value of production ($X_4$)
- Total cash flow generated from operations/Sales revenues ($X_5$)

Model F :

- Conditional tax-free allocations/Total assets ($X_1$)
- Total direct production costs/Costs of raw materials ($X_2$)
- Financial revenues/Gross revenues ($X_3$)

Model G :

- Value of stocks/Sales revenues
- Equity/Total assets
- New investments/Equity
- Total revenues fish production/Gross revenues
- Cash Flow/Insurance value of assets

Model H :

- Long term debt/Total assets
- Sales revenues/Total assets
- Financial expences/Value added
- Extraordinary revenues/Gross revenues
- Quick assets/Short term debt

Model I :

- Total debt/Total assets
- Total indirect cost/Cost of raw materials
- Sales revenues/Insurance value of assets
- Total revenues white-fish production/Total revenues fish production
- Financial expences/Total debt

We have tested model A to F in the probit study and modell E to I and compared results from the two methods by testing modell E and F.

It will be noted that some of the financial key ratios have been included in several models. This is no incidence. The purpose is to test the various ratios in different combinations. It turns out that the combination of ratios in some cases are just as important as the ratios themselves.

The predictive power of the models are tested with the "log likelihood ratio test" (LRT), defined as

$$C = - 2(\ln L(0) - \ln L(\beta^*))$$

where ln L(0) is the log of the likelihood function evaluated at the null hypthesis (i.e. all $\beta_k = 0$, except the constant, which is the ratio of observed $Y_i = 1$ to the total observtions. ($\beta^*$) is the log of the likelihood function when using the optimal estimated values of $\beta$.

The test observator, C, is chi-squared distributed with K-1 degrees of freedom. The following table gives the critical value of the test observator for a few combinations of degrees of freedom and levels of significance. As $R^2$ tests for probit models do not mean the same thing as for standard regression models, we will restain from using $R^2$ test in this section. "Pseudo $R^{2}$" tests are presented in Hensher and Johnson (1981). Similarly the standard F-tests are invalid for a probit model (see table 2).

The table 3 summarizes the results from applying the log likeliood ratio test for testing the predictive power of the selected models.

The null hypothesis is rejected one, two and three years before bankruptcy for all six models. This means that the models significantly increases the ability to predict bankruptcy up to three years before it happens. The predictive power of Model A is clearly less than the other models. Four and five years before bankruptcy only Model E and Model F are able to reject the null hypothesis. The implications are that these two models have satisfactorily predictive power from one to five years. The identification of the last two models we will call one of the major findings of the study.

One method to appraise the success of predictive models, could be to compare the actual number of bankruptcies and non-bankruptcies with the predicted numbers. The success rate in percentages are close to 90 % for the best models, and may even be more than 70 % when the models are not significant according to the log likelihood ratio test. Model A, which clearly have low predictive power four and five years before failure, actually has a success rate of 68 % four years before, and of 63 % five years before. What such a success rate does not show, however, is that almost all the correct predictions are of the type non-bankruptcy, whereas there are very few correct predictions of the bankruptcy cases.

### *3.2 Results from the discriminant model*

In this section, we will present five financial ratio models that have been selected by the discriminant model to give the best score. The models presented 4 years and 5 years before financial distress, have formerly been called Model E and Model F, respectively. The models 1, 2, and 3 years before distress are new, and have not been compared with probit models (see table 4).

The results from the discriminant study, as well as in the probit study, indicate that the modells perform well as far as separeting the two groups of companies.

There is a clear tendency that differences in the ratios between the two groups of firms are decreasing the further away from the time when the firms go bankrupt. The function which best classify the two groups is based on accounts one year before failure, and this function classified only 1.2 % of the firms wrongly. The function which classified most firms incorrect is based on accounting five years before failure. In this case, the function classified 18.4 % of the firms wrongly.

The model shows that the path towards bankruptcy consists of several steps, indicating that different ratios have different meanings as indicators of failure at different steps of the path against failure. This also explains why the functions, in terms of which ratios that are put together, are different. It also indicates the importance of knowing on which step the firm is, when analysing the ratios as indicators of bankruptcy. In our search for good indicators for separating the groups, our experience is that one should select ratios that show differences in value in between the two groups of firms, but they must also show small variance within the group. In the study of the fish processors it has been shown that the most common financial ratios often are poor indicators. Therefore they are avoided in our models due to great variance within the group and lack of stability over the years.

In the present study ratios that are composed for this spesific industry are frequently used. This approach has been useful in our struggle for finding indicators which may separate the two groups of firms well. First of all these ratios are not strongly correlated with other more common financial ratios, and therefore contribute the indication of whether a firm is doing well or not. Secondly these ratios incorporate factors that are essential and spesific for success among fish processors.

In the literature it is often discussed which capability discriminant models have to predict failure, and how to measure such capability. The conclusion of these discussions have been that the best test is to use the model on a different period of time and/or differrent firms than from which the model is developed. As far as the model is concerned in predicting failure, it has been emphasizied that the model should be tested in a period which comes after the years from which the model is developed. At the same time it is also stressed that the model should be tested on firms which are as identical as possible in terms of size, nationality and business.

It is difficult to know how well our models are able to predict distress, as we have only been able to test it for a period of two years on Norwegian fish processors. However, our experience so far indicate that the models are quite sensitive to which period of time analysed. This also indicates that further develpoment of the models by incorporating a longer period of time, may create changes in the functions as far as which ratios and the discriminant coefficients are concerned.

Whether the model is able to predict distress among fish producers, depends on whether the relationships between the different ratios in the discriminant functions are the same in the future as in the period of time from which the model was developed. This is the main issue of all kind of predictions. The issue of a certain stability among the ratios over the years, is difficult to ensure among the fish processors. This is connected to the turbulent contingency factors with which these firms are working. There is a vast uncertainty connected to the quantity of fish available at a given time, what price they will have to pay for it and what price they will get for their finished products. At the same time, the difference between the price of the raw materials and the price of their products is the main factor for their profitability. Importantly, this factor is not under the control of the single firm as the Norwegian processors often do not have their own fishing vessels integrated in their company.

The prediction of failure or success amongst fish processors are therefore more dependent of external changes, than the information which is recorded in their accounts. Since the changes in these external factors are rather radical and frequent, it is difficult to predict if a fish processor will fail or not in the near future based only on last years accounting.

This, of course, is a general problem with any prediction, but the problem is less among other industries which are working under more stable conditions than Norwegian fish processors. It also illustrates the importance of limitting the use of such prediction models to one spesific industry and also the importance of knowing the business thoroughly on which the model is applied. This restriction is also well illustrated by the fact that the ratios contstructed spesific for this industry, are of great importance in the modells which are developed in this study.

This study, both the discriminant and the probit study, indicates that there at two sucess factors among in this industry in the period we have studied which the single firm itself are able to controll. The two factors are cost controll and capacity utilization.

## 4. CONCLUSIONS

In this paper two statistical methods have been presented and applied. The methods have their advantage in situations when the dependent variable is binary, that is represented by two mutally exclusive events. The probit model and the linear discriminant model have been used for model building purposes.

Both methods made it possible to construct very reliable predictions of financial distress. We have also identified two models which could predict coming financial distress up to five years before its occurance. We are in addition in the position to tell which variables in the models that are most important in the explanation. The variables can be tested using the standard student t-test. The elasticities of the probabilitry of bankruptcy as a function of changes in one of the variables can also be calculated. The elasticity is a valid measure of the relative importance of the financial key ratios in each model.

Our experience with discriminant models on Norwegian fish processors is that their capability to classify correctly drops when there are dramatic changes in the external factors. The predictions are therefore strongly dependent on periode of time analysed and also on which periode of time the model is designed.

The results from this analysis show that the strength of the model is not in predicting failure or sucess. The contingency factors of the selected industry are too turbulent and unstable for that. The lack of stable external factors makes the indicators fluctuate widely from one year to another. The model might preform better if it is developed on a longer period of time, but we will never get away from the problem of frequent and dramatic changes in the external factors which the single producers neither can foresee nor contoll and which are essential for the firms profitability.

The findings in this study also emphasize that using such modells as reported in this study is restricted to the industry from which the modells are developed.

## REFERENCES

**Altman E.I.** (1968). "Financial Ratios, Dicriminant Analysis and Prediction of Corporate Bankruptcy" *The Journal of Finance,* Vol **31**, No 4.

**Altman E.I. and R.A. Eisenbeis** (1978). "Financial Applications of Discriminant Analysis : A Clarification". *Journal of Banking and Finance,* No **1**.

**Barnes P.** (1987). "The Analysis and Use of Financial Ratios : A Review Article. "*Journal of Business and Accounting,* Vol **14**, No 4, Winter.

**Beaver W.** (1966). "Financial Ratios as Predictors of Failure." Empirical Research in Accounting : Selected Studies. *Journal of Accounting Research,* Supplement to Volume 4.

**Bendiksen B.I. and B. Dreyer** (1989). "Driftsunderskelsen i Fiskeindustrien. Driftsret 1988." FTFI-Rapport, A-62, November, Troms.

**Collins R.A. and R.D. Green** (1985). "Statistical Methods for Bankruptcy Forcasting", *Journal of Economics and Business,* Vol **34**.

**Dreyer B.** (1991). "Diskriminantmodeller i fiskeindustrien - prediksjon og tilstandsklassifikasjon", FTFI- delrapport, Prosjekt 4405, Troms.

**Dreyer, B. and T. Vassdal** (1991). "Prediction of Financial Distress with Probit and Discriminant Methods", Paper presented at *SIB-seminar* in Lofoten, July.

**Edmister R.O.** (1972). "An Empirical Test of Financial Ratio Analysis for Small Business Prediction", *Journal of Finance and Quantitative Analysis,* March.

**Eisenbeis R.A.** (1977). "Pitfalls in the Application of Discriminant Analysis in Business, Finance, and Economics", *The Journal of Finance,* Vol **32**, No 3.

**Henshe D.A. and L.W.J. Johnson** (1981). *"Applied Discrete-Choice Modelling",* Croom Helm, London and John Wiley & Sons, New York.

**Inman M.L.** (1988). *"The Crash of 1987 and Its Impact on Z-score Analysis",* Management Accounting.

**Joy M.O. and J.O. Tollefson** (1978). "Some Clarifying Comments on Discriminant Analysis". *Journal of Financial and Quantitative Analysis.*

**Lo A.W.** (1986). "Logit versus Discriminant Analysis. A Specification Test and Application to Corporate Bankruptcies." *Journal of Econometrics,* Vol **31** : 151-178.

**Mensah Y.M.** (1984). "An Examination of Stationarity of Multivariate Bankruptcy Models : A Methodological Study", *Journal of Accounting Research,* Vol **22**, No 1.

**Press J.S. and S. Wilson** (1978). "Choosing Between Logistic Regression and Discriminant Analysis", *Journal of the American Statistical Association,* Dec, Vol **73**, No 364 : 699-705.

**Richardson F.M. and L.F. Davidson** (1983). "An Exploration into Bankruptcy Discriminant Model Sensitivity", *Journal of Business Finance and Accounting,* Vol **10**, No 2.

**Rubin Paul A.** (1990). "A Comparison of Linear Programming and Parametric Approaches to the Two-Group Discriminant Problem", *Decision Sciences,* Vol **21**, No 2 : 373-386.

**Scott J.** (1981). "The Probability of Bankruptcy - A Comparison of Empirical Predictions and Theoretical Models", *Journal of Banking and Finance,* No **5.**

**Vassdal T.** (1991). "Konkursprognoser ved bruk av probit modeller." Working Paper, FTFI-prosjekt 4405, Tromsø.

**Wilcox J.W.** (1971). "A Simple Theory of Financial Ratios as Predictors of Failure", *Journal of Accounting Research.*

TABLE 1.
NUMBERS OF THE TWO GROUPS OF COMPANIES FROM YEAR ONE TO FIVE.

| Years before bankruptcy | Number Bankrupt | Number Nonbankrupt |
|---|---|---|
| 1 | 24 | 29 |
| 2 | 23 | 29 |
| 3 | 18 | 29 |
| 4 | 15 | 29 |
| 5 | 13 | 29 |

TABLE 2.
A FEW SELECTED CRITICAL VALUES FROM THE CHI-SQUARE TABLES.

| | $\alpha = 0.05$ | $\alpha = 0.01$ |
|---|---|---|
| K-1 = 3 | 7.8 | 11.3 |
| K-1 = 4 | 9.5 | 13.3 |
| K-1 = 5 | 11.1 | 15.1 |

(Source: Judge et al (1988)).

TABLE 3.
THE TEST OBSERVATOR FOR THE LOG LIKELIHOOD RATIO TEST.

| Model | 1 | 2 | 3 | 4 | 5 | K-1 |
|---|---|---|---|---|---|---|
| A | 12.5 | 14.9 | 11.6 | 2.02 | 2.05 | 4 |
| B | 39.5 | 14.8 | 18.2 | 6.8 | 11.9 | 3 |
| C | 45.3 | 15.4 | 13.7 | 3.8 | 9.1 | 4 |
| D | 46.2 | 17.1 | 15.2 | 8.7 | 3.2 | 3 |
| E | 48.3 | 20.8 | 21.6 | 20.6 | 11.6 | 5 |
| F | 19.1 | 18.0 | 17.4 | 13.9 | 24.2 | 3 |

(Source: Vassdal (1991))

TABLE 4.
DISCRIMINANT FUNCTIONS IN THE PREDICTION MODEL WITH DISCRIMINANT VARIABLES AND CLASSIFICATION ERRORS.

| YEAR | RATIO | CLASS. ERROR |
|---|---|---|
| 1 year before distress | Value of stocks/Sales revenues | |
| | Equity/Total assets | |
| (G) | New investments/Equity | |
| | Total revenues fish production/Gross revenues | 1.2 % |
| | Cash Flow/Insurance value of assets | |
| 2 years before distress | | |
| | Long term debt/Total assets | |
| (H) | Sales revenues/Total assets | |
| | Financial expences/Value added | |
| | Extraordinary revenues/Gross revenues | 11.5 % |
| | Quick assets/Short term debt | |
| 3 years before distress | | |
| | Total debt/Total assets | |
| (I) | Total indirect cost/Cost of raw materials | |
| | Sales revenues/Insurance value of assets | |
| | Total revenues white-fish production/ | |
| | Total revenues fish-production | 13.0 % |
| | Financial expences/Total debt | |
| 4 years before distress | | |
| | Operating revenues/Total assets | |
| (E) | Changes in stocks/Sales revenues | |
| | New investments/Insurance value of assets | |
| | Financial expences/Value of production | |
| | Total cash flow generated from operations/ | 7.5 % |
| | Sales revenues | |
| 5 years before distress | | |
| | Conditional tax-free allocations/Total assets | |
| | Total direct production cost/Cost of raw materials | 18.4 % |
| (F) | Financials revenues/Gross revenues | |

# Unemployment Insurance and the Length of the Fishing Season

**Noel Roy, Eugene Tsoa, William E. Schrank[a] and Leigh Mazany[b] ***

[a]Department of Economics, Memorial University of Newfoundland, St. John's NF A1C5S7Canada

[b]Department of Economics, Dalhousie University, Halifax, NS B3H3J5 Canada

ABSTRACT

*The standard economic theory of labour supply suggests that a worker's budget constraint is piecewise-linear in the presence of income taxes or subsidies such as unemployment insurance. Estimation of labour supply functions when the budget constraint is piecewise-linear have been commonplace for more than a decade. Such studies have been used, for example, to investigate the effect of income taxes and unemployment insurance on the willingness to work and the length of the average work spell.*

*Virtually all existing studies assume that workers are subject to a given wage in the work-leisure choice model. While appropriate for industrial workers, fishermen usually do not work for a fixed wage. Seasonal differences in resource availability imply a non-linear relationship between fishing income and the length of the fishing season. As a result, the budget constraint of a fisherman in a work-leisure choice model is non-linear, and with the presence of unemployment insurance benefits the fisherman would be facing a kinked non-linear budget constraint.*

*The paper consists of three parts. First, the basic structure of the Canadian unemployment insurance program as it affects inshore fishermen is outlined. Second, a theoretical model is developed which analyzes the length of fishing season decision in the presence of an unemployment insurance plan essentially similar to the one described in Part I. Third, some econometric difficulties encountered in the statistical estimation of these theoretical relationships are described. Fourth, the model is subjected to a series of numerical simulations, to determine its sensitivity to parameter changes.*

* The analysis underlying this paper was supported by a research grant from the Institute of Social and Economic Research, Memorial University ; a Donner research fellowship from the Canadian-American Center, University of Maine ; and a Science Subvention from the Department of Fisheries and Oceans and the Natural Sciences and Engineering Research Council of Canada. We wish to thank the Department of Fisheries and Oceans and the Employment and Immigration Commission of the Government of Canada for providing us with the data used in this paper.

## 1. INTRODUCTION

The Canadian unemployment insurance program was established to enable government to insure employees against the consequences of job loss. It has been a fixture of the Canadian social welfare system since 1940. The present Unemployment Insurance Act has been in force since 1972.

In order to qualify for unemployment insurance benefits, a claimant must necessarily have been involved in an employment contract with an employer. Self-employed persons, in other words, normally do not qualify for coverage.

There is one exception to this. Section 146 of the Act enables the Canada Employment and Immigration Commission to operate a scheme of unemployment insurance for "self-employed persons engaged in fishing." Such a scheme has been in existence since 1957.

Section 146 is found in a part of the Act labelled "Transitional and Repeal Provisions," and contains a sub-section stating that "this section shall be repealed on a day to be fixed by proclamation." However transitional this provision was intended to have been when it was established, the Special Seasonal Fishermen's Benefits Program, as it is called, has since taken on a political life of its own, and has become a fundamental element of and support mechanism for inshore fisheries on the Atlantic coast of Canada.

The present Unemployment Insurance Act was passed by Parliament in 1971 and replaced somewhat less generous legislation. After an initial period of stability, perceived difficulties with the Act led to a series of amendments, mostly in a more restrictive direction, over the period between 1976 and 1980. Other than amendments passed in 1983 in response to recommendations by the Kirby Task Force on the Atlantic Fisheries, the Act has remained essentially unchanged since then, at least insofar as it affects inshore fishermen in Newfoundland.

The purpose of this paper is to examine how the 1971 Act and subsequent amendments have influenced the behaviour of inshore fishermen. This influence could potentially have been felt in three ways :

i) by altering the attractiveness of fishing relative to other forms of economic activity, unemployment insurance can affect the number of people engaging in fishing as a full-time or part-time occupation ;

ii) by modifying the returns to fishing, it can change the length of time that fishermen engage in this activity over the fishing season ; and

iii) it can also change the intensity with which fishermen are prepared to fish at any particular time.

This paper is primarily concerned with changes of the second kind, that is to say, with changes in the length of time spent fishing over a season as a result of the unemployment insurance program.

The basic structure of the Canadian unemployment insurance program as it affects inshore fishermen is outlined in Part II of the paper. Part III develops a behavioural model of the decision to fish in a particular week within the season, which we subsequently use to evaluate the impact of seasonal fishermen's benefits on the length of the fishing season. Some econometric difficulties are discussed in Part IV. The simulation possibilities which exist with a fully specified model are illustrated in Part V.

## 2. THE UNEMPLOYMENT INSURANCE PROGRAM

The Canadian Unemployment Insurance program works in the following manner. Employees who earn income in excess of a predefined minimum in a week are deemed to have insurable earnings in that week. Both the employee and the employer then contribute premiums at a given rate to an Unemployment Insurance Account. If the employee works a sufficient number of insured weeks, then upon an interruption of earnings (s)he may, after a two-week waiting period, obtain weekly unemployment insurance benefits equal to a percentage of the average weekly insured earnings received during the qualifying period. The level of weekly earnings which is insurable is subject to a ceiling, which limits the level of both the premiums which must be contributed and the benefits which can be received.

The length of the period over which benefits can be received depends on the number of insured weeks in the qualifying period, and on the national and regional rates of unemployment. Earnings received during the benefit period may be kept if they are less than 25 percent of the weekly benefit ; earnings in excess of this result in a dollar-for-dollar reduction in benefits.

Most inshore fisheries in Atlantic Canada are organized as a co-adventurer rather than an employer-employee relationship. In the co-adventurer system, the boat owner receives a predefined share of the value of the catch net of operating costs. The remainder is shared evenly among the crew of the vessel. The structure of the unemployment insurance program is not well suited to this arrangement. It is not obvious who should be considered to be the employer ; what should be treated as insured earnings ; and when an interruption of earnings is deemed to take place.

Usually, the fish buyer is deemed to be the employer ( *Regulations*, s.76). The insured earnings of a crewman consist of the crewman's share. For the boat owner (or lessee), insured earnings are deemed to be the net value of the catch after deducting (a) his/her crewmen's shares and (b) 25 percent of the value of the catch to account for operating expenses. If the boat owner's earnings fall short of the minimum level of earnings required for a week's earnings to be insurable under the Act, these earnings are deemed to be at that minimum level (*Regulations*, s. 78). This implies that even a minimal level of fishing activity qualifies a boat owner for unemployment insurance, and qualifies him or her at an artificially high rate.

Fishermen are permitted to arrange their affairs with buyers in such a way as to accumulate their catches over more than one week, and to average the accrued value over that number of weeks (*Regulations* , s. 79(5)). This means that earnings in weeks during which catches are high can be applied to weeks in which earnings are lower. This enables fishermen to obtain increased benefits from weeks during which earnings exceed the ceiling, and to include as an insured week one in which earnings are below the minimum level. This practice became more widespread after 1986, when Revenue Canada released a statement which gave a broadened interpretation to this section of the *Regulations*. As landings have declined as a result of resource depletion, this characteristic of the program has increased in importance.

Fishermen are categorized into year-round fishermen and seasonal fishermen for unemployment insurance purposes. The requirements for classification as a year-round fisherman are extremely stringent (*Regulations* , s. 84), and almost all inshore fishermen in Newfoundland, which is the primary focus of our analysis, are classified as seasonal fishermen. A seasonal fisherman can receive benefits only during the 'off season', which for most fishermen is the period between November and May (*Regulations*, s. 85(7)). For this reason, potential claimants regard entitlement to fishing benefits as inferior to entitlement to benefits from regular employment, which can be taken at any time in the year, and usually for a longer period of time.

To qualify for regular benefits, regular employment must be obtained for a minimum number of weeks during the qualifying period. For the most part, fishermen in Newfoundland, especially full-time fishermen, have not been able to obtain sufficient regular employment to avail themselves of regular benefits. Table 1 presents a breakdown of the UI dependence of Newfoundland fishermen actively fishing in 1984, based on a survey conducted by the Department of Fisheries and Oceans. [1]

## 3. A MODEL OF THE LENGTH OF THE FISHING SEASON

Fishing is a seasonal occupation, and boat owners, if they are rational, will decide whether to fish in a given week on the basis of a comparison of the marginal benefits and costs of doing so. We model this decision-making process on the basis of a theoretical analysis similar to that formulated by Ferris and Plourde (1980, 1982).

The model is based on the supposition that fishing income varies over the year because of changes in resource availability. As a result, fishing income is subject to diminishing returns as the fishing season is extended past the peak season. The longer a fisherman continues to fish, the smaller the incremental returns from fishing an additional week. This relationship between fishing income and fishing weeks can be represented as a concave function similar to the FF curves in Figures 1(a) and 1(b).[2]

The factors that determine whether a fisherman will fish in a particular week depends on the nature of the alternative activities available to him or her. In Canada, fishermen are classified by the regulatory authority into full-time and

1. Source : Department of Fisheries and Oceans, *1984 Survey of Atlantic Fishermen*, unpublished data. In Newfoundland, 65 percent of active fishermen held full-time status in 1984.
2. The weeks in Figure 1(a) and 1(b) need not be consecutive ; there may be alternating periods of fishing and inactivity over the year, in response to variations in resource availability over time.

part-time categories. Part-time fishermen typically have other employment activities available to them ; they usually fish only during the peak of the season.[3] When incremental fishing income falls below the wage that could be earned in alternative employment, they discontinue fishing. This choice decision is represented in Figure 1(a), where the slope of the tangent line WW equals the wage rate obtainable in alternative employment.

Full-time fishermen must fish on a consistent basis throughout the fishing season in their area in order to maintain full-time status for licensing purposes. They cannot work longer than 30 days at other employment within the fishing season, and can pursue only limited self-employment in specified primary industries outside the fishing season. Alternative employment is not a major consideration for such fishermen.[4] Their behaviour can be modelled as selecting the level of fishing activity which places them on the highest possible indifference curve between work and income. This choice is represented in Figure 1(b).

Let us represent net fishing income $F$ in a season as a concave function of the number of fishing weeks $L$.

$$F = f(L), \tag{1}$$

where $f\,' > 0, f\,'' < 0$.

In this model, part-time fishermen divide their working weeks between fishing and non-fishing employment so as to maximize income earned in the work period. If non-fishing employment is available at a weekly wage $w$, income during the working period is maximized when fishing income in the marginal fishing week equals this wage.

$$f'(L) = w. \tag{2}$$

Full-time fishermen,[5] on the other hand, seek to maximize the value of a utility function $U(F,L)$, where $U_F > 0$ and $U_L < 0$. This occurs where

$$f'(L) = -\frac{U_L}{U_F} = \mathrm{MRS}_{LF}. \tag{3}$$

For both groups of fishermen, the seasonal fishermen's benefits program alters this pattern of incentives. The benefits received supplement earnings from fishing, and in so doing alter the incentives to fish, through both income and substitution effects.

The income effects are discussed first. If leisure is a normal good, then the higher income from unemployment insurance leads to an increase in the demand for leisure. In the case of full-time fishermen, this would result in a reduction in the number of weeks spent fishing, in order to enjoy this additional leisure. Part-time fishermen would also reduce their work activity, while still maintaining the equilibrium condition $f'(L) = w$. However, any reduction in fishing weeks $L$ would result in an increase in $f'(L)$ (since $f'' < 0$), so that this condition would no longer be satisfied. It must be the case then that *all* the reduction in work effort must be outside fishing. There is thus no income effect on fishing weeks in the case of part-time fishermen with alternative employment opportunities[6].

The substitution effects are more complex, and are best represented through formal modelling. The amount of unemployment insurance income $S$ earned in a benefit period is the product of three factors :

- the benefit-earnings or replacement ratio $r$, which is the proportion of average weekly insured earnings during the qualifying period which is returned to the claimant as benefits during a week of unemployment ;

3. In 1984, active full-time fishermen fished an average of 19.1 weeks in Newfoundland ; active part-time fishermen, only 11.8 weeks. (Source : Department of Fisheries and Oceans, *1984 Survey of Atlantic Fishermen*. Economic and Commercial Analysis Series, Surveys and Statistics Report 37. Ottawa, 1987. Tables 4.8 and 4.9.)
4. In 1984, active full-time fishermen in Newfoundland earned an average of only $664 in non-fishing employment income, as opposed to $6,798 in net fishing income and $3,421 in seasonal fishermen's benefits (Source : Department of Fisheries and Oceans, *1984 Survey of Atlantic Fishermen*. Economic and Commercial Analysis Series, Surveys and Statistics Report 37. Ottawa, 1987. Table 9.8.)
5. We are using the terms part-time and full-time here rather loosely, to distinguish between fishermen who have, or do not have, alternative employment opportunities within the fishing season. This distinction may not strictly correspond to the licensing classification used by the Department of Fisheries and Oceans.
6. For a further elaboration on this point, see Ferris and Plourde (1980), chapter 4.

- the average level of weekly insured earnings $E$ during the claimant's qualifying weeks, which is the basis on which the level of weekly benefits is calculated ; and
- the number of weeks $B$ over which the claimant is entitled to draw benefits.

This can be written as

$$S(L) = rE(L)\ B(L). \tag{4}$$

The benefit-earnings ratio $r$ is a constant, which was equal to 2/3 over the period 1972-1978 and to 60 percent thereafter.[7]

Until 1983, the average value of insured earnings was calculated over qualifying weeks in either the entire qualifying period (which usually begins in April), or in the last 20 weeks of this period, whichever was to the fisherman's advantage. We have assumed (equation (1) above) that fishing income increases at a diminishing rate as the number of fishing weeks increases. If weekly earnings are below the insurable ceiling, this implies that average weekly insured earnings decline as the number of fishing weeks is increased. This would have a negative effect on the level of unemployment benefits, which would act as a disincentive to extend the number of fishing weeks. Thus, we can specify that $E'(L) \leq 0$, with the strict inequality holding where $f'(L)$ is below the maximum level of weekly insurable earnings.

In 1983, this provision was modified so that those fishermen with at least 15 qualifying weeks of fishing would receive benefits based on earnings in the *best* ten weeks of fishing. This would render $E(L) = E(10)$ for $L \geq 15$, which would remove the disincentive to extend the number of fishing weeks for those fishing at least 15 weeks.

The relationship $B(L)$ between the number of benefit weeks and the number of insured weeks during which income was earned can be separated into four stages. In Stage 1, the number of insured weeks $L$ is less than the minimum number of qualifying weeks required to entitle a claimant to benefits, denoted by $q$. In Newfoundland, this minimum level of insured weeks was 8 until 1978, when it was raised to 10 weeks. In this stage, obviously, there are no benefits ; i.e.,

$$B(L) = 0 \text{ if } L < q. \tag{5a}$$

Once a claimant qualifies for benefits, the number of weeks in which he can claim benefits increases with the number of insured weeks, up to some maximum. In Stage 2, this maximum has not yet been reached, so there is a positive relationship between the number of benefit weeks and the number of insured weeks. This positive relationship creates an incentive to extend the number of fishing weeks in order to qualify for a longer period of unemployment benefits. In other words, $B'(L) > 0$ in this stage. Specifically, claimants are entitled to 5 weeks of benefits for every 6 qualifying weeks, so $B'(L) = 5/6$. As well, since 1976 fishermen have been entitled to a certain number of weeks of so-called "extended benefits", $B_{ext}$, which is independent of the number of qualifying weeks they have worked. Thus, in Stage 2 the number of benefit weeks can be written as the linear relationship

$$B(L) = 56\,L + B_{ext} \tag{5b}$$

In Stage 3, the maximum number of benefit weeks $B_{max}$ has been reached. Additional fishing does not increase the period over which a fisherman is entitled to benefits. The positive incentive to extend the number of fishing weeks which exists in Stage 2 is removed. In this stage we have $B'(L) = 0$, and

$$B(L) = B_{max}. \tag{5c}$$

Ultimately, as the number of fishing weeks is extended further, fishing takes place during the 'off-season', when seasonal benefits could be claimed. Obviously, in this stage, every additional week spent fishing is a week in which unemployment benefits could have been received. This is Stage 4, where there exists an incentive to *reduce* the number of fishing weeks. Here we have $B'(L) = -1$, and so (allowing for the two-week waiting period)

$$B'(L) = 50 - L. \tag{5d}$$

7. There was a special 3/4 rate for low-income claimants with dependants over the period 1972-74. However, this rate appears to have been almost irrelevant to fishermen in Newfoundland. In a 10 percent sample of fishing UI claimants over this period, only 31 out of 1350 claimants had insured earnings below the level required to qualify for this rate.

Overall, then, the relationship $B(L)$ is piecewise linear, with 4 distinct segments, and can be expressed as

$$\begin{aligned} B(L) &= \min\left[\frac{5}{6}L + B_{ext},\ B_{max},\ 50 - L\right], \quad L \geqslant q, \\ &= 0, \quad L < q. \end{aligned} \tag{6}$$

An example is presented in Figure 2 ; this is the relationship which prevailed over the period 1972-75. The relationship was altered by amendments in 1976 and in 1977, which modified the $q$ , $B_{ext}$, and $B_{max}$ parameters. These changes are summarized in Table 2 and illustrated in Figure 3. They are considered in greater detail in Roy, Tsoa, Schrank and Mazany (1992).

When income from seasonal fishermen's benefits is added to earned fishing income, total fishing income $F$ becomes

$$\begin{aligned} F(L) &= f(L) + S(L) \\ &= f(L) + rE(L)\,B(L). \end{aligned} \tag{7}$$

An example of such a relationship, appropriate to the period 1972-75, is provided in Figure 4. This figure shows a typical pattern for earned fishing income $f(L)$, seasonal fishermen's benefits $S(L)$, and total fishing income $F(L)$. The shape of these relationships are obviously dependent on that of the $f(L)$ function, which affects the average insured earnings function $E(L)$ and therefore the $S(L)$ and $F(L)$ functions as well.

The optimum conditions can then be written as

$$F'(L) = f'(L) + S'(L) = w \tag{8a}$$

for part-time fishermen, and

$$F'(L) = f'(L) + S'(L) = \mathrm{MRS}_{LF}(F, L) \tag{8b}$$

for full-time fishermen.

The slope of $S(L)$ can be derived as

$$S'(L) = r[E(L)\,B'(L) + E'(L)\,B(L)]. \tag{9}$$

As was explained above, $E'(L)$ is generally negative,[8] since average weekly insured earnings decline as the number of fishing weeks is increased, so this factor will act to algebraically reduce the slope of the $S(L)$ function. The behaviour of $B'(L)$ is more complex, as we have seen, and depends on the stage in which the value of $L$ falls. It is worthwhile to consider each of the four stages separately.

In Stage 1, $S(L) = 0$, so the $F(L)$ and $f(L)$ curves are identical.

Fishermen working in Stage 2 are subject to two conflicting forces. On the one hand, $B'(L) > 0$, which implies that additional fishing increases the number of benefit weeks. On the other hand, $E'(L) < 0$, which implies that additional fishing reduces the level of average insured earnings as fishing becomes less lucrative, and so lowers the size of the unemployment benefit. Under normal circumstances, we expect that the former effect will dominate[9], so that normally $S'(L) > 0$ in Stage 2.

8 Unless the fisherman earns the maximum qualifying income throughout the qualifying period, in which case it is zero.

9. One simple example, reflecting a not particularly favourable circumstance, arises when the fisherman's benefits are based on the average earnings over the qualifying period, and these earnings never exceed the qualifying ceiling. Then $E(L) = f(L)/L$, and so

$S(L) = r\frac{f(L)}{L}\left[\frac{5}{6}L\right] = \frac{5rf(L)}{6}$. *Since* $f'(L) > 0$, $S'(L) > 0$ as well.

In Stages 3 and 4, it remains true that $E'(L) < 0$, but here $B'(L) \leq 0$, so it is necessary that $S'(L) < 0$. The level of seasonal fishermen's benefits, then, must decline as the number of fishing weeks is extended into Stages 3 and 4. Total fishing income inclusive of unemployment insurance F(L) will continue to increase for a while, but we would expect that normally there will be a point at which extending the number of fishing weeks will add less to earned income $f(L)$ than will be lost from seasonal benefits $S(L)$ (i.e., $f'(L) + S'(L) < 0$), so that total fishing income would decline if the number of fishing weeks were extended beyond that point. The value of L at which this happens depends on the slope of the $f(L)$ and $E(L)$ functions.

Let us now examine the implications of these relationships for the behaviour of fishermen. Consider a part-time fisherman with less than the minimum number of insured weeks (Stage 1). Unless (s)he increases his/her insured weeks to at least the minimum level (Stage 2), (s)he will not receive benefits. It may be worth his/her while to extend his/her fishing effort into Stage 2, if the unemployment benefits received, plus the attendant fishing income, exceed the foregone wages. This case is illustrated in Figure 5(a), where the introduction of seasonal benefits leads to a change in the tangency from point E to point $E'$. On the other hand, if the foregone wage income is high enough, as it is in Figure 5(b), the fisherman will not modify his/her behaviour, because it remains optimal to fish less than the number of weeks required to qualify for unemployment insurance. In summary, a fisherman in Stage 1 may not modify his/her behaviour as a result of the unemployment insurance program, but if (s)he does, it will be to increase his/her insured weeks into Stage 2.

If a part-time fisherman works enough weeks to qualify for seasonal benefits, (s)he is in equilibrium when $F'(L) = w$. The availability of fishermen's benefits clearly changes the value of $L$ at which this occurs.[10] This value is increased if $S'(L) > 0$, and is decreased if $S'(L) < 0$. Thus, the behaviour of part-time fishermen is governed by the sign of $S'(L)$, so that they fish longer if $S'(L)$ is positive and cut back if it is negative. For full-time fishermen this effect is supplemented by an income effect as well, which if leisure is a normal good would induce a reduction in the number of weeks spent fishing.

In Stage 2 it is normally the case that $S'(L) > 0$, because additional insured weeks permit more benefit weeks. Therefore, part-time fishermen in Stage 2 are predicted to fish longer as a result of seasonal benefits. This is illustrated in Figure 6. For full-time fishermen, this may be offset to a greater or lesser degree by a negative income effect, so that such fishermen may choose to work less as a result of the higher income.

Fishermen working in Stages 3 and 4, whether full-time or part-time, suffer from no such ambiguity. Additional fishing effort lowers the value of insured earnings, as in Stage 2 ; in addition, the number of benefit weeks either does not change (Stage 3) or falls (Stage 4). Therefore additional fishing lowers the amount of unemployment benefits received, and this creates an incentive to fish less, which augments any negative income effect. This effect is illustrated in Figure 7.

To summarize, then : the model predicts that seasonal fishermen's benefits will cause fishermen working in Stages 3 or 4 to reduce the number of weeks spent fishing. Those fishing less than this *may* be induced to increase the number of weeks spent fishing. The effect is one of compaction in the variance in fishing effort from that experienced without unemployment insurance. The basic conclusion of this theoretical analysis is that there is no theoretical presumption that seasonal fishermen's benefits will either increase or reduce the *average* amount of time spent fishing.

## 4. SOME ECONOMETRIC CONSIDERATIONS

The authors have elsewhere (Roy, Tsoa, Schrank and Mazany 1992) examined the impact of the various changes which have taken place in the seasonal fishermen's benefits program on the number of inshore fishermen in Newfoundland and on the number of weeks they have spent fishing over the year. This analysis is based on the application of the theoretical model outlined above to a ten percent sample of seasonal benefit recipients over the period 1972-1981, and a one hundred percent sample over the period 1981-1985. For the most part, the predictions of the theoretical model are reflected in the data.

In the final analysis, however, we would like to use econometric techniques to estimate the optimizing conditions in equation (8). Unfortunately, such estimation poses severe challenges. In rough order of seriousness, these are (1)

10. Throughout this analysis we assume that while alternative employment opportunities are available to part-time fishermen, these opportunities are insufficient to permit such fishermen to qualify for regular unemployment insurance benefits. Fishermen who qualify for regular benefits are ineligible to receive special seasonal fishermen's benefits.

problems of parameter identification, (2) suitable treatment of the piecewise non-linearities and discontinuities in the benefit function $S(L)$, and (3) the adjustments appropriate to the upper and lower limits associated with the number of insured weeks and the level of average insured earnings. We discuss each of these problems in turn.

### *4.1 Identification of parameters*

The number of weeks worked by seasonal benefit recipients varies widely across our sample, from the minimum 8 or 10 weeks needed to qualify for benefits, up to nearly a full year. Such differences can be explained by the model as being due either to differences in the shape of fishermen's catch functions $f(L)$ (i.e., differences in their opportunity sets) or to differences in the shape of their indifference curves (i.e., differences in their preferences). That is to say, one fisherman may work a shorter period than another either because his/her productivity falls off more rapidly as his/her season is extended, or because (s)he has a stronger preference for "leisure" (understood to mean non-market activities generally). We can incorporate these parameters into the optimum condition for a full-time fisherman (8b), which then becomes

$$F'(L_i\,;\,\beta_i) = \mathrm{MRS}_{LF}(L_i,\,F_i\,;\,\delta_i)\,, \tag{10}$$

where $\beta_i$ are the parameters associated with the $i^{\text{th}}$ fisherman's catch function and $\delta_i$ are those associated with his/her utility function.

The difficulty is that neither $\beta_i$ nor $\delta_i$ are directly observable. We cannot infer from the data to what extent differences in the behaviour of fishermen are due to differences in opportunities or to differences in preferences.

This problem is *potentially* less serious for part-time fishermen, whose optimum condition can be written as

$$F'(L_i\,;\,\beta_i) = w_i\,. \tag{11}$$

Since the $w_i$, unlike the preference function parameters $\delta_i$, are observable in principle, we should be able to identify the catch function parameters $\beta_i$. Unfortunately, our data sets do not contain information on alternative wage opportunities, so the identification problem exists in this case as well.

To evaluate the seriousness of this difficulty, we estimated a version of the optimum condition (10) under two alternative specifications : (1) all fishermen have identical preferences (all $\delta_i$ identical), so that all behavioural differences are due to differences in catch functions, and (2) all fishermen have identical catch functions $f(L)$ up to a scalar multiple ($\beta_i$ identical), so that behavioural differences are due entirely to differences in tastes. The sample we utilized was the set of fishermen qualifying for seasonal benefits during 1982 in Newfoundland, meeting the following characteristics :

i) worked between 10 and 23 insured weeks, so that they fall in Stage 3 of the benefit-weeks relationship (8) ;

ii) drew the maximum 27 weeks of benefits, so that they were unemployed throughout the benefit period ; and

iii) earned less than the maximum weekly insured earnings of $350 in their qualifying weeks.

We are left with a sample of 5,631 out of a potential 13,142 claimants. Unfortunately, our data source does not distinguish between full-time and part-time fishermen. The 1984 DFO Income Study reveals that in that year, 77 % of seasonal fishermen's benefit recipients were full-time fishermen, so we feel justified in using the full-time model on this sample.

We use log-linear approximations for both the catch functions $f(L)$ and the utility functions $U(F, L)$. We represent the catch function as

$$f_i = \alpha_i\, L_i^{\beta_i}\,. \tag{12}$$

The elasticity of the seasonal catch $f$ with respect to the number of fishing weeks $L$ is measured by the $\beta$ parameter, which should be between 0 and 1. The greater the curvature of the $f(L)$) curve, the lower is $\beta$.

The $\alpha$ parameter reflects the productivity of the fisherman for a particular value of $L$. This is known to vary considerably from person to person, depending on such factors as experience, location, and innate skills. We assume that $\alpha$ is related to various socio-demographic indicators by a semi-logarithmic relationship of the form

$$\ln \alpha_i = Z_i \gamma + \epsilon_i , \tag{13}$$

where $Z_i$ is the vector of relevant socio-demographic indicators and $\epsilon_i$ captures otherwise "unexplained" variations in $\alpha$. In the regressions, we use the following indicators in $Z$:

1. Age of the claimant (AGE).
2. A binary sex dummy variable (SEX) which equals zero if the claimant is male and one otherwise.
3. A binary occupation dummy variable (FISHER) which equals one if the claimant is classified as a fisherman in the database and zero otherwise.
4. A number of binary dummies for CEIC management areas (AREA) where the claimant has filed his/her claim. [11]

The first three variables are expected to be indicators of experience. The fourth should reflect local fish abundance.

Substituting (13) into (12) gives the catch equation

$$\ln f_i = Z_i \gamma + \beta_i \ln L_i + \epsilon_i . \tag{14}$$

The utility function used is a Cobb-Douglas function in income $F_i$ and weeks of 'leisure' $52 - L_i$,

$$U_i = F_i^{\delta_i}(52 - L_i)^{1-\delta_i} , \tag{15}$$

which implies the marginal rate of substitution function

$$MRS_{FL} = \frac{1 - \delta_i}{\delta_i} \frac{F_i}{52 - L_i} \tag{16}$$

Within the selected sample, $B(L) = B_{max}$ since all claimants are in Stage 3 of the $B(L)$ function. As well, we can reasonably assume that $E(L) = f(L)/L$, since weekly insured earnings are below the maximum. Thus from equation (4) unemployment benefits are

$$S_i = rB_{max} \frac{f(L_i)}{L_i} . \tag{17}$$

Substituting (17) into (7) and differentiating with respect to $L$ gives the slope of the fishing income function

$$F'(L_i) = \left[1 + \frac{rB_{max}}{L_i}\right] f'(L_i) - \frac{rB_{max}}{L_i^2} f(L_i) . \tag{18}$$

The optimum condition (8b) can be arrived at by equating the slope of the fishing income function (18) with that of the indifference curve (16). After simplifying, we can express the optimum condition as

11. The CEIC management areas are coded as follows, with St. John's as datum : AREA40 = Clarenville, AREA41 = Happy Valley, AREA51 = St. John's Central, AREA52 = St. John's West, AREA53 = Harbour Grace, AREA54 = Gander, AREA55 = Marystown, AREA57 = Grand Falls, AREA58 = Stephenville, AREA60 = Corner Brook.

$$\frac{1-\delta_i}{\delta_i}\frac{L_i}{52-L_i}+\frac{rB_{max}}{L_i+rB_{max}}=\beta_i\,, \tag{19}$$

where $L_i$ is shown to be a function of both $\delta_i$ and $\beta_i$. Since neither parameter is directly observable, neither can be identified without further restrictions.

If we assume that fishermen have identical preferences ($\delta_i = \delta$), then we can, by substituting (19) into (14), express the optimum condition as the linear-in-parameters relationship

$$\ln f_i - \frac{rB_{max}}{L_i+rB_{max}}\ln L_i = Z_i\,\gamma + \theta\frac{L_i}{52-L_i}\ln L_i + \varepsilon_i\,, \tag{20}$$

where $\theta = \delta/(1-\delta)$. Since in this sample the replacement rate $r$ is 0.6 and the maximum benefit period $B_{max}$ is 27, we can estimate the parameters $\theta$ and $\gamma$ through ordinary least squares. Values of $\beta_i$ corresponding to various values of $L_i$ can then be obtained from equation (20).

The regression results are reported in the column of Table 5 labelled Run 1. The estimated value of $\theta$ is 0.52, which corresponds to a value of the utility function parameter $\delta$ equal to 0.34. The $\gamma$ parameters are also presented. Age is positively related to productivity, although not significantly. Males are significantly more productive than females, and those classified in the database as fishermen are more productive than those not so classified. There are also significant geographic differences, as reflected in the AREA dummies.

Values of the catch function parameter $\beta$ which are implied by equation (20) are presented in Table 3 for various levels of $L$. The median value of $L$ in the sample is 12.

Suppose now that all fishermen have identical values for the catch function parameter $\beta$, rather than for the utility function parameter $\delta$. We continue to permit the $\alpha$ parameter in the catch equation (12) to differ among fishermen, so only the curvature, and not the position of the catch function is invariant. Then the catch function in equation (14) is linear in parameters and can be estimated directly using ordinary least squares.

The regression results are reported in the column of Table 5 labelled Run 2. The estimated values of the $\gamma$ parameters are similar to those estimated from the identical preferences model in Run 1, although the influence of the age is much greater in the latter model. The estimated value of the catch function parameter $\beta$, however, is 0.91, which is significantly higher than those values implied in the identical preferences model and reported in Table 3. Similarly, the values of the utility function parameter $\delta$ implied by equation (19) for this value of $\beta$ are presented in Table 4. We see values considerably higher than the value 0.34 estimated in the identical preferences model. The implication is that the model specification *does* matter.

It does not necessarily follow that we have to choose between two extreme specifications, those of identical preferences and identical opportunities. We may be able to identify the two sets of parameters on the basis of much weaker assumptions on the distribution of these parameters, through the utilization of maximum likelihood techniques. The existence of piecewise segments in the opportunities set should enhance the possibility of identifying the two sets of parameters, as should the parameter changes to which the unemployment insurance program (and therefore the opportunities set) has been subjected over the years. However, we have not yet solved this statistical problem to our satisfaction.

### *4.2 Piecewise non-linear opportunity sets*

The theoretical structure outlined in Part II demonstrates that the optimum relationship governing the determination of the fishing season can be decomposed into four distinct segments. Linear estimation of this relationship across the entire spectrum of fishing seasons is clearly unacceptable, even as an approximation. This is clear from an examination of the relationships portrayed in Figure 4.

The easiest solution to this problem, and the one used in the early literature on non-linear budget constraints (see Hausman 1985 for a survey), is simply to estimate the relationship for each segment separately from the others.

There are two problems with this procedure. First, it is relatively inefficient in that information from data contained in one segment (on preferences, say) is not utilized in the estimation of the relationship across other segments. Second, optimization errors on the part of fishermen (as a result of uncertainty, for example) can result in behaviour which would introduce bias into the parameter estimates.

The source of this bias is twofold (Pudney 1989, pp. 198-201). First, optimization errors result when a random variable is added to equation (20). Then variable $L_t$ becomes random as well, and therefore regression estimates of equations such as (14) or (20) are subject to simultaneity bias.

The second source of bias is that with optimization errors, the observed and optimum positions of a given data point may lie on different segments. For example, a fisherman who would best locate in Stage 2 mistakenly fishes into Stage 3. When such points are grouped into the "wrong" segment, the resultant estimates are biased.

A problem related to the above is that points whose optimum position is at the corner vertex formed by two segments will generally satisfy a tangency condition for neither segment. Inclusion of these boundary points in the estimation will also bias the results. When fishermen make optimization errors, however, we cannot identify cases with corner optima.

This is not a new problem. There exists an extensive literature (Wales and Woodland 1979 ; Zabalza 1983 ; Phipps 1990 ; Osberg and Phipps 1989) on the impact of piecewise-linear constructs such as progressive income taxes and unemployment insurance on the length of work spells. Maximum likelihood methods have been successfully utilized to resolve these difficulties (Pudney 1989, pp.201-205). The problem, however, is simplified considerably by the assumption usually made that work is available throughout the year at a fixed wage. The challenge is to adopt these techniques to contexts, such as the present one, in which the "wage" varies systematically through the year.

### *4.3 Upper and lower limits and partially observable data*

In the regressions reported above, we removed from our sample claimants whose average insured earnings were at the maximum $350 per week, because we could no longer use the level of insured earnings as a measure of earned income. This required discarding 939 observations, a considerable loss of information. Moreover, there is considerable danger in this procedure of sample selection bias resulting from the removal from our sample of the most productive fishermen. Fortunately, there is an extensive econometric literature on this so-called partial observability problem (Pudney 1989, ch. 4).

We have tested two alternative specifications of the identical opportunities model. The first, labelled Run 3, re-estimates Run 2 using a sample which includes claimants reporting the maximum insured earnings during their qualifying weeks. The second, labelled Run 4, is a Tobit regression analogous to Run 3. The outcome, which frankly surprised us, is that there is only a negligible difference in the estimated values of $\beta$ and most of the components of $\gamma$ among these three runs. The truncation in the value of maximum insured earnings does not appear to be a serious problem, at least in this sample.

## 5. SIMULATION EXERCISES

Successful estimation of the optimal conditions would enable us to simulate the impact of changes in the parameters underlying the unemployment insurance program on the length of the fishing season. For example, let us take the identical opportunities model underlying Run 2 as valid. We can rewrite the optimum condition (19) as

$$\theta_i = \beta \frac{52 - L_i}{L_t} - \frac{rB_{max}(52 - L_t)}{(rB_{max} + L_i) L_i}, \tag{21}$$

which enables us to associate a value $\theta_t$ with each value of $L_i$, for an estimated value of $\beta$ such as the 0.91 in Run 2. The implied $\delta_i$ values are reported in Table 3. Now rewrite equation (21) as

$$(\beta + \theta_i) L^2 - [(52 - rB_{max}) \beta + rB_{max}(1 - \theta_i)] L + 52 rB_{max}(1 - \beta) = 0 , \quad (22)$$

a quadratic equation in $L$. For the given $\beta$ and $\theta$, we can evaluate the value of the number of fishing weeks $L$ which would prevail if either of the unemployment insurance parameters $r$ and $B_{max}$ were modified.

Table 6 presents the simulated outcome of (a) a reduction in the benefit-earnings ratio $r$ from 0.6 to 0.5 ; (b) a reduction in the maximum number of benefit weeks $B_{max}$ from 27 to 20 weeks ; and (c) both changes simultaneously. The first change increases the number of fishing weeks by anywhere from 1.6 to 2.6 weeks, depending on the initial value of $L$. The second change increases the number of fishing weeks by from 2.2 to 3.9 weeks. The two changes together increase the number of fishing weeks by from 3.1 to 5.4 weeks. These are fairly large changes. As expected, the impact of the two changes together is not additive. Note that the simulated changes occasionally go outside Stage 3, and this would have to be taken into consideration in a full simulation.

## REFERENCES

**Ferris S. and C. Plourde** (1980). *Fisheries Management and Employment in the Newfoundland Economy.* Ottawa : Economic Council of Canada, Discussion Paper No. 173.

**Ferris S. and C. Plourde** (1982). "Labour mobility, seasonal unemployment insurance, and the Newfoundland inshore fishery," *Canadian Journal of Economics*, **15** (3) : 426-441.

**Hausman J.A.** (1985). "The econometrics of nonlinear budget sets," *Econometrica*, **53** (6) : 1255-82.

**Osberg L. and S. Phipps** (1989). "Quantity constraints in the analysis of labour supply," Dept. of Economics, Dalhousie University, Working Paper no. 89-04.

**Phipps S.** (1990). "Quantity-constrained household responses to UI reform," *Economic Journal* , **100** (399) : 124-40.

**Pudney S.** (1989). *Modelling Individual Choice : the Econometrics of Corners, Kinks and Holes.* Cambridge : Basil Blackwell.

**Roy N., E. Tsoa, W.E. Schrank and L. Mazany** (1992). "Canadian unemployment insurance and its impact on inshore fishermen : a preliminary analysis." St. John's, mimeo.

**Wales T.J. and A.D. Woodland** (1979). "Labour supply and progressive taxes," *Review of Economic Studies*, **46 :** 83-95.

**Zabalza A.** (1983). "The CES utility function, non-linear budget constraints and labour supply. Results on female participation and hours," *Economic Journal*, **93** : 312-330.

TABLE 1.
DISTRIBUTION OF ACTIVE FISHERMEN BY TYPE OF UNEMPLOYMENT INSURANCE BENEFIT AND LICENSING CLASSIFICATION, NEWFOUNDLAND, 1984.

| | Full-time Fishermen | Part-time Fishermen | All Fishermen |
|---|---|---|---|
| Fishermen's benefits | 79.3% | 36.4% | 63.6% |
| Regular benefits | 7.7% | 26.1% | 14.4% |
| Both | 1.4% | 4.8% | 2.7% |
| Neither | 11.6% | 32.7% | 19.3% |

TABLE 2.
UNEMPLOYMENT INSURANCE BENEFIT WEEK PARAMETERS NEWFOUNDLAND, 1972-91.

| | $q$ | $B_{ext}$ | $B_{max}$ |
|---|---|---|---|
| 1972-75 | 8 | 0 | 22 |
| 1976 | 8 | 18 | 27 |
| 1977- | 10 | 20 | 27 |

TABLE 3.
VALUES OF B IMPLIED BY RUN 1 RESULTS.

| $L_i$ | $\beta_i$ | $L_i$ | $\beta_i$ |
|---|---|---|---|
| 10 | 0.742 | 17 | 0.740 |
| 11 | 0.735 | 18 | 0.748 |
| 12 | 0.730 | 19 | 0.759 |
| 13 | 0.728 | 20 | 0.772 |
| 14 | 0.728 | 21 | 0.787 |
| 15 | 0.730 | 22 | 0.805 |
| 16 | 0.734 | 23 | 0.825 |

TABLE 4.
VALUES OF Δ IMPLIED BY RUN 2 RESULTS.

| $L_i$ | $\delta_i$ | $L_i$ | $\delta_i$ |
|---|---|---|---|
| 10 | 0.449 | 17 | 0.535 |
| 11 | 0.460 | 18 | 0.548 |
| 12 | 0.472 | 19 | 0.561 |
| 13 | 0.484 | 20 | 0.575 |
| 14 | 0.497 | 21 | 0.588 |
| 15 | 0.509 | 22 | 0.601 |
| 16 | 0.522 | 23 | 0.615 |

**TABLE 5.**
**REGRESSION COEFFICIENTS AND STANDARD ERRORS.**

| Run | Run 1 | Run 2 | Run 3 | Run 4 |
|---|---|---|---|---|
| Model | Identical preferences | Identical Opportunities | | |
| Upper bound treatment | Data with $E(L) < \$350$ only | | All Data | |
| Estimator | Ordinary Least Squares | | | Tobit |
| $\theta$ | 0.519 (0.007) | | | |
| $\beta$ | | 0.914 (0.014) | 0.907 (0.013) | 0.896 |
| AGE | 0.0036 (0.0025) | 0.00007 (0.00024) | 0.0015 (0.0023) | 0.0002 |
| SEX | -0.192 (0.015) | -0.172 (0.011) | -0.176 (0.011) | -0.188 |
| FISHER | 0.035 (0.007) | 0.034 (0.007) | 0.041 (0.007) | 0.051 |
| AREA40 | -0.027 (0.018) | -0.136 (0.018) | -0.0005 (0.0166) | 0.007 |
| AREA41 | -0.062 (0.023) | -0.056 (0.023) | -0.060 (0.022) | -0.059 |
| AREA51 | -0.051 (0.036) | -0.036 (0.036) | 0.009 (0.032) | 0.021 |
| AREA52 | 0.021 (0.019) | 0.031 (0.019) | 0.082 (0.017) | 0.129 |
| AREA53 | 0.053 (0.018) | 0.068 (0.018) | 0.095 (0.017) | 0.130 |
| AREA54 | 0.039 (0.017) | 0.047 (0.016) | 0.056 (0.016) | 0.067 |
| AREA55 | -0.153 (0.029) | -0.155 (0.029) | -0.172 (0.029) | -0.178 |
| AREA57 | -0.0001 (0.018) | 0.0006 (0.018) | 0.019 (0.017) | 0.031 |
| AREA58 | -0.160 (0.033) | -0.137 (0.033) | -0.104 (0.030) | -0.096 |
| AREA60 | -0.042 (0.017) | -0.043 (0.017) | -0.039 (0.016) | -0.035 |
| Constant | 6.223 (0.019) | 5.788 (0.040) | 5.907 (0.127) | 5.847 |
| Adjusted $R^2$ | 0.53 | 0.48 | 0.48 | |

**TABLE 6.**
**SIMULATED NUMBER OF FISHING WEEKS, VARIOUS UNEMPLOYMENT INSURANCE PARAMETER VALUES.**

| $r = 0.6$ $B_{max} = 27$ | $r = 0.5$ $B_{max} = 27$ | $r = 0.6$ $B_{max} = 20$ | $r = 0.5$ $B_{max} = 20$ |
|---|---|---|---|
| 10 | 12.65 | 13.89 | 15.43 |
| 11 | 13.46 | 14.65 | 16.14 |
| 12 | 14.31 | 15.45 | 16.89 |
| 13 | 15.18 | 16.28 | 17.67 |
| 14 | 16.07 | 17.13 | 18.48 |
| 15 | 16.97 | 17.99 | 19.29 |
| 16 | 17.88 | 18.86 | 20.13 |
| 17 | 18.80 | 19.75 | 20.97 |
| 18 | 19.72 | 20.64 | 21.82 |
| 19 | 20.65 | 21.53 | 22.67 |
| 20 | 21.59 | 22.43 | 23.53 |
| 21 | 22.52 | 23.34 | 24.40 |
| 22 | 23.46 | 24.25 | 25.27 |
| 23 | 24.40 | 25.16 | 26.14 |

FIGURE 1A.
PART-TIME FISHERMAN EQUILIBRIUM.

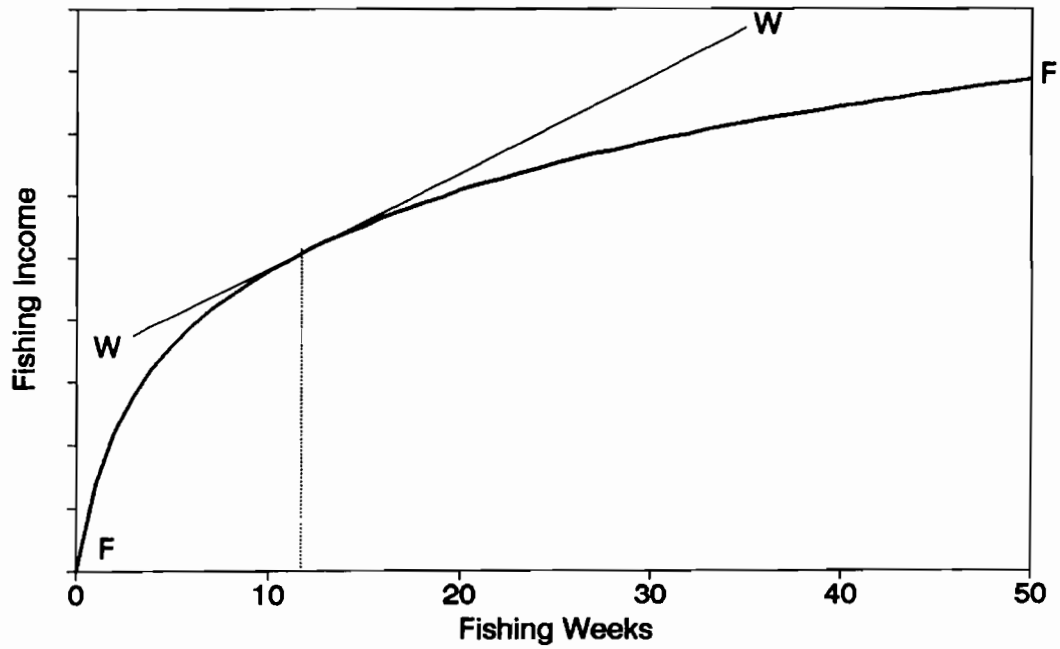



FIGURE 1B.
FULL-TIME FISHERMAN EQUILIBRIUM.

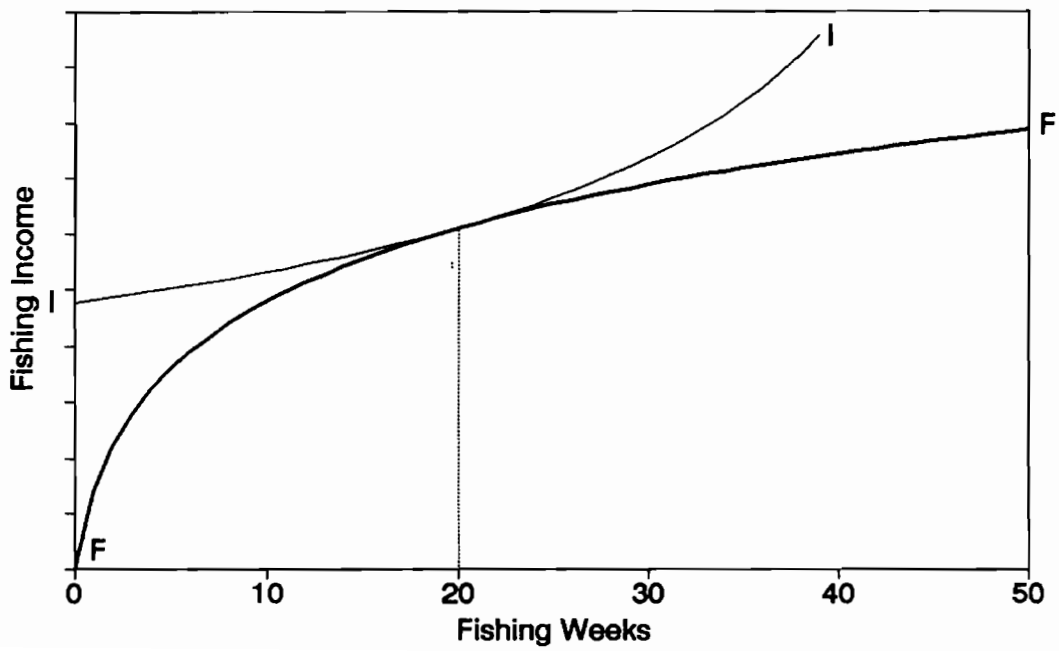


FIGURE 2.
BENEFIT WEEKS, SEASONAL FISHING 1972–75.

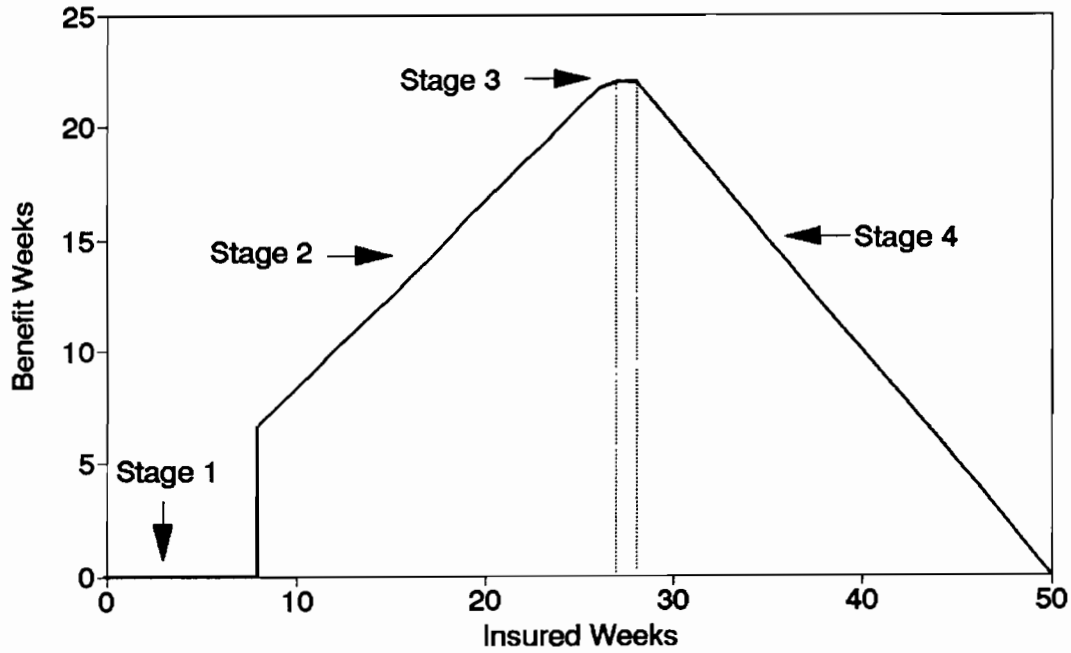



FIGURE 3.
CHANGES IN BENEFIT WEEK RELATIONSHIP.

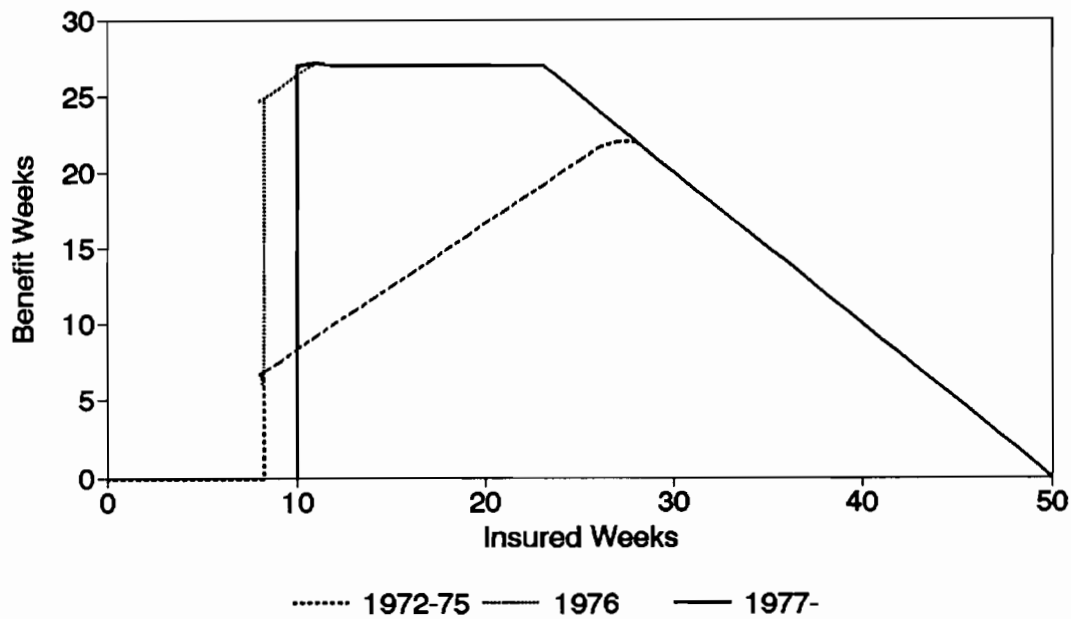


FIGURE 4.
FISHING INCOME RELATIONSHIP, 1972–75.

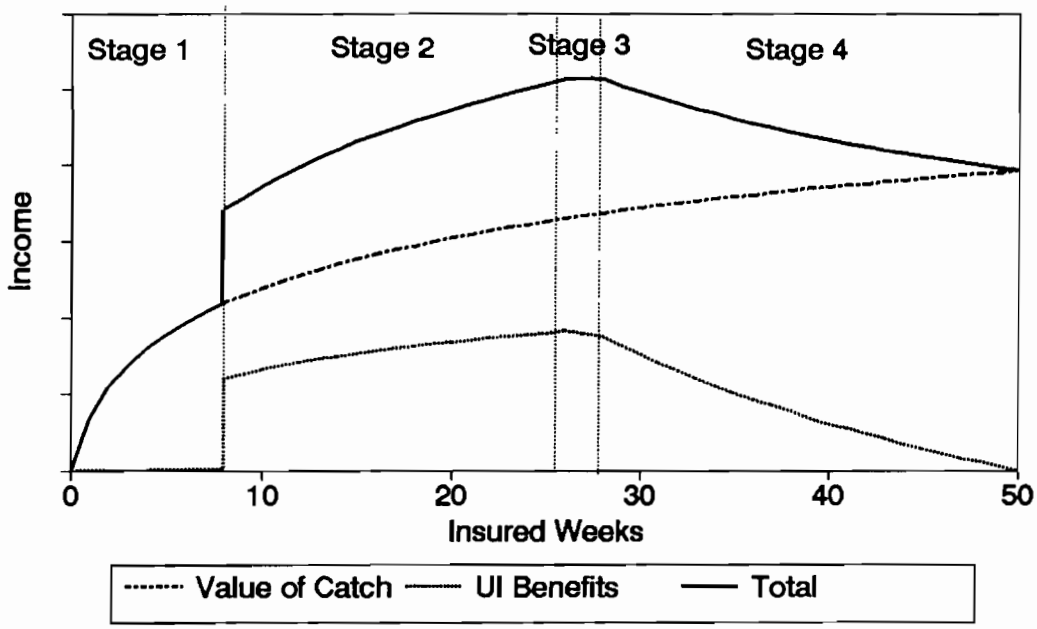



FIGURE 5A.
STAGE 1 EQUILIBRIUM - CASE 1.

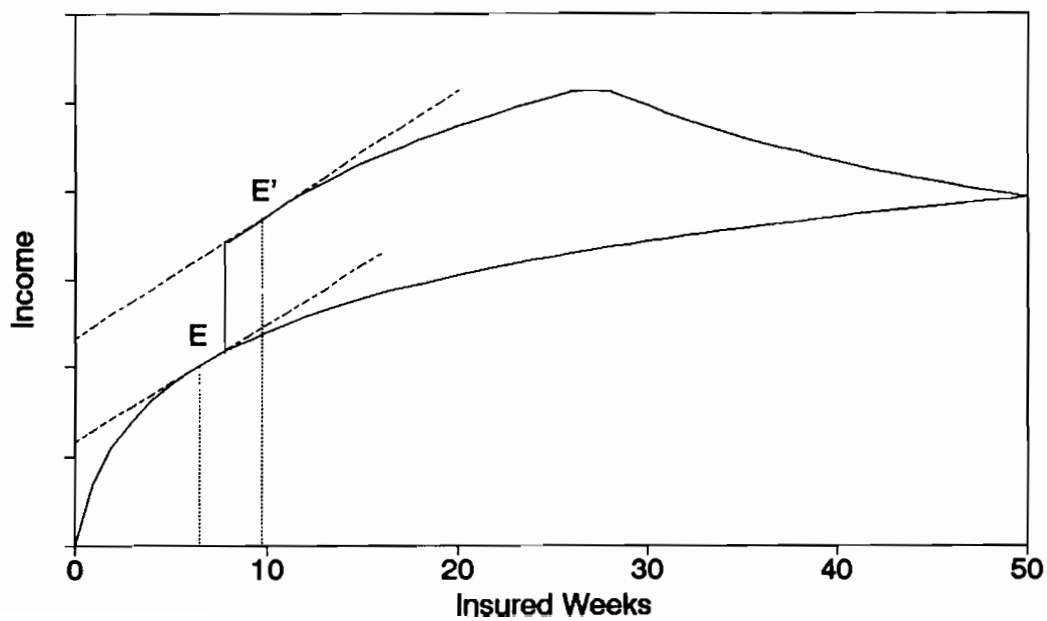


**FIGURE 5B.**
**STAGE 1 EQUILIBRIUM - CASE 2.**

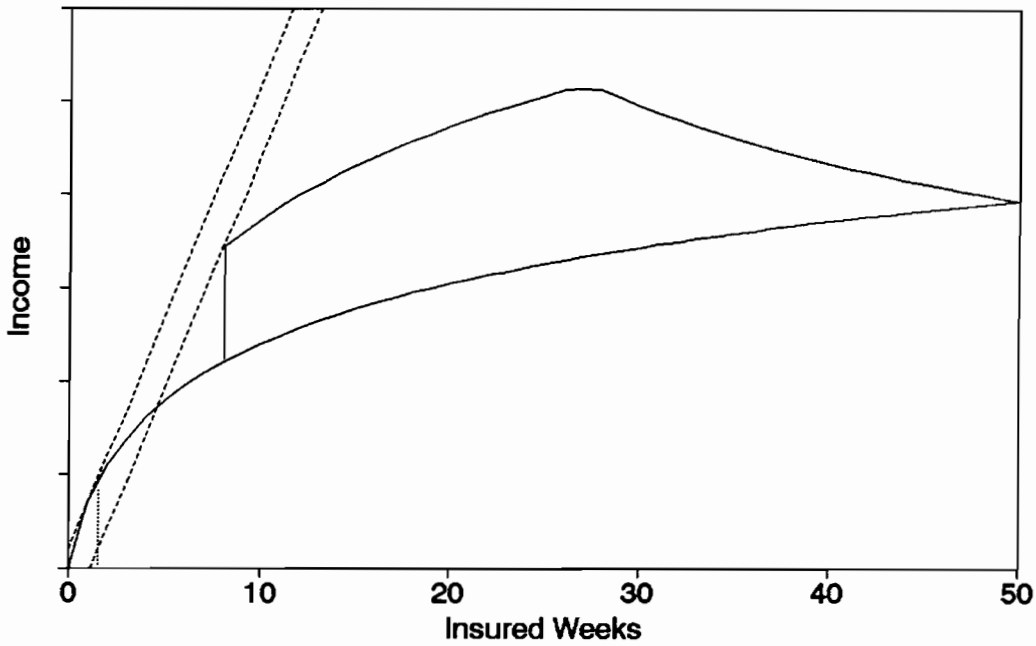



**FIGURE 6.**
**STAGE 2 EQUILIBRIUM.**

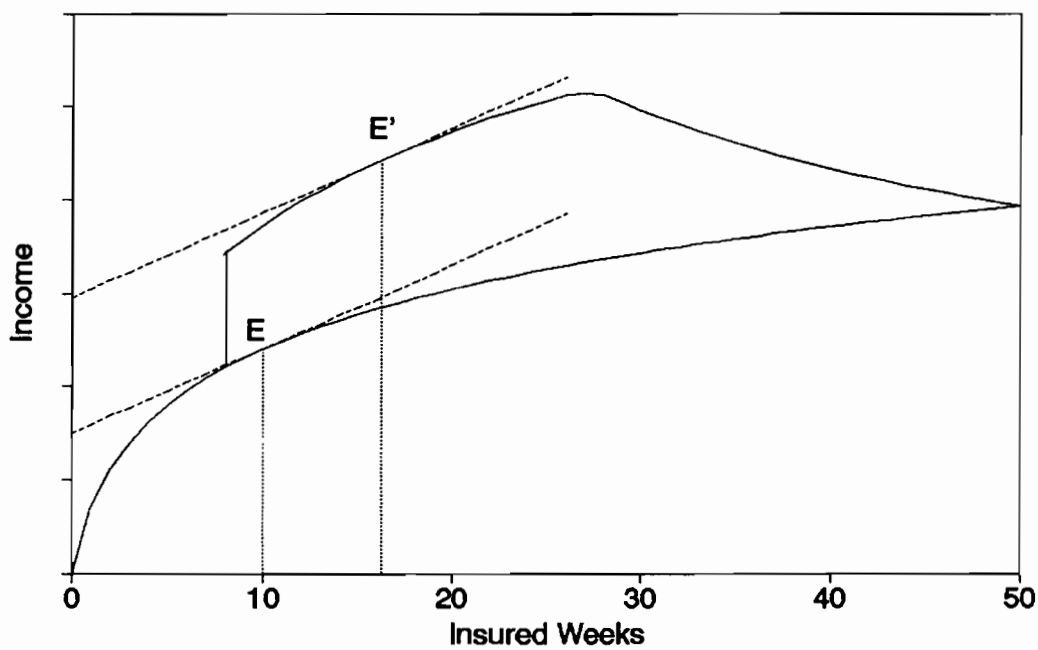
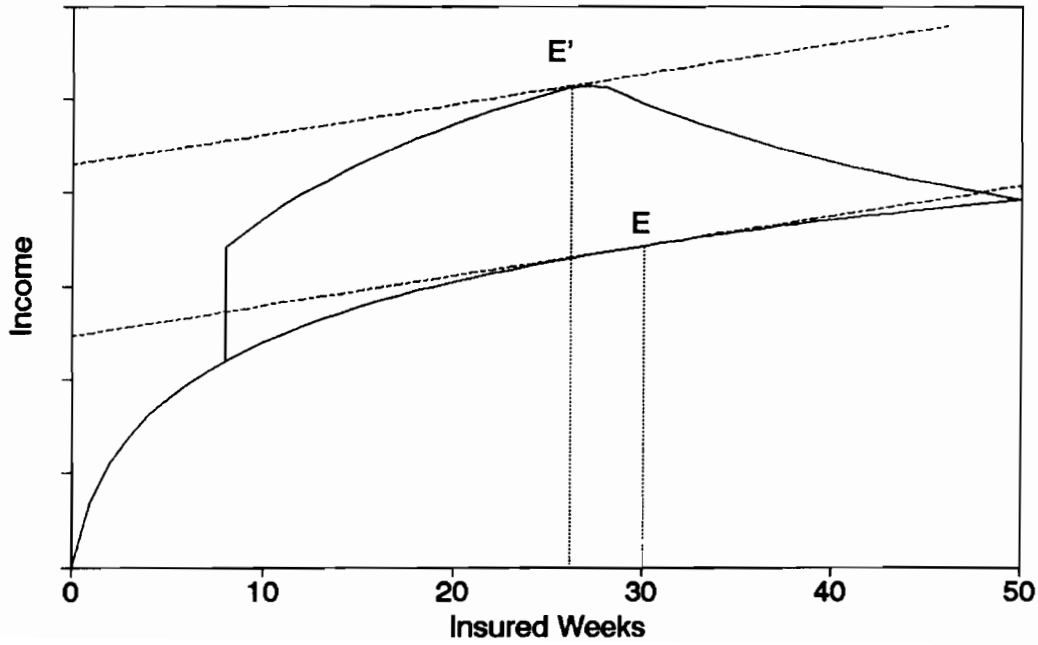


**FIGURE 7.**
**STAGE 3–4 EQUILIBRIUM.**



# Multiproduct Tuna Fisheries in the South West Pacific

**Harry F. Campbell[a], A. McIlgorm[b] and R.B. Nicholl[a]**

[a]University of Queensland, Brisbane Qld 4072, Australia

[b]Australian Maritime College, GPO Box 4, Beaconsfield, 7251, Tasmania, Australia

[c]University of Tasmania, Dept of Economics, GPO Box 252C, Hobart, Tasmania, Australia

ABSTRACT

*The major tuna fisheries in the southwest Pacific are the purse seine fishery catching skipjack and juvenile yellowfin, and the longline fishery catching a range of species including albacore, yellowfin, bigeye, marlin, and swordfish. The paper describes studies of three of these fisheries - the eastern longline fishery in the Australian Fishing Zone, and the purse seine and longline fisheries in Papua New Guinea's Exclusive Economic Zone. The studies involve calculating fishing costs and estimating multi-species production functions. An example of the policy application of this work is the question of whether purse seine catches should be restrained to conserve juvenile yellowfin for the longline fishery. The cost of such a policy depends upon whether purse seiners are able to target their fishing effort on particular species. The paper reports evidence that suggests that targeting is possible and shows that a policy of yellowfin conservation will be less costly in these circumstances than otherwise.*

## 1. INTRODUCTION

Bioeconomic modelling of fisheries involves specifying a biological production (or growth) function and an economic production (or harvest) function. Early bioeconomic models (see for example, Schaefer (1967)) adopted a single species approach to both the biological and economic production functions. Later work recognized that biological interactions among species should be taken into account even if the aim of the model was to predict the impact of fishing a single species. The recognition of competition among species for food, as in the case of the Peruvian anchovy and Californian sardine (see Murphy (1967)), or of predator-prey relationships, such as the relationship among capelin, cod and seals in the Barents Sea (see Flaaten (1986)), led to more complete modelling of the biological production process and presumably to more robust management prescriptions.

Recent work has developed a multi-species approach to the economic production relationship in the bioeconomic model. In many cases, such as trawl fisheries, a number of species are regularly harvested by the fleet. Some species may be regarded as major species while others are by-catch. This situation can be modelled within a multi-output/multi-input production function framework. The fact that vessels simultaneously harvest more than one species imposes a constraint on the fishery manager. In an extreme case in which species are caught in fixed proportions, the fishery manager is tightly constrained in his ability to regulate the stock of any individual species. How tight the constraints imposed by the nature of the economic production process are can be ascertained by estimating the inter-relationships among species in the form of a multi-species production function.

The present study uses the multi-species production function approach to estimate the relationships between the harvests of various species in the tuna fisheries of the South West Pacific region. Two fisheries are considered : the longline fishery which harvests seven species - yellowfin, big eye, albacore, swordfish, black marlin, blue marlin, and striped marlin ; and the purse-seine fishery which catches two main species - skipjack and juvenile yellowfin. The longline fisheries studied are located in the North East portion of the Australian Fishing Zone, and in Papua New Guinea's Exclusive Economic Zone (EEZ). In the former area the operations of both Australian and Japanese vessels are analysed, while in the latter area the study is concerned with Japanese vessels only. The purse-seine fishery studied is pursued by Japanese and United States vessels in Papua New Guinea's EEZ.

In Part 2 of the study the multi-species production function approach is outlined and its relevance for fishery management is discussed. Part 3 describes the objectives and approach of the individual studies referred to above. In Part 4 one of the studies is described in more detail and its results are used to illustrate the importance for policy making of understanding the multi-species structure of the economic production function. The example chosen is that of the tuna purse-seine fishery, and the policy issue used as an illustration is the question of reducing the purse-seine harvest of juvenile yellowfin to benefit the longline fishery. The paper concludes with a brief discussion of the importance of the multi-species approach.

## 2. THE MULTI-SPECIES APPROACH TO FISHERY PRODUCTION

The multi-species approach to estimating the technology of the economic production function for a fishery has been adopted in several recent studies. Squires (1987, 1988) uses a translog multi-product restricted profit function to estimate the technology of the New England otter trawl fishery which harvests cod, flounders, haddock, redfish and pollock. Kirkley and Strand (1988) estimate a dual revenue function for the New England, Georges Bank trawl fishery which exploits a similar range of species. Squires and Kirkley (1991) use a generalized Leontief revenue function to estimate input-compensated supply functions for five species - dover sole, thorny heads, sable fish (Alaska or black cod), other flatfish, other rockfish - plus miscellaneous species in the multi-species trawl fishery off the California coast. The Kirkley and Strand (1988) and Squires and Kirkley (1991) studies treat fishing effort as a single composite input, whereas the Squires (1987, 1988) papers consider three inputs - labour, energy, and capital.

The purpose of the above studies is to establish which of those features of the technology of the economic production function should be taken into account in developing fishery management policy. The implications of the multi-input nature of the economic production function for fishery management through gear regulation have been developed by Anderson (1985), Campbell and Lindner (1990), and Campbell (1991). Since the focus of the present paper is on the implications of the multi-species nature of the fishery for management through various forms of output regulation, the single input case will be used for illustrative purposes.

The two main features of the technology of the economic production function can be established by tests for input-output separability and non-jointness-in-inputs (see Squires (1991)). In describing these two characteristics of technology it will be assumed that the firm's short-run behaviour involves maximizing revenue subject to a fixed input constraint. In the long-run the firm varies its input level to maximize profit. Revenue is maximized in the short-run by choosing a point on the product transformation curve where the marginal rate of product transformation is equal to the relative price of the species. Input-output separability implies no specific interaction between any one output and any one input. In the two output, one input case, this means that the marginal rate of transformation between any two outputs is independent of scale. Figure 1 shows product transformation curves for two levels of effort contributed by a vessel in a two-species fishery. The marginal rate of product transformation is given by the negative of the slope of the product transformation

curve. The revenue maximizing output combinations are indicated by the points marked A in Figures 1(a) and 1(b). In Figure 1(a) the product transformation curve exhibits input-output separability as the catch per unit effort of both species is independent of the level of effort. In other words, the product transformation map is homothetic. In Figure 1(b) the proportion of species 1 in the total harvest falls as scale increases because of an absence of input-output separability.

Non-jointness in inputs implies that separate production functions exist for each output. This means that the proportion of each species in total harvest depends only upon the level of effort and is not influenced by price. A technology which is joint in inputs allows vessels some control over the proportions of species in their harvest. They are able to "target" particular species. Figure 2(a) illustrates a production technology which is non-joint in inputs since the catch per unit effort for both species depends only on scale. Figure 2(b) illustrates jointness-in-inputs so that a change in the price ratio from $P_1$ to $P_2$ changes the catch per unit effort of each species, holding effort constant.

The generalized Leontief revenue function for the two output, one input case can be used to illustrate the two main features of the production technology described above. The revenue function is :

$$R(P, E) = \sum_i \sum_j \beta_{ij} (P_i P_j)^{1/2} E + \sum_i \alpha_i P_i E^2 \qquad (2.1)$$

where $P_i$ is the price of output $i$ and $E$ is the level of fishing effort. The supply functions are given by :

$$h_i(P, E) = \beta_{ii} E + \alpha_i E^2 + \sum_{j \neq i} \beta_{ij} (P_j / P_i)^{1/2} E \qquad (2.2)$$

If there is input-output separability, $\alpha_i = 0$ , and the catch per unit effort is independent of the level of effort, although it may be influenced by the relative price of the species. If there is non-jointness-in-inputs, $\beta_{ij} = 0$ for $i \neq j$, and catch per unit effort is independent of the relative price, although it may vary with the level of effort. In this case the harvest of each species is described by a species-specific quadratic function of fishing effort. If both input-output separability and non-jointness in inputs hold, catch per unit effort is a constant.

It is evident that the restrictive forms of the harvest production function impose severe constraints on the fishery manager. If the technology exhibits non-jointness-in-inputs the catch per unit effort of each species is technologically determined. This means that vessels are unable to respond to price signals conveyed through differential royalties on species, or to observe species quotas which are in proportions other than those determined by the technology. If there is input-output separability the species proportions will be unaffected by changes in the amount of fishing effort. The effect of these constraints will be to raise the cost of fishery management. Imposing a low TAC on an overexploited fishery may imply a relatively low harvest from a relatively unexploited fishery. Quotas which are enforced in different species proportions to those dictated by the harvest technology may result in dumping of catches of the relatively low quota species. Quotas or royalties which are tightly enforced may result in vessels withdrawing from the fishery. Fishery managers will need to make the appropriate trade-offs between sustainability and catchability and this will require information about technology.

## 3. MULTIPRODUCT STUDIES OF THE SOUTH WEST PACIFIC TUNA FISHERIES

Three studies are currently underway of multiproduct production technology in the South West Pacific tuna fishery. A study of the longline fishery in the North East portion of the Australian Fishing Zone, funded by the Australian Fishing Industry Research and Development Corporation, is being undertaken by Campbell and McIlgorm (1992a, 1992b). This study is part of a more comprehensive study by McIlgorm (forthcoming). The other two studies are of fisheries in Papua New Guinea's EEZ and are being undertaken by Campbell and Nicholl (1992a, 1992b). One study recently completed is of the tuna purse-seine fishery and the other in progress is of the longline fishery. Both studies are funded by the Australian Centre for International Agricultural Research (ACIAR).

*3.1 The Australian East Coast Tuna Longline Fishery*

### 3.1.1 Introduction

The fishery extends along the Australian east coast from Cape York in the north to Sydney in the south. The tuna fishery in this area is multi-species, with catches of yellowfin, albacore, bigeye, and billfishes, (black, blue and striped marlin and swordfish). The fishery has both foreign and domestic fleets. The Japanese catch in this area of the Australian Fishing Zone (AFZ) totalled approximately 6000 tonnes of all species in 1990. The fishery is primarily based on yellowfin tuna destined for the Japanese frozen sashimi tuna market. However the fishery also has significant catches of marlin and swordfish. Catch from the east coast fishery had a value of approximately 20 million Australian dollars in 1990. This is smaller than Australia's largest tuna fishery, Southern Bluefin tuna, which was worth 72.2 million dollars in 1990 (Geen, 1991).

During the 1980's smaller domestic vessels became involved in the inshore tuna fishery. The domestic vessels have aimed at supplying the more lucrative fresh Japanese sashimi market. The domestic fishers catch approximately 600 tonnes of yellowfin with a small by-catch of other species. In 1991 the domestic fishery was worth approximately 7 million dollars at first point of sale.

There is also an Australian recreational sports fishery operating from ports along the East coast. These big-game fishing vessels target marlin and billfish as well as yellowfin and albacore tuna.

### 3.1.2 Management

The Japanese have been longlining for tuna in the East Australian fishery since the mid 1950s. The Australian Fishing Zone was formed in 1979. Since extended fisheries jurisdiction, Japanese access has been managed by a combination of restricted areas, seasons and licencing agreements negotiated annually with the Australian Government. An agreed number of vessels pay access fees and have not been subject to any catch limits until the most recent negotiations for 1992.

The domestic fishery is managed by the East Coast Tuna Management Advisory Committee (ECTUNAMAC). Entry to the fishery is by licence, referred to as an endorsement. Developmental endorsements have been introduced in the hope of promoting further development of the fishery. The domestic vessels are only capable of fishing inshore. Since the late 1980s an area extending to 50 miles from the coast has been kept exclusively for domestic access.

### 3.1.3 The Research Project

Research into the future management of the fishery has been promoted by the ECTUNAMAC of the Australian Fisheries Service. Workshops promoting discussion of future management options have prompted research on the economics of the fishery (McIlgorm, 1990).

### 3.1.4 The Objectives of the Research Project

The objective of the project is to provide management with an economic analysis that will assist in future management of the east coast region. This takes account of :

i) The costs and returns of the Australian vessels in the domestic fishery ;

ii) The benefits to Australia from licensing the Japanese fleet compared to other arrangements ; and

iii) The interactions between inshore and offshore fisheries.

Resource rent in the fisheries is estimated and the following policy issues are addressed :

i) Access fees - what type of scheme is most appropriate ?

ii) The potential economic benefits of Australianisation ;

iii) Interactions between inshore and offshore fisheries.

### 3.1.5 Data

Detailed catch and effort data for Japanese and domestic fishing vessels were made available to the project by the Australian Fisheries Service, (AFS), now the Australian Fisheries Management Authority (AFMA). This was in the form of computer logbook records for Australian and Japanese vessels for the 1980-1990 period. Japanese market price data was also made available by AFS for the same period. Data quality in the years immediately following the establishment of the AFZ was judged to be poor and therefore the 1984-1989 period was chosen for analysis. Domestic tuna price data were obtained from the New South Wales Fish Marketing Authority. Prices for the fresh sashimi market in Japan were obtained from the Fortuna-Daito fishing company, New South Wales.

### 3.1.6 The Cost Study

The rapid development of the domestic fishery has been monitored by fisheries management. However there has not been an economic survey of costs and incomes in the domestic fishery. Under the present project research a survey of approximately 100 domestic fishers was undertaken. This involved fieldwork along the east coast area. The results of the survey will be published in Campbell and McIlgorm, (1992). The methodology and detailed results can be seen in McIlgorm, (in prep). The domestic cost survey and logbook information were used to calculate the cost of effort for the domestic fishery. Estimates of the economic cost and profitability of the world-wide activities of the Japanese longline tuna fleet are reported in Campbell and Nicholl (1991). The cost of effort for the Japanese fleet in the east Australian area has been calculated by using the information reported in Campbell and Nicholl's study.

### 3.1.7 Multi Species Production

The fishery has not hitherto been subject to an examination of the economics of multispecies production, although targeting by Japanese vessels has been recognised as an issue in biological research (Ward et al., 1991). A dual revenue function approach is used to estimate the production technology in the fishery (McIlgorm, in prep). Results and policy implications of multi-species production are reported in Campbell and McIlgorm, (1992b).

### 3.1.8 Rent

To date there has been one attempt to calculate potential access fee levels in the fishery (Brown and Dann, 1991). This study used the approach developed by Geen (1990) and did not account for the possibility of multispecies joint production in the fishery.

The dual revenue function approach to production can be used to estimate potential rent from the Japanese fishery. The effect of access charges or royalties on the harvest of the various species will depend on the nature of the harvest technology. An understanding of joint production behaviour will contribute to the management of the fishery, particularly where restrictions on the catch of different species may be envisaged. Campbell and McIlgorm, (1992b) reports results of a spatial or zonal approach to production and rent calculation. Details of the estimation of spatial or zonal production can be found in McIlgorm (in prep.).

### 3.1.9 Future Policy and Foreign Fishing

In reviewing the management of the fishery McIlgorm (1990) concluded that management had managed the foreign fishery offshore and the domestic fishery as two separate entities. Given the likelihood that the fisheries are based on the same stocks it is evident that management policy should address both fisheries.

The foreign fishery has been managed by access to permitted zones. Through the 1980s the domestic fishery has increased the area reserved for Australian vessels to 50 miles from shore. The Japanese have been displaced from the

innermost coastal zone. However, the boundary between zones has not been subject to an economic assessment of potential economic benefits to Australia. Similarly, the cost to the Japanese of being displaced from these areas has not been specifically addressed. Quantification of economic benefits will assist in answering these questions. It is hoped that this research may have benefits for the general analysis of foreign fishing issues.

### *3.2 The Tuna Purse Seine and Longline Fisheries in Papua New Guinea's EEZ*

#### 3.2.1 Introduction

The tuna industry of the Western Pacific provides an important source of income for fishing fleets of a number of nations and island states which sell access rights to the stocks which are exploited from their EEZs. The size and potential value of the fisheries is such that management regimes which control the level of exploitation and account for interactions and conflicts between the different fisheries within the industry are being developed. However, in order to design and implement regulatory frameworks which take account of the conflicts and overexploitation which may arise from an unregulated industry, an understanding of the biological and economic basis of production is required. A review of some of the relevant issues is provided in Campbell, Menz and Waugh (1989).

Within the region one of the most productive fishing grounds for both the longline and purse seine fisheries is Papua New Guinea's EEZ. Moreover, the fact that both these fisheries are multiproduct fisheries with a range of vessel types, sizes and nationalities, make the task of the policy maker a complicated one. Separate analyses of both these fisheries have been conducted in order to examine how possible restrictions placed on the activities of vessels in these fisheries may result in shifts in emphasis of effort within or between the fisheries and changes in the benefits arising from them. A lack of understanding about the objectives and technical constraints which govern the workings of a fishery can result in the introduction of regulatory measures which lead to inefficiencies and the dissipation of potential benefits.

The longline fishery in Papua New Guinea supplies high quality tunas to the Japanese sashimi market. The main species caught are yellowfin, big eye, albacore, swordfish and black, blue, and striped marlins. For much of the history of this fishery, the only vessels to operate within Papua New Guinea's EEZ have been those of the Japanese fleet although more recently, longliners from Korea and Taiwan have fished in Papua New Guinea waters. The Japanese fleet has been the largest to operate in the region. South Pacific Commission (SPC) records show that for the period covering the economic analysis of the Papua New Guinea longline fishery a total of 238 Japanese vessels were active at some point in time. There were only two other nationality of vessels which operated in Papua New Guinea for this period according to official records, Korean (3 vessels) and Taiwan (1 vessel). The Japanese vessels ranged in size from 59 GRT to 379 GRT, the Korean vessels 110 GRT to 424 GRT and the Taiwanese vessel was 95 GRT.

The purse seine fishery harvests skipjack and juvenile yellowfin which is supplied to the canning industry in the region. The main purse seine fleets active in Papua New Guinea's EEZ during the period investigated were the US fleet (26 vessels) and the Japanese fleet (51 vessels). Vessels of other nationality such as Korea and Taiwan also fished in the EEZ during the period. The US vessels ranged in size from 985 to 1,559 GRT, and the Japanese vessels ranged from 116 to 999 GRT.

#### 3.2.2 The Research Project

Both the purse seine and longline studies are based on an analysis of monthly catches by individual vessels. The period of analysis for the purse seine fishery is 1983-1987 when both U.S. and Japanese vessels were engaged in the fishery. The longline study analyses the catch returns of the Japanese fleet over the period 1979-1989.

In both studies vessels were assumed to act as revenue maximizers during their fishing trips within the EEZ. A dual revenue function was used to estimate the production technology. In the longline study, attention focussed on the degree to which species caught in the fishery were produced jointly, while in the purse seine study the focus of the investigation was on the ability of vessels to target juvenile yellowfin. The implications for purse seine yellowfin targeting are that it could lead to overexploitation of this species and could reduce the returns and therefore benefits derived from the longline fishery.

### 3.2.3 The Data

The data which were used to analyse the longline fishery were obtained from the SPC data based held at the Tuna and Billfish Assessment Programme. The data describe the daily catch and effort activity at the individual vessel level, giving detail of data, vessel name and identification, gross registered tonnage of the vessel, the duration of the particular fishing trip the vessel made for any observation, latitude and longitude at 12 :00 noon (which is around the end of the period of hauling in the line), the number of hooks for a given set and the number and average weight of albacore, yellowfin, bigeye, bluefin, marlin, swordfish and sailfish caught for a given set. The data are believed to be a fairly accurate account of longline fishing activity in the zone, at least for the Japanese fleet. Price data are from the FAO GLOBEFISH data base and are average monthly ex-vessel prices for all species mentioned above, for the Japanese port of Yaizu. Although all longline catch is not unloaded at Yaizu, these prices are widely regarded as representative of the tuna market situation in Japan.

The longline analysis was conducted using monthly vessel level data for the period 1979 to 1989. Daily observations on each vessel were aggregated to give monthly records of catch and fishing effort (measured as the number of hooks set) which together represent a cross-section of the longline fleet in any month and year. These monthly records of each vessel's fishing activity for the period of the analysis were then combined and used to estimate supply functions for each of the species harvested.

The data used in the purse seine analysis were very similar to that of the longline investigation : vessel level daily observations of fishing effort (size of vessel and number of sets), type of set (log or free-school) and catch records for the two main species of this fishery (skipjack and yellowfin). Yaizu monthly ex-vessel prices were used for the analysis of the fishing activity of the Japanese fleet and American Tuna Sellers' Association (ATSA) prices for the U.S. fleet. Daily vessel observations for the Japanese and U.S. fleets were aggregated to monthly observations on each vessel. The cross-section data for the period of the analysis (1983-1987) were used to estimate a supply function for each of the two species. No records of U.S. fleet activity prior to 1983 are evident and the access agreement between Japan and Papua New Guinea expired in March 1987 and has not been re-negotiated since.

### 3.2.4 The Cost Study

In recent studies, Campbell and Nicholl (1991, 1992a) analysed information published by Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF) on the costs and returns of Japanese fishing vessels. They report the economic profit and return to invested fixed capital for the Japanese offshore and distant-water tuna fishing fleets for the fiscal years 1979-80 to 1988-89. The three gear types covered by this analysis are longline, pole and line and purse seine. The information provided for purse seiners is for group purse seine operations.

End of year financial data published by the Japanese Ministry of Agriculture, Forestry and Fisheries are used to calculate average annual per vessel operating profit. The opportunity cost of capital is calculated using estimates of the (annual average) required rate of return to Japanese capital over the period. Two estimates of the required rate of return are used. One is a basic measure evaluated on observed debt-equity ratios for a cross-section of Japanese firms. The other is an adjusted measure which reflects the prevalence of cross-holdings and subsidiary ownership amongst Japanese firms. Together with reported depreciation on fixed assets, these estimates of cost of capital are deducted from operating profit to give estimates of economic profitability. Operating profit less depreciation is calculated as a proportion of the fixed capital employed to give an actual rate of return to fixed capital which is then compared with the required rate of return over the period.

They also calculate the cost of fishing effort for the various categories of Japanese tuna vessels. A day fished is taken as a unit measure of fishing effort (searching and catching). The estimated average total cost per day of owning and operating a vessel type is adjusted by a factor which reflects implicit "support costs" (such as land preparation, steaming to and from fishing grounds, etc.) for a day fished to give the total cost per fishing day of different vessel types. This information can be used to gauge the expected costs of Japanese tuna vessels operating as distant-water fishing nation vessels in the EEZs of the Pacific Island States.

## 4. THE COST OF REDUCING PURSE SEINE CATCHES OF JUVENILE YELLOWFIN : AN APPLICATION OF THE MULTI-SPECIES APPROACH

Yellowfin tuna is an important species in both the purse seine and longline fisheries in the Pacific Islands Region. In 1984 yellowfin constituted 28 % by weight of the purse seine catch, and 37 % of the longline catch. Yellowfin is the only species which has an important role in both fisheries. The purse-seine fishery harvests juvenile yellowfin for canning whereas the longline fishery catches adult yellowfin for sashimi. Obviously there is a potential for the purse seine harvests to reduce the population, and hence the catch rates, of adult yellowfin. It may be in the interests of the Pacific Islands nations to attempt to reduce purse-seine juvenile yellowfin catches in order to increase the value of the longline fishery. Before a policy of reducing juvenile harvests is adopted some estimates of the economic costs and benefits are required. To estimate the costs imposed by the policy on the purse seine fishery, an estimate of the production function for that fishery is required. The production function is a two-product relationship, with skipjack tuna as the other product.

Campbell and Nicholl (1992a) examine the question of whether purse-seine vessels can "target" yellowfin tuna. By "targeting" is meant the ability to vary the proportion of yellowfin in the catch in response to relative price incentives. If targeting is not possible the catch proportions are determined by technology and the state of nature. Campbell and Nicholl use the data described in Section 3.2.3 above to test various hypotheses about the determination of the proportion of yellowfin in the catch of purse-seine vessels. They establish that the proportion of yellowfin is higher in free-school than in log sets ; that U.S. purse-seine vessels are better suited than Japanese vessels to make free-school sets ; and that, in fact, U.S. vessels are more likely to make free-school sets. They found no strong evidence that certain vessels within the U.S. fleet were consistently able to catch a higher proportion of yellowfin, or that this could be accomplished by choice of fishing ground.

Having established that the choice of the type of set influences the proportion of yellowfin harvested, Campbell and Nicholl then proceed to the main part of their analysis which is the estimation of supply curves derived from a generalized Leontief revenue function, assuming that in the short-run vessels act as revenue maximizers. The form of the revenue function is given by equation (2.1) and equation (2.2) describes the supply functions which are obtained through the assumption of revenue maximization. The supply functions are estimated on a per unit of effort basis.

If targeting is not possible, the input-compensated price elasticities of supply of both species, given by equations (4.1) will be zero. The only effect of product prices on harvests will be through their effect on the level of fishing effort. It can be seen from equations (4.1) that zero input-compensated price elasticities imply $\beta_{ij} = 0$, $i \neq j$. In other words,

$$\epsilon_{ii} = -\tfrac{1}{2} \sum_{j \neq i} \beta_{ij} (P_j / P_i)^{1/2} (E / Q_i)$$
$$\epsilon_{ij} = \tfrac{1}{2} \sum_{j \neq i} \beta_{ij} (P_j / P_i)^{1/2} (E / Q_i) \qquad (4.1)$$

the hypothesis of targeting can be tested by estimating the supply curves (2.2) and ascertaining whether the coefficient on relative price in the supply per unit effort function is significantly less than zero.

Campbell and Nichol test the hypothesis of targeting for both the Japanese and U.S. purse-seine fleets operating in Papua New Guinea's EEZ in the period 1983-87. They find no evidence of targeting by the Japanese fleet, but fairly strong, though not conclusive, evidence of targeting by the U.S. fleet. This result is consistent with the finding that U.S. vessels are better suited to making free-school sets which tend to yield a higher proportion of yellowfin.

Because of the inconclusive nature of their results, Campbell and Nicholl report alternative estimates of the various elasticities which are needed to estimate the cost of reducing purse-seine yellowfin catches by means of an ad valorem royalty. These elasticities are :

$$\varepsilon_y = \varepsilon_{yy} + \varepsilon_{yE}\, \varepsilon_{EPy}$$
$$\varepsilon_s = \varepsilon_{sy} + \varepsilon_{sE} \cdot \varepsilon_{EPy} \qquad (4.4)$$

where $\epsilon_y$ and $\epsilon_s$ are the percentage effects on yellowfin and skipjack harvests of a 1 % change in yellowfin price,
$\epsilon_{yy}$ and $\epsilon_{ys}$ are the input-compensated price elasticities,

$\epsilon_{yE}$ and $\epsilon_{sE}$ are the product specific scale elasticities,
and $\epsilon_{EPy}$ is the elasticity of demand for effort in response to a change in yellowfin price. The estimate of $\epsilon_{EPy}$ is based on the assumption that vessels are in long-run equilibrium with respect to the level of effort they devote to the fishery. This assumption was tested and found to be supported by the data. The estimates of these elasticities evaluated at mean values of the variables are reported in Table 1. The estimates tell two very different stories about the flexibility of the purse-seine fleet. In the targeting case $\epsilon_y = 5.249$ and $\epsilon_s = -5.247$ ; whereas in the no targeting case $\epsilon_y = 0.00012$ and $\epsilon_s = 0.00016$.

In the targeting case a policy of discouraging the harvesting of yellowfin through the imposition of a royalty is considered. The elasticity estimates indicate that a 1.9 % ad valorem royalty on yellowfin would reduce the yellowfin harvest of the average purse-seine vessel by 10 % and increase its skipjack catch by roughly the same proportion. Since skipjack is regarded as an under-exploited species there is no need for concern about the impact of the increased purse-seine skipjack catch on the pole-and-line fishery which mostly catches skipjack. The royalty causes a small reduction in fishing effort and the net of royalty revenue of the average vessel fishing in Papua New Guinea's EEZ falls by 2.4 %. The real economic cost of the royalty is given by the fall in revenue less the share going to the host country, and less any increase in revenue from transfering effort to another fishery. Campbell and Nicholl's estimate is that the cost of the policy is negligible.

If targeting is not possible, the relative price of yellowfin is not an effective policy variable. A policy of reducing juvenile yellowfin harvests would need to operate by discouraging purse-seine effort. This could be done by increasing the per unit effort access fee payable. Given, as noted above, that individual vessels in the sample are contributing their long-run equilibrium levels of effort to the fishery, an estimate of the elasticity of demand for effort with respect to the cost of effort can be calculated. The estimate is $\epsilon_{Ec} = -0.89$ (t-ratio - 2.467). Using this information together with the elasticity estimates reported in Table 1, it can be calculated that a 10 % decline in yellowfin harvest by the average vessel would result from a 21 % increase in the cost of effort through an increased access charge levied on a per unit effort basis. The cost to the average vessel in terms of reduced gross revenue is estimated to be 12 %. The 12 % fall in vessel revenues would likely be partially offset by increased revenues from fishing elsewhere. The decline in effort contributed by the average vessel to the EEZ can be calculated from the elasticity $\epsilon_{Ec}$ to be 19 %. The economic cost of the policy is the deadweight loss resulting from the increase in the access charge. As a percentage of monthly vessel revenue this loss is measured by one half of the percentage increase in the charge times the percentage reduction in effort. This can be calculated to be 2 % of revenue. The average monthly revenue for the sample of vessels operating in PNG's EEZ is $US333,000, so that the average monthly per vessel cost of the policy is around $6,600. Since the additional access fee payments are a transfer, being a benefit to the host country and a cost to the vessels, they are not relevant to the calculation of economic cost.

It is obvious from the above calculations that the cost of a policy of limiting catches of juvenile yellowfin depends upon the technology of the two-species production function. If there is non-jointness in inputs, targeting of individual species is not possible. This means that a decline in yellowfin catch will be accompanied by a decline in skipjack harvest. Alternatively, if the production function exhibits jointness in inputs, vessels can substitute skipjack for yellowfin in their harvests. The cost of the policy is then reduced to approximately the difference between the value of the foregone yellowfin and the increased skipjack catch. Campbell and Nicholl's results indicate that the cost of reducing per vessel yellowfin harvests by 10 % is negligible if targeting is possible, and around 2 % of revenue if it is not.

## 5. CONCLUSIONS

It is clear from the example discussed in Section 4 of the paper that the issue of targeting is of considerable practical importance in the economic analysis of the optimal allocation of the yellowfin stock between two fisheries. There are many other examples of fishery management issues where information about the multi-species production technology is required. An obvious example is the design of an ITQ management system for a multi-species fishery. The technique of analysis described in this paper can be readily applied to provide the information required.

## REFERENCES

**Anderson L.G.** (1985). "Potential economic benefits from gear restrictions and licence limitation in fisheries regulation", *Land Economics*, Vol. **61** : 409-418.

**Campbell H.F., K. Menz and G. Waugh** (1989). *Economics of Fishery Management in the Pacific Islands Region* , ACIAR Proceedings No. 26, 169p.

**Campbell H.F. and R.K. Lindner** (1990). "The production of fishing effort and the economic performance of licence limitation programmes", *Land Economics*, Vol. **66**, No. 1 : 56-66.

**Campbell H.F.** (1991). "Estimating the elasticity of substitution between restricted and unrestricted inputs in a regulated fishery : a Probit approach", *Journal of Environmental Economics and Management*, Vol. **20** : 262-274.

**Campbell H.F. and R.B. Nicholl** (1992a). *A Cost and Income Survey of the East Coast Tuna Longline Fishery, Australian Fishing Industry Research and Development council, Project 90/98, Final Report, Part 1, pp.36.*

**Campbell H.F. and R.B. Nicholl** (1992b). *A Bioeconomic Analysis of the East Coast Tuna Longline Fishery, Australian Fishing Industry Research and Development council, Project 90/98, Final Report, Part 2, pp.44.*

**Campbell H.F. and R.B. Nicholl** (1991). *The Cost of Fishing Effort and Profitability for the Japanese Tuna Fleet : 1979 to 1989*, ACIAR Project No. 8928, Research Report 1990/1.

**Campbell H.F. and R.B. Nicholl** (1992a). *The Economics of Yellowfin Tuna Targeting by Japanese and American Purse Seine Vessels*, ACIAR Project No. 8928, Research Report.

**Campbell H.F. and R.B. Nicholl** (1992b). *Economic Analysis of Papua New Guinea's Tuna Longline Fishery* , ACIAR Project No. 8928, Research Report.

**Campbell H.F. and R.B. Nicholl** (1992c). *The Cost of Fishing Effort and Profitability for the Japanese Tuna Fleet (Supplement for the Fiscal Year 1983-84 and 1985-86)* , ACIAR Project No. 8928, Research Report.

**Flaaten O.** (1986). *Multispecies Harvesting of the Barents Sea : Theory and Application*, University of Tromso, Institute of Fisheries, 142p.

**Kirkley J.E. and I.E. Strand** (1988). "The technology and management of multi-species fisheries", *Applied Economics*, Vol. **20** : 1279-1292.

**McIlgorm A.** (1990) . Potential Economic Research Issues in the Fisheries Management of the East Coast Tuna Longline Fishery. Ed P.J. Ward, *Papers and Summary of Discussions of the East Coast Tuna and Billfish Monitoring Workshop*, Bureau of Rural Resources (BRR), Proceedings No. 15-16, March 1990.

**McIlgorm A.** (forthcoming). "Management of Australia's North East Tuna Longline Fishery", University of Queensland, Department of Economics, PhD Thesis.

**Murphy G.I.** (1967). "Vital statistics of the Pacific Sardine (Sardinops caerula) and the population consequences", *Ecology*, Vol. **48** : 731-736.

**Schaefer M.B.** (1967)."Fishery dynamics and the present status of the yellowfin tuna population of the eastern Pacific Ocean", *Inter-American Tropical Tuna Commission Bulletin*, Vol. **12**, No. 3 : 27-56.

**Squires D.** (1987). "Public regulation and the structure of production in multiproduct industries : an application to the New England otter trawl industry", *Rand Journal of Economics*, Vol. **18** : 232-247.

**Squires D.** (1988). "Production technology, costs, and multiproduct industry structure : an application of the long-run profit function to the New England fishing industry", *Canadian Journal of Economics* , Vol. **21**, No. 2 : 359-378.

**Squires D. and J. Kirkley** (1991). "Production Quota in Multiproduct Pacific Fisheries", *Journal of Environmental Economics and Management* Vol. **21** : 109-126.

**Ward, P.J., C. Ramirez and A. Caton** (in prep.). A Description of the type of Longlining conducted by Japanese in the East Australian Fishing Zone. in Ed. **P.J. Ward** *Japanese Longline in the East Australian Area*, Bureau of Rural Resources (BRR), Occasional Paper in preparation.

**TABLE 1.**
**ESTIMATES OF (AVERAGE) INDIVIDUAL VESSEL SUPPLY ELASTICITIES**

| Elasticity | Targeting | No Targeting |
|---|---|---|
| $\epsilon_{yy}$ | 5.248 | 0 |
| $\epsilon_{sy}$ | -5.248 | 0 |
| $\epsilon_{yE}$ | 0.491 | 0.533 |
| $\epsilon_{sE}$ | 0.720 | 0.696 |
| $\epsilon_{EPy}$ | 0.002 | 0.00023 |

Note: all elasticity estimates are significantly different from zero at the 5% level.

**FIGURE 1.**
**INPUT-OUTPUT SEPARABILITY**

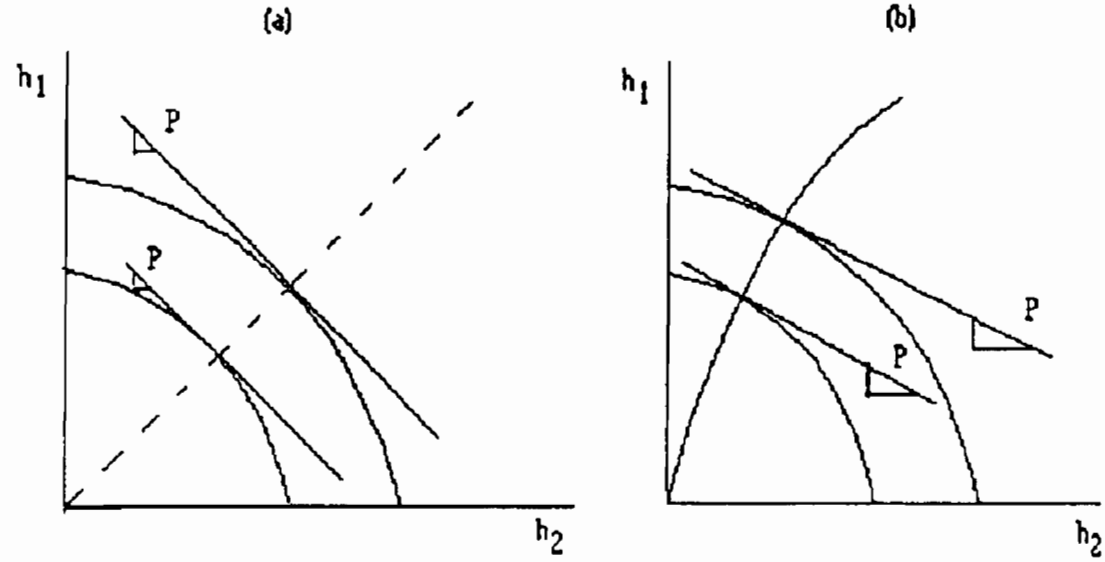
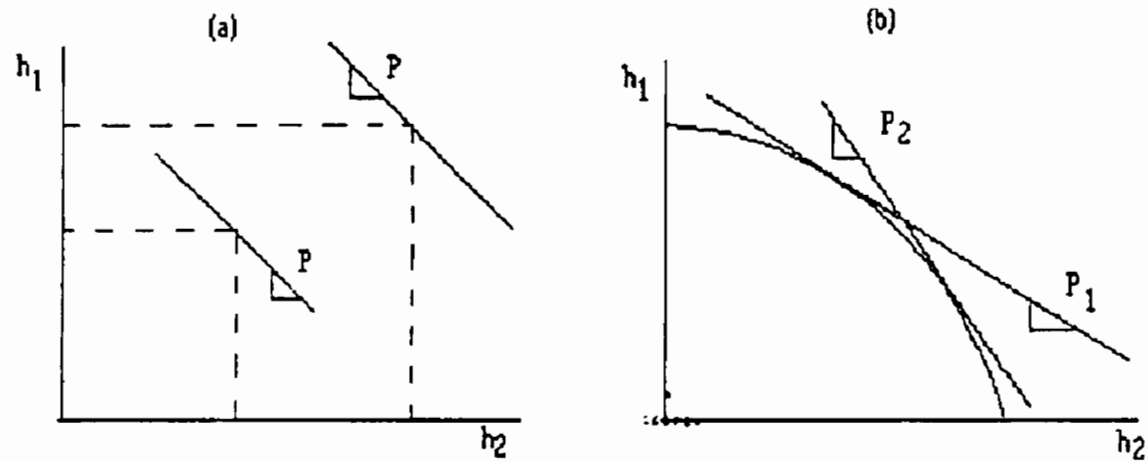



**FIGURE 2.**
**NON-JOINTNESS IN INPUTS**



# Portfolio Selection in Fishing Strategies in a Multispecies Trawl Fishery [1*]

**Susan Hanna**

Department of Agricultural and Resource Economics, Oregon State University, Corvallis, Oregon 97331 USA

ABSTRACT

*This paper examines the selection of fishing strategies in the West Coast U.S. groundfish fleet. The analysis in this paper is the beginning step in the definition of portfolio characteristics of fishing strategies and to examine the implication of portfolio selection in fishing strategies for fishery management. Fisheries are commonly defined and managed on a biological, single species basis. Linkages between stocks created by the operation of multipurpose fishing fleets create new fishery systems that cross species boundaries. Linkages between fisheries have both a biological and economic basis. This paper describes an important three-fishery system on the West Coast : groundfish trawl, shrimp trawl, and crab pots. The nature of fishery interactions is described. Factors linking the fisheries are detailed, including biological dynamics, economic dynamics, and risk reduction strategies. Implications of the three-fishery system for fishery management are discussed in the context of the timing of fishing seasons, interstate fishing effort, access limitation, and multifishery management.*

## 1. INTRODUCTION

Fisheries are commonly defined and managed by the biological distinctions of fish populations. Biologically-based definitions of fisheries are an outgrowth of years of fisheries management in which quotas have been set according to best estimates of the reproductive requirements of a single stock. On the few occasions that groupings of stocks do occur in management, they are at most groupings of similar categories of species ; e.g. finfish, shellfish.

1. Paper to appear in *Journal of Shellfish Research* 1992. An earlier version of this paper was presented at the Conference of the National Shellfisheries Association, Portland, Maine, June 23-27, 1991.

* This publication is the result of research sponsored by Oregon Sea Grant with funds from the National Oceanic and Atmospheric Administration, office of Sea Grant, Department of Commerce, under Grant No. NA85AA-D-SG095 (project no. R/ES-13) and from appropriations made by the Oregon State Legislature. The U.S. Government is authorized to produce and distribute reprints for governmental purposes, notwithstanding any copyright notation that may appear hereon. Joint research with Courtland L. Smith on fishing patterns in the West Coast trawl fleet provided background to the discussion. Review comments of Eric Thunberg and Paul Heikkila were extremely helpful. The assistance of Jim Golden, Jerry Lukas and Jean McCrae of the Oregon Department of Fish and Wildlife in providing research reports and unpublished data is gratefully acknowledged.

Although undertaken for legitimate conservation reasons, biologically based definitions of fisheries miss an important element of fishery structure and function : system properties which result from the linkages between stocks created by the operation of multipurpose fishing fleets. Such linkages cross species and species category lines, and may include, for example, both shellfish and finfish species caught by multipurpose vessels using an array of gears.

The history of development in capture fisheries has been one of increasing degree of interactions between target fisheries. In the initial stages of fishery development, stock abundance may allow fishermen to target single stocks or assemblages of similar species. As the fishery develops, the increase in fishing effort and the concomitant decrease in population levels results in the need for fishermen to diversify their fishing strategies. In the West Coast groundfish fishery, for example, over time fishermen have diversified over the number of groundfish species as well as over the number of fishing activities in groundfish and other fisheries. (Carter 1981 ; Hanna 1991).

Once multispecies or multifishery fishing strategies are established, single-species biologically-based management approaches become obsolete, reflective of an earlier and simpler stage of interaction between human systems and fish populations. Multifishery fishing strategies define a new fishery environment which requires that management broaden its approach from biological considerations alone to a system of biological and economic components.

One implication of multispecies and multifishery fishing strategies is that components of fishing effort become more heterogeneous and therefore more difficult to link to a single population of fish. Wilen (1979) notes that because fishing technology is flexible, attempts to manage fisheries on the basis of restrictions placed on only a few components of effort are futile. Lieberman (1986) supplements Wilen's argument about flexible technology by arguing for an approach to fishery management that includes social as well as technical factors and is explicitly dynamic to accommodate for changing fishing patterns. Golden (1991) details the structure of "transfer capacity" in the West Coast trawl fleet which introduces complexity into the definition of a fleet.

Charles (1989) concludes that because one component of management is to predict the response of both fishermen and fish stocks to changing fishery conditions, management must account for the joint dynamics of both fish stocks and fishermen. Similarly, in earlier work I describe the increasing diversification of assemblage fishing in the West Coast groundfish trawl fishery and argue for using the economic and biological properties of groundfish assemblages as the structural basis for management (Hanna 1987). Mitchell (1982) notes that understanding the tradeoffs facing fishermen in their choice of fisheries is necessary for adequate control of multispecies fishing effort.

A common multifishery interaction on the West Coast exists in the Dungeness crab (*Cancermagister* ), pink shrimp (*Pandalusjordani*), and groundfish (*Sebastes* spp., flatfish, and roundfish) fisheries. The dynamic relationship between these finfish and shellfish fisheries provides a classic example of fishery linkages which create a new definition of a fishery system.

This paper begins by describing the historical development and current status of groundfish, shrimp and crab interactions. Data from Oregon fisheries are used to illustrate the interaction. Next, the nature of these linkages are outlined through the identification and analysis of several factors which create the biological and economic dynamics of these fisheries. In the following sections, several management questions related to these multifishery interactions are discussed, including implications for system management in this fishery and others.

## 2. MATERIALS AND METHODS

Data on Oregon fisheries were acquired from several sources. Summaries of landings and gross revenue by fishery are published by the Oregon Department of Agriculture (1990). Unpublished data on individual vessel landings by gear type were provided by the Oregon Department of Fish and Wildlife. Data on individual vessels cover landings in Oregon from 1977 - 1990 by the three major gear types in the groundfish, shrimp and crab fisheries : trawl and pots. Yearly summaries of Oregon crab and shrimp fisheries appear in a series of reports (Demory 1991 ; Bruneau 1980 ; Jones and Hannah 1991 ; Lukas 1978 ; Oregon Department of Fish and Wildlife 1984 ; Saelens et al 1981 ; 1982 ; Saelens 1983 ; Saelens and Zirges 1985 ; Zirges and Robinson 1980). Histories of fishery development and regulation are presented in documents of the Pacific Fishery Management Council (1979 ; 1981 ; 1990).

Two major categories of fishery participation strategy are defined : specialists and generalists. The categorization of fishing strategy as specialist or generalist, advanced by Smith and McKelvey (1986), depends on the number of fishing

activities in which a fisherman participates. Specialists pursue a single fishing activity and adapt to a changing environment by modifying this activity. Generalists adapt to change by adopting an array of fishing activities. Specialists are defined here as fishermen who in a given year pursue only one fishery within the three fishery system. Generalists are defined as fishermen who in a given year use a fishing strategy which includes more than one of the three fisheries.

Because this paper looks at data from the trawl and pot fisheries only, the strategy categories are defined within the context of these two gear types. The terms "specialist" and "generalist" are used in the context of this trawl-pot fishery system definition. Therefore crab fishermen who are defined as "specialists" are specialists within the context of the three target fisheries discussed herein. These same crab fishermen may in fact develop generalist fishing strategies which combine crab fishing with line fisheries such as albacore and salmon. For the purposes of simplicity of discussion, the paper is limited in focus to the three-fishery system of groundfish trawl, shrimp trawl and crab pot gear. However, the conclusions reached about management of this system also apply to other strategy combinations.

## 3. WEST COAST SHELLFISH-FINFISH FISHERY INTERACTIONS

One component of fishery interaction is the timing of fishing seasons. Existing Oregon fishing seasons for crab, shrimp, and groundfish are depicted in Figure 1 (Oregon Department of Fish and Wildlife 1991). The Dungeness crab ocean season (pot gear) opens in December and continues until August. The groundfish trawl fishing season begins in January and continues until quotas are filled in the fall, with specific closing dates varying by species. Season length is regulated to some extent by trip quotas which are set to prevent a glut of landings at the beginning of the fishing year. The shrimp fishing season opens in April and generally continues until October.

Figure 1 illustrates that for 10 months of the year, from January until October, fishing seasons of the three fisheries overlap. The existence of overlapping seasons means that fishermen with vessels capable of fishing any of the three fisheries can choose between fisheries. Fishermen will choose a fishery or combination of fisheries on the basis of expectations about earnings, expectations about stock abundance and prices, and costs of investing in or changing gear.

The proportion of the fleet using a specialist strategy varies from fishery to fishery. The proportion of specialists also varies within a fishery over time. Table 1 illustrates the range of proportion of each fleet which participated in a specialist strategy in the years between 1977 - 1990. Percentages represent the proportion of boats landing that species category in a given year which land only that category.

Within the three-fleet combination of groundfish trawl, shrimp trawl and crab, fishermen using crab pot gear tend to use more specialized strategies than either shrimp or groundfish trawlers : an average of 81.8 % of the crab fleet fished only for crab during the time period, with small variation about the mean. This high proportion of specialists is due in large part to a masking effect of the database. The crab fleet includes both trawl-pot boats which use trawl gear for shrimp and groundfish and pot-troll boats which use pot and line gear to pursue crab, salmon and albacore (Fletcher et al. 1988 ; Demory 1991). The pot-troll boats do not have the capability of using trawl gear to catch shrimp or groundfish. Of the boats which are estimated to be trawl capable, the percentage of crab specialists is much lower. For most commercial fishermen, the crab season is not long enough to sustain a specialist crab fishing strategy.

The proportion of specialist shrimp trawlers which landed only shrimp in a given year varied between 51 and 71 % in the 13 year period, averaging 60.4 %. The proportion of specialist groundfish trawlers landing only groundfish in a given year was the smallest (49.2 %) of the three fisheries and had the largest variation about the mean. Some of the specialist vessels change their specialization from year to year ; for example, a fisherman may fish only shrimp one year, only groundfish the next.

The most common combination of fishing strategies in the specified three fleet combination is the groundfish/shrimp combination (Table 1). The number of boats using this strategy is calculated as the number of boats whose landings are primarily groundfish, who also land shrimp. The pursuit of this fishing strategy varies widely, from 11 to 71 % of the total number of groundfish boats over the time period. The shrimp and crab combination strategy comprises between 15-36 % of the vessels landing shrimp. This combination is economically important to some fishermen who fill in the period of closed shrimp season with two or three months of crab fishing (Zirges and Robinson 1980). The current fishing season structure, based on times of biological availability, promotes groundfish-shrimp and shrimp-crab as the most compatible strategy combinations (Figure 1).

Port differences influence the choice of fishing strategy. Oregon has three major fishing ports : Astoria, Newport, and Coos Bay. Astoria has the largest number of groundfish specialists. Severe winter weather prevents many Astoria fishermen from actively pursuing crab fishing. Newport is the most diverse of the three ports, with all fishing strategies represented. The most common generalist strategy in Coos Bay is the groundfish and shrimp combination (Smith and Hanna 1991).

## 4. MULTIFISHERY LINKAGE FACTORS

The fishing strategies which link the three fisheries are the result of incentives created by both biological and economic dynamics.

### *4.1 Biological Dynamics*

The changing patterns of landings of crab, shrimp and groundfish between 1970 and 1989 are a partial representation of the biological variation of stocks (Figure 2). Landings of Dungeness crab reflect well-recognized but little understood population cycles. High points in landings occurred in 1970-71, 1977, 1980. Intra-year fluctuations are caused by variation in the timing of the molt period which influences both the catchability and the "fullness" of crab (Demory 1991).

Shrimp populations are also subject to cycles. Peaks in Oregon landings in 1977, 1978, and 1989 reflect recent cycle crests. Variation in the timing of spawning will also affect fishing, as seasons are set to protect gravid shrimp. Deterioration in flesh quality during spawning also influences the timing of fishing for shrimp (Zirges and Robinson 1980).

Groundfish landings increased continually between 1977 and 1982 as post-Magnuson Act fishing effort fished down the surplus of relatively unexploited stocks. Substantial in-year variation in landings exists as a result of seasonal onshore-offshore migration of stocks (Hanna 1987). Flesh quality of some species, e.g. Dover sole, is affected by season and water depth (J. Easley 1990). Community dynamics of groundfish assemblages, i.e. the structural compensation to selective harvesting of species, are still little understood (Tyler et al 1982). Since 1982 various groundfish regulations have been put in place to maintain stocks at equilibrium yield levels, including single-species trip quotas and some initial attempts at assemblage trip quotas (Pacific Fishery Management Council 1990).

Population cycles, inter-year variability in stock location, and intra-year changes in location, spawning periods, and molt periods create a system of biological relationships characterized by high levels of variability. West Coast fishermen respond to this variability in their formation of expectations about biological influences on fishing opportunities in groundfish, shrimp and crab. Fishermen's expectations in turn underlie their planning and investment decisions which drive the distribution of fishing effort linking the three fisheries.

### *4.2 Economic Dynamics*

Economic dynamics are also at work creating connections between the three fisheries. Some of these dynamics reflect the results of individual fishermen's decisions, others reflect economic forces at levels beyond the control of individual fishermen.

The influence of various economic factors in directing fishing effort between the three fisheries underlies patterns illustrated in Figure 3, which shows vessels landing in Oregon ports between 1977 and 1989. It is important to note that because vessels participate in more than one of these fisheries, a single vessel may be represented in the shrimp fishery in one year, and the crab fishery in another year. Fishermen using specialist strategies will be represented in only one fishery in a given year, although they may be represented in different fisheries in different years. Fishermen using generalist strategies will be represented in more than one series in a given year.

A major driver of the economic dynamics of the fishery are individual fishing strategies developed to reduce the risk posed by a variable earnings environment. Changes in both landed quantity and exvessel price in the three fisheries lead

to large variability in exvessel gross revenues to fishermen, illustrated in Figure 4. In any economic system, economic variability and the uncertainty it creates lead risk-averse people to adopt various uncertainty-reducing strategies. One of the common strategies used to reduce economic variability is to diversify over several sources of revenue. Multifishery fishing strategies are an example of such diversification.

Diversification usually, but not always, benefits fishermen in the form of reduced variability of landings and earnings. Table 2 illustrates one of these benefits : reduced year-to-year variability in production and earnings. Variability is measured as the coefficients of variation (c.v.) of landings and gross revenues (revenues before costs) for the various fishing strategies.

Looking first at quantities landed, three specialist strategies of groundfish, shrimp, and crab show coefficients of variation in quantities landed of 49 %, 53 %, and 54 % respectively. Groundfish fishermen who also fished shrimp (strategy G/S) were able to reduce the c.v. of their landings to 38 %. By adding a third fishery to their fishing strategy, they realized a further reduction of the c.v. of their landings to 35 %. Groundfish fishermen were able to stabilize inter-year production by increasing the number of fishing activities.

The reduction in variability of landings for shrimp fishermen through generalization of strategy showed a similar trend. Specialist shrimp fishermen had a c.v. of landings of 53 %. Adding crab fishing to their strategy reduced the c.v. of landings to 48 %. Fishermen who fished the groundfish/shrimp combinations had even lower c.v.'s ; 38 %. A generalist strategy which included all three fisheries lowered the c.v. to 35 %.

For crab fishermen, adopting a generalist strategy reduced the variation of landings from 54 % to 48 % when shrimp fishing was added, to 35 % when the fishing strategy included all three fisheries.

In terms of stabilized earnings, where earnings are represented here by average gross revenues, the benefits to fishermen of adopting generalized fishing strategies are mixed. In the case of shrimp fishermen, the addition of groundfish fishing to their strategy reduces variability in average gross revenues from 50 % to 37 %. Variability in earnings is reduced still further to 34 % with the addition of the third fishery, crab, to the strategy.

For groundfish fishermen, the coefficient of variation of a combined groundfish/shrimp strategy (37 %) is actually greater than for groundfish alone (35 %), but is reduced slightly to 34 % with the addition of the third fishing activity, crab, to the strategy. The addition of crab to the groundfish strategy also increases the c.v. of average gross revenues. This phenomenon is largely due to the lower variability of landings of groundfish and fairly constant exvessel prices for groundfish species over the time period examined. However, the continued existence of groundfish/shrimp generalists indicates that other factors besides stability in earnings are important to fishermen in this fishery. Despite the failure to reduce variability in earnings through this strategy of groundfish and shrimp, trawl fishermen reap benefits from the combination in the form of higher, albeit cyclical, earnings.

In contrast to the other two types of specialists, crab fishermen gain nothing in reduction of variability of revenues through the adoption of generalist fishing strategies. Variability in earnings from crab fishing alone was 26 % over the time period, for crab combined with shrimp it was 37 %, and for crab combined with shrimp and groundfish it was 34 %. This phenomenon is due in part to the influence of the large number of very small specialized crab vessels in the "fleet" database which land small, unvarying quantities of groundfish throughout the season and from year to year.

A second major element of individual decision making which drives the economic dynamics of the groundfish-shrimp-crab fishery are the short-term effort responsiveness to changes in relative prices of groundfish, shrimp, and crab, changes in regulations, market conditions, and processor arrangements. Fishing effort is the outcome of a multicomponent choice set which includes expected net earnings of the primary fishery, expected net earnings of substitute fisheries. The choice set is modified by a constraint set which includes available technology, regulations, biological availability, processor limits, and general market conditions.

The short term responses between fisheries are extremely complex, as evidenced by the groundfish-shrimp interaction between 1979-1989. Figure 4 illustrates the changes. Between 1979 and 1983, real shrimp prices were generally increasing, while real groundfish prices were in general decline. However, volumes of available groundfish were high, and the increase in shrimp prices did not attract increases in the number of groundfish fishermen who landed shrimp. Processor constraints also played a role, as groundfish processors were reluctant to diversify their operations to include shrimp. In 1984, shrimp landings were low despite high prices, as the stock responded to the 1983 El Nino southern oscillation event (ENSO) (Jones and Hannah 1991). Between 1985-1987, average real shrimp prices increased 89 %,

from $.35 to.66. This price increase was followed by a corresponding increase in the proportion of groundfish vessels who fished the groundfish/shrimp combination activity : from 31 % in 1985 to 58 % in 1987. During this same period, groundfish prices were low as processors imported cheaper Canadian product. The proportion of groundfish specialists fell from 69 % to 42 %. Between 1987 and 1989, real shrimp prices fell 42 % to an average of $.33, but the percent of groundfish vessels fishing the groundfish-shrimp activity remained at 58 %. The price responsiveness of substitution between groundfish and shrimp was diminished over this period due to regulatory constraints in groundfish which introduced strict quantity controls on landings per trip.

Fishing in a single activity is often interrupted when price disputes between fishermen and processors cannot be resolved. For example, a mid-season downward price adjustment the 1989 Oregon shrimp fishery interrupted shrimp landings for a period of one month as processors and fishermen negotiated prices. Large landings early in the season left processors with large inventory holdings, leading processors to lower prices offered as a means to reduce inventory and cover storage costs (Jones and Hannah 1991).

Markets and general economic forces outside the control of individual fishermen are the second driver of economic dynamics. The exvessel market for groundfish, shrimp and crab is influenced by an array of economic factors. One is the buying patterns of fish processors. Oregon processors have at times objected to simultaneous landings of crab and shrimp, preferring to direct labor and equipment to one species (Zirges and Robinson 1980). In the period of early expansion of the groundfish fishery, many groundfish processors would buy only groundfish from groundfish trawl vessels, forcing a degree of specialization on vessels. In recent years, limitations on the supply of groundfish and shrimp have meant that processors have been more willing to buy both groundfish and shrimp from individual vessels (R. Young 1991).

Fluctuations in the exchange rate also influence the exvessel market for Oregon-caught groundfish, shrimp and crab. When foreign source groundfish are available at lower price than Oregon groundfish, West Coast processors have substituted imported groundfish for local groundfish in their production line. For example, in 1985 and 1986 a strong U.S. dollar in the Canada-U.S. exchange rate created a situation favorable to the import of relatively cheaper Canadian groundfish by U.S. processors. As Canadian groundfish were substituted for U.S. groundfish at the processing level, many vessels redirected their effort from groundfish to shrimp (Figure 3).

Finally, in each of the three fisheries ex-vessel prices paid to fishermen are influenced by larger national or international markets characterized by their own substitution relationships. For example, Oregon wild shrimp compete in regional, national and international markets with cultured shrimp. Dungeness crab compete domestically with surimi-based crab analogues and in a European export market with other crab species and substitute shellfish species (Demory 1991). Groundfish compete at the retail level with other protein sources, namely poultry (P. Leipzig 1990).

## 5. IMPLICATIONS OF MULTIFISHERY LINKAGES FOR SYSTEM MANAGEMENT

Both generalist fishing strategies and inter-year changes in specialist strategies create linkages between the fisheries which in turn create unique management issues not faced in specialized fisheries. Major issues in the management of the West Coast groundfish, shrimp and crab fisheries include the timing of fishing seasons, the management of interstate fishing effort, the limitation of access to fishing opportunities, and the economic attributes of multifishery activities.

### *5.1 Timing of Fishing Seasons*

The existence of an array of choices for fishermen who fish generalist strategies means that the composition of a fishing fleet is not static, but varies within and between seasons as fishermen combine fishing activities into strategies of their choice. Predictions of actual fishing effort on an individual stock are therefore difficult to make, but are assisted by an understanding of economic linkages and of the proportion of the fleet with transfer capacity.. The timing of fishing seasons becomes a critical factor in the management of effort levels and in the time spacing of effort in a single fishery. Setting seasons on a per-fishery basis in isolation of other fisheries in the system guarantees that one fishery's season will generate external impacts on another fishery.

There are two general complementary outcomes of coordinated timing of fishing seasons across fisheries. The first is to maximize the probability of controlling the timing and level of fishing effort on various stocks. The second is to maximize

the planning and coordination of the fishing year in ways that allow explicit consideration of enhancing the landed value of fish. Fishery interactions require that for maximum management effect in these two areas, the timing of fishing seasons should be decided on a coordinated basis with both biological and economic linkages taken into account. Pre-season information on market conditions (demand, availability of substitutes, expected exvessel price) combined with information on biological conditions (stock size, recruitment, flesh quality, timing of molt) can be used to good effect in the planning of season timing.

For example, as Figure 1 illustrates, managers have the ability to lessen the impact of fishing effort on Dungeness crab in the early season by delaying the season opening one month to coincide with the groundfish season opening. By the same token, managers may pace crab landings throughout the season by avoiding the initial surge of fishing effort on December. The potential economic benefits of paced landings include the avoidance of landings gluts which depress market prices, and the harvest of "full" animals. The coincidence of the shrimp and groundfish seasons combined with the popularity of the shrimp-groundfish strategy combination provides the opportunity to alternate open and closed periods in these two fisheries if needed to lessen effort impacts on stocks or avoid market gluts. Joint groundfish-shrimp seasons could be planned on the basis of a market strategy to maximize joint value.

### *5.2 Interstate Fishing Effort*

The crab, shrimp, and groundfish fisheries on the West Coast are managed under different jurisdictions in a mixed system of regulations. Although Dungeness crab is regulated separately by California, Oregon and Washington, no state's system of regulations operates in isolation. The timing and quantity of crab landings in a given state are influenced by the timing of seasons in a neighboring state. For example, in the years when Washington crabs molt late and are not available to the fishery at the December 1 opening, the Washington fleet shifts south for December fishing. The effect of effort location shifts is to increase the early-season fishing pressure on Oregon stocks as well as create landings gluts in Oregon ports and markets (Demory 1991 ; Heikkila 1991).

In the fall of 1990, a Tri-State Dungeness Crab Committee of crab fishermen was organized under the auspices of the Pacific States Marine Fisheries Commission to address the interstate effort issue and other concerns facing the crab fleet. In the organization of the committee, attempts were made to ensure representation from each port and vessel size class. Five issues were defined by the industry group for discussion and negotiation : early season opening date to be responsive to molt condition, late season closing date to respond to molt condition, a moratorium on new entry, enforcement of preseason gear placement regulations, and uniform gear marking (P. Heikkila 1991).

Shrimp have been managed under a license limitation system in Oregon since 1979 (Zirges and Robinson 1980 ; Saelens and Zirges 1985 ; Jones and Hannah 1991). No limitation on shrimp licenses exists in Washington or California. The Oregon license limitation program varies the number of permits available for purchase according to estimated of biological availability and includes a provision for commercial fisherman licensed to fish shrimp in other states to purchase up to six "single delivery" licenses per year for landing shrimp in Oregon ports. Since 1989 the number of permits has been limited to 187, with new permits to be sold by lottery only when the number of permits falls below that number. The single delivery provision creates a situation easily taken advantage of by cross-border fishing. Each fisherman in the Washington shrimp fleet, can fish in federal waters off Oregon and land in Washington, or buy 6 single delivery licenses to use for bad weather landings in Oregon (Oregon Department of Fish and Wildlife 1991).

Groundfish, under coordinated state and federal management jurisdiction, is managed consistently in California, Oregon and Washington. Nevertheless, the existence of mobile, multipurpose fleets means that the location of effort concentrations are difficult to predict. Under the current system, managers must account for a confusing array of sources of effort on the groundfish stock in question in the design of regulations to reach conservation goals for each stock. Within the three-fishery system, the practice of partial-system regulation has the effect of redirecting effort from one state to another as well as from one stock to another.

### *5.3 Access Limitation*

The crab, shrimp, and groundfish fisheries have each reached a level of exploitation which will require strong effort controls. Unless managers and industry members are willing to continue down the path of increasingly strict effort controls in the form of short seasons or trip quotas, some form of access limitation is the obvious answer.

The current regulatory situation is a tangle of different controls, based on political boundaries. Shrimp is managed by one of the three states - Oregon - in a license limitation system of questionable effectiveness in controlling effort. No license limitation exists in California or Washington. Under the Oregon system, licenses are in fact limited in number, but the number of licenses outstanding and the provision for "single delivery" license purchase enables high levels of effort to be maintained. Supported by strong year classes, shrimp landings were at record high levels between 1988-1990. The concern has been expressed that the fishery is vulnerable to the continued strong recruitment of age 1 shrimp and that without it the stock will not support current effort levels (Jones and Hannah 1991).

A federal license limitation program has recently been developed for three major gears in the groundfish fishery in all three states : trawl, longline, and pots. This program, adopted by the Pacific Fishery Management Council in September 1991, will be implemented in 1993. Groundfish will continue to have an open access quota set aside for fishermen not qualifying under the license limitation program.

Although none of the three states has an access limitation program for crab, recent developments on coordinated interstate management by the Tri-State Dungeness Crab Committee look promising for effort control. A moratorium date which closes options for new entry has been adopted. A process will be initiated to consider the implementation of a limited access program. The Committee has agreed that the long-term goal of such a program is to reduce both the number of crab pots and the number of boats. An individual quota system for pots will be one of the alternatives for consideration (P. Heikkila 1991).

A striking characteristic of the development of the groundfish limited access plan and the establishment of the Tri-State Dungeness Crab Committee has been the coordination between industry and managers. Although the move toward cooperative industry-agency management planning is promising, the element of fishery system planning is missing. Under current separate planning efforts, these three interrelated fisheries will have at best a piecemeal system of access limitation. Vessels excluded by a particular access limitation program will likely redirect fishing effort to substitute fisheries which remain open access. Regulatory inconsistencies between the three fisheries pose a further challenge to managers. The uncertainty created by the sporadic adoption of limited access programs has resulted in strategic positioning of fishermen to qualify in several fisheries in the expectation of continued limitation of their operations. Individuals fishing in new fisheries to qualify increase aggregate fishing effort, exacerbating the already difficult management task of controlling levels of exploitation.

### *5.4 Multifishery Management*

As discussed above, there are various economic reasons why fishermen engage in multifishery activity. Stocks vary in availability as oceanographic conditions affect spawning, molt, and recruitment. Stock variability creates variability in earnings from the fishery which in turn creates the incentive to diversify over several target species. Market conditions affect relative prices of substitute species. Generalist fishing strategies result from the biological and economic variability which are a normal part of any ocean system. The ramifications of continuing these linked fisheries on the traditional individual fishery basis are many : inconsistently timed fishing seasons, external market effects, and unpredictable effort shifts in response to piecemeal restrictions on access.

Multifishery system management could address these problems. An explicit recognition of the three fisheries as a fishery system for management would allow the design of a regulatory system that internalizes external effects of single fishery management. The traditional practice has been that fishery management proceeds along single species lines. Although recognition of multi-fishery interactions exists, the inertia of habit and traditional thinking have slowed the evolution of management to reflect actual fishery operations.

The practical question of how to implement management planning at the system level remains. This is not a trivial question and requires systematic development of a procedure within the context of the system at hand. However, some basic components of system management can be outlined here : system definition, supporting data, the planning process, definition of management goals, and system evaluation.

Defining the system to be managed is an element which is obviously dependent on context. In the case of the Oregon crab, shrimp, and groundfish system discussed in this paper, multi-fishery management would require a broader system definition. While crab, shrimp, and groundfish are the large-volume components of the system, a critical role is played for generalist strategies by the albacore and ocean salmon fisheries as well. System definition requires a thorough knowledge of fishery operations which cannot be acquired through secondary data sources.

Data to support analysis and monitoring of both biological and economic components of the fishery system, once defined, are of course a basic need. Current systems of data collection and entry are based on the historical practice of single-species management. The definition of a data base along single fishery lines presents a practical barrier facing analysts of fishing fleet activity. The activity of multi-purpose vessels is thus included in several data bases which are often formatted in uncoordinated ways, prohibiting cross-fishery analysis. A vessel may "drop out" of a data base once it switches fishing activity. Another difficulty with the current system of data storage is the tracking and analysis of multi-fishery fishing effort. Effort units are often multiple-counted as separate data bases are analyzed.

The planning process for fishery system management is also critical, and should include pre-season information on both the biological and economic components of the system as well as a clear definition of the authorized planning parties. The definition of the legitimate "players" comes from the context of the fishery itself. Coordinated planning, to be successful, will have to involve representation of all the commercial fishery constituents ; i.e. fishery managers, fishing industry, and consumers. Also necessary is a clear definition of objectives for the fishery system beyond the basic conservation goals.

Comanagement by managers and industry has taken various forms in the Oregon crab, shrimp and groundfish fisheries. Industry has played a strong and constructive role. Efforts to initiate discussions about limited access in the groundfish and crab fisheries originated in industry groups who felt that more effective management should be and could be implemented. Industry committees in both fisheries have been instrumental in outlining the problems to be addressed, defining management objectives, and discussing alternative means to reach goals.

One of the goals of multi-fishery management would be to avoid the problems illustrated by the case study of Oregon crab, shrimp and groundfish : uncoordinated timing of fishing seasons, interstate fishing effort shifts, and piecemeal regulatory programs. The coordination of multifishery seasons could minimize the surges in off-season effort in substitute fisheries. Interstate effort distributions could be stabilized through the coordination of state regulations and season timing. Bycatch issues, e.g. groundfish caught in shrimp trawls, could be explicitly addressed as components of a single system.

System evaluation will incorporate the other four elements : system definition, supporting data, the planning process, and the definition of management goals.

## 6. SUMMARY AND CONCLUSIONS

This case study of Oregon shellfish and finfish fisheries illustrate two principles which have application to other fisheries with multifishery activity. The first principle is that economic factors, although often not explicitly incorporated into management plans, are often instrumental in creating linkages between fisheries and so affect the efficacy of management plans. The second principle is that when linkages exist, management of fisheries must proceed on a level which recognizes these linkages and accounts for multifishery fishing strategies.

Fishery management on a system level which explicitly recognizes biological and economic linkages offers several potential benefits : coordinated timing of fishing seasons, more predictable control of the spatial and temporal components of fishing effort, and fewer unintended "external" impacts of regulations.

What we find instead in the management of these fisheries and indeed in the management of most capture fisheries is a jumble of biological controls mixed with political boundaries of jurisdictions, without an accounting of the economic forces creating interrelationships.

As populations of fishermen have increased and as fishing technology has become more sophisticated, fish populations have become more interconnected. The fishery is becoming smaller just as our political and economic world is becoming smaller. As the interconnectedness of fishery operations increases, it becomes increasingly important for fishery management to understand the heterogeneity of fishing strategies and their economic basis.

What is defined as a "fishery" has as much to do with human patterns of exploitation as with biological attributes of fish populations. The continuance of single-stock biological approaches to management is not sufficient to capture the full sphere of fishery components. It is also necessary to understand and account for the economic and social incentives facing people who catch and process the fish, and incorporate the human environment into a system of management. Defining new fishery systems is one approach.

## REFERENCES

**Bruneau C.** (1980). *The 1979 Oregon shrimp fishery.* Oregon Department of Fish and Wildlife Informational Report 80-1. Oregon Department of Fish and Wildlife Marine Region, Newport, OR 97365, 12 pp.

**Carter C.N.** (1981). *Multi-Fishery Activity in Oregon Commercial Fishing Fleets : An Economic Analysis of Short-Run Decision-Making Behavior.* Unpublished Ph.D. dissertation, Department of Agricultural and Resource Economics, Oregon State University, Corvallis, OR 97331.

**Charles A.T.** (1989). Bio-socio-economic fishery models : labour dynamics and multi-objective management. *Canadian Journal of Fisheries and Aquatic Science* **46 :** 1313-1322.

**Demory D.** (1991). Oregon dungeness crab fishery data report series 1977-1990. Oregon Department of Fish and Wildlife Marine Region, Newport, OR, 97365, 159 pp.

**Easley J.** (1990). Personal communication. Administrator, Oregon Trawl Commission, 250 36th St., PO Box 569, Astoria, OR 97103-0569.

**Fletcher J.J., R.E. Howitt and W.E. Johnston** (1988). Management of multipurpose heterogeneous fishing fleets under uncertainty. *Marine Resource Economics* **4 :** 249-270.

**Golden J.T.** (1991). *Fishing strategies for multi-fisheries resources : a conceptual model of fleet dynamics and harvesting potential.* Oregon Department of Fish and Wildlife, unpublished manuscript.

**Hanna S.S** (1987). The structure of fishing systems and the implementation of management policy : 264-275 in T.L. Vincent, Y. Cohen, W.J. Grantham, G.P. Kirkwood, and J.M. Skowronski, eds. , *Modeling and Management of Resources Under Uncertainty,* Vol. 72 in Lecture Notes in Biomathematics, Berlin : Springer-Verlag.

**Hanna S.S.** (1991). The supply of Pacific U.S. groundfish : harvesting, processing, marketing, and regulation : 225-240 in W.E. Schrank and N. Roy, eds. , *Econometric Modelling of the World Trade in Groundfish.* The Hague, Netherlands : Kluwer Academic Publishers.

**Heikkila P.** (1991). Personal communication. Marine Extension Agent, Coos County Extension Office, 290 North Central, Coquille, OR 97423.

**Jones S.A. and R.W. Hannah** (1991). *The Oregon pink shrimp fishery : 1985-1989.* Oregon Department of Fish and Wildlife, unpublished manuscript, 35 pp.

**Leipzi P.** (1990). Personal communication. General Manager, Fishermen's Marketing Association, 320 2nd St. Suite 2B, Eureka, CA 95501

**Lieberman W.H.** (1986). Towards improving fishery management systems. *Marine Policy* **10** (1) : 42-50.

**Lukas J.** (1978). *The 1977 Oregon shrimp season.* Oregon Department of Fish and Wildlife Informational Report 78-2, Oregon Department of Fish and Wildlife Marine Region, Newport, OR 97365, 10 pp.

**Mitchell C.L.** (1982). Bioeconomics of multispecies exploitation of fisheries : management implications. p. 157-162 in M.C. Mercer, ed., Multispecies approaches to fisheries management advice. *Canadian Special Publications in Fisheries and Aquatic Science* **59.**

**Oregon Department of Agriculture** (1990). *Oregon Agriculture and Fisheries Statistics 1989-1990.* Oregon Department of Agriculture, Oregon Agricultural Statistics Service, 1735 Federal Building, 1220 SW Third Ave., Portland, OR 97204-2899.

**Oregon Department of Fish and Wildlife** (1984). *The 1983 Oregon shrimp fishery.* Information Reports 84-3, Fish Division, Oregon Department of Fish and Wildlife, 2501 S.W. First Ave., P.O. Box 59, Portland, OR 97207.26pp.

**Oregon Department of Fish and Wildlife** (1991). *Synopsis of Oregon Commercial Fishing Regulations.* Oregon Department of Fish and Wildlife, 2501 S.W. First Ave., P.O. Box 59, Portland, OR 97207.

**Pacific Fishery Management Council** (1979). *Draft Fishery Management Plan for the Dungeness Crab Fishery of Washington,* Oregon, and California. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 S.W. First Avenue, Portland, OR 97201.

**Pacific Fishery Management Council** (1981). *Fishery management plan for the pink shrimp fishery off Washington,* Oregon and California, Discussion Draft. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 S.W. First Avenue, Portland, OR 97201.

**Pacific Fishery Management Council** (1990). *Status of the Pacific Coast Groundfish Fishery Through 1990 and Recommended Accep table Biological Catches for 1992.* Pacific Fishery Management Council, Metro Center, Suite 420, 2000 S.W. First Avenue, Portland, OR 97201.

**Saelens M., B. Hunt and J. Golden** (1981). *The 1980 shrimp fishery.* Oregon Department of Fish and Wildlife Informational Report 81-1, Oregon Department of Fish and Wildlife Marine Region, Newport, OR 97365, 17 pp.

**Saelens M., B. Hunt and J. Golden** (1982). *The 1981 shrimp fishery.* Oregon Department of Fish and Wildlife Informational Report 82-1, Oregon Department of Fish and Wildlife Marine Region, Newport, OR 97365, 22 pp.

**Saelens M.R.** (1983). *The 1982 Oregon shrimp fishery.* Shrimp Investigations Report 83-5, Oregon Department of Fish and Wildlife, Marine Region, Newport, OR, 97365, 25 pp.

**Saelens M.R. and M.H. Zirges** (1985). *The 1984 Oregon shrimp fishery.* Shrimp Investigations Report 85-6, Oregon Department of Fish and Wildlife, Marine Region, Newport, OR, 97365, 29 pp.

**Smith C.L. and S.S. Hanna** (1991). Occupation and community as determinants of fishing behaviors. Manuscript under review at Human Organization.

**Smith C.L. and R. McKelvey** (1986). Specialists and generalists : roles for coping with variability. *North American Journal of Fishery Management* **6 :** 88-99.

**Tyler A.V., W.L. Gabriel and W.J. Overholtz** (1982). Adaptive management based on the structure of fish assemblages of northern continental shelves. In M.C. Mercer, ed., Multispecies Approaches to Fisheries Management Advise, *Can. Spec. Publ. Fish. Aquat. Sci.* **58.**

**Wilen J.E.** (1979). Fisherman behaviour and the design of efficient fisheries regulation programs. *J. Fish. Res. Board.* Can. **36 :** 855-858.

**Young R., Ph.D.** (1991). Personal communication. Trawl fisherman and member, Scientific and Statistical Committee, Pacific Fishery Management Council. 2400 Sunrise Avenue, Crescent City, CA 95531.

**Zirges M.H. and J.G. Robinson** (1980). *The Oregon pink shrimp fishery, management history and research activities.* Oregon Department of Fish and Wildlife Informational Report 80-1, Oregon Department of Fish and Wildlife Marine Region, Newport, OR, 15 pp.

TABLE 1.
RANGE OF FISHERY PARTICIPATION STRATEGIES IN THREE MAJOR OREGON FISHERIES, 1977 TO 1990.

| | Percent of Fleet |
|---|---|
| **Specialists** | |
| Crab Pots | 80-92% |
| Shrimp Trawl | 51-71% |
| Groundfish Trawl | 29-89% |
| **Generalists** | |
| Groundfish/Shrimp | 11-71% GF* |
| Shrimp/Crab | 15-36% S** |
| Groundfish/ Crab | 28-20% GF* |
| Groundfish/Shrimp/Crab | 5-15% GF* |

* GF = Fleet landing primarily groundfish
** S = Fleet landing primarily shrimp

Data Source: Unpublished fish ticket data, Oregon Department of Fish and Wildlife.

**TABLE 2.**
**COEFFICIENTS OF VARIATION (%) OF QUANTITIES LANDED AND AVERAGE REVENUES EARNED USING DIFFERENT FISHING STRATEGIES IN OREGON, 1977-1989.**

A. Coefficient of Variation (%) of Quantities Landed

| Specialist Strategy* | | | Generalist Strategy* | | | |
|---|---|---|---|---|---|---|
| **G** | **S** | **C** | **G/S** | **G/C** | **S/C** | **G/S/C** |
| 49% | 53 | 54 | 38% | 42 | 48 | 35 |

B. Coefficient of Variation (%) of Average Revenues

| Specialist Strategy* | | | Generalist Strategy* | | | |
|---|---|---|---|---|---|---|
| **G** | **S** | **C** | **G/S** | **G/C** | **S/C** | **G/S/C** |
| 35% | 50 | 26 | 37% | 58 | 40 | 34 |

* G = groundfish
S = shrimp
C = crab
G/S = groundfish/shrimp
G/C = groundfish/crab
S/C = shrimp/crab
C/S/G = crab/shrimp/groundfish

Data Source: Oregon Department of Agriculture (1990)

TABLE 3.
FISHERY PARTICIPATION STRATEGIES IN THREE MAJOR OREGON FISHERIES, 1977 TO 1990.

**Specialists**

| | Percent of Fleet | | |
|---|---|---|---|
| | Range | Mean | Std. Dev. |
| Crab Pots | 80-92% | 81.8 | 1.92 |
| Shrimp Trawl | 51-71% | 60.4 | 6.83 |
| Groundfish Trawl | 29-89% | 49.2 | 20.63 |

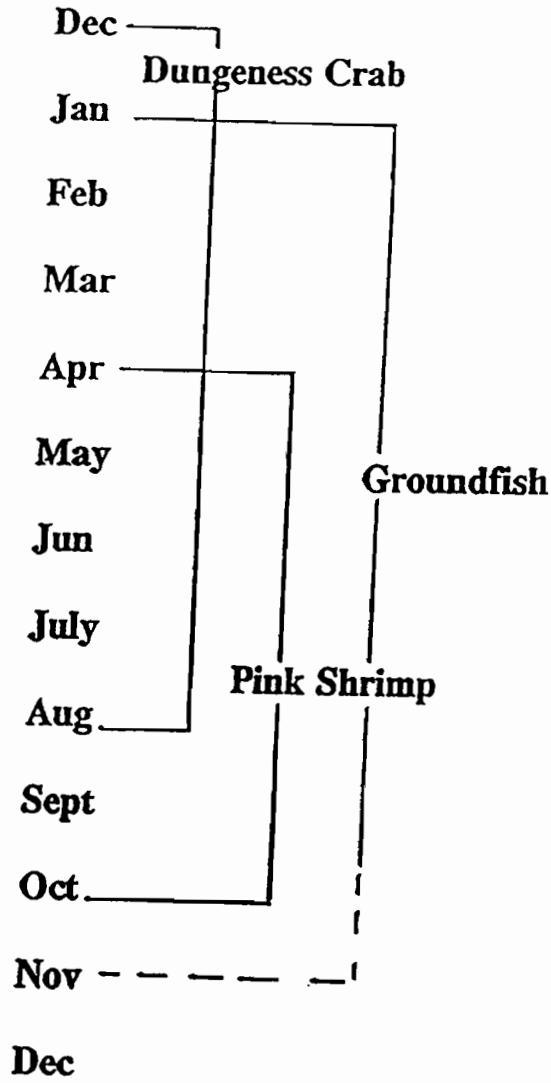
**Generalists**

| | | | |
|---|---|---|---|
| Groundfish/Shrimp | 11-71% GF* | 46.5 | 15.57 |
| Shrimp/Crab | 15-36% S** | 25.3 | 9.86 |
| Groundfish/ Crab | 28-20% GF* | 11.8 | 3.03 |
| Groundfish/Shrimp/Crab | 5-15% GF* | 9.9 | 3.31 |

* GF = Fleet landing primarily groundfish
** S = Fleet landing primarily shrimp

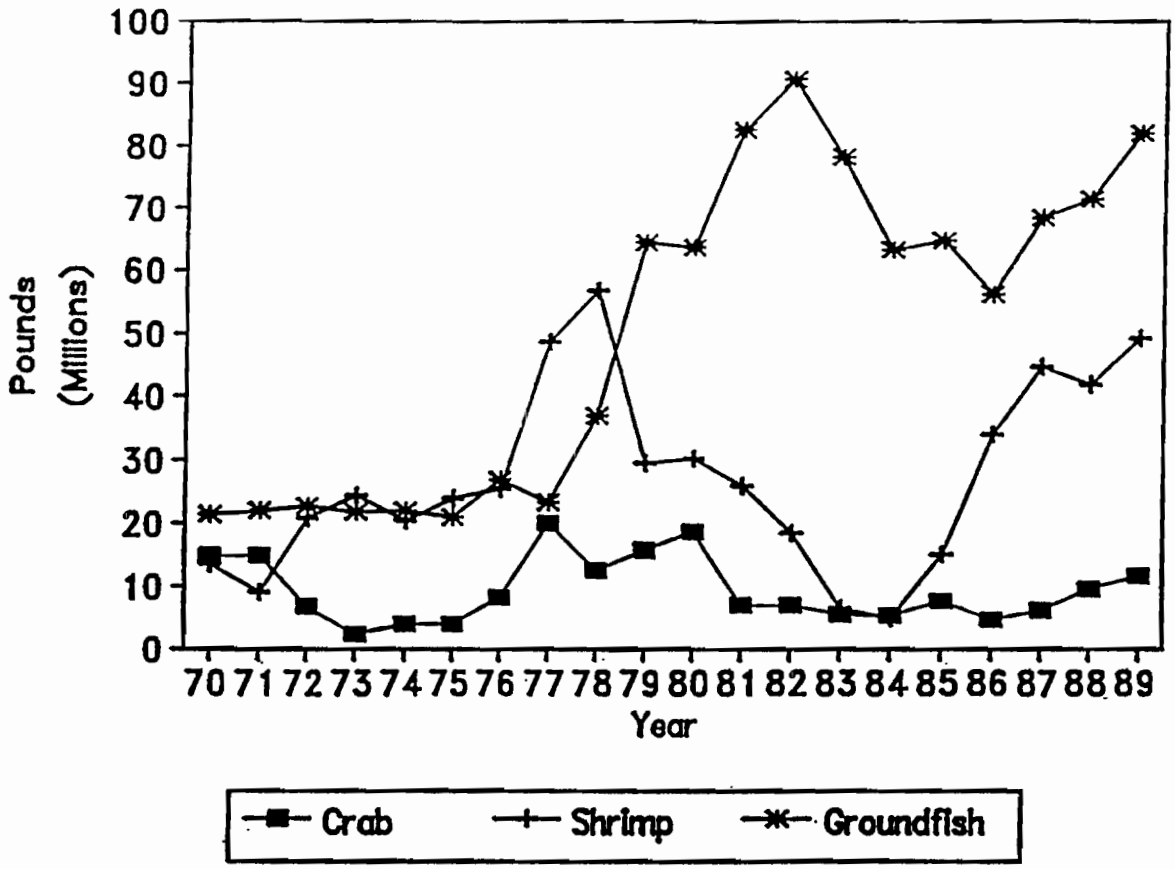
Data Source: Unpublished fish ticket data, Oregon Department of Fish and Wildlife.

**FIGURE 1.**
**OREGON FISHING SEASONS FOR GROUNDFISH, SHRIMP AND CRAB.**



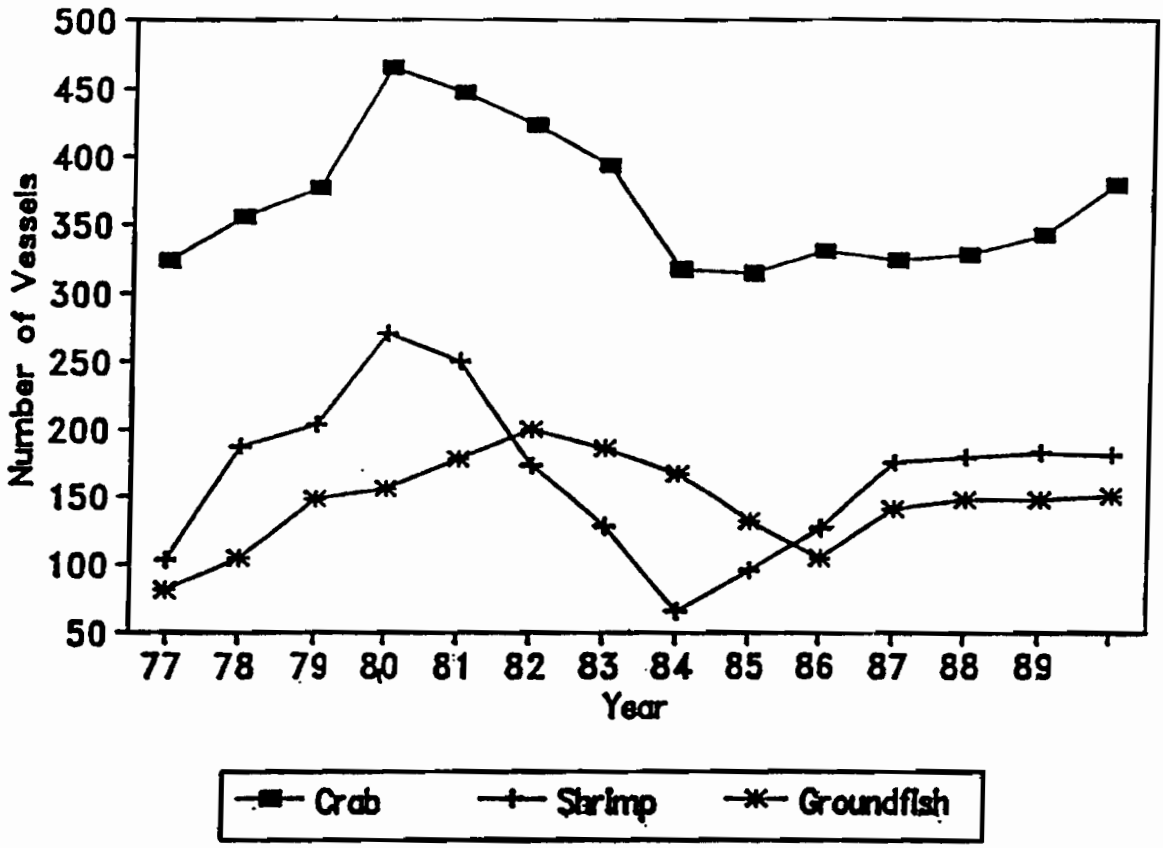

Data Source: Oregon Department of Fish and Wildlife 1991.

FIGURE 2.
LANDINGS OF GROUNDFISH, SHRIMP AND CRAB INTO OREGON PORTS, 1990–1989.




Data Source: Oregon Department of Agriculture 1990

FIGURE 3.
VESSELS LANDING GROUNDFISH, SHRIMP AND CRAB INTO OREGON PORTS, 1977–1989.




Data Source: Unpublished Data, Oregon Department of Fish and Wildlife

# Un essai d'identification des stratégies de pêches : le cas de la pêche artisanale dans le nord de la France

**Frédéric Lantz [a], Marie-Odile Allard [b] and Rui Junaueira-Lopez [c] ***

[a] IFP Institut Français du Pétrole
[b] Administration des Postes Françaises
[c] Université d'Evora, R. Prof Franscisco Gentil 6, 3e, 16 000 Lisboa, Portugal

RÉSUMÉ

*Les interactions entre les flottilles jouent un rôle majeur dans la dynamique des pêcheries. Ainsi, la gestion des pêcheries artisanales requiert une analyse des stratégies de pêche pour appréhender la diversité qui les caractérise. Dans cette communication, nous étudions plus particulièrement les stratégies de pêche à travers l'analyse statistique des journaux de bord (captures, temps de pêche, engins). A cette fin, nous avons utilisé les journaux de bord quotidiens (pour l'année 1989) des deux cents navires artisans de Boulogne-sur-mer, qui est le plus grand port du nord de la France. Dans un premier temps, les statistiques descriptives sur les calendriers d'activité, les espèces cibles et les caractéristiques des bateaux ont permis de mettre en évidence la concentration et la saisonnalité de l'activité des unités de pêche. Ensuite, une analyse factorielle sur la répartition mensuelle du chiffre d'affaires annuel permet d'établir une typologie de la flottille artisanale. Enfin, une analyse des stratégies des pêcheurs est réalisée à partir d'une classification automatique. Le principal résultat de cette typologie est que la diversité de la pêche artisanale en termes d'espèces, d'engins de pêche et de calendrier recouvre un ensemble de métiers bien spécifiés. L'identification des différentes stratégies montre les interactions entre les flottilles et les possibilités de réallocation de l'effort de pêche.*

ABSTRACT

*The interactions between fleets play a major role in the fishery dynamic. Thus, the management of small scale fisheries requires an analysis of fishing strategies to understand the diversity of the fisheries. In this paper, we focus on the fishermen behaviour through the statistical analysis of the log-book data (catches, fishing time, gears). For this purpose, we have used the daily log-books (for 1989) of the two hundred "artisanal" ships of Boulogne-sur-mer which is the main*

* Frédéric Lantz et Marie-Odile ALLARD travaillaient à IFREMER pour cette recherche, Rui Junqueira Lopez était un professeur invité pour cette recherche

*port of northern France. At first, we compute some descriptive statistics upon the fishing calendar, the target species and the technical characteristics of the ships which give some informations about the concentration and the seasonality of the fishing activity. Then, we carry out a factorial analysis of the monthly shares of the annual gross-earnings to define a typology of the "artisanal" fleet. Finally, we perform a cluster analysis to identify the fishermen strategies. The main issue of this typology is that the diversity of the small scale fishery in terms of species, fishing gears and seasonality recovers a sum of well specified activities ("métier" in french) for separate groups of fishermen. The identification of the different strategies shows the interactions between the fleets and the possibilities of fishing effort reallocation.*

## 1. INTRODUCTION

La pêche artisanale est généralement caractérisée par un grand nombre d'espèces cible et de techniques de pêche. Ainsi, l'analyse des pêcheries pluri-spécifiques (multi-espèces, multi-engins) nécessite d'identifier les interactions entre les espèces et les flottilles.

Dans cette communication, nous nous intéressons plus particulièrement au comportement des pêcheurs à travers l'analyse statistique des journaux de bord (captures, calendrier d'activité, engins de pêche). Dans un premier temps, nous définissons une typologie de la flottille artisanale afin d'obtenir des groupes de bateaux ayant une activité homogène. Ensuite, nous interprétons le comportement de chacun des groupes grâce aux caractéristiques de leur activité.

La détermination d'un nombre limité de flottilles répond à la fois aux besoins de modélisation et de gestion des pêcheries. Elle nous amène à réaliser une classification à partir de nos résultats précédents. Ainsi, nous pouvons choisir un niveau d'agrégation qui nous donne un nombre réduit de flottilles qui soit cependant suffisant pour rendre compte de la diversité de la pêcherie.

Pour cette analyse, nous avons utilisé les journaux de bord quotidiens (pour l'année 1989) des deux cent cinquante bateaux artisans de Boulogne-sur-Mer qui est le plus grand port du nord de la France, et l'un des deux plus grands ports de France avec Lorient dans le sud de la Bretagne.

Dans la section 2, nous décrivons l'évolution de la flottille de pêche artisanale qui s'est fortement accrue durant les années quatre-vingt et qui représente 45 % de la valeur des apports en 1989. La troisième section est consacrée à une analyse statistique des journaux de bord pour définir une typologie des flottilles. Enfin, nous essayons d'identifier les stratégies de pêche en utilisant les résultats des analyses multivariées dans la section 4.

## 2. DYNAMIQUE DE LA PECHE ARTISANALE A BOULOGNE-SUR-MER

Boulogne-sur-Mer reste le premier port de pêche français pour quantités débarquées avec 65.000 tonnes (T) en 1989, mais n'est plus le premier port de pêche français pour la valeur des apports : le chiffre d'affaires de la pêche était de 570 millions de Francs (MF) à Lorient contre 510 MF à Boulogne pour cette même année.

L'évolution du secteur des pêches a été caractérisée, depuis le milieu des années soixante-dix (les captures les plus élevées furent de 145.000 T en 1973), par une diminution régulière des débarquements correspondant au déclin de la pêche industrielle [1]. Cette récession a été atténuée par l'expansion de la flottille artisanale jusqu'au milieu des années quatre-vingt, avant sa stabilisation.

Cependant, Boulogne-sur-mer est maintenant une place importante en terme de marché des produits de la mer (250.000 T en 1989) ceci étant en relation avec le développement des industries de transformation depuis le milieu de la dernière décennie.

Le développement de la pêche artisanale durant les années quatre-vingt a été favorisée par l'instauration de la ZEE Européenne en 1977 et par la forte valorisation des captures (ainsi, la sole représente 2 % des quantités débarquées à

1. L'appellation de "pêche industrielle" est donnée par rapport à la dénomination légale des entreprises industrielles en France. Les bateaux industriels de Boulogne sont des chalutiers de haute-mer de 55 mètres qui débarquent du poisson frais pour la consommation humaine.

Boulogne mais 15 % de la valeur de celles-ci). Deux principales composantes peuvent être distinguées dans cette flottille : il s'agit d'une part des plus petits navires (navires de *petite pêche*) qui ont une longueur de moins de 12 mètres et des marées de moins d'une journée et, d'autre part, des navires dits *"artisans "* [2]. Le tableau 1 résume la contribution de chacune des flottilles aux apports de Boulogne en 1989. On se reportera à Lemoine et al. (1988) pour une description détaillée des flottilles boulonnaises.

La flottille de petite pêche a été caractérisée par une forte croissance des trémailleurs et des fileyeurs au début des années quatre-vingt (Lantz et Célimene, 1989) : le nombre de navires s'est accru jusqu'en 1987 avant de stabiliser.

Par ailleurs, les bateaux les plus représentatifs de la flottille artisanale sont les chalutiers de 16-25 mètres (*"chalutiers étaplois"*). La puissance motrice de ces navires a augmenté de 20.200 KW en 1983 à 30.580 KW en 1990 (la puissance motrice par unité a progressé de manière encore plus rapide en passant de 325 KW à 495 KW durant la même période) : ceci explique que ces navires réalisent 43 % des débarquements en 1989. Toutefois, l'analyse des performances économiques de ces navires a mis en évidence la stagnation de leur rentabilité et de l'accroissement de leur endettement pendant ces dernières années.

## 3. TYPOLOGIE DE LA PECHE ARTISANALE

Les données utilisées pour notre analyse sont les statistiques mensuelles issues des journaux de bord qui sont collectés et informatisés par le CRTS (Centre Régional de Traitement Statistique qui est situé à Boulogne pour le Nord de la France). Les fichiers de données contiennent pour chaque marée de chaque bateau les informations suivantes [3] :

- Quantités et valeur de chaque espèce par catégorie commerciale (quand elles sont vendues en criée),
- Zone de pêche (par rectangle statistique pour les trois quart des captures, par rectangle CIEM autrement),
- Temps de pêche pour chaque engin.

Les données que nous venons de décrire représentent un fichier informatique de 3 mega-octets pour Boulogne-sur-mer en 1989. Ainsi, l'analyse des activités de pêche à travers une analyse statistique des fichiers de données implique l'utilisation des méthodes multivariées pour résumer l'information disponible.

Cependant, nous nous sommes intéressés au préalable aux corrélations entre les espèces, les engins et les zones de pêche. Cette étude a mis en évidence que les bateaux sont extrêmement spécialisés. Pour un mois donné, les combinaisons entre engins et espèces : par exemple, les chalutiers (chalut de fond) ne réalisent que 57 % des apports de cabillaud en janvier (compétition avec les filets) mais représentent 73 % des débarquements de cette même espèce en juillet. Ainsi, les statistiques univariées (corrélations, indices de concentration) nous ont permis d'observer que l'activité de chaque type d'unité de pêche est marquée par une forte saisonnalité. Nous avons donc décidé de faire porter notre analyse des correspondances multiples (ACM) sur les chiffres d'affaires (C.A.) mensuels.

Le choix d'un indicateur d'output plutôt qu'un indicateur d'input vient principalement de ce que la variable "C.A." peut être utilisée pour toutes les unités de pêche. A l'opposé, on ne peut pas utiliser un indicateur d'effort de pêche sans distinguer les navires suivant leurs caractéristiques techniques (engin, longueur, puissance). Un indice d'input ne peut donc qu'être que de nature différente suivant le type d'activité (qui lui-même peut varier suivant les saisons) : ainsi, le temps de pêche est pertinent pour un chalutier mais ne l'est pas pour un fileyeur.

La fiabilité des données utilisées a été pu être mesurée sur les chalutiers de plus de 20 mètres pour lesquels nous disposions d'un échantillon représentatif de comptabilités de navires. L'écart entre les chiffres d'affaires observés sur la criée et dans les données comptables est inférieur à 1 %. Toutefois, les unités de moins de 12 mètres n'étant pas tenues à l'époque (1989) de tenir un livre de bord, les débarquements des plus petites unités sont sans doute sous-évalués.

2. Cette flottille peut elle-même être subdivisée en deux catégories suivant que la longueur du navire est inférieure ou supérieure à 16 mètres et que la durée de la marée est de plus ou de moins de 3 jours.
3. Pour plus de détails on peut se reporter à Allard (1991).

Nous avons calculé la répartition mensuelle du C.A. annuel pour chaque unité de pêche pour éviter un effet de taille entre les différents types de navire. Puis nous avons construit un tableau disjonctif avec quatre modalités pour chaque variable mensuelle :

- 1 : Pas d'activité durant le mois,
- 2 : La part du C.A. est inférieur à 33 %, i.e. le bateau fait parti des 33 % des navires qui réalisent leur part du chiffre d'affaires la plus faible durant le mois considéré : faible activité durant le mois au regard de l'ensemble de la flottille artisanale,
- 3 : Part du C.A. compris entre 33 % et 66 % : activité médiane,
- 4 : Part du C.A. supérieur à 66 % : forte activité.

Le tableau disjonctif ainsi constitué comprend 48 modalités actives (12 mois * 4 modalités) et 255 individus (255 navires artisans). Nous avons ajouté les caractéristiques techniques (longueur, TJB, puissance motrice et année de lancement) et le C.A. annuel comme variables supplémentaires. Ces variables ont elles-même été réparties en quatre modalités.

Les quatre premiers axes expliquent respectivement 18.4 %, 8.6 %, 6.6 % et 4.8 % de l'inertie totale. La figure 1 représente la projection sur l'axe 1-2 (on se reportera à l'annexe 1 pour la signification des libellés).

Le premier axe oppose les modalités d'inactivité hors vacances estivales (janvier à juin : JV1 à JN1, septembre à décembre : SE1 à DE1) qui ont des valeurs positives aux modalités d'activité moyenne ou déjà importantes (indices 2 et 3 associés à l'ensemble des mois). Aux valeurs positives de l'axe correspondent les petites unités de faible longueur et TJB (L1,J1) et relativement anciennes (A1). A l'opposé, on trouve des unités de plus forte taille. De manière similaire, les C.A. totaux vont du plus fort au plus faible sur cet axe. Ainsi, la première distinction entre les unités de pêche artisanale se fait entre celles qui ont une activité régulière tout au long de l'année à celles qui ont une activité plus saisonnière et peuvent être éventuellement bloquées par les intempéries.

L'axe 2 oppose les activités saisonnières marquées de début d'année (janvier à avril : JV4 à AV4) à celles de fin d'année (septembre à décembre : SE4 à DE4) sans que nous puissions distinguer au regard des variables supplémentaires. Il devient alors nécessaire d'étudier les captures et les engins utilisés pour caractériser les navires. Nous reviendrons sur cette opposition entre deux groupes de navires dans la prochaine section (les unités de pêche correspondent respectivement aux groupes 3 et 2).

L'axe 3 permet de distinguer les fortes et les faibles activités durant la période mai-juin-juillet. Ceci correspond à une opposition entre grands et petits bateaux, ces derniers (et plus particulièrement les trémailleurs à sole) étant très actifs durant cette période. Enfin, l'axe 4 est déterminé par les unités de pêche qui concentrent leur activité sur la fin de l'année.

L'interprétation des axes permet ainsi de distinguer les bateaux qui présentent une activité très saisonnière (les plus petites unités) des grands navires artisans qui ont une activité plus régulière sur l'année. Ensuite, les unités se répartissent suivant la saisonalité de leurs activité. Il est intéressant de noter que les modalités définies à partir de la répartition mensuelle du chiffre d'affaires ne semblent pas se différencier sensiblement durant un même trimestre. Ceci va dans le même sens que l'approche trimestrielle retenue pour la modélisation bio-économique de la Mer du Nord par le CSTP (STCF North Sea WG, 1990).

## 4. CLASSIFICATION DE LA FLOTTILLE ARTISANALE

La classification a été réalisée à partir des coordonnées factorielles des 255 unités obtenues par l'ACM. Au niveau 8 (Groupes 1 à 8), nous avons calculé la moyenne, la médiane et les extremums des variables supplémentaires de l'analyse (puissance, année de lancement, C.A. annuel) qui ont permis d'observer une relative homogénéité au sein de chaque groupe (cf annexe 2).

De même, nous avons calculé pour chaque groupe et chaque mois les engins de pêche les plus utilisés, les espèces cibles et les zones de pêche fréquentées. Les cartes présentées en annexe 2 décrivent la concentration de l'activité des navires

(en terme de chiffre d'affaires) suivant les rectangles statistiques : alors que les groupes 1,2 et 3 travaillent presque exclusivement en Manche orientale, le groupes 6 et 7 ont une activité mieux répartie entre la Manche orientale et le sud de la Mer du Nord.

Le regroupement suivant fait apparaître quatre classes (groupes A à D) puis deux catégories (I et II). Le tableau 2 résume les caractéristiques des flottilles ainsi identifiées. Le regroupement au niveau 8 permet donc de distinguer les unités en terme de type d'unité (longueur, Tjb), d'engins de pêche, d'espèces cible, de zone de pêche et de saisonalité de l'activité. Au niveau 4, on différencie les navires en terme d'engins de pêche et de saisonalité. Enfin, au niveau 2 la flottille artisanale se répartie suivant que les bateaux se caractérisent par une activité régulière tout au long de l'année ou non.

Une analyse détaillée des flottilles les unes par rapport aux autres permet de mieux cerner les stratégies de pêche et les compétitions entre les différents types de pêche. A titre d'exemple, le groupe 2 est une flottille qui utilise des filets durant toutes les saisons sauf l'été où elle utilise le chalut. Cette flottille se caractérise par une très grande part du C.A. réalisé pendant les quatre derniers mois de l'année et capture principalement du cabillaud et de la sole. Les bateaux sont des unités de 14 mètres qui travaillent principalement en Manche orientale où ils réalisent 75 % de leur chiffre d'affaires. Toute mesure de régulation sur les filets se traduirait par une augmentation de la seconde activité de ces navires : le chalut. Dès lors ces unités pourraient rentrer en compétition avec celles du groupe 3 qui utilisent les mêmes engins de pêche et travaillent sur les mêmes zones.

## 5. CONCLUSION

L'analyse statistique de la pêche artisanale à Boulogne-sur-mer nous a montré que cette pêcherie qui est caractérisée par un grand nombre d'espèces capturées et de techniques de pêche utilisées recouvre un ensemble de "métiers" plus ou moins spécialisés. La diversité de la pêche artisanale doit donc se comprendre comme une multitude d'activités spécifiques plutôt qu'"une flottille" qui pêcherait beaucoup d'espèces avec de nombreuses techniques.

Chaque flottille pêche plusieurs espèces avec plusieurs engins tout au long de l'année mais réalise en général plus des deux tiers de son chiffre d'affaires avec au plus deux engins de pêche et moins de quatre espèces au cours du même mois. Ceci a pour conséquence, en terme de gestion des pêches, qu'il est difficile d'opérer des changements importants d'espèces cibles sans toucher très sensiblement au revenu des pêcheurs à court terme.

Enfin, les différences de stratégies de pêche met en évidence la difficulté d'une gestion globale de la pêcherie qui ne prendrait pas en compte les particularités et la dynamique de chaque flottille ainsi que les interactions entre celles-ci. Les outils de régulation "classiques" de l'effort de pêche (taille des maillages, quotas...) appliqués de manière uniforme ont un impact distinct suivant les bateaux artisans caractérisés par leur pluri-spécificité qu'il est donc important de préciser à travers l'identification de métiers.

## REFERENCES

**Allard M.O.** (1991). Analyse du comportement des flottilles de pêche de Boulogne-sur-Mer, Rapport de stage ENSAE.

**Catanzano J., B. Gilly B. and F. Lantz** (1989). Les entreprises de pêche artisanale : essais de typologie, *Economie Rurale* n° 194, Nov.-Déc. : 9-14.

**Kennedy J.** (1987). A computable theoric approach to modelling competitive fishing, *Marine Resource Economics*, Vol. 4 : 1-14.

**Lantz F. and F. Célimene** (1989). La pêche artisanale et l'emploi : les exemples de la Martinique et des trémailleurs boulonnais. In Durand J.R. and Weber J. Eds, Actes du Symposium *"La Recherche face à la pêche artisanale"*, ORSTOM-IFREMER, Montpellier, 3-7 Juillet

**Lemoine M., L. Reynal L. and A. Souplet** (1988). Les flottilles de pêche boulonnaises, *Equinoxe,* IFREMER, Nantes, Hors Série n° 1 : 21-32.

**STCF North Sea WG** (1990). Report of the meeting of the STCF North Sea Working Group on improvements of the exploitation pattern of the North Sea stocks, Nantes, april 1990.

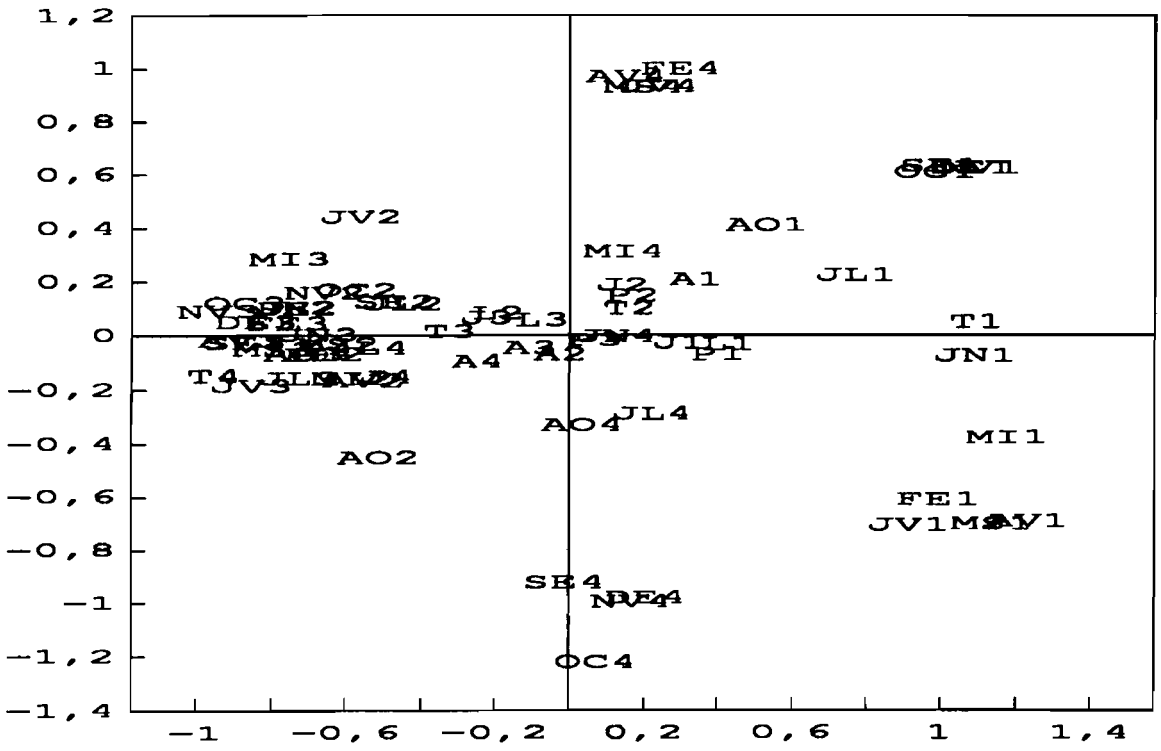
TABLEAU 1.
DEBARQUEMENTS A BOULOGNE-SUR MER EN 1989

| Flottille | Quantités (T) | Valeur (1000 F) | Prix (Fr/Kg) |
|---|---|---|---|
| Petite pêche | 3034 | 60269 | 19.87 |
| Artisans | 27558 | 211095 | 7.66 |
| Semi-Indus. | 3533 | 17557 | 4.97 |
| Industriels | 29967 | 196815 | 6.57 |
| Total | 64092 | 485736 | 7.58 |

TABLEAU 2.
CARACTERISTIQUES DES FLOTILLES ISSUES DE LA CLASSIFICATION

| Niveau d'agr. | Groupe | Nb de bateaux | Caractéristiques |
|---|---|---|---|
| 8 | 1 | 52 | petits chalutiers + autres engins, faible activité en 1989 |
| 8 | 2 | 18 | Filets, unités de 12-16 mètres |
| 8 | 3 | 20 | Chalut de fond + filets, unités de 12-26 mètres |
| 8 | 4 | 9 | Filets + chalut de fond, unités de 12-16 mètres |
| 8 | 5 | 30 | Chalutiers de 16 mètres, activité régulière |
| 8 | 6 | 29 | Chalutiers de 20 mètres, activité régulière |
| 8 | 7 | 57 | Chalut + filets, unités de 12-16 mètres |
| 8 | 8 | 40 | Chalut + filets, forte activité au printemps (unités de 12-16 mètres) |
| 4 | A=1+2 | 70 | Activité principale en fin d'année, unités de moins de 16 mètres |
| 4 | B=3+4 | 29 | Activité principale durant le premier semestre, |
| 4 | C=5+6 | 59 | Chalutiers étaplois |
| 4 | D=7+8 | 97 | Chalut + filets à activité régulière |
| 2 | I=A+B | 99 | Activité saisonnière marquée |
| 2 | II=C+D | | Activité régulière durant l'année |

**FIGURE 1.**
**PROJECTION SUR LE PLAN 1-2**



## ANNEXE 1 : ANALYSE FACTORIELLE DES CORRESPONDANCES MULTIPLES

L'analyse factorielle des correspondances multiples a été réalisée à partir d'un tableau de 48 modalités (12 variables réparties en 4 classes) et 255 observations. Les modalités ont été construites à partir de la répartition mensuelle du chiffre d'affaires des 255 unités de pêche artisanale qui sont analysées. L'ACM a été réalisée sur le logiciel ADDAD.

Les libellés des variables ont les significations suivantes :

JVi, FEi, MSi, AVi, MIi, JNi, JTi, AOi, SEi, OCi, NVi,DEi : Janvier, Février, Mars, Avril, Mai, Juin, Juillet, Août, septembre, Octobre, Novembre, Décembre et i =1, 2, 3, et 4.

Li, Ji, Pi, Ti = Longueur, TJB, Puissance Motrice Power et Chiffre d'affaires et i =1,2,3 et 4.

Les indices i sont définis dans la section 3.

```
LES VALEURS  PROPRES        VAL(1)=   1.00000
!NUM ! VAL PROPRE ! POURC.! CUMUL !VARIAT.!*! HISTOGRAMME DES VALEURS PROPRES

!..2.!      .5239..!.18.413!.18.413!*******!*!***************!***************!***
!  3 !      .25907 !  8.636! 27.049!  9.777!*!***************!*************
!  4 !      .19140 !  6.380! 33.429!  2.256!*!***************!******
!  5 !      .14508 !  4.836! 38.265!  1.544!*!***************!*
!  6 !      .12614 !  4.205! 42.469!   .632!*!***************
!  7 !      .12220 !  4.073! 46.543!   .131!*!**************
!  8 !      .10938 !  3.646! 50.189!   .427!*!*************
!  9 !      .10483 !  3.494! 53.683!   .152!*!************
! 10 !      .09628 !  3.209! 56.892!   .285!*!***********
! 11 !      .09212 !  3.071! 59.963!   .139!*!***********
! 12 !      .09031 !  3.010! 62.973!   .060!*!***********
! 13 !      .08791 !  2.930! 65.903!   .080!*!***********
! 14 !      .07972 !  2.657! 68.560!   .273!*!*********
! 15 !      .07586 !  2.529! 71.089!   .129!*!********
! 16 !      .07080 !  2.360! 73.449!   .169!*!********
! 17 !      .06832 !  2.277! 75.726!   .083!*!*******
! 18 !      .06405 !  2.135! 77.861!   .142!*!*******
! 19 !      .05809 !  1.936! 79.798!   .199!*!******
! 20 !      .05622 !  1.874! 81.672!   .062!*!******
! 21 !      .05485 !  1.828! 83.500!   .046!*!******
```

| J1 | QLT | POID | INR | 1ØF | COR | CTR | 2ØF | COR | CTR | 3ØF | COR | CTR | 4ØF | COR | CTR | 5ØF | COR | CTR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 JV1 | 673 | 27 | 19 | 915 | 397 | 41 | -710 | 239 | 52 | 245 | 28 | 8 | -134 | 9 | 3 | 10 | 0 | 0 |
| 2 JV2 | 237 | 17 | 22 | -561 | 79 | 9 | 437 | 48 | 12 | 511 | 65 | 23 | 248 | 15 | 7 | -343 | 29 | 16 |
| 3 JV3 | 466 | 23 | 20 | -855 | 271 | 30 | -190 | 13 | 3 | -331 | 41 | 13 | -206 | 16 | 7 | 580 | 125 | 60 |
| 4 JV4 | 356 | 17 | 22 | 237 | 15 | 2 | 926 | 225 | 57 | -440 | 51 | 18 | 237 | 15 | 7 | -440 | 51 | 27 |
| 5 FE1 | 675 | 25 | 19 | 995 | 420 | 45 | -614 | 160 | 36 | 285 | 35 | 11 | -368 | 58 | 23 | -73 | 2 | 1 |
| 6 FE2 | 286 | 23 | 20 | -658 | 167 | 18 | -73 | 2 | 0 | 499 | 96 | 30 | 202 | 16 | 7 | 106 | 4 | 2 |
| 7 FE3 | 312 | 19 | 21 | -756 | 168 | 20 | 38 | 0 | 0 | -538 | 85 | 29 | -110 | 4 | 2 | 429 | 54 | 28 |
| 8 FE4 | 437 | 16 | 22 | 299 | 22 | 3 | 993 | 240 | 62 | -519 | 66 | 23 | 400 | 39 | 18 | -537 | 70 | 37 |
| 9 MS1 | 740 | 23 | 20 | 1138 | 481 | 53 | -707 | 185 | 43 | 164 | 10 | 3 | -416 | 64 | 27 | 22 | 0 | 0 |
| 10 MS2 | 141 | 20 | 21 | -622 | 124 | 14 | -37 | 0 | 0 | -81 | 2 | 1 | -211 | 14 | 6 | -26 | 0 | 0 |
| 11 MS3 | 227 | 21 | 21 | -795 | 216 | 24 | -54 | 1 | 0 | -66 | 1 | 0 | 114 | 4 | 2 | 102 | 4 | 2 |
| 12 MS4 | 375 | 19 | 21 | 199 | 12 | 1 | 925 | 257 | 64 | -35 | 0 | 0 | 582 | 102 | 45 | -110 | 4 | 2 |
| 13 AV1 | 750 | 22 | 20 | 1231 | 540 | 60 | -696 | 173 | 41 | -56 | 1 | 0 | -317 | 36 | 15 | 6 | 0 | 0 |
| 14 AV2 | 258 | 21 | 21 | -554 | 101 | 11 | -172 | 10 | 2 | 58 | 1 | 0 | 516 | 87 | 38 | -425 | 59 | 29 |
| 15 AV3 | 416 | 21 | 21 | -888 | 264 | 30 | -22 | 0 | 0 | -332 | 37 | 12 | -484 | 78 | 34 | 331 | 37 | 18 |
| 16 AV4 | 373 | 20 | 21 | 152 | 7 | 1 | 964 | 292 | 72 | 349 | 38 | 13 | 324 | 33 | 14 | 86 | 2 | 1 |
| 17 MI1 | 576 | 21 | 21 | 1176 | 454 | 52 | -382 | 48 | 12 | -454 | 68 | 22 | 54 | 1 | 0 | -133 | 6 | 3 |
| 18 MI2 | 185 | 23 | 20 | -584 | 132 | 14 | -163 | 10 | 2 | -209 | 17 | 5 | 165 | 11 | 4 | 205 | 16 | 8 |
| 19 MI3 | 257 | 18 | 22 | -752 | 159 | 19 | 280 | 22 | 6 | -184 | 10 | 3 | -119 | 4 | 2 | -471 | 62 | 32 |
| 20 MI4 | 312 | 21 | 21 | 146 | 7 | 1 | 307 | 32 | 8 | 827 | 234 | 76 | -130 | 6 | 2 | 310 | 33 | 16 |
| 21 JN1 | 568 | 24 | 20 | 1088 | 475 | 51 | -79 | 2 | 1 | -458 | 84 | 26 | 118 | 6 | 2 | -47 | 1 | 0 |
| 22 JN2 | 382 | 22 | 20 | -740 | 195 | 22 | 96 | 3 | 1 | -581 | 120 | 39 | -324 | 37 | 16 | -271 | 26 | 13 |
| 23 JN3 | 282 | 18 | 22 | -677 | 126 | 15 | -3 | 0 | 0 | 253 | 18 | 6 | 407 | 46 | 21 | 580 | 93 | 48 |
| 24 JN4 | 312 | 20 | 21 | 123 | 5 | 1 | -8 | 0 | 0 | 973 | 291 | 97 | -155 | 7 | 3 | -172 | 9 | 5 |
| 25 JT1 | 565 | 27 | 19 | 770 | 292 | 30 | 217 | 23 | 5 | -606 | 180 | 53 | 123 | 7 | 3 | 356 | 62 | 28 |
| 26 JT2 | 413 | 19 | 22 | -449 | 58 | 7 | 109 | 3 | 1 | -205 | 12 | 4 | 151 | 7 | 3 | -1076 | 333 | 171 |
| 27 JT3 | 387 | 22 | 20 | -727 | 192 | 21 | -162 | 10 | 2 | 105 | 4 | 1 | 186 | 13 | 5 | 682 | 169 | 82 |
| 28 JT4 | 476 | 15 | 23 | 223 | 11 | 1 | -292 | 19 | 5 | 1205 | 320 | 114 | -686 | 104 | 49 | -325 | 23 | 13 |
| 29 AO1 | 469 | 34 | 16 | 531 | 198 | 18 | 404 | 114 | 22 | -385 | 104 | 27 | 196 | 27 | 9 | 195 | 27 | 10 |
| 30 AO2 | 507 | 14 | 23 | -513 | 53 | 7 | -457 | 42 | 11 | 676 | 93 | 34 | 740 | 111 | 53 | 1011 | 208 | 114 |
| 31 AO3 | 317 | 16 | 22 | -715 | 125 | 15 | -74 | 1 | 0 | -204 | 10 | 4 | -214 | 11 | 5 | -834 | 170 | 90 |
| 32 AO4 | 272 | 19 | 22 | 36 | 0 | 0 | -334 | 32 | 8 | 378 | 41 | 14 | -731 | 154 | 69 | -390 | 44 | 22 |
| 33 SE1 | 639 | 25 | 19 | 997 | 438 | 46 | 624 | 172 | 38 | -122 | 7 | 2 | 81 | 3 | 1 | 210 | 19 | 9 |
| 34 SE2 | 258 | 21 | 21 | -474 | 77 | 9 | 118 | 5 | 1 | 637 | 139 | 45 | 324 | 36 | 15 | -79 | 2 | 1 |
| 35 SE3 | 296 | 17 | 22 | -872 | 199 | 24 | -33 | 0 | 0 | -417 | 46 | 16 | -401 | 42 | 19 | 174 | 8 | 4 |
| 36 SE4 | 306 | 19 | 21 | -13 | 0 | 0 | -927 | 258 | 64 | -166 | 8 | 3 | -104 | 3 | 1 | -348 | 36 | 18 |
| 37 OC1 | 668 | 27 | 19 | 983 | 475 | 48 | 601 | 178 | 38 | 20 | 0 | 0 | -41 | 1 | 0 | 171 | 14 | 6 |
| 38 OC2 | 294 | 17 | 22 | -572 | 84 | 10 | 163 | 7 | 2 | 660 | 112 | 39 | 569 | 83 | 38 | -182 | 8 | 4 |
| 39 OC3 | 581 | 21 | 21 | -873 | 261 | 29 | 112 | 4 | 1 | -520 | 92 | 30 | -788 | 212 | 91 | -177 | 11 | 5 |
| 40 OC4 | 468 | 18 | 22 | 73 | 1 | 0 | -1227 | 404 | 103 | -41 | 0 | 0 | 465 | 58 | 26 | 123 | 4 | 2 |
| 41 NV1 | 737 | 25 | 19 | 1103 | 516 | 55 | 619 | 163 | 37 | 168 | 12 | 4 | -289 | 35 | 14 | 160 | 11 | 5 |
| 42 NV2 | 317 | 20 | 21 | -659 | 137 | 16 | 152 | 7 | 2 | 659 | 136 | 45 | 111 | 4 | 2 | -325 | 33 | 17 |
| 43 NV3 | 442 | 19 | 22 | -942 | 256 | 30 | 85 | 2 | 1 | -383 | 42 | 14 | -660 | 126 | 56 | 237 | 16 | 8 |
| 44 NV4 | 644 | 20 | 21 | 166 | 9 | 1 | -1002 | 315 | 77 | -509 | 82 | 27 | 866 | 236 | 103 | -96 | 3 | 1 |
| 45 DE1 | 722 | 25 | 19 | 1081 | 505 | 53 | 617 | 165 | 37 | 159 | 11 | 3 | -276 | 33 | 13 | 134 | 8 | 4 |
| 46 DE2 | 282 | 21 | 21 | -732 | 176 | 20 | 95 | 3 | 1 | 545 | 98 | 32 | -84 | 2 | 1 | -104 | 4 | 2 |
| 47 DE3 | 332 | 19 | 21 | -843 | 209 | 24 | 45 | 1 | 0 | -409 | 49 | 17 | -396 | 46 | 20 | 303 | 27 | 14 |
| 48 DE4 | 595 | 19 | 22 | 206 | 12 | 1 | -985 | 279 | 70 | -401 | 46 | 16 | 868 | 217 | 97 | -375 | 40 | 21 |
| | | | 1000 | | | 1000 | | | 1000 | | | 1000 | | | 1000 | | | 1000 |

**ANNEXE 2**
**DESCRIPTION DES ACTIVITES DE PECHE DES GROUPES ISSUS DE LA CLASSIFICATION**

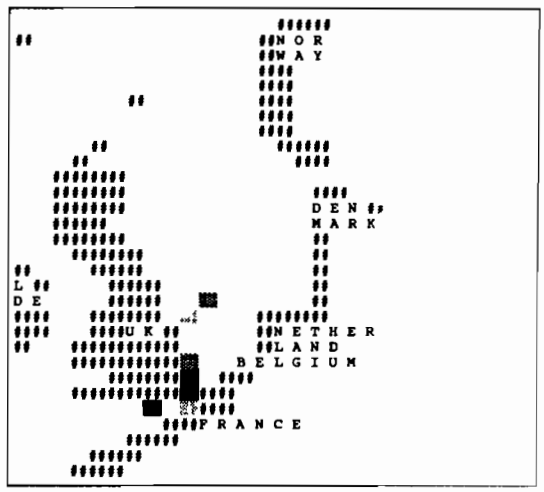
| groupes | effectif | caractéristiques techniques | | | activité | |
|---|---|---|---|---|---|---|
| | | puissance (KW) | année de lancement | longueur (Mètre) | C.A. annuel (KF) | période d'activité |
| Groupe 1 | 52 | 128<br>93<br>9-442 | 1975<br>1976<br>1932 | 11<br>10<br>4-21 | 143<br>33<br>0,1-1128 | 1 mois seulement en 1989 |
| Groupe 2 | 18 | 183<br>178<br>44-324 | 1977<br>1979<br>1958 | 14<br>14,5<br>8-20 | 474<br>270<br>6-1793 | 4 derniers mois |
| Groupe 3 | 20 | 200<br>162<br>33-510 | 1973<br>1973<br>1953 | 14<br>15,5<br>7-25 | 405<br>253<br>15-1377 | 4 premiers mois |
| Groupe 4 | 9 | 188<br>147<br>17-442 | 1980<br>1982<br>1968 | 13<br>11<br>5-22 | 517<br>610<br>26-1415 | Janvier à Juin |
| Groupe 5 | 30 | 276<br>234<br>16-552 | 1978<br>1980<br>1954 | 16<br>16<br>5-24 | 1743<br>1265<br>40-5925 | toute l'année diminution de Mai à Aout |
| Groupe 6 | 29 | 364<br>368<br>73-551 | 1981<br>1983<br>1968 | 19,5<br>20,5<br>5-24 | 2550<br>2710<br>915-3956 | régulière, diminution en Juillet |
| Groupe 7 | 57 | 172<br>148<br>10-626 | 1978<br>1980<br>1956 | 13<br>12<br>5-24 | 1110<br>746<br>35-4998 | régulière, diminution en Aout |
| Groupe 8 | 40 | 178<br>124<br>14-515 | 1976<br>1978<br>1954 | 13,5<br>12<br>4-22 | 1320<br>783<br>61-4081 | toute l'année + forte de Mars à Juillet |

N.B. : Pour la puissance, la longueur et le chiffre d'affaires annuel, sont indiquées respectivement la moyenne, la médiane ainsi que les valeurs minimum et maximun du groupe concerné.
Pour l'année de lancement sont données les valeurs moyenne et médiane et l'année la plus ancienne, l'année la plus récente étant toujours 1988 ou 1989, quelque soit le groupe.

IFREMER Service D'Economie Maritime

FLOTTILLE GROUPE 1 ANNEE 1989

ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE



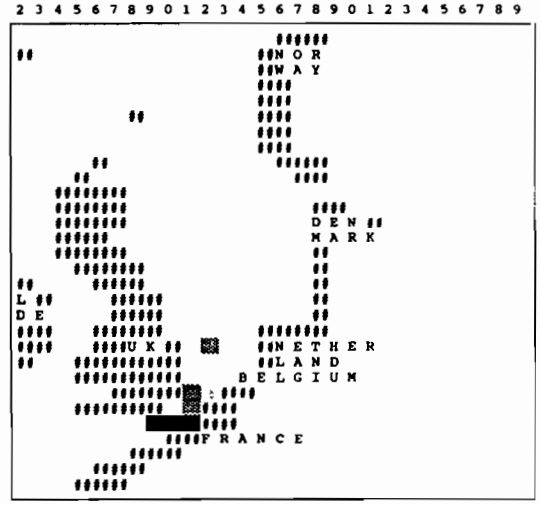

[ 14684.; 37781.[
[ 37781.; 38767.[
[ 38767.; 71846.[
[ 71846.; 7049812.[

| SECT. | TOTAL | POURCENT. |
|---|---|---|
| 4B | 71846. | 0.64% |
| 4C | 388270. | 3.48% |
| 7D | 10686334. | 95.87% |

IFREMER Service D'Economie Maritime

FLOTTILLE GROUPE 2 ANNEE 1989

ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE



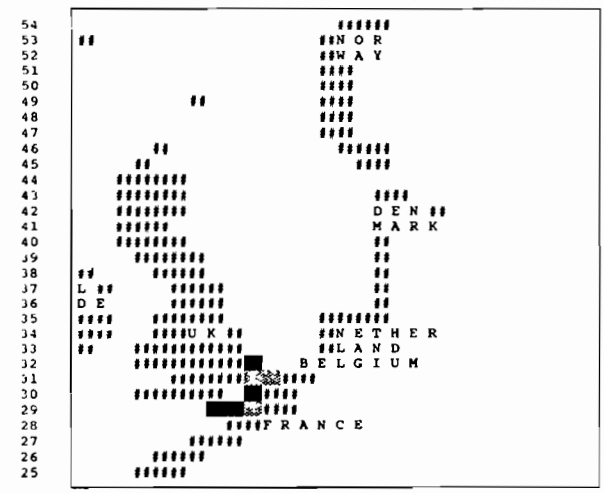

[ 5902.; 159688.[
[ 159688.; 477187.[
[ 477187.; 723934.[
[ 723934.; 2657332.[

| SECT. | TOTAL | POURCENT. |
|---|---|---|
| 4B | 159688. | 1.87% |
| 4C | 1942283. | 22.77% |
| 7D | 6426459. | 75.35% |

IFREMER Service D'Economie Maritime

FLOTTILLE GROUPE 3 ANNEE 1989

ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE



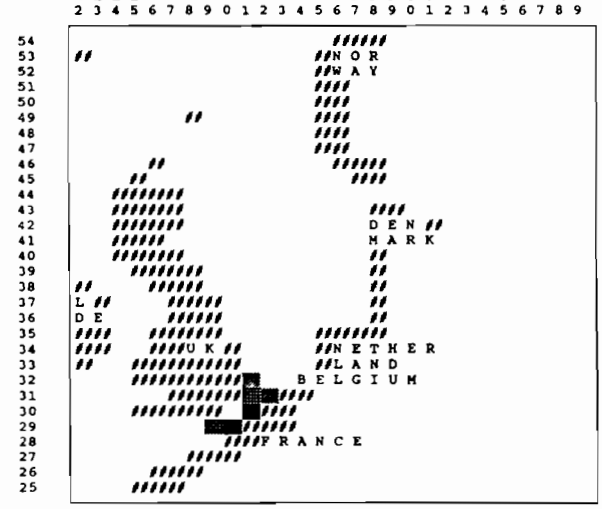

```
  : [    16694.;    32346.[
  : [    32346.;   201161.[
  : [   201161.;   418969.[
  : [   418969.;  3542951.[
```

| SECT. | TOTAL | POURCENT. |
|---|---|---|
| 4B | 201161. | 2.48% |
| 4C | 1496930. | 18.46% |
| 7D | 6410749. | 79.06% |

IFREMER Service D'Economie Maritime

FLOTTILLE GROUPE 4 ANNEE 1989

ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE




```
  : [    23394.;    23394.[
  : [    23394.;    99948.[
  : [    99948.;   970694.[
  : [   970694.;  3446448.[
```

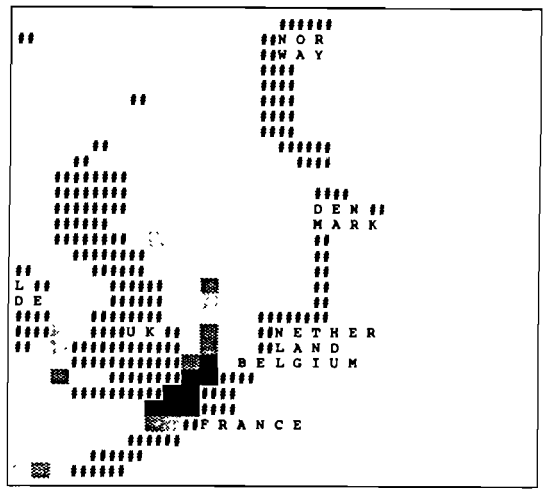
| SECT. | TOTAL | POURCENT. |
|---|---|---|
| 4C | 537203. | 7.63% |
| 7D | 6507001. | 92.37% |

IFREMER Service D'Economie Maritime

FLOTTILLE GROUPE 5 ANNEE 1989

ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE

E E E E E E E E F F F F F F F F G G G G G G G G G
2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9




: [ 602.; 32027.[
: [ 32027.; 146638.[
: [ 146638.; 1770379.[
: [ 1770379.; 12860047.[

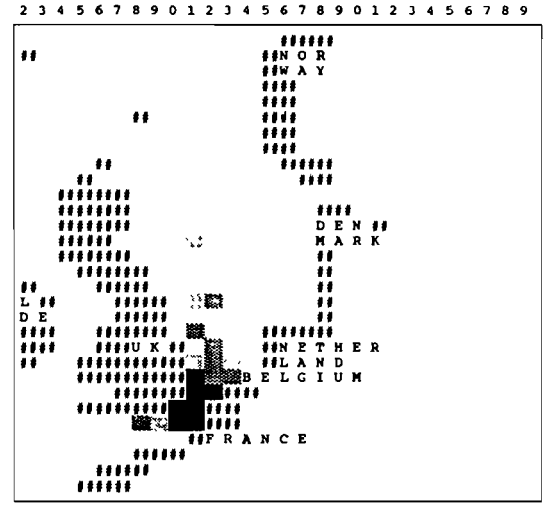
| SECT. | TOTAL | POURCENT. |
|---|---|---|
| 4B | 539084. | 1.03% |
| 4C | 18792886. | 35.95% |
| 7A | 122392. | 0.23% |
| 7D | 31788910. | 60.80% |
| 7G | 223217. | 0.43% |
| 7H | 814342. | 1.56% |

IFREMER Service D'Economie Maritime

FLOTTILLE GROUPE 6 ANNEE 1989

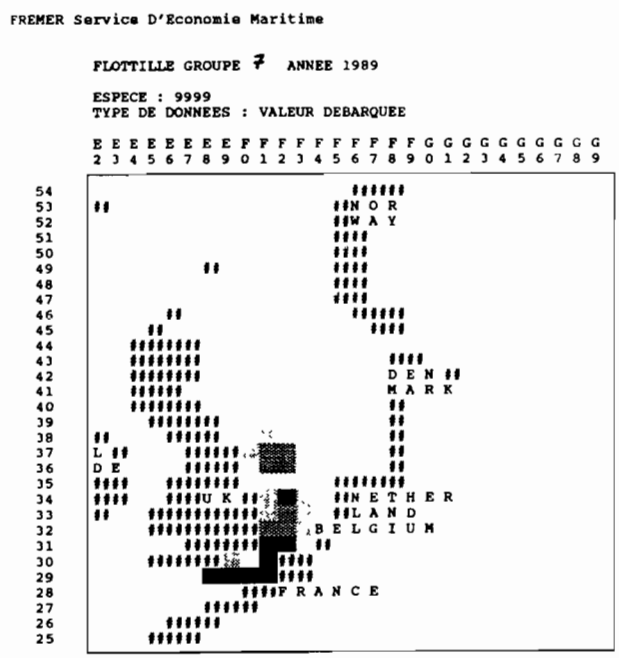
ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE

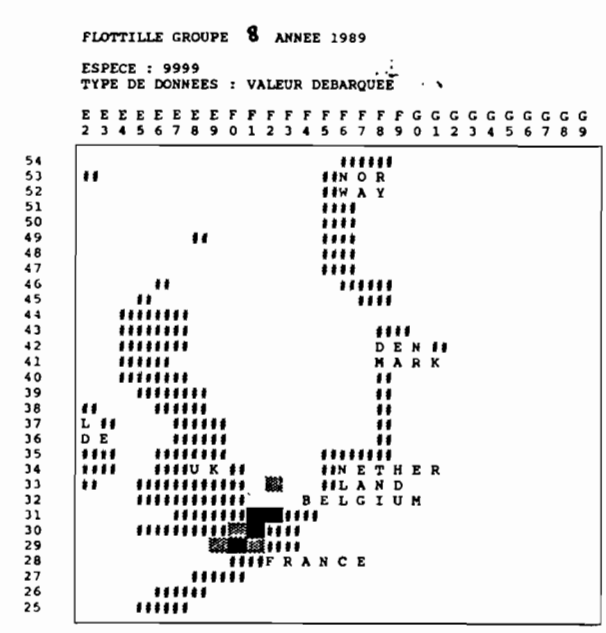
E E E E E E E E F F F F F F F F G G G G G G G G G
2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9




: [ 2205.; 31985.[
: [ 31985.; 135246.[
: [ 135246.; 2180689.[
: [ 2180689.; 18427296.[

| SECT. | TOTAL | POURCENT. |
|---|---|---|
| 4B | 912708. | 1.23% |
| 4C | 25970324. | 35.11% |
| 7D | 47076072. | 63.65% |


FREMER Service D'Economie Maritime
FLOTTILLE GROUPE 7 ANNEE 1989
ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE
E E E E E E E F F F F F F F F F G G G G G G G G G G
2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
N O R
W A Y
D E N
M A R K
U K
N E T H E R
L A N D
B E L G I U M
F R A N C E
: [ 3419.; 81681.[
: [ 81681.; 252217.[
: [ 252217.; 1245395.[
: [ 1245395.; 20767094.[
SECT. TOTAL POURCENT.
4B 3489253. 5.52%
4C 17680002. 27.95%
7D 42079472. 66.53%


KEMER Service D'Economie Maritime
FLOTTILLE GROUPE 8 ANNEE 1989
ESPECE : 9999
TYPE DE DONNEES : VALEUR DEBARQUEE
E E E E E E E E F F F F F F F F F G G G G G G G G G
2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
N O R
W A Y
D E N
M A R K
U K
N E T H E R
L A N D
B E L G I U M
F R A N C E
: [ 14582.; 19215.[
: [ 19215.; 875159.[
: [ 875159.; 1649062.[
: [ 1649062.; 27582138.[
SECT. TOTAL POURCENT.
4B 241306. 0.46%
4C 11881193. 22.47%
7D 40760880. 77.08%

# The effect of government subsidies on the formation of collusions in an oligopolistic fishery

**Per Mickwitz[a] and Mikael Hildén[b]**

[a]Finnish Game and Fisheries Research Institute, P.O. Box 202, SF-00151 Helsinki, Finland

[b]National Board of Waters and the Environment, P.O. Box 250, SF-00151 Helsinki, Finland

ABSTRACT

*Subsidies are used widely in fisheries for many different objectives. A theoretical analysis using a Cournot model demonstrates that some systems of subsidization may create incentives to form stable collusions although a collusion would not be viable without subsidies. In a simulation using Finnish herring data this effect is obtained for reasonably realistic parameter values. The approach could form the basis for an extended analysis of the effects of the removal of subsidies, but an assessments would require more reliable data on demand and production functions of fishing enterprises and information on exit and entry behaviour of fishermen.*

## 1. INTRODUCTION

Producer subsidies are used by governments as policy instruments in many sectors throughout the world. In industrialized countries subsidies are often justified as means of correcting for market failures (e.g. Peacock 1990) whereas they are seen as initiators of development in foreign aid programs to developing countries (e.g. Greboval 1989). The liberation of trade has raised an interest in the macro economic effects of subsidies and OECD publishes regular reports on subsidization in the fisheries sector. In the US countervailing duties have been used against Canadian fish on the grounds of subsidies (Shrank et al. 1987, Rugman and Anderson 1987).

Subsidies have a large range of micro economic effects and the subject has been touched upon in several studies of fisheries economics. The efficiency of subsidies as policy instrument has been doubted by e.g. Copes (1978) and Jentoft

and Mikalsen (1987). Plourde and Smith (1989) and Hämäläinen et. al (1990) included subsides as a factor influencing share fishing. Kaitala and Leitmann (1991) and Kaitala et al. (1992) investigated the use of subsidies as an instrument for stabilization in fisheries.

In an earlier paper we presented the structure of the system of price subsidies in Finland (Hildén and Mickwitz 1990). In this paper we extend the analysis by a theoretical investigation of the potential role of subsidies in facilitating collusions formed by producers. Our study is based on a game-theoretic approach using a static game describing an oligopolist market with Cournot conjectures (e.g. Kreps 1990). In this simple model mergers have been examined and found to be nonviable, unless the merger succeeds in effectively monopolizing the market (Salant et al. 1983).

In order to capture some essential features of the Finnish fisheries the basic model has extended been to allow the inclusion of a heterogenous fleet consisting of two types of fishing enterprises and two production seasons. The second type has different marginal costs, but only the first type of enterprises is able to produce during both seasons. The fish population dynamics has been excluded because the present exploitation of the Finnish herring is at such a low level that the sustainability is guaranteed for a wide range of exploitation levels and exploitation strategies and chiefly limited by market conditions (Hildén 1991).

Using the model we examine two aspects of the price subsidization. First we analyze the general contribution of the subsidization to the total revenues under non-cooperation and cooperation. Thereafter we turn to the stability of the collusion formed by the enterprises belonging to the second group by examining the total revenues of an outsider and the insiders.

## 2. THE MODELS

### *2.1 Individual choice*

The basic model has two periods, the first we will call summer (s) and the second winter (w). Two different types of fishermen are identified. The fishermen within a type are assumed to be identical with n enterprises of the first type and m of the second type. The two types use different techniques with different costs. The techniques also differ in that the second type is able to fish only during summer.

The demand for fish by the processing industry in the summer is :

$$P_s = A - a^* \sum_{i=1}^{n} q_{is} - a^* \sum_{j=1}^{m} q_{js} \tag{2.1}$$

and in the winter it is :

$$P_w = B - b^* \sum_{i=1}^{n} q_{iw} - f^* \left( \sum_{i=1}^{n} q_{is} + \sum_{j=1}^{m} q_{js} \right) \tag{2.2}$$

$P_s$ = The price in the summer
$P_w$ = The price in the winter
$q_{is}$ = The quantity produced in the summer by a fisherman of the first type
$q_{js}$ = The quantity produced in the summer by a fisherman of the second type
$q_{iw}$ = The quantity produced in the winter by a fisherman of the first type
n = number of fishermen in the first type
m = number of fishermen in the second type
A,B,a,b,f = coefficients

We assume that A,B,a,b and f all are greater or equal to zero and that f<a and f<b, i.e. the quantities in the summer affects the price in the summer more than they affect the price in the winter and they also affect the winter price less than the quantity caught in the winter.[1]

The fishermen make their decisions on how much they should fish by maximizing their profit. The fishermen of the first type which can fish also during the winter, discount the profit from the second period. The decisions by the fishermen are made simultaneously.

The fishermen of the first type make the decision on production in the summer and in the winter by maximizing their total profit for $P > 0$ and $q > 0$ :

$$TR_i = (P_s - c_{is})^* q_{is} + \delta^*(P_w - c_{iw})^* q_{iw} - FC_i \qquad (2.3)$$

$TR_i$ = The revenue of a fisherman of the first type
$c_{is}$ = The marginal costs in the summer for a fisherman of the first type
$c_{iw}$ = The marginal costs in the winter for a fisherman of the second type
$FC_i$ = The fixed costs for a fisherman of the first type
$\delta$ = The discounting factor (if $\delta$ is purely economic, then $\delta = 1/(1+r)$, where r = rate of interest)

The fishermen of the second type base their decision on how much to fish by maximizing their profit :

$$TR_j = (P_s - c_{js})^* q_{js} - FC_j \qquad (2.4)$$

$TR_j$ = The revenue of a fisherman of the second type
$c_{js}$ = The marginal costs in the summer for a fisherman of the second type
$FC_j$ = The fixed costs for a fisherman of the second type

The P intercepts of the demand curves are greater than the marginal costs in order to allow positive production, i.e. $c_{is}$, $c_{js} < A$ and $c_{iw} < B$.

When these profit functions are maximized the quantity produced by each fisherman of the first type in the summer is a function of the demand in summer, the constant f, his own marginal costs in the summer, how much the other fishermen of the first type will fish in the summer, how much the fishermen of the other type will fish in the summer and the discounted value of his production in the winter. This is the reaction function, i.e the function which describes what would be the best response for a fisherman to a quantity produced by another fisherman.

In a Nash equilibrium formed by identical fishermen all fishermen of the same type produce the same quantity (e.g. Salant et al. 1983). Therefore the reaction function of a single fisherman can be simplified by noting that in the equilibrium all the $q_i$s are identical and therefore $\Sigma q_i = n^* q_i$ . Because the same is true for the fishermen of the second type the quantity the group produces is m times the production of one fisherman ($\Sigma q_j = m^* q_j$).

The reaction function for a fisherman of the first type is :

$$q_{is} = \{[(n-1)\,bA - \delta fB] - [(n+1)\,b]\,c_{is} + \delta f c_{iw} - [(n+1)\,ab - \delta f^2]\,mq_{js}\}/C1\,, \qquad (2.5)$$

where $$C1 = [(n+1)^{2*} a^* b - \delta^* n^* f^2]$$

1. The constant f can be interpreted as the determining the amount of frozen or otherwise stored fish or fish products. An alternative interpretation is that it reflects consumer behavior which depends on quantities or prices in the first period.

In the same way the reaction function for a fisherman of the second type is :

$$q_{js} = [A - n*a*q_{is} - c_{js}] / [(m + 1)*a] \tag{2.6}$$

### 2.1.1 Optimal individual choice

Using the equations 2.1 - 2.4 and first calculating the reaction functions for a fisherman of each type, then taking into account that all the fishermen of the same type have to produce an equal amount in a Nash equilibrium, the optimum is found by substituting the reaction functions for a fisherman of one type into that of a fisherman of the other type. This will give the optimal production in summer and winter and the corresponding prices. By subsituting the results into the revenue functions (2.3) and (2.4) the profits can be derived as functions of $c_{js}$, $c_{is}$, $c_{iw}$, interaction terms and fixed costs (see appendix).

### 2.1.2 Optimal individual choice with capacity constraints on the more efficient type of fishermen

If the fishermen of the second type have a capacity constraint, they cannot fish more than the quantity $\hat{q}$. Such a situtation may arise if unsubstitutable production resources are limited, for example the places where the gear can be used, or if scale effects are such that costs increase drastically with an expansion of scale. This appears to be a reasonable approximation in the Finnish herring fishery where small scale gillnetters and trap netters can be seen to represent this type of fishing.

The reaction function (2.6) will now take the form :

$$\begin{aligned} q_{js} &= [A - n*a*q_{is} - c_{js}] / [(m + 1)*a], \quad && q_{js} < \hat{q} \\ &= \hat{q} \quad , && q_{js} \geq \hat{q} \end{aligned} \tag{2.7}$$

When the constraint is binding ($q_{js} \leq \hat{q}$) the optimal production of the fisherman of the first type is obtained directly by inserting $\hat{q}$ for $q_{js}$ in equation (2.5).

### *2.2 Collusions among fishermen*

Due to the nature of the fishing operations of the fishermen of the second type we assume that these fishermen have lower marginal costs in the summer than the fishermen of the first type (i.e $c_{js} < c_{is}$) and all know this. From this follows that the greatest joint profit is obtained when all the fishermen of the second type can produce their full capacity $q_j$ and the fishermen of the second type decide the price according to the residual-demand $Q^R_s = Q_s - m* \hat{q}_j$, where Q indicates total quantities. To achieve such a complete monopoly there has to be an agreement on transfer of revenues between fishermen in order to share the revenues equally. Such a monopoly's objective function is

$$TR = (P_s - c_{js})* m* \hat{q} + (P_s - c_{is})\, Q^R_s + \delta *(P_w - c_{iw})* Q_w - mFC_j - nFC_i \tag{2.8}$$

The assumption of revenue transfer is, however, highly unrealistic in a fishery such as that of the Finnish herring fishery. Therefore we will not consider the complete monopoly further. Instead we turn to a more realistic situation in which the more efficient type of fishermen simply form a constraint experienced by the other type of fishermen. They can respond to this constraint by forming a collusion among themselves or act as individual fishermen. In order to be able to treat the production of the other type of fishermen as a constant constraint it is necessary that the capacity constraint of the second group is so low that the optimal response is to produce the maximum quantity $m*\hat{q}$ for a wide range of quantity strategies by the first group. We thus assume [2] that the reaction curves always cross where $q_{js} = \hat{q}$.

2. The solution under the condition of a non binding quantity constraint can be obtained by setting n = 1 (=collusion) in the appendix and setting the condition (2.7) such that it is not binding.

With the additional assumptions we now get for the fishermen of the first type the following objective function which sets the amounts to be produced [3] after optimization :

$$TR = (P_s - c_{is})^* Q_s^R + \delta^*(P_w - c_{iw})^* Q_w - n^* FC_i \quad (2.9)$$

Each fisherman receives an equal share (i.e. $TR_1 = TR/n$) of the total revenue of the collusion.

$Q^R_s$ is obtained from the definition and by subtituting the prices from (2.1) and (2.2) quantities for each fisherman can be obtained simply by dividing the resulting $Q^R_s$ and $Q_w$ with n. The demand functions (2.1 and 2.2) give the corresponding prices and hence the revenues for each fisherman. The revenue per fisherman will always be higher in the case of a complete collusion than in the case of non-cooperation.

The collusion does not, however, represent a Nash equilibrium in this case. A single fisherman will increase his revenue if he leaves the collusion when everybody else stays in [4]. To see this we examine the difference between the total revenue of a single outsider and the individual revenue in a complete collusion :

$$D_{TR} = - C2 * C3 / C4, \quad (2.10)$$

where $C2 = 9\,ab - 2f^2\delta - 4\,abn + f^2\delta n$

$C3 = b\,(A - c_{ik})^2 + a\delta\,(B - c_{it})^2 - f\delta\,[(B - c_{it})\,(A - c_{ik})]$
$+ (A - c_{ik})\,(f^2\delta m\hat{q} - 2\,abm\hat{q}) - af\delta m\hat{q}\,(B - c_{it}) + a^2b\,(m\hat{q})^2$

$C4 = (-4\,ab + f^2\delta) * (-9\,ab + 2f^2\delta) * n$

The necessary conditions for this expression to be greater than zero is that $n \geq 3$ and that the assumptions about a,b,f,$c_{ik}$ and $c_{it}$ hold (see section 2). In addition the expression is quadratic in $m\hat{q}$. The capacity constraint on the second type of fishermen will thus affect the profitability of leaving. We can show, however, that the $D_{TR} > 0$ for all $m\hat{q}$. Therefore it is always profitable for a single fisherman to leave the collusion, and as identical fishermen will make the same decision the collusion breakes down to complete competition. We do not consider here the possibility of a certain fraction of the fishermen remaining in the collusion by separate decisions of insiders and outsiders as analyzed by Salant et al. (1983). In order to achieve this additional assumptions have to be made on differences in decision making between insiders and outsiders.

## 3. COLLUSIONS WITH SUBIDIZED PRICES

### *3.1 Price subsidy on all fish*

When price subsidies (s per quantity) is paid on all fish to any fisherman it is equal to a reduction of all marginal costs by a fixed amount. The fishermen of the second type will experience an increase in their revenue, but the increase will depend on how much the fishermen of the first type increase their production. The increase in production will in turn depend on whether the fishermen form a collusion or act as independent producers.

The objective function of the fishermen of the first type is now

$$max\ TR = (P_K + s - c_{IK})^* q_{iK} + \delta^*(P_T + s - c_{IT})^* q_{iT} - FC_i \quad (3.1)$$

3. When the fishermen act like a monopoly price and quantity setting is equal. We will base our argument on quantity setting for sake of simplicity although for example the Finnish herring negotiations aim at fixing a price.
4. In order to find the profit of the outsider the optimization is repeated in the form of a two actor game, the outsider against the collusion. This will change both total quantities and prices.

The maximization gives the optimal quantities, prices and revenues. Again we can show that a complete collusion is profitable, and more profitable than one without a subsidy. As above the difference in total revenue between a single outsider and the insiders can be calculated. The expression is analogous to that in (2.10), i.e.

$$D_{TR(s)} = - C2 * (C3 + C5) / C4,$$

where $C5 = s\{b\,(2A - 2c_{ik} + s) + a\delta\,(2B - 2c_{it} + s)$
$+ c\delta\,(c_{ik} - A + c_{it} - B - s) + m\hat{q}\,(f^2\delta - 2\,ab - fa\delta)$

The necessary conditions for $D_{TR(s)} > 0$ for all $s > 0$ is that $n \geq 3$ and that the assumptions of the parameters hold as in 2.10. As before $D_{TR(s)}$ is a quadratic function in $m\hat{q}$, but we can show that it is $> 0$ for all $m\hat{q}$ and s. Thus the collusion breakes down as in the case with no subsidies. Quantities will increase and prices go down. This will affect the revenue of the second type of fishermen, although they continue to produce at the level set by their capacity constraint.

### *3.2 Price subsidies paid only on fish sold at the price determined by the collusion*

A pecularity of the Finnish system of price subsidies is that a collusion agrees on a minimum price with buyers and that subsidies are paid only for fish bought at or above the minimum price (Hildén and Mickwitz 1990). In practice this means that subsidies are paid only to those forming the collusion. The total revenue received by the collusion will be determined by the same function as in section 3.1, but the difference in revenue between a single outsider and the individual revenue in a total collusion will change, because the outsider loses the subsidy. We can show that the difference in total revenue is a concave function and that the sign of the first derivative for $s = 0$ will depend on the parameter values. Further we can show that there are levels of subsidies for which the difference in revenue is $< 0$. *Thus this system of subsidization may make the collusion into a Nash equilibrium.*

## 4. SIMULATIONS

The following simulation illustrates our approach on the Finnish herring data. The parameter values, the demand functions and the production functions have not been rigorously estimated and thus the results are given for illustrative purpose only.

With the simulations we aim to answer two basic questions :

i) Is it possible that the collusion which exist in the Finnish herring fishery could arise due to government subsidies ?

ii) What would happen if subsidies were removed completely ?

The simulations are based on the case of subsidies paid to the collusion only, because this has the closest correspondence to the situation in the Finnish herring fishery. In order to be able to investigate the effects of a single outsider, we assume that the collusion is able to react on the production of the outsider as required by the Cournot conjecture. This mechanism is available in the Finnish system for price negotiations, which can be initiated at any stage by any of the contracting parties.

The parameter estimates are based on information on the quantities and prices of herrings sold to be used by the food industry and on guesstimates of the production functions. The following values were used in the simulations :

| **Demand functions** | **Capacity constraint** |
|---|---|
| A = 4000 a = 0.25 | q = 10.5 |
| B = 4200 b = 0.35 f = 0.01 | |
| **Costs** | **Number of fishermen** |
| $FC_i$ = 50000 $c_{is}$ = 2100 $c_{iw}$ = 2400 | n = 80 |
| $FC_j$ = 1000 | m = 250 |

| **Discount rate** | **Subsidy** |
|---|---|
| discount factor $\delta = 1/(1.1)$ | s = 1200 |

According to the simulations the collusion turns into a Nash equilibrium with subsidies > 1089 FIM per ton (Fig. 1). The present subsidy is 1200 FIM per ton, suggesting that the level could be sufficient for creating incentives to remain in a collusion.

With a removal of the subsidy considerable changes would occur. Assuming that the present level of revenue corresponds to a stable situation in an open entry fishery a decrease in revenues would create incentives to leave the fishery. A rough estimate can be obtained by comparing the revenues at the equilibrium points with and without subsidies. The number of fishermen can then be adjusted to correspond to a constant revenue per fisherman of the first type. The second type of fishermen are assumed to continue fishing at the level set by their capacity constraint. The simulations suggest that a removal of the subsidy and the breakdown of the collusion would cause 71 of 80 fishermen to leave the fishery. The removal of the subsidy would somewhat change the price on herring paid by the industry. In winter the price would decrease from 2.66 FIM per kg to 2.57 but in summer the price would increase from 2.14 to 2.23 FIM per kg. The loss of the subsidy means that the fishermen of the second type lose on the change, but they are assumed to remain in the fishery due e.g. to sunken costs. If they would leave as well fewer fishermen of the first type would have to leave. This shows the necessity of analyzing the exit and entry dynamics in the fishery.

## 5. DISCUSSION

The simple Cournot model used in this paper has offered some insights into the role of subsidies by demonstrating that certain systems of subsidization may contribute to the stability of collusions. Stable collusions may emerge even though the game is not based on an indefinite time horizon, which for example Salant et al. (1983) has mentioned as a possible explanation for stable merger.

If a system of subsidies stabilizes collusions the subsidies carry a double benefit to the producers, the subsidy per se and the gains obtained from a monopolistic price setting. In Finland this effect is partly off set by the buyers' organizations, which are able to somewhat adjust the demand curve. A more extensive game illustrating the herring markets in Finland would require the inclusion of the first hand buyers as players. It would also include the small scale fishermen (the second type) as active players and possibly the heterogeneity within the types of fishermen. The result would be an asymmetric game for which no general formulations on factors affecting the formation of collusions appears to be available (e.g. Tirole 1989).

The dynamics of the fish stock has not been included in our investigation because of the present situation on the herring market. Subsidies and collusions could, however, affect the exploitation rates in counter intuitive ways. For example it is possible that the removal of a subsidy would increase the exploitation rates due to the break down of a collusion.

A preliminary sensitivity analysis of the model suggests that the model is sensitive to the choice of parameters. The linear demand functions and costs appear to explain a part of the sensitivity. More realistic simulations would require better estimates of production functions and the demand. These are, however, difficult to obtain, because the history of regulation with fixed prices makes estimation nearly impossible. Yet they are essential for the evaluation of what will happen after the removal of subsidies as demanded by a recent EFTA agreement.

The present analysis has explicitly included a market structure and a crude approximation of the heterogeneity within the fishery. The results show that these features may affect the consequences of a fisheries policy based on subsidies. In addition the comparison of the equilibrium points suggest that knowledge of dynamic changes of market conditions and fleet size will influence any decision on alterations of policy.

## REFERENCES

**Copes P.** (1978). Canada's Atlantic coast fisheries : Policy development and the impact of extended jurisdiction. *Can. Public Policy* **4** : 155-171.

**Greboval D. F.** (1989). The financing of small-scale fisheries. *FAO Fish. Techn. Pap.* **307** : 1 - 22.

**Hämäläinen R. P., J. Ruusunen and V. Kaitala** (1990). Cartels and dynamic contracts in share fishing. *J. Environ. Econ. Manage.* **19** : 175-192.

**Hildén M. and P. Mickwitz** (1990). Between the devil and the deep blue sea - Finnish price subsidies for herring. Paper presented at the IIFET conference, Chile (in print).

**Hildén M.** (1991). Sustainable use of Baltic Sea fishery resources. In : J. H. Williams (ed.) Nordic/Eastern European Symposium on cooperation in fisheries. *Nordiske seminar- og arbejdsrapporter* 1991 : **549** : 21-28.

**Jentoft S. and K. H. Mikalsen** (1987). Government subsidies in Norwegian fisheries : Regional development or political favouritism ? *Mar. Policy* **11** : 217 - 228.

**Kaitala V., M. Hildén and G. Leitmann** (1991). Income subsidizing and fisheries development - an analysis of stabilizing management. In : G. Feichtinger (ed.) Proceedings of the 4th Viennese *Workshop on Dynamic Economic models and Optimal Control.*, Vienna, Austria, 12-14 June, 1991, North Holland. (in print).

**Kaitala V. and G. Leitmann** (1991). Stabilizing management of fluctuating resources, *ZOR* (Methods and models of operations research : Theory) **35** : 1-16.

**Kreps D.M.** (1990). *A course in microeconomic theory.* Harvester Wheatsheaf, New York.

**Peacock A.T.** (1990). Identifying and applying norms for subsidies to industry. In R. Gerritse (ed.) *Producer Subsidies*, Pinter Publishers, London : 20-31.

**Plourde C. and J. B. Smith** (1989). Crop sharing in the fishery and industry equilibrium. *Mar. Resour. Econ.* **6** : 179 - 193.

**Rugman A. M. and A. Anderson** (1987). A fishy business : the abuse of American trade law in the Atlantic Groundfish case of 1985 - 1986. *Can. Public Policy* : 152 - 164.

**Salant S. W., S. Switzer and R. J. Reynolds** (1983). Losses from horizontal merger : the effects of an exogenous change in industry structure on Cournot-Nash equilibrium. *Quarterly Journal of Economics* **48** : 185 - 200.

**Schrank W. E., B. Skoda, N. Roy and E. Tsoa** (1987). Canadian government financial intervention in a marine fishery : the case of Newfoundland 1972/73-1980/81. *Ocean Dev. Int. Law.* **18** : 533 - 584.

**Tirole J.** (1989). The theory of industrial organization. MIT Press, Cambridge, Mass.

**Appendix**

The reaction functions for the case without subsidies and the corresponding functions giving optimum production and prices.

The optimal production for a firm of the firts type is $q^*_{is}$ in the summer and $q^*_{iw}$ in the winter :

$$q^*_{is} = \frac{(n+1)\,abA + \delta mf^2 A - \delta(m+1)\,afB}{(n+1)^*(n+m+1)\,a^2 b - \delta naf^2} + \frac{[(n+1)\,mab - \delta mf^2]^* c_{js}}{(n+1)^*(n+m1)\,a^2 b - \delta naf^2} - \\ - \frac{[(n+1)^*(m+1)^* b]^* c_{is}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} + \frac{[\delta^*(m+1)^* f]^* c_{jw}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} \quad (A.1)$$

$$q^*_{iw} = \frac{(n+m+1)\,aB - (n+m)\,fA}{(n+1)^*(n+m+1)\,ab - \delta nf^2} + \frac{[m^* f]^* c_{js}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} + \\ + \frac{[n^* f]^* c_{is}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} - \frac{[(n+m+1)^* a]^* c_{iw}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} \quad (A.2)$$

The optimal production for a firm of the second type in the summer ($q^*_{js}$) can be calculated in the same way :

$$q^*_{js} = \frac{(n+1)\,av^* A - \delta nf^2 A + \delta nafB}{(n+1)^*(n+m+1)\,a^2 b - \delta naf^2} - \frac{[(n+1)^2 ab - \delta nf^2]^* c_{js}}{(n+1)^*(n+m+1)\,a^2 b - \delta naf^2} + \\ + \frac{[n^*(n+1)^* b]^* c_{is}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} - \frac{[\delta nf]^* c_{iw}}{(n+1)^*(n+m+1)\,ab - \delta nf^2} \quad (A.3)$$

By substituting n times the optimal production for a fisherman of the firts type (A.1) and m times the optimal production for a fisherman of the second type (A.3) into (2.1). We get the price in the summer :

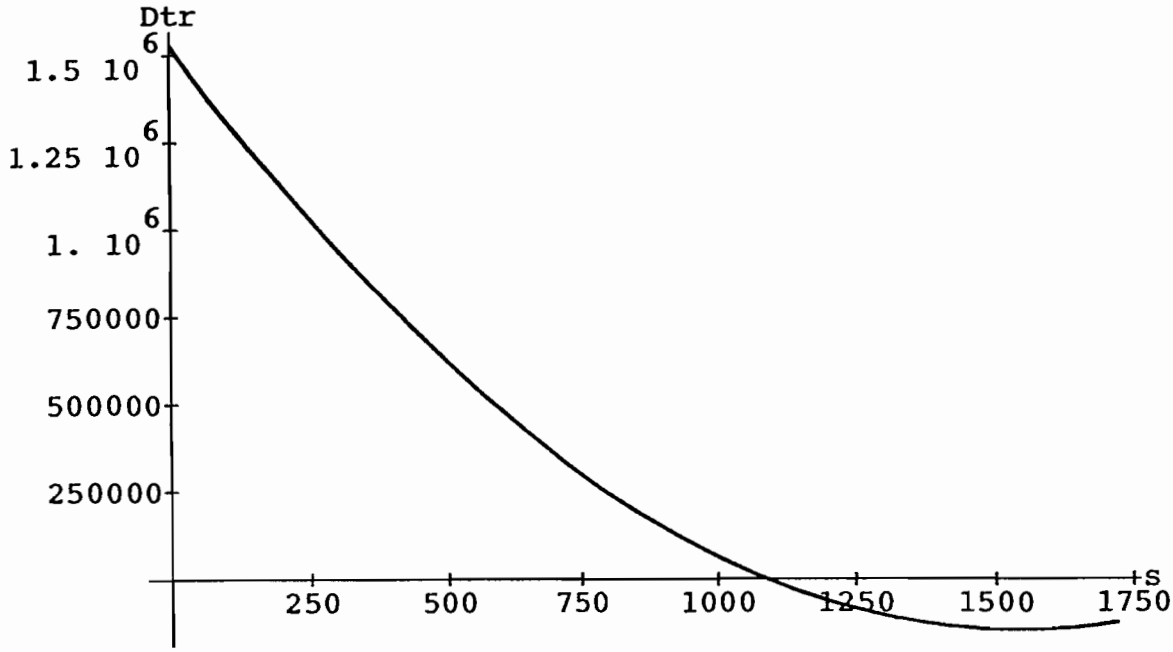
$$P^*_s = \{(n+1)\,abA - \delta nf^2 A + \delta nafB + \\ + [(n+1)\,mab]^* c_{js} + [n^*(n+1)\,ab]^* c_{iK} - [\delta naf]^* c_{iw}\}/[(n+1)^*(n+m+1)\,ab - \delta nf^2] \quad (A.4)$$

In the same way by using (A.1), (A.2) and (A.3) together with (2.2), we receive :

$$P^*_w = \{(n+m+1)\,abB - (n+m)\,bfA + [mfb]^* c_{js} + [nfb]^* c_{iK} + \\ + [n^*(n+m+1)\,ab - \delta nf^2]^* c_{iT}\}/[(n+1)^*(n+m+1)\,ab - \delta nf^2] \quad (A.5)$$

The total revenues are then easily obtained through subsitution.

**FIGURE 1.**
**THE DIFFERENCE IN PROFIT BETWEEN A SINGLE OUTSIDER AND THE AVERAGE REVENUE PER FISHERMAN (DTR) IN A COMPLETE COLLUSION WHICH RECEIVES SUBSIDIES. SUBSIDIES (S) ARE EXPRESSED IN FIM PER TON HERRING. THE CURVE IS LIMITED BY THE CONSTRAINT $S \geq 0$, $P \geq 0$ AND $Q \geq 0$.**



# Productivity Measurement in Common Property Resource Industries : an Application to the Pacific Coast Trawl Fishery

**Dale Squires** *

National Marine Fisheries Service, Southwest Fisheries Science Center, P.O. Box 271, La Jolla, California 92038, USA

ABSTRACT

*This study measures total factor productivity in industries that exploit resources held in common. Particular attention is paid to the valuation and specification of in situ common property resources in a neoclassical production technology, catchability of the resource, and variations in economic capacity utilization. An empirical analysis of the open-access Pacific coast trawl fishing industry demonstrates that disentangling the productivity residual from changes in resource abundance, its catchability, and variations in capacity utilization hones the productivity residual to finer precision, lowering mean productivity growth by about half. Removing biological noise from highly variable resources is also important. The results are related to a program limiting the number of vessels and can contribute to sustainable resource management whenever resources are held in common.*

## 1. INTRODUCTION

Productivity measurement in industries utilizing common property natural resources faces the thorny problem of accounting for the nonpriced contributions from these resources. When changes in abundance of the resource stock are not disentangled from measures of productivity or technical progress, results will be biased.

* The comments of an anonymous referee, Kevin Carlson, Jon Conrad, Chris Dewees, Susan Hanna, Tom Hertel, Sam Herrick, Jim Kirkley, Alec MacCall, Gordon Munro, Sam Pooley, Robert Pindyck, James Poterba, Anthony Scott, and Jim Wilen on an earlier version of this manuscript are gratefully acknowledged. The author is also grateful to Bob Francis, Jim Golden, Frank Henry, Joe Hightower, Dan Itoh, Larry Jacobsen, Bill Lenarz, Alec MacCall, Rick Star, Jack Taggart, and Pat Tomlinson for assistance with the population dynamics, and to Ralph Brown and Larry Schock, two commercial fishermen for insights into technical change. The authors remain responsible for any errors. The results are not necessarily those of the National Marine Fisheries Service.

The crucial factors for studies of productivity or technical progress in these industries are the proper specification and valuation of the common property resources in a production technology and the related issue of market failure and external diseconomies to firms. In turn, these factors depend upon : the structure of property or access rights ; the level of aggregation of the analysis (the firm or society/industry) ; and the stock-flow relationship between the resource stock and its extractive activity. Smith and Krutilla (1982), Smith (1980), Brown and Field (1978) and Fisher (1979) touched upon these concerns, but they have yet to be fully developed.

This study develops a framework for measuring total factor productivity (hereafter TFP) in industries that exploit renewable resources held in common, paying particular attention to their valuation and specification in a neoclassical production technology. The method of growth accounting and economic index numbers is modified to accommodate the resource and to measure productivity growth in the Pacific coast trawl fishery. Accounting for changes in resource abundance, its catchability, and capacity utilization hones the productivity residual to finer precision, lowering it by about half.

## 2. SPECIFICATION AND VALUATION OF THE RESOURCE STOCK

Common property natural resources have traditionally been treated like any other input in a neoclassical production technology. Beginning with Scott (1954), the common property resource stock entered the production process as a factor of production and was treated as an asset, particularly as a stock of capital. This approach was applied to both renewable and nonrenewable resources.

In an analysis rooted in the theory of the firm, it is inappropriate to treat a common property resource stock as a conventional input. Instead, this stock is specified as a technological constraint on the individual firm's stock-flow technology because the stock's abundance affects the production environment within which firms operate but remains beyond the control of any individual firm. That is, conventional inputs such as capital, labor, and energy are organized conditional upon expected resource stock abundance levels to generate the extractive flow. Increases (decreases) in resource abundance then shift the production technology, increasing (decreasing) the rate of extractive flow for any given input bundle. McFadden (1978) develops this approach within the framework of the firm's production possibilities set, treating environmental parameters (such as resource abundance) similar to disembodied technical change. Also, the resource stock places a maximum limit upon the extraction rate.

Resource abundance as a technology shift parameter can be specified in the firm's neoclassical production function. This function F expresses the stock-flow relationship between the resource stock and the extractive activity at a given time period. F takes the vector of inputs X and applies it to the resource stock to extract flow Y, conditional upon the state of technical knowledge t and resource stock abundance level, B. It is written : $Y = F(X[V]\ t,B)$.

An increase in the size of B allows an increase in the flow rate of resource extraction for any given X and t, so that $\delta F/\delta B > 0$. Similarly, technical progress shifts F, given X and t, so that $\delta F/\delta t > 0$. Thus both the abundance of the resource stock and disembodied technological change may be treated as technology shift parameters.

Gordon (1954) treated fish abundance as a technological constraint in his seminal article on marine fisheries as common property resource industries. While this approach does not preclude managing the fishery *as if* the resource stock was an asset, the framework does properly specify the resource stock in the same manner as any other environmental parameter, as a technological constraint, instead of an input under the control of individual firms.

Proper valuation of the common-property resource stock depends upon the specific property right structure governing its use. Under competitive open-access conditions, the firm's utilization decision for the resource is not endogenous, and each firm ignores the effects of its production upon the resource stock. Each firm instead behaves as if the resource has a zero user cost, because the effect of a unit change in resource abundance on the open-access firm's profits is zero due to rent dissipation (Gordon ; Smith, 1969 ; Capalbo, 1986). The firm's marginal costs and the market prices it faces include only the extraction component and not the user cost component (the latter which is zero).

In contrast, a sole owner must explicitly contend with the user cost, because the resource utilization decision is now endogenous through the choice of extraction rate and input usage (Capalbo ; Smith). Social costs associated with the resource externality are now private costs to the firm, and along with extraction costs, factor into the firm's optimization

problem (Smith). Market prices include the marginal user cost of the resource as a component of the full extraction costs. Similarly, the user cost is explicitly considered as a cost when property rights are not assigned but the emphasis is given to social evaluation of productivity growth.

## 3. THE FIRM'S OPTIMIZATION PROBLEM AND PRODUCTIVITY MEASURES

Specification of the firm's profit maximization problem depends upon the nature of property or access rights (or aggregation level). Both sole owner and open access *in situ* common property resources are considered. Following standard practice (cf. Clark), a Schaefer (1957) type production technology is assumed, where each vessel's catch per unit of time is proportional to the resource stock, and its costs are inversely proportional to the resource stock. Non-capital costs and inputs are distinguished from capital to facilitate capital's role in a later discussion of capacity utilization (CU), but full static equilibrium in all inputs is initially allowed to not confound the discussion of property rights with that of CU. Only the germane results are given, with full development in Squires (1991).

The Lagrangian for the optimization problem of a sole owner (or society) is :

$$\max_{Y_t,\, K_t,\, B_t} L = \{ P_t Y_t - G(Y_t, K_t, W_{jt}, B_t t) - W_{Kt}K_t \} + \phi_1 [B_t - Y_t] + \phi_2 [B_{t+1} - B_t - h(B_t, Y_t, E_t, U_t)], \quad (1)$$

where $P_t$ is the product price, $W_{jt}$ is the price of the $j^{th}$ variable input $X_{jt}$, $W_{Kt}$ is the rental or services price of capital $K_t$, t indexes the state of technical progress (assumed Hick's-neutral and disembodied), $B_t$ is the resource stock, $h(\cdot)$ is the biological growth function, $Y_t$ is the current resource extraction rate, $G(Y_t,K_t,W_t,B_t,t)$ is the variable cost function for the optimal combination of variable inputs, where $\delta G/\delta B < 0$, and $\phi_i$ is the Lagrangian multiplier for constraint i.

The first constraint indicates that the extractive flow from the resource cannot exceed the resource stock itself. The second represents discrete-time growth of the resource stock. Abundance in time t is determined by its level in the previous time period ($B_{t-1}$), its growth function (h), the resource extraction rate ($Y_t$), environmental parameters ($E_t$ ), and any public regulations ($U_t$). Not only are $Y_t$ and $K_t$ decision variables to the sole owner, but so is $B_t$ via the choice of current extraction rate $Y_t$ and the long-run planning decision for $K_t$ (Capalbo ; Smith). All *ex-ante* expectations are assumed realized *ex-post.*

The first-order conditions for an interior solution are :

$$L_Y = P_t - G_Y - \phi_1 - \phi_2 h_Y = 0 \quad \text{or} \quad P_t - \phi_1 - \phi_2 h_Y = G_Y \quad (2a)$$

$$L_K = -W_K - G_K = 0, \quad \text{or} \quad W_K = -G_K \quad (2b)$$

$$L_{\phi 1} = B_t - Y_t = 0, \quad \text{or} \quad B_t = Y_t, \quad (2c)$$

$$L_{\phi 2} = B_{t+1} - B_t - h(B_t, Y_t, E_t, U_t) = 0, \quad \text{or} \quad B_{t+1} - B_t = h(B_t, Y_t, E_t, U_t), \quad (2d)$$

$$L_B = -G_B + \phi_1 - \phi_2[1 + h_B] = 0 \quad \text{or} \quad -G_B = -\phi_1 + \phi_2[1 + h_B]. \quad (2e)$$

Condition (2a) states that the harvest rate should be selected such that marginal extraction cost $G_Y$ (= $\delta G/\delta Y$) equals product price less the marginal value of non-extinction $\phi_1$ less the marginal rent from additional fish recruits $\phi_2$ times the marginal impact of the current harvest rate on the resource stock $h_Y$ (=$\delta h/\delta Y$). Extinction is generally irrelevant and $\phi_1$ may be set equal to 0. Sole ownership implies $\phi_2 > 0$, so from (2a), $P_t = G_Y + \phi_2 h_Y$ .
(2b) gives the reduction in variable costs, $- G_K = \delta G/\delta K$, from using one more unit of capital to produce a given output, or the shadow price of capital.

Condition (2e) demonstrates two benefits from a unit of resource in place at time t (with $\phi_1 = 0$) : (1) harvesting costs are lowered and, (2) additional value accrues from future growth of the resource stock (Clark). These two benefits form the user cost, i.e., the opportunity cost to the user of taking a unit of the resource in the present period. Because the analysis is positive, concerned with measuring productivity growth, the stationary state equilibrium conditions for the stock in a normative analysis are not considered.

The continuous time Divisia index of total factor productivity using nonparametric growth accounting is :

$$-\frac{\delta \ln C}{\delta t} = \frac{[P - \phi_2 h_Y] Y}{C}\frac{\dot{Y}}{Y} - \Sigma_j \frac{W_j X_j}{C}\frac{\dot{X}_j}{X_j} - \frac{W_K K}{C}\frac{\dot{K}}{K} - \frac{\phi_2[1 + h_B] B}{C}\frac{\dot{B}}{B}, \tag{3}$$

where $C = \Sigma_j W_j X_j + W_K K + \phi_2 h_Y Y + \phi_2[1+h_B]B = PY$ with linear homogeneity, and the dots over variables represent time derivatives.

Equation (3) shows TFP measured as the residual after allocating the growth rate of output among changes in variable inputs, capital, and resource abundance, the latter specified as Hick's-neutral and disembodied. The user cost of the marginal unit of the *in situ* resource, $\phi_2$, is explicitly considered in this sole owner problem.

In the individual competitive firm's profit maximization problem, $B_t$ is not a decision variable, so that $h_B$ is not relevant, and each firm ignores $\phi_2$ . Only indirectly through $h(B_t,Y_t,E_t,U_t)$ do changes in firms' resource extraction rates affect the resource stock level. The productivity measure is a special case of (3) :

$$-\frac{\delta \ln C}{\delta t} = \frac{\dot{Y}}{Y} - \Sigma_j \frac{W_j X_j}{X}\frac{\dot{X}}{X_j} - \frac{W_K K}{C}\frac{\dot{K}}{K} - \frac{\dot{B}}{B} \tag{4}$$

where $C = \Sigma_j W_j X_j + W_K K = PY$ under constant returns to scale.

The productivity residual is biased without disentangling variations in $B_t$. In contrast to the sole owner, because $B_t$ is not a decision variable to firms and $\phi_2 = 0$, proportional changes in abundance are simply pared away from the conventional productivity residual without weighting by cost shares in this positive analysis.

Regulation of a competitive open-access fishery can either develop property or access rights or impose production constraints. This section considers constraints on the extraction process for the competitive open-access fishery, since rights-based regulation is related to the sole owner problem. Market failure remains because rights are underdeveloped, and the analysis remains firm-level and positive rather than normative.

Under a catch quota, $Y^*$, the constraint $Y_t \leq Y^*$ is added to equations (1) and (2) (Denny et. al. 1981). The Lagrangian for a binding constraint, $\phi_Y$, is the virtual price of the quota (Rothbarth 1941) and the unit quota rent is $P_t - \phi_Y$. The first-order condition in the open-access problem is now : $P_t - \phi_Y = G_Y$ ; vessels adjust catch rates until the unit quota rent equals marginal extraction cost. Alternatively, the cost of market failure can be imposed on firms by a landings tax $\Gamma$. (2a) is now : $P_t = G_Y + \Gamma$ ; firms adjust the catch rate until price equals private marginal extraction cost plus tax.

With a binding regulation $K_t \leq K^*$ , $\phi_K > 0$, production costs increase, and the net services price of capital becomes $W_K + \phi_K$ .

Changes in the size of $B_t$ do not affect productivity measures as directly as indicated in equations (3) and (4). An input bundle often catches an increasing proportion of the residual resource stock as $B_t$ declines, due to the concentrating or schooling behavior of many fish species and the nature of the fishing technology (MacCall, 1990). As $B_t$ decreases in size, so does its spatial distribution, but the density of fish over an area or school size changes little. Fishing firms can quickly locate the remainder, even of a heavily depleted stock, and harvest at rates similar to those of a higher stock level. Thus the "catchability" of stock is not directly related to $B_t$'s size and must be adjusted. Following standard procedures (MacCall, 1976), the catchability coefficient weighting $B_t$'s abundance is a power function (see below).

Productivity measures are biased when output growth comes from changes in capacity utilization of quasi-fixed factors (CU) along with those of variable factors and productivity (Berndt and Fuss) and common property resource abundance. Altering the value and not the quantity of the quasi-fixed factors adjusts the productivity residual for variation in CU with growth accounting (Berndt and Fuss). Under constant returns to scale for the unregulated competitive open-access fishery,

$P_t Y_t = G(Y_t,K_t,W_t,B_t,t) + Z_{Kt}K_t = \Sigma_j W_{jt}X_{jt} + Z_{Kt}K_t$.

Rearranging : $Z_{Kt} = [P_t Y_t - G(\cdot)]/K_t = [P_t Y_t - \Sigma_j W_{jt}X_{jt}]/K_t$. The quasi-rent $Z_{Kt}$ is the residual income not accruing to variable inputs per unit of capital stock (Hulten).

## 4. THE INDUSTRY, DATA, AND INDEX CONSTRUCTION

The Pacific coast trawl fishery is comprised of vessels in Washington, Oregon, and California harvesting a wide variety of groundfish and pelagic fish species and pink shrimp. The three important trawl gear are groundfish (bottom or roller), shrimp, and midwater, the latter used by vessels making at-sea deliveries of pelagic Pacific whiting in a joint venture with foreign fleets ; production between gears is nonjoint. Vessels flow between the groundfish and shrimp trawl sectors with the rise and fall of shrimp abundance. Larger vessels may also fish in Alaskan waters.

A more complete description of the industry and data are available in *The Rand Journal of Economics*, vol 23, n° 2, 1992.

### *4.1 Data*

The analysis covers 1981-1989, the only years with comprehensive economic and biological data. Squires (1988) gives details on all data and index construction except the biological, which are reported in Squires (1991). Electronic spreadsheets with all calculations and data or summary tables of the raw data are available upon request. The output indices require pounds landed and revenues by US vessels at ports in Washington, Oregon, and California by species. Revenue and landings data are from the PacFIN Management Data Base (PacFIN) of the National Marine Fisheries Service (NMFS). All values are deflated by the GNP implicit deflator.

By 1989, sablefish production faced a consistently binding quota. Hence 1989 sablefish output was valued by P-$\phi_Y$ , its implicit unit rent, where $\phi_Y$ was its virtual price. Coastwide estimates of $\phi_Y$ were unavailable, but based on a study of a Northern California trawl fishery (Squires 1990), $\phi_Y$ was set at 68 % of the product price.

### *4.2 Tornqvist productivity index*

A discrete-time approximation to the continuous Divisia index of (4) is given by the Tornqvist approximation. This index for an unregulated open-access fishery allowing for variations in CU and resource abundance becomes :

$$\begin{aligned} \ln (TFP_t / TFP_{t-1}) = {} & 0.5\, \Sigma_i (R_{it} + R_{i,t-1}) \ln (Y_{it} / Y_{i,t-1}) \\ & - 0.5\, \Sigma_j (S_{jt} + S_{j,t-1}) \ln (X_{jt} / X_{j,t-1}) \\ & - 0.5\, (S_{Kt} + S_{K,t-1}) \ln (K_t / K_{t-1}) - \ln (B_t / B_{t-1}), \end{aligned} \tag{5}$$

where B is the composite index of resource abundance, $R_i = (P_i Y_i) / (\Sigma_i P_i Y_i)$ is the revenue share for output i, $S_j = (W_j X_j) / (\Sigma_i P_i Y_i)$ is the cost share for variable input $X_j$, and $S_K = (Z_K K) / (\Sigma_i P_i Y_i)$ is the capital cost share allowing for variations in CU.

## 5. EMPIRICAL RESULTS

The empirical results for the open-access Pacific coast trawl fishery demonstrate the importance of adjusting the multifactor productivity residual for variations in : (1) capacity utilization ; (2) resource abundance ; and (3) the catchability coefficient. Failure to make these adjustments biases productivity measures.

Biomass growth (Table 1) indicates generally declining Pacific whiting biomass, punctured by occasional increases, reflecting young age at maturity and the sporadic recruitment of strong year classes of juvenile fish into the fishable stock. The unstable pink shrimp growth reflects the unstable growth rate due to fluctuations in environmental parameters. The overall biomass index is strongly influenced by whiting and pink shrimp due to their large, fluctuating biomasses and revenue shares.

The rockfish, flatfish, and sablefish growth rates (Table 1) reflect the steady, prolonged decline in biomass due to unsustainable catch rates (Table 3) greater than the slow net growth of the biomass (this reflects long lives, slow growth and steady recruitment rates).

The late 1970s and early 1980s were generally years with CU > 1 (Table 6). Production moderately expanded (Table 3) because the domestic fleet no longer faced foreign competition following the MFCMA of 1977 (which restricted foreign fishing and created exclusive fisheries zones out to 200 miles) and because several resource stocks (particularly rockfish) were harvested at rates exceeding maximum sustainable yield (MSY). New vessels were constructed, increasing fleet size and aggregate input use (Table 7). Around late 1982, pink shrimp virtually disappeared due to El Nino (which substantially altered ocean temperature) and output and input prices declined (Table 8). The quasi-rent to capital was less than the capital services price, i.e. $Z_K < W_K$, and CU < 1 (Table 6). Bankruptcies increased and a number of vessels were idled or left the fleet (Table 7), transferring activities to Alaska, sunk, or burnt ; disinvestment occurred with a lag.

Around 1985-1986, overall biomass began to rebuild, primarily from a dramatic resurgence of the high-priced pink shrimp as El Nino resided and growth in Pacific whiting biomass (Table 1). Real fuel prices and interest rates also dropped, while real output prices for most species rose, except for a dip in 1988 (Table 8). Hence, $Z_K > W_K$ and CU > 1, signalling investment incentives (Table 6). Fleet size and aggregate input (Table 7) responded, expanding, albeit only with a lag, and jumped by 6.3 % in 1987.

In 1988-89, the overall biomass slightly declined due to a plunge in rockfish abundance beginning in 1987 and a decline in Pacific whiting (Table 1), and output prices dropped in 1988 but climbed in 1989 (Table 8). $Z_K$ fell by 36 % but remained above $W_K$, CU remained above one, and the fleet size remained stable.

In sum, CU signaled private investment incentives for most of the decade, but the fishery was overcapitalized from a social perspective due to the open-access externality, and harvesting rates were often greater than MSY. By the decade's end, most resources had fallen to near or below MSY levels with stable or declining trends.

Table 5 reports total factor productivity measures. There are no adjustments for changes in resource abundance in columns (1) or (2). Column (1) measures productivity assuming full equilibrium of capital. The combined effect of technical progress and resource abundance changes in column (1) indicates two cycles of declines followed by increases in productivity. Column (2), which adjusts for CU variations, shows reduced productivity growth, dampened fluctuations in growth rates, and a more complex pattern.

Excluding resource growth biases productivity measures. Column (3) of Table 5 reports TFP incorporating variations in CU and biomass, but not catchability. In years of declining biomass, such as 1981-1984 and 1988-1989, TFP is otherwise understated. Similarly, when biomass increased, such as during 1985-1987, the greater ease of finding and catching fish, unless accounted for in this stock-flow production technology, overstates TFP growth. Annual productivity growth can also reverse signs unless resource growth is included.

Adjusting the biomass estimates for variations in catchability in column (4) of Table 5 generally dampens the effects of changes in resource abundance upon productivity growth and its year-to-year fluctuations. This enhanced stability follows from the density dependent habitat selection of fish as discussed above. Mean productivity growth is about half after the full set of corrections.

Productivity growth over the decade averaged a disappointing 0.65 %. The productivity growth rate over 1981-84, years of declining biomass in all species, averaged a strong 5.33 %. Growth averaged -2.15 % over 1985-89, years of rising overall biomass (or modest declines but nonetheless falling for all species except shrimp).

Productivity in this stock-flow technology ostensibly rose when overall output growth was unsustainable but fell under sustainable harvesting rates. More accurately, however, exploitation rates for most species except shrimp were unsustainable in most years. Growth in productivity and overall biomass were instead driven by, and inversely related to, the large rises and falls in shrimp biomass (responding to environmental conditions), and to a lesser extent, whiting biomass (due to young age at maturity and sporadic recruitment of large year classes). High revenue shares gave emphasis. Yet their biomass growth and variation, particularly for shrimp, are largely dependent upon biological and environmental processes beyond the control of regulators or industry. Firms suffer low apparent productivity growth because of the large biological noise and the corresponding difficulty in organizing efficient harvesting.

To assess productivity growth without the swamping effect from the whiting and shrimp biomasses, all indices were recalculated for only groundfish vessels, the heart of the Pacific trawl fleet. Shrimp biomass was excluded entirely, while

whiting biomass was included but weighted by a revenue share excluding joint venture trawlers (groundfish trawlers catch some whiting). Table 9 reports the chain indices and growth rates for productivity, aggregate output and input, and biomass. Productivity growth averaged 2.79 % and the annual variation declined considerably as the biological noise (from pink shrimp and joint venture-caught whiting) was removed from the system. Productivity growth also became consistently positive from mid-decade, except in 1987 when CU and aggregate input surged. These changes followed from exiting vessels transferring to Alaska and the resurging shrimp biomass, both of which attracted vessels out of groundfishing. The rate of groundfish biomass decline also slowed (Table 9). Productivity also grew from extensive technical progress (discussed below), even in the face of excessive input use under open access.

The productivity growth rate in both the entire fleet and solely groundfish trawlers displayed considerable annual variation. The ability of mobile vessels to rapidly enter and exit an open-access fishery and switch gear, coupled with fluctuations in resource abundance, generated sharp productivity swings.

License limitation programs, which limit the number of vessels, are plagued by the continued increase in productivity and consequent pressures on the resource, even though vessel numbers have been capped. Programs to remove vessels dampen harvesting pressures, but continued productivity growth of the remaining vessels gives countervailing pressures. A recent license limitation program for groundfish vessels could be hampered by productivity growth without compensating vessel reductions, or by eligible shrimp vessels reentering the groundfish sector.

TABLE 1.
PERCENTAGE ANNUAL GROWTH RATES OF BIOMASSES

| | Species: No catchability correction | | | | | Aggregate | | |
|---|---|---|---|---|---|---|---|---|
| Year | Flatfish | Rockfish | Sablefish | Whiting | Shrimp | (1) | (2) | (3) |
| 1982 | -1.05 | -9.90 | -0.07 | 7.15 | -10.42 | -5.84 | -2.92 | -4.78 |
| 1983 | 2.29 | -13.42 | -0.24 | -1.20 | -15.59 | -14.41 | -7.21 | -8.91 |
| 1984 | -4.13 | -10.97 | -0.33 | -0.59 | -4.31 | -9.75 | -4.88 | -6.87 |
| 1985 | -1.00 | -5.92 | -0.49 | -0.65 | 15.98 | 7.68 | 3.84 | 5.65 |
| 1986 | -0.98 | -4.05 | -0.63 | 4.75 | 27.27 | 22.52 | 11.26 | 15.02 |
| 1987 | -0.19 | -5.58 | -0.41 | -1.37 | 11.09 | 6.17 | 3.09 | 4.70 |
| 1988 | -0.52 | -9.84 | -0.18 | -2.86 | 1.91 | -3.51 | -1.75 | -1.67 |
| 1989 | -0.66 | -1.60 | -0.23 | -3.44 | 3.56 | -0.97 | -0.48 | -0.22 |
| Mean | -0.78 | -7.66 | -0.32 | 0.22 | 3.69 | 0.24 | 0.12 | 0.37 |

Note: (1) No catchability correction for aggregate biomass index
(2) Uniform square root catchability correction
(3) Differential power catchability correction (see text)

TABLE 2.
REVENUES SHARES

| Year | Dover Sole | Other Flatfish | Rockfish | Sable-fish | Misc Groundfish | Pink Shrimp | Pacific Whiting |
|---|---|---|---|---|---|---|---|
| --1981 | 0.114 | 0.095 | 0.258 | 0.026 | 0.136 | 0.284 | 0.088 |
| 1982 | 0.131 | 0.109 | 0.262 | 0.043 | 0.156 | 0.174 | 0.125 |
| 1983 | 0.138 | 0.109 | 0.254 | 0.037 | 0.179 | 0.137 | 0.145 |
| 1984 | 0.146 | 0.099 | 0.240 | 0.044 | 0.222 | 0.067 | 0.182 |
| 1985 | 0.198 | 0.140 | 0.311 | 0.063 | 0.053 | 0.164 | 0.069 |
| 1986 | 0.125 | 0.088 | 0.229 | 0.049 | 0.021 | 0.371 | 0.118 |
| 1987 | 0.097 | 0.082 | 0.201 | 0.041 | 0.036 | 0.432 | 0.110 |
| 1988 | 0.115 | 0.081 | 0.227 | 0.044 | 0.054 | 0.317 | 0.162 |
| 1989 | 0.107 | 0.094 | 0.237 | 0.041 | 0.048 | 0.265 | 0.208 |

Source: PacFIN Management Data Base

TABLE 3.
PERCENTAGE ANNUAL OUTPUT GROWTH RATES

| Year | Dover Sole | Petrale Sole | Other Flatfish | Rockfish |
|---|---|---|---|---|
| 1982 | 2.97 | 0.93 | 1.37 | 0.37 |
| 1983 | -0.75 | -0.79 | -1.32 | -8.44 |
| 1984 | -0.83 | -1.04 | -0.60 | -6.32 |
| 1985 | 1.70 | 0.34 | 1.34 | -0.03 |
| 1986 | 3.79 | -0.70 | -1.77 | -3.06 |
| 1987 | -0.75 | 0.87 | 0.89 | -8.78 |
| 1988 | 0.23 | -0.18 | -1.09 | 11.41 |
| 1989 | 1.02 | 0.02 | 1.66 | 2.14 |
| Mean | -0.02 | -0.07 | 0.06 | -1.59 |

| Year | Pacific Whiting Groundfish Trawl | Miscellaneous Groundfish | Pink Shrimp | Pacific Whiting Joint Venture |
|---|---|---|---|---|
| 1982 | 0.05 | 4.96 | -7.72 | 4.66 |
| 1983 | 0.01 | 0.89 | -11.56 | 0.90 |
| 1984 | 0.43 | 1.53 | -3.23 | 1.47 |
| 1985 | 0.30 | -49.72 | 11.31 | -11.44 |
| 1986 | -0.11 | -0.10 | 20.28 | 8.86 |
| 1987 | 0.20 | 0.68 | 8.72 | 2.99 |
| 1988 | 0.05 | -0.87 | 1.51 | 3.35 |
| 1989 | 0.29 | -0.94 | 2.74 | 7.52 |
| Mean | 0.15 | -5.44 | 2.75 | 2.29 |

| Year | Sablefish | Pacific Cod & Lingcod | Aggregate Output |
|---|---|---|---|
| 1982 | 2.12 | 0.01 | 0.59 |
| 1983 | -1.39 | -0.13 | -3.75 |
| 1984 | 0.41 | -0.12 | 1.37 |
| 1985 | -0.51 | 1.84 | 1.44 |
| 1986 | -0.98 | -3.61 | 7.18 |
| 1987 | -0.04 | 0.06 | 2.34 |
| 1988 | -0.83 | 3.54 | 3.66 |
| 1989 | 0.15 | -1.13 | 2.98 |
| Mean | -0.13 | 0.06 | 1.63 |

TABLE 4.
INPUT COST SHARES

| | Pacific Trawl Fleet | | | | | | Groundfish Trawlers - | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cap.Services Price | | | Quasi-Rent to Capital | | | Quasi-Rent Capital | | |
| Year | Labor | Fuel | Capital | Labor | Fuel | Capital | Labor | Fuel | Capital |
| 1981 | 0.418 | 0.180 | 0.402 | 0.363 | 0.156 | 0.481 | 0.544 | 0.163 | 0.292 |
| 1982 | 0.421 | 0.175 | 0.404 | 0.364 | 0.152 | 0.484 | 0.506 | 0.169 | 0.325 |
| 1983 | 0.453 | 0.157 | 0.390 | 0.454 | 0.158 | 0.388 | 0.610 | 0.189 | 0.201 |
| 1984 | 0.500 | 0.137 | 0.403 | 0.468 | 0.140 | 0.392 | 0.547 | 0.168 | 0.285 |
| 1985 | 0.459 | 0.156 | 0.386 | 0.510 | 0.173 | 0.317 | 0.588 | 0.198 | 0.214 |
| 1986 | 0.523 | 0.088 | 0.389 | 0.395 | 0.066 | 0.539 | 0.581 | 0.082 | 0.337 |
| 1987 | 0.478 | 0.098 | 0.424 | 0.306 | 0.071 | 0.628 | 0.477 | 0.086 | 0.437 |
| 1988 | 0.479 | 0.090 | 0.431 | 0.402 | 0.076 | 0.522 | 0.563 | 0.095 | 0.342 |
| 1989 | 0.484 | 0.098 | 0.418 | 0.349 | 0.070 | 0.581 | 0.485 | 0.086 | 0.428 |

Source: See text
Note: Pacific trawl fleet includes groundfish, shrimp, and midwater joint venture trawl vessels

TABLE 5.
TOTAL FACTOR PRODUCTIVITY GROWTH IN THE PACIFIC COAST TRAWL FISHERY, 1981–1989

| Year | No correction (1) | CU correction (2) | CU & biomass correction (3) | Full correction (4) |
|---|---|---|---|---|
| 1982 | -8.139 | -6.538 | -0.700 | -1.755 |
| 1983 | -5.028 | -3.889 | 10.526 | 5.017 |
| 1984 | 9.623 | 5.871 | 15.622 | 12.737 |
| 1985 | 2.967 | 7.763 | -6.902 | -4.873 |
| 1986 | 14.163 | 9.928 | -12.589 | -5.089 |
| 1987 | -8.916 | -3.988 | -10.161 | -8.689 |
| 1988 | 2.255 | 7.662 | 11.171 | 9.332 |
| 1989 | 1.653 | -1.664 | -0.697 | -1.444 |
| Mean | 1.072 | 1.020 | 0.783 | 0.654 |

Columns: (1) Long-run equilibrium in capital and no biomass correction
(2) Correction for variation in capacity utilization (CU) but not biomass
(3) Correction for variation in capacity utilization (CU) and biomass but not for variation in catchability coefficient
(4) Correction for variation in capacity utilization and biomass, and variability in catchability coefficient.
Note: Calculated by Tornqvist bilateral chain indices
Percentage annual growth rate

TABLE 6.
CAPITAL PRICES AND CAPACITY UTILIZATION PER VESSEL

| Year | Capital services price ($W_K$) | Quasi-rent of capital ($Z_K$) | Capacity utilization |
|---|---|---|---|
| 1981 | 60,535 | 79,487 | CU > 1 |
| 1982 | 62,859 | 84,067 | CU > 1 |
| 1983 | 55,405 | 53,041 | CU < 1 |
| 1984 | 56,082 | 51,096 | CU < 1 |
| 1985 | 53,501 | 38,002 | CU < 1 |
| 1986 | 47,628 | 82,228 | CU > 1 |
| 1987 | 56,728 | 116,133 | CU > 1 |
| 1988 | 57,535 | 77,486 | CU > 1 |
| 1989 | 55,437 | 96,756 | CU > 1 |

Note: $1981. Mean per vessel values.

TABLE 7.
AGGREGATE INPUT GROWTH RATES

| Year | Washington | Oregon | N. Calif. | C. Calif. | Fleet Aggregate |
|---|---|---|---|---|---|
| 1982 | -10.30 | 2.53 | 20.52 | 3.27 | 7.12 |
| 1983 | 4.25 | 3.38 | -11.15 | -10.93 | 0.14 |
| 1984 | -9.40 | -7.48 | -2.49 | -9.11 | -7.24 |
| 1985 | -2.45 | -6.87 | 5.90 | 19.81 | 0.67 |
| 1986 | 4.93 | 1.91 | -14.76 | -34.99 | -2.75 |
| 1987 | 5.70 | 9.50 | 5.21 | -28.40 | 6.33 |
| 1988 | 6.91 | -7.55 | -3.96 | -8.41 | -4.00 |
| 1989 | -2.61 | 8.85 | 0.02 | -0.40 | 4.65 |
| Mean | -0.37 | 0.53 | -0.09 | -4.96 | 0.61 |

Note: Tornqvist bilateral chain index. Percentage growth rate. Full static equilibrium of capital not imposed. Capital valued by quasi-rent rather than capital services price.

TABLE 8.
IMPLICIT AGGREGATE OUTPUT AND INPUT PRICE INDICES

| Year | Output | Input |
|---|---|---|
| 1981 | 1.000 | 1.000 |
| 1982 | 1.042 | 1.003 |
| 1983 | 0.839 | 0.876 |
| 1984 | 0.886 | 0.940 |
| 1985 | 0.957 | 0.926 |
| 1986 | 1.201 | 1.030 |
| 1987 | 1.385 | 1.020 |
| 1988 | 0.662 | 1.016 |
| 1989 | 1.199 | 0.938 |

Note: Formed by Fisher's factor-reversal test.

TABLE 9.
TOTAL FACTOR PRODUCTIVITY GROWTH FOR ONLY GROUNDFISH TRAWL

| Year | Multifactor Productivity | Aggregate Output | Aggregate Input | Aggregate Biomass | Capacity Utilization |
|---|---|---|---|---|---|
| 1982 | -10.64 | 2.88 | 15.90 | -2.39 | < 1 |
| 1983 | -11.24 | -4.51 | 7.07 | -3.36 | < 1 |
| 1984 | 11.71 | -2.57 | -8.05 | -6.23 | < 1 |
| 1985 | 3.18 | 0.64 | -0.37 | -2.17 | > 1 |
| 1986 | 28.79 | -4.25 | -31.08 | -1.96 | < 1 |
| 1987 | -12.23 | -7.95 | 6.35 | -2.07 | > 1 |
| 1988 | 10.40 | 10.35 | 3.26 | -3.31 | < 1 |
| 1989 | 2.37 | 2.50 | 1.78 | -1.65 | > 1 |
| Mean: | 2.79 | -0.36 | -0.64 | -2.52 | |

Note: Differential power catchability correction (see text).
Pink shrimp and joint venture midwater trawl vessels excluded.
Correction for variation in capacity utilization (see text).
Tornqvist bilateral chain indices and percentage annual growth rates.

**SESSION 1 : FISHERIES COMMON POLICY**

**A : PLENARY SESSION**

The EEC-Common Fisheries Policy and the 1991-Report
P. Andersen ..... 15

The Fisheries Structural Policy on the Horizon of the Year "2000"
E. Mastracchio ..... 19

Définition et mise en œuvre de la Politique Commune des Pêches de la CEE : le point de vue d'un Etat membre
C. Bernet ..... 25

**B : INSTITUTIONS AND FISHERIES COMMON POLICY**

The Relationship between Fleet Capacity and Fishing Effort
G. Valatin ..... 29

The European Community Decision Making Process : Fisheries with Reference to the Role of the European Parliament
D.I.A. Steel ..... 37

The Common Fisheries Policy and the Role of Producer Organisations in South West England : Economic Considerations
J. Slaymaker, A. Hatcher and S. Cunningham ..... 45

**C : EVALUATING THE SOCIO-ECONOMIC IMPACT OF THE E.E.C. FISHERY POLICY**

Evaluating Socio-Economic Impact of EEC Fishery Policy Using a Social Accounting Matrices Approach
G. Cella, V. Placenti and M. Spagnolo ..... 53

**SESSION 2 : AQUACULTURE SECTORAL DYNAMICS**

**A : GENERAL SESSION**

A Comparative Study of the Development of Mussel Farming in Scotland and Ireland with Emphasis on the Development of Marketing
M. Gabbot, S.A. Shaw and J. Gibbs ..... 77

Economic Evaluation of the Red Sea Bream Ranching in Kagoshima, Japan
J.R. Ungson, H. Hirata and Y. Matsuda ..... 87

Adoption of Innovations in the Norwegian Aquaculture Industry - Perceived Attributes
K. Hansen ..... 97

Scandinavian Aquaculture in a Global Perspective. A Study Concerning Structural and Marketing aspects
R. Cedrins ..... 109

**B : PANEL SESSION - SALMON PRICE AND MARKET**

What is the "Right" Price of Norwegian Salmon?
R. Hannesson ..... 119

Why 1991 Alaskan Salmon Prices Crashed
M. Herrmann and J.A. Greenberg ..... 129

**SESSION 3 : FISHERIES MODELLING**

**A : MULTI-OBJECTIVES MODELLING**

Multi-Objective Programming : an Application to the Pacific Whiting (Merluccius productus) Fishery
R.R. Enriquíez and G. Sylvia ..... 145

A Multiple-Criterion Optimization Approach for the Management of a Multispecies Fishery with Ecological and Technological Interdependencies
J.C. Seijo, O. Defeo and A. de Alava ..... 161

The Role of Multiobjective Policy Models in Fisheries and Aquaculture Development
G. Sylvia ..... 171

Bioeconomic Multispecies Modelling of the Barents Sea Fisheries
A. Eide and O. Flaaten ..... 183

**B : FISHERMEN BEHAVIOUR**

A Bioeconomic Model for Fish Harvest Technology
D.B. Sampson ..... 197

Dynamics of Resource and Fishermen Behaviour in Coastal Invertebrate Fisheries
J.C. Seijo and O. Defeo ..... 209

**C : OTHERS**

Analysis of Some Management Options for a Small Pelagic Fishery in Central Philippines
J.E. Padilla and P. Copes ..... 223

The Usefulness of Bioeconomic Models under biological Uncertainty : a Case Study of the Australian Southern Shark Fishery
S. Pascoe, T. Battaglene and D. Campbell ..... 237

Simulation Model of Factory Trawler Operation
I. Arnarson and P. Jensson ..... 247

The Nordic Fisheries Management Model - Themodel and the data for the Icelandic version
A. Danielsson ..... 261

Sources of Variance in the Economic Performance of New England Otter Trawl Vessels
I.J. Anwar, P. Lallemand and J. M. Gates ..... 273

A General Bioeconomic Simulation Model ofthe catching Sector of a Multispecies Fishery
P. Rodgers ..... 283

BEAM 4 - A Bio-Economic Model for the Simulation of Space-Structured Multi-Species and Multi-fleet Fisheries
P. Sparre and R. Willmann ..... 293

Gérez Vos Pêcheries
C. de Verdelhan ..... 305

**SESSION 4 : AQUACULTURE ENTERPRISE MANAGEMENT**

**A : GENERAL SESSION**

Profitability of Catfish on a Representative Multiple Enterprise Farm in the Southeastern United States Under Conditions of Risk
R.S. Pomeroy, S.M. Carlier and C.E. Curtis ..... 315

The Management Schemes for Brackishwater Pond Production
Mudiantono ..... 331

Dynamic Cash Flow Models in Aquaculture: Amplifying the Scope of Managers
C.S. Wright ..... 343

**B : PANEL SESSION**

Elaboration d'un modèle bio-économique dynamique relatif à l'élevage de la palourde de l'Atlantique *(Spisula solidissima)*
M. Martin, J.R. Wilson, L. Adambounou and R. Bouchard ..... 355

A Model for the Optimal Management of Sea-Bass Aquaculture
G.F. Rizzo and M. Spagnolo ..... 367

Simulation of Aquaculture Production for Economical and Environmental Impact
M. Spratt ..... 401

**SESSION 5 : CONSUMPTION AND DEMAND**

**A : CONSUMPTION AND DEMAND**

Consumer Ability to Discern Seafood Quality : Results of Experimental Studies
J.G. Anderson, C.R. Wessels ..... 417

Conjoint Analysis of the Japanese Salmon Market
Y. Kusakabe and J.L. Anderson ..... 427

Seafood Consumption and Giffen Behavior
R.S. Johnston and D.M. Larson ..... 437

The Changes Affecting the Demand for Fish and Fishery Products in Poland
A. Gwiazda ..... 449

Testing the Consistency of Fish Consumption Data with Neo-Classical Demand Theory
M. Burton and T. Young ..... 457

**B : FOOD SAFETY**

The Northeast United States Market for Blue Mussels : Consumer Perceptions of Seafood Safety and the Demand for Mussels
P.M. Brooks and J.L. Anderson ..... 463

Seafood Safety Assurances : Implications for Seafood Marketing and International Trade
C.R. Wessels and J.G. Anderson ..... 475

**SESSION 6 : INTERNATIONAL EXCHANGES**

**A : INTERNATIONAL TRADE POLICY AND COMPETITION**

Development of the International Trade in Seafood Products in the Context of European Economic Integration
J.P. Boule and P. Guillotreau ..... 485

U.S. Demand for and Canadian Supply of Fish Products
R.L. Mazany, N. Roy and W.E. Schrank ..... 501

Price Fluctuation and Substitution in the Groundfish Market
T. Trondsen ..... 517

The Icelandic Cod Trade : An Econometrically Based Simulation Model
R. Arnason and T. Felixson ..... 531

An Approach to the Management of Market and Resource Uncertainties : The Globalisation of Trade Information
J.-F. Mittaine ..... 555

The Market Outlook for Shrimp
M.-C. Yang ..... 561

Changes in Poland's Foreign Trade Management and Impacts on the Foreign Trade of Fishery Products
H. Nakonieczna-Kiesiel and J. Zieziula ..... 573

Le commerce extérieur français des produits de la mer en 1991
J. Dari ..... 581

Monopsony, Trade Restrictions and International Markets for Intermediate Seafood Products : The U.S.-Canada Herring Dispute
A. Emami, L.E. Queirolo and R. Johnston ..... 589

Price Linkages between Japanese and United States Markets for Sablefish and Thornyheads
J.D. Hastie, D. Squires and J.A. Elston ..... 599

The Alaskan King Crab Industry - An Industry in Transition
J.A. Greenberg, S.C. Matulich and M. Herrmann ..... 609

Java Sea purse seiners : the impact of innovation on performance
J.K. McElroy and Wijoprono ..... 617

**SESSION 7 : FISHING ENTERPRISE MANAGEMENT**

**A : ACADEMIC**

Coastal State Fisheries Management : Fleet Development Versus Trade in Fisheries Services
S. Cunningham and D. Whitmarsh ..... 639

La théorie économique de l'investissement dans le rétablissement des ressources naturelles renouvelables, avec référence spéciale au cas de la pêche du pétoncle géant aux Iles-de-la-Madeleine, Québec (Canada)
J.R. Wilson, F. Mendez and M. Fréchette ..... 647

Fishermen's Time Discounting Rates and other Factors to be Considered in Planning the Rehabilitation of Depleted Fisheries
J.P. Hillis and B.J. Whelan ..... 657

Hysteresis et comportements adaptatifs des pêcheurs artisanaux
H. Rey ..... 671

Prediction of Financial Distress in the Norwegian Fish Processing Industry
B. Dreyer and T. Vassdal ..... 683

**B : FISHING ENTERPRISE MANGEMENT**

Unemployment Insurance and the Length of the Fishing Season
N. Roy, E. Tsoa, W.E. Schrank and L. Mazany ..... 693

Multiproduct Tuna Fisheries in the South WestPacific
H.F. Campbell, A. McIlgorm and R.B. Nicholl ..... 715

Portfolio Selection in Fishing Strategies in a Multispecies Trawl Fishery
S. Hanna ..... 727

Un essai d'identification des stratégies de pêches : le cas de la pêche artisanale dans le nord de la France
F. Lantz, M.-O. Allard and R. Junaueir-Lopez ..... 745

The effect of government subsidies on the formation of collusions in an oligopolistic fishery
P. Mickwitz and M. Hildén ..... 759

Productivity Measurement in Common Property Resource Industries : an Application to the Pacific Coast Trawl Fishery
D. Squires ..... 769

**SESSION 8 : FISHING REGULATORY TOOLS**

Fundamental Issues in the Design of ITQ Programs
L.G. Anderson ..... 787

Marketing Losses in Regulated Open Access Fisheries
J.E. Wilen and F.R. Homans ..... 795

The Role of Economics in the Development of Limited Entry Programs : Two Examples from Groundfish Fisheries in the Western United States
J.D. Hastie ..... 803

Exvessel Price Behavior in West Coast U.S. Groundfish : Implications for the Choice of Fishery Management Technique
S. Hanna ..... 813

Multiproduct Supply under Production Quota : an Application to Pacific Fisheries
D. Squires ..... 827

The potential Benefits of Individual Transferable Quotas and their Effects on Industry Structure
D. Squires ..... 839

Productivity and Efficiency of the Fishing Fleet : the Case of the Small Scale Fishing Enterprises in Boulogne
C. Ioannidis and F. Lantz ..... 851

Setting Total Allowable Catches based on Market Conditions : Economics of Atlantic Herring Roe Production
R. Nowak ..... 859

Fisheries Regulation and the Incentives to Overfish
R.L. Mazany, A.T. Charles and M.L. Cross ..... 873

Fixed or Variable Catch Quotas with Irreversible Investments
S.I. Steinshamm ..... 881

Renewable Resource Market Obeying Difference Equations : Stable Points, Stable Cycles, and Chaos
C.C. Duarte ..... 891

Individual Fishing Rights : Some Implications of Transferability
P. Copes ..... 907

Considerations for an Individual Transferable Quota Program for the South Atlantic Mackerel Fishery
K.F. Wellman, J.W. Milon and J. Gauvin ..... 917

From Open Access to Communal Property : the Case of the Fishing Community in Muxía.
A.G. Allut ..... 929

Impact of Product Mix on Optimal Fishing Quota
I. Arnarson and P. Jensson ..... 937

**SESSION 9 : DISTRIBUTION AND PROCESSING**

UK Fish Processing Industry Strategies: From the CFP Decade to the Single Market
J.A. Young and J.F. Muir ..... 955

Stratégies des industries de transformation et approvisionnement en produits halieutiques : le cas du Sénégal
M. Dème and M. Bakhayokho ..... 971

Stratégies technologiques dans les industries de transformation
L. Temri ..... 979

Consumption of Seafood, Poultry and Meat in Restaurants vs. Supermarkets
T. Naito, R.S. Johnston and A.L. Shriver ..... 989

Cross-Hedging Fishmeal with Soybean Meal Futures
T. Vukina and J.L. Anderson ..... 1001

Market Analysis Institutional Behaviour and Marketing of Fish in Portugal
S. Cruz ..... 1015

Monopolistic Aspects of Word Trade of Fishing Industries in Portugal
S. Cruz ..... 1029

**SESSION 10 : MARKET, PRICE AND PRODUCTION SYSTEMS**

**A : GENERAL SESSION**

Market Structure and Prices : the Marseille Fish Market
A. Kirman ..... 1051

Relative Price Variability in Fisheries some Policy Implications
C. Ioannidis ..... 1059

The Market Interaction of Wild Salmon Fisheries and Salmon Aquaculture
C.S. Wright and P. Copes ..... 1071

Determinants of Price in the Portland, Maine Fish Auction
N. Ty and J.M. Gates ..... 1093

The Price Equalization Fund of the Fisheries in Iceland A Descriptive Study
O.Ö. Klemensson ..... 1105

**B : MARKET ORGANIZATION AND FISHERIES STATISTICS IN JAPAN**

Fish Marketing System Developed in Japan and Price Maintenance Mechanism
K. Miki and T. Yamamoto ..... 1115

Fishery Cooperative Association in Japan and its Vital Role in Fish Marketing
N. Odaka and T. Yamamoto ..... 1125

Supply and Demand of Fish and Fisheries Products in Japan
G. Bourguignon ..... 1131

Dual Structure of Japanese Marine Fisheries and Role of Fisheries Statistics in Fisheries Administration
T. Yamamoto ..... 1143

**SESSION 11 : RESOURCES VALUE AND CONFLICTS**

**A : RESOURCE VALUATION AND CONFLICTS**

On Inferior Goods and Giffen Effects in Recreation Demand Analysis
D.M. Larson and R.S. Johnston ..... 1163

International Issues in Valuation of Commercial and Recreational Fisheries
R.S. Johnston and A. Emami ..... 1175

Production Domestique, Absence de Marchés et Marchés Manquants dans les Economies en Développement : Analyse d'Impact de Projet dans le Secteur des Pêches
P. Failler and J.R. Wilson ..... 1189

Commercial Fisheries and Sport Fishing: Conflict and Cooperation
T. Kusakawa ..... 1201

Subsistence Fisheries in Alaska : Conflicts Within a Multiple Use Resource
H.T. Geier, J.A. Greenberg and M. Herrmann ..... 1213

**B : INFORMATION**

Information Needs and the Management of Joint Commercial and Recreational Fisheries : the UK Fishery for Sea Bass (*DicentrarchusLabrax*)
S. Potten, M. Dunn and D. Whitmarsh ..... 1223

The New Institutional Economics (NIE) Applied to the Fisheries : the Role of Information in the (Continuing) Solution of Resource Problems
J.R. Wilson and R. Lent ..... 1233

Cooperative Fishing Arrangements between Coastal Countries and Distant Water Fleets
L.E. Queirolo and R.S. Johnston ..... 1249

La comptabilité des ressources naturelles: une application aux ressources salmonicoles
A. Webster ..... 1259

**SESSION 12 : FISHING AND DEVELOPMENT**

Quelle Place pour les Pêches Africaines dans le Cadre de la Nouvelle Donne Mondiale ?
S.C. Nana Sinkam ..... 1273

Problématiques du Développement des Pêches
J. Weber ..... 1293

La Pêcherie de Crabe des Neiges au Canada en tant que Système : Variables, Interactions et Incertitudes
J.C. Brêthes and R. Dufour ..... 1301

Development and Diversification : Sustainability Strategies for a Costa Rican Fishing Cooperative
A.T. Charles and A. Herrera ..... 1315

Structure, Constraints and Development Options of Fish Processing and Marketing in Namibia
R. Lasch ..... 1325

The Welfare Impact of Improved Boat Modernisation Schemes (IBMS) in Pemalang Regency, Central Java - Indonesia
I. Susilowati ..... 1337

The Establishment of Chinese Marine Fisheries Laws and their Management Practice
Z. Guanghua ..... 1351

Évaluation de l'Impact de la Flotte des Pays de la CEE dans l'Économie du Sénégal
M. Kébé ..... 1357

**SESSION POSTER**

Bioeconomic Considerations regarding the Opening of a Autumn Fishery on Capelin in 1991
P. Sandberg and P. Gullestad ..... 1367

"Sevryka" - A new Competitor in the European Seafood Market ?
F. Nilssen ..... 1371

Contraintes Économiques et Sociales et Développement de l'Aquaculture extensive et diversifiée dans un Pays en Voie de Développement. "Le Cas de la Côte orientale de Madagascar"
G. Rafomanana ..... 1381

Canadian Household Demand for Protein : a Lifecycle Approach
D.J. DeVoretz and K.G. Salvanes ..... 1391

La pêcherie artisanale maritime des filets dormants à sole (*cynoglossus sp.*) en Casamance (Sénégal)
H.D. Diadhiou ..... 1405

Skipjack Pole and Line Fishing in EastIndonesia
J.K. McElroy and J.C.B. Uktolseja ..... 1417

Production planning and the managerial behaviour of the fish-farm entrepreneur in Italy
C. Iandoli, E. Alaio, R. Bianco and G. Vito ..... 1431

# Index des auteurs


## A

Adambounou L., 355
Alaio E., 1431
Alava A. de, 161
Allard M.-O., 745
Allut A.G., 929
Andersen P., 15
Anderson J.G., 417, 475
Anderson J.L., 427, 463, 1001
Anderson L.G., 787
Anwar I.J., 273
Antona M., 73, 311, 1047
Arnarson I., 247, 937
Arnason R., 531

## B

Bailly D., 73
Bakhayokho M., 971
Battaglene T., 237
Bernet C., 25
Bianco R., 1431
Bouchard R., 355
Boule J.P., 485
Bourguignon G., 1131
Brêthes J.C., 1301
Brooks P.M., 463
Burton M., 457

## C

Campbell D., 237
Campbell H.F., 715
Carlier S.M., 315
Catanzano J., 5, 11, 781, 1159, 1269
Cedrins R., 109
Cella G., 53
Charles A.T., 873, 1159, 1315
Copes P., 223, 907, 1071
Cross M.L., 873
Cruz S., 1015, 1029
Cunningham S., 45, 635, 639
Curtis C.E., 315

## D

Danielsson A., 261
Dari J., 581
Defeo O., 161, 209
Dème M., 971
Diadhiou H.D., 1405
Dreyer B., 683
Duarte C.C., 891
Dufour R., 1301
Dunn M., 1223

## E

Eide A., 183
Elston J.A., 599
Emami A., 589, 1175
Enriquíez R.R., 145

## F

Failler P., 1189
Felixson T., 531
Flaaten O., 183
Fréchette M., 647

## G

Gabbot M., 77
Gates J.M., 139, 273, 1093
Gauvin J., 917
Geier H.T., 1213
Gibbs J., 77
Greenberg J.A., 129, 609, 1213
Guanghua Z., 1351
Guillotreau P., 485, 949
Gullestad P., 1367
Gwiazda A., 449

## H

Hanna S., 727, 813
Hannesson R., 119
Hansen K., 97
Hastie J.D., 599, 803

Hatcher A., 45
Herrera A., 1315
Herrmann M., 129, 609, 1213
Hildén M., 759
Hillis J.P., 657
Hirata H., 87
Homans F.R., 795

## I

Iandoli C., 1431
Ioannidis C., 851, 1059

## J

Jensson P., 247, 937
Johnston R.S., 437, 589, 989, 1163, 1175, 1249
Junaueir-Lopez R., 745
Josselin C., 7

## K

Kirman A., 1051
Klemensson O.Ö., 1105
Kusakabe Y., 427
Kusakawa T., 1201
Kébé M., 1357

## L

Lallemand P., 273
Lantz F., 745, 851, 1047
Larson D.M., 437, 1163
Lasch R., 1325
Lent R., 1233

## M

Martin M., 355
Mastracchio E., 19
Matsuda Y., 87
Matulich S.C., 609
Mazany R.L., 501, 693, 873
McElroy J.K., 617, 1417
McIlgorm A., 715
Mendez F., 647
Mickwitz P., 759
Miki K., 1115
Milon J.W., 917
Mittaine J.-F., 555
Mudiantono, 331
Muir J.F., 955

## N

Naito T., 989
Nakonieczna-Kiesiel H., 573
Nana Sinkam S.C., 1273
Nicholl R.B., 715
Nilssen F., 1371
Nowak R., 859

## O

Odaka N., 1125

## P

Padilla J.E., 223
Papon P., 1
Paquotte P., 311
Pascoe S., 237
Placenti V., 53
Pomeroy R.S., 315
Potten S., 1223

## Q

Queirolo L.E., 589, 1249

## R

Rafomanana G., 1381
Rey H., 671
Rizzo G.F., 367
Rodgers P., 283
Roy N., 501, 693

## S

Salvanes K.G., 1391
Sampson D.B., 197
Sandberg P., 1367
Schrank W.E., 501, 693
Seijo J.C., 161, 209
Shaw S.A., 77
Shriver A.L., 989
Slaymaker J., 45
Spagnolo M., 53, 367

Sparre P., 293
Spratt M., 401
Squires D., 599, 769, 827, 839
Steel D.I.A., 37
Steinshamm S.I., 881
Susilowati I., 1337
Sylvia G., 145, 171
Sutinen J.G., 781

## T

Temri L., 979
Trondsen T., 517
Tsoa E., 693
Ty N., 1093

## U

Uktolseja J.C.B., 1417
Ungson J.R., 87

## V

Valatin G., 29
Vassdal T., 683
Verdelhan C. de, 305
Vito G., 1431
Voretz D.J. de, 1391
Vukina T., 1001

## W

Weber J., 1293
Webster A., 1259
Wellman K.F., 917
Wessels C.R., 413, 417, 475
Whelan B.J., 657
Whitmarsh D., 639, 1223
Wijoprono, 617
Wilen J.E., 795
Willmann R., 293
Wilson J.R., 355, 647, 1189, 1233
Wright C.S., 343, 1071

## Y

Yamamoto T., 1115, 1125, 1143
Yang M.-C., 561
Young J.A., 955
Young T., 457

## Z

Zieziula J., 573

Imprimé par JOUVE, 18, rue Saint-Denis, 75001 PARIS
N° 213292B. — Dépôt légal : Novembre 1994




Avec la participation de :

With the support of :

CEE DGXIV Programme FAR
Secrétariat d'Etat à la Mer, Direction des Pêches Maritimes et des Cultures Marines
Comité Central des Pêches Maritimes
Institut Français de Recherche Scientifique pour le Développement en Coopération
Crédit Maritime Mutuel
Fonds d'Intervention et d'Organisation des Marchés des Produits
de la Pêche Maritime et des Cultures Marines
Fédération des Organisations de Producteurs de la Pêche Artisanale
Union des Armateurs à la Pêche de France
Confédération de la Coopération, de la Mutualité et du Crédit Maritimes
Caisse Centrale de Crédit Coopératif
Centre Français du Commerce Extérieur, Direction des Produits Agro-alimenta
ORMES
International Institute of Fisheries Economics and Trade
Institut Français de Recherche pour l'Exploitation de la Mer.

# PROCEEDINGS OF THE SIXTH CONFERENCE OF THE INTERNATIONAL INSTITUTE OF FISHERIES ECONOMICS AND TRADE




Edited by

Martine ANTONA
Joseph CATANZANO
John G. SUTINEN

TOME II

INTERNATIONAL INSTITUTE
OF FISHERIES ECONOMICS
AND TRADE

ORGANIZED BY
IFREMER

# CONFÉRENCE INTERNATIONALE DE L'IIFET
# 6-9 JUILLET — PARIS

# ACTES DE LA SIXIÈME CONFÉRENCE DE L'ASSOCIATION INTERNATIONALE D'ÉCONOMIE DES PÊCHES

*PROCEEDINGS OF THE SIXTH CONFERENCE OF THE INTERNATIONAL INSTITUTE OF FISHERIES ECONOMICS AND TRADE*

TOME II

Publié par / Edited by :
**M. ANTONA, J. CATANZANO, J.G. SUTINEN**

Institut Français de Recherche pour l'Exploitation de la Mer

COPYRIGHT 1994 ©
IFREMER
155, rue Jean-Jacques ROUSSEAU
99138 Issy-les-Moulineaux
France

Session 1 : Fisheries Common Policy
A : Plenary Session ..... 11
B : Institutions and Fisheries Common Policy ..... 29
C : Evaluating the Socio-Economic Impact of the E.E.C. Fishery Policy ..... 53

Session 2 : Aquaculture Sectoral Dynamics
A : General Session ..... 73
B : Panel Session - Salmon Price and Market ..... 119

Session 3 : Fisheries Modelling
A : Multi-objectives Modelling ..... 139
B : Fishermen Behaviour ..... 197
C : Others ..... 223

Session 4 : Aquaculture Enterprise Management
A : General Session ..... 311
B : Panel Session ..... 355

Session 5 : Consumption and Demand
A : Consumption and Demand ..... 413
B : Food Safety ..... 463

Session 6 : International Exchange
A : International Trade Policy and Competition ..... 485

Session 7 : Fishing Enterprise Management
A : Academic ..... 635
B : Fishing Enterprise Mangement ..... 693

Session 8 : Fishing Regulatory Tools ..... 781

Session 9 : Distribution and Processing ..... 949

Session 10 : Market, Price and Production Systems
A : General Session ..... 1047
B : Market Organization and Fisheries Statistics in Japan ..... 1115

Session 11 : Resources Value and Conflicts
A : Resource Valuation and Conflicts ..... 1159
B : Information ..... 1223

Session 12 : Fishing and Development ..... 1269

Session Poster ..... 1367

# Fishing Regulatory Tools
# by
# J. Catanzano and J. G. Sutinen

Du fait de l'évolution du Droit de la Mer vers le milieu des années soixante-dix, le secteur de la pêche dans le monde a subi des changements majeurs. Depuis lors, pratiquement tous les Etats côtiers ont mis en œuvre différentes formes de gestion de leurs nouvelles zones économiques exclusives, recherchant dans une large part à éviter les effets négatifs du libre accès. Les programmes de gestion existant n'arrivent pas à produire, quels que soient les moyens choisis, de bonnes performances économiques. Cette limite est essentiellement due à l'incapacité de ces systèmes de gestion à résoudre le problème fondamental du libre accès. Les méthodes de régulation les plus communément employées (restrictions des engins de pêche, limitation des heures ou zones de pêche, quotas et capture totale autorisée) ne visent pas à contrôler l'accès aux ressources. Ainsi, aujourd'hui, la plupart des systèmes de gestion des pêcheries s'assimilent davantage à la forme d'un libre accès contrôlé, n'étant ni véritablement un libre accès non régulé ni un accès complètement contrôlé. Les progrès des programmes de gestion vers l'amélioration des performances économiques et le maintien dans le même temps de l'objectif biologique de conservation de la ressource, ont été lents.

Il y a dix ans, les pêcheries gérées par quotas individuels représentaient moins d'une douzaine de cas documentés dans la littérature alors qu'aujourd'hui les cas sont nombreux et en croissance rapide. Certains pays paraissent même évoluer vers la voie d'une régulation exclusivement orientée vers des systèmes d'appropriation, transférant quelque uns des droits et responsabilités de gestion directement aux utilisateurs de la ressource. D'une certaine façon, la boucle semble bouclée. Alors les gouvernements renoncent aux principes de micro-gestion et leur préfèrent des systèmes de gestion directe par les utilisateurs, assimilables à une forme moderne de système de tenure qui ne sont pas sans rappeler

The world has witnessed significant changes in its marine fisheries since the wave of extended fisheries jurisdiction of the mid-1970s. Since then nearly all coastal states have implemented some form of fishery management in their extended economic zones, motivated in large part to avoid the hazards of open access fishing. Existing management programs, however, generally fail to produce good economic performance from fisheries. This failure is largely due to the inability of these management programs to overcome the fundamental problem of open access. The most common management regulations (gear restrictions, time and area closures, and quotas on total catch) do not control access to fishery resources. Thus, most fisheries today take the form of regulated open access, being neither pure unregulated open access nor complete controlled access. Progress towards management programs which yield good economic performance and biological conservation in tandem has not been swift, though it is improving.

Ten years ago fisheries managed with individual quotas numbered less than a dozen documented cases, while today there are scores of individual quota programs and the number is growing rapidly. Some countries even appear to be moving in the direction of regulated sole ownership, transferring many of the rights and responsibilities of fishery management to the direct users of the resources. To some extent, management appears to be coming full circle. As government withdraws from the micro-management of fisheries and turns over management responsibility to users, there seems to be a trend towards the modern equivalent of marine tenure systems, so common in traditional coastal communities [1].

(1) This is not to say that it is appropriate to convert all fisheries to a modern form of marine tenure systems. Many near-shore coastal fisheries are competing with other uses of the ocean space and resource. The externalties are so numerous and complex that the traditional marine tenure system cannot be expected to properly resolve the allocation issues in this modern setting.

les anciens systèmes courants de gestion des pêcheries-côtières par les communautés traditionnelles [1].

Les économistes attribuent les problèmes du libre accès à l'absence de droits de propriété pour l'usage exclusif des ressources halieutiques. Les quotas individuels et les systèmes de limitation des entrées sont deux formes de gestion par allocation de droits souvent proposées pour résoudre le problème fondamental du libre accès. Plusieurs des papiers contenus dans cette session abordent les problèmes et conditions spécifiques associés à de tels programmes de gestion.

A l'heure actuelle, la demande pour des analyses bio-économiques plus pertinentes se traduit par un intérêt des chercheurs vers une meilleure prise en compte des aspects plus réalistes des systèmes pêche ainsi que des objectifs de gestion. C'est dans cet esprit que les points de référence classiques pour le biologiste ou l'économiste (par exemple MSY et MEY), ont été dépassés et enrichis au travers de modèles plus élaborés de gestion des pêches. En ce sens les analyses contenues ici tentent d'explorer des voies pour la prise en compte des objectifs d'efficience assignés au système de gestion et des objectifs de redistribution, la prise en compte des comportements des pêcheurs visant à contourner la réglementation, l'analyse comparée des coûts de chacune des propositions de gestion envisagée. Un grand nombre d'études témoignent du besoin d'améliorer la mise en œuvre des programmes de gestion par allocation de droits en tenant compte des conditions plus réalistes qui sont celles de la production, du marché, des conflits.

Les caractéristiques fondamentales du système pêche sont revues pour incorporer des relations plus complexes telles que celles exprimées en terme de chaos pour la dynamique des stocks, ou encore d'instabilité en référence aux systèmes économiques de taxes et décalages temporels dans les processus de régulation.

Une des formes les plus courantes d'allocation de droits dans les systèmes de gestion des pêches est représentée par les quotas individuels, forme dans laquelle il est attribué à chaque utilisateur un droit de capture pour une quantité de poisson donnée et pour une saison délimitée. Plusieurs papiers de cette session abordent les questions associées aux systèmes de gestion par quota individuel. Elles concernent notamment des considérations sur

(1) Il ne s'agit pas de dire ici qu'il est envisagé et envisageable de transformer toutes les pêcheries en système moderne de tenure. Certaines pêcheries très côtières sont en compétition avec d'autres usages de l'espace marin et des ressources. Les externalités sont si nombreuses et complexes que les systèmes traditionnels de tenure maritime ne peuvent pas suffire à résoudre les problèmes d'allocation dans le contexte moderne des économies et des sociétés.

Economists argue that the problems of open access are directly related to the lack of property rights to the exclusive use of fishery resources. Individual quotas and limited entry are two rights-based management measures often proposed to overcome this fundamental problem of open access. Many of the papers in this section address specific problems and conditions associated with such rights-based management programs.

The demand these days for more relevant bioeconomic analysis is reflected by researchers' interest in explicitly accounting for more realistic aspects of the fishery system and objectives of fishery management. In this respect, the classical biological and economic reference points (e.g., MSY, MEY) are being extended and enriched in more elaborate models of fishery management. For example, the analyses and discussions contained herein explore ways to take into account distributional, as well as efficiency objectives, and to account for fishermen's evasive behavior and the cost of managing a fishery. The need to improve the implementation of rights-based management programs under more realistic conditions of production, markets, and resource conflict, is shared by a number of the studies in this section. The fundamental characteristics of the fishery system are revised to incorporate more complex relationships, e.g., chaos in the stock dynamics, and instability produced by taxes and lags in the regulatory process.

One popular form of rights-based fishery management is individual quotas, where users are assigned the right to harvest a given quantity of fish in a season. Several papers in this section address issues associated with individual quota management. These issues include consideration of eligibility and transferability, the consequences of multiproduct firms, and the linkages with product markets, when evaluating the prospects of individual quota programs.

Anderson addresses a set of important issues involved in the practical implementation of individual quota programs: eligibility, duration, transferability, ownership caps, management units, monitoring and enforcement, and initial allocation. Copes examines the differential impacts of transferable and non-transferable fishing rights in the context of limited entry and individual quota programs. He argues that transferability leads to a "transitional gains trap" that limits improvements in fishermen's incomes. Wellman *et al.* explore many practical aspects of implementing an individual transferable quota program in a mixed recreational-commercial fishery. Their analysis, conducted in the context of the pelagic mackerel fishery off the southeast coast of the United States, addresses the unique problems of initial allocation and transferability inherent in this two sector, recreational and commercial, fishery.

l'éligibilité et la transférabilité associés à ces droits, les conséquences de ce type de gestion pour les unités de pêche non spécialisées et les liens avec les marchés des produits pour l'évaluation des perspectives des programmes de quotas individuels.

Anderson développe un ensemble de questions majeures relatives à la mise en œuvre de programmes de quotas individuels : éligibilité, durée, transférabilité, choix du propriétaire, unité de gestion, suivi et contrôle et enfin première allocation. Copes examine les différents impacts de droits de pêche transférables ou non transférables dans des cas de limitation des entrées et de quotas individuels. Il énonce que la tran§férabilité aboutit à ce qu'il appelle « le piège des gains transitoires » qui limite l'amélioration des revenus du pêcheur. Wellman *et al.* présentent plusieurs aspects pratiques de la mise en œuvre de quotas individuels transférables dans le cas d'une pêcherie mixte, faite d'activités récréatives et d'activités de pêche professionnelle. Leur analyse, développée à partir de l'exemple des pêches pélagiques de maquereaux de la côte sud-est des Etats-Unis, aborde le problème spécifique à ces pêcheries mixtes, à savoir la première allocation des droits puis la transférabilité de ceux-ci entre les deux secteurs, récréatif et professionnel en présence. Les pêcheries plurispécifiques présentent également pour l'aménageur et les chercheurs des problèmes et questions complexes dès lors qu'il s'agit de l'introduction de droits de propriété. Au travers de ses deux communications, Squires analyse quelques-unes de ces questions au regard des firmes non spécialisées. Dans la première il tente de caractériser formellement le comportement d'offreur pour une entreprise multi-produit avec ou sans système de régulation par quota et il présente ensuite une application empirique illustrée par le cas des pêcheries américaines de « sablefish ». Dans son second papier, Squires utilise la nouvelle technique du prix virtuel pour modéliser les effets d'un système de gestion par quota individuel pour une pêcherie composée de deux groupes d'unités de pêche multi-produit dissemblables par la taille des entreprises. Son modèle lui permet d'évaluer les gains potentiels de rente dans de telles pêcheries.

Hastie s'intéresse quant à lui au rôle joué par l'analyse économique dans la configuration de deux programmes de gestion par introduction de droits. Il discute tout d'abord du développement d'un plan de gestion pour un système de licence d'entrée dans les pêcheries de poissons démersaux de la côte ouest des Etats-Unis puis, d'un programme de quotas individuels transférables pour les pêcheries de « sablefish » d'Alaska et pêcheries de flétan des Etats-Unis. Hastie conclut de ces exemples que l'analyse économique joue un rôle limité et qu'à l'inverse les questions d'ordre politique ou social étaient

Multispecies fisheries present managers and researchers with a variety of complex problems and issues. Squires' two papers analyze some important aspects of multiproduct firms subject to individual quotas. In the first paper he formally characterizes the supply behavior for a multiproduct firm with and without a quota regulation and presents an empirical application to the United States sablefish fishery. In the second paper Squires employs the new analytical technique of virtual prices to model the effects of individual quotas for a fishery with two sizes of multiproduct fishing firms. His model allows him to evaluate the potential gains in resource rent in such a fishery.

The role economic analysis played in shaping two rights-based management programs is described by Hastie. He discusses the development of management plans for a license limited entry program in the groundfish fishery off the west coast and an individual transferable quota program for the Alaskan sablefish and halibut fisheries in the United States. Hastie concludes that economic analysis played a limited role and that political and social issues were more influential in the decision-making process which produced the final plans.

Rights-based management is commonly believed to allow fishermen more flexibility to take advantage of market opportunities. This and other connections between the market and management is emphasized in papers by Arnarson and Jensson, Wilen and Homans, Hanna and Nowak. All of these papers support the argument by Arnarson and Jensson, and Hanna that policy measures, such as quotas, cannot be properly set without considering the production attributes of catch and the associated interaction with the market. There is a natural feedback loop between harvesting and market prices that needs to be taken into account if managers are concerned with the economic performance of management programs.

Nowak explores the prospects of setting a total quota based on market conditions in the context of the Atlantic Canadian herring roe fishery, concluding that such approach would not work well if the sole objective were to maximize industry profits. Wilen and Homans argue that it is difficult to foresee the magnitude and kinds of revenue gains that might be induced by efficient management, and cite three cases where management programs produced market effects that significantly exceeded production efficiency gains.

The efficiency gains or losses in harvesting needs to be assessed when deciding among management alternatives. A method for measuring efficiency is explored by Lantz and Ioannidis in their study of a small-scale French fishing fleet.

davantage actives dans les modes de prise de décision qui produisaient le programme final.

On tend à associer communément aux systèmes de droit des qualités supérieures en terme de flexibilité offerte aux pêcheurs pour saisir au mieux les opportunités commerciales. Ce point ainsi que d'autres connections entre système de gestion et marchés sont considérés dans les textes d'Arnarson et Jensson, Wilen et Homans, Hanna et Nowak. Tous ces auteurs mettent en avant le fait que les mesures de politique de gestion telles que les quotas ne peuvent pas être instaurées convenablement sans considérer les effets sur la production et les interactions associées aux marchés. Il y a une boucle naturelle entre captures et prix qui doit être prise en compte si le gestionnaire de la pêcherie s'intéresse aux performances économiques du programme de gestion.

Nowak s'intéresse aux perspectives que présente un système de quota global basé sur les conditions de marché avec l'exemple des pêcheries canadiennes d'œufs de hareng de l'Atlantique, et conclu que de telles options de gestion ne pourraient fonctionner que si le seul objectif était de maximiser le profit des entreprises. Wilen et Homans quant à eux, aboutissent à la conclusion qu'il est difficile de prévoir l'ampleur et la nature des gains qui devraient résulter d'un système de gestion efficient et citent trois cas pour lesquels les systèmes de gestion ont produit des effets sur le marché qui ont largement dépassé les gains de productivité. L'efficience des gains ou pertes de capture doit être évaluée entre les différentes alternatives de gestion. A cet effet, Lantz et Ioannidis proposent une mesure possible d'efficience mise en œuvre à partir de données relatives aux flottilles françaises de pêche artisanale.

Les caractéristiques dépendant directement des dynamiques propres aux ressources peuvent avoir des implications significatives pour l'efficience et l'efficacité de la gestion. Sur ce point, Duarte explore les implications pour la gestion de dynamiques de population qui suivent des équations de séries temporelles discrètes. Certaines valeurs des paramètres font référence au chaos, et à d'autres obstacles à la gestion.

Steinshamm s'intéresse à la question de l'efficience comparée de quotas fixes ou variables dans certaines conditions avec ou sans investissements irréversibles. Il apparaît que sous certaines conditions, les systèmes de contrôle des inputs sont supérieurs aux systèmes de contrôle des outputs.

Cette question du choix entre une option de contrôle des inputs ou des outputs est également traitée par Mazany *et al.* qui comparent les performances économiques de chacune des méthodes. Les pêcheurs sont supposés

Characteristics of the underlying resource dynamics can have significant implications for the efficiency and effectiveness of management. Duarte explores the implications for management of a population dynamics following a discrete time difference equation. Certain parameter values give rise to chaos, and other troublesome management problems. Steinshamm explores the issue of whether fixed or variable quotas are more efficient under uncertainty, with and without irreversible investment. Under some conditions, fixed input controls are superior to fixed output controls.

The issue of input vs. output controls is also explored by Mazany *et al.* who examine the relative economic performance of each method. Fishermen are assumed to be willing to violate management regulations under certain conditions. This paper develops a framework for evaluating which form of controls is more efficient when enforcement of the regulations is both costly and imperfect.

Another form of rights-based management is where a fishery is operated under communal property. The paper by Allut reminds us that theoretical predictions of the so-called tragedy of the commons is not always born out. Where access to a fishery is limited to a given group of fishermen, social dynamics can result in self-regulation, requiring no state control of the fishery. This is illustrated by the example of a Mediterranean fishery in which both access and resource use is controlled by a local community of fishermen through a cooperative system of exploitation. Fishermen actively protect their resource from outside competitors with the use of force. This system was not effective until an equitable method for sharing the returns from the resource was implemented.

This set of research papers has some unique qualities. Ten years ago, conference papers on management would not have given the prominence to rights-based methods that the present set of papers do. These papers also exhibit a depth of analysis and treat a diverse set of critical issues underlying rights-based management that is novel. This novel emphasis on rights-based management and depth of analysis appears to us to be a reflection of the strong shift on the policy front towards the consideration of rights-based management measures.

violer la réglementation sous certaines conditions. Ce papier développe une méthode pour choisir parmi les formes de gestion la plus efficiente quand le contrôle de cette gestion est à la fois coûteux et imparfait.

Une pêcherie fonctionnant sous un régime de propriété commune correspond à une autre forme de droit dans les systèmes de gestion. Allut nous rappelle ainsi que les prévisions théoriques liées à la « tragédie des choses communes » ne sont toujours pas « born out ». Lorsque l'accès à une pêcherie est limité à un groupe donné de pêcheurs, les dynamiques sociales peuvent apparaître comme une autorégulation, ne nécessitant pas de contrôle de la pêcherie par l'Etat. Ceci est illustré par un exemple de pêcherie méditerranéenne dans laquelle à la fois l'accès et l'usage de la ressource sont contrôlés par la communauté locale de pêcheurs au travers d'un système d'exploitation coopératif. Les pêcheurs protègent leur ressource vis-à-vis des compétiteurs extérieurs par l'usage de la force. Ce système n'était pas effectif jusqu'au moment où une méthode de partage équitable des résultats a été mise en œuvre.

Les textes regroupés dans cette session présentent des qualités particulières. Il y a dix ans, les communications relatives à la gestion, ne témoignaient pas d'une aussi forte référence aux méthodes de gestion par allocation de droits comme c'est le cas dans cette session. Ces communications illustrent un approfondissement de l'analyse et un traitement nouveau des questions majeures liées à la gestion par allocation de droits. Cette nouvelle priorité donnée aux droits et l'élargissement des analyses nous paraissent refléter un fort changement sur le plan politique vers la prise en considération de mesures de gestion conçues en terme de droit.

# Fundamental Issues in the Design of ITQ Programs

**Lee G. Anderson** *

College of Marine Studies and The Department of Economics, University of Delaware, Newark, DE 19716-3501, USA

ABSTRACT

*Because of their potential to alleviate or reduce many of the problems associated with traditional management i.e., depressed resources, overexpanded fishing fleets, low fishermen incomes, interest group conflict, and the treadmill operation of management agencies as they try to keep with the system, ITQs have been implemented in, or are being considered for, many fisheries throughout the world. However, the actual benefits achieved from ITQ will depend upon how the specific program is adapted to the particular fishery.*

*The purpose of this paper will be to list the necessary components of an ITQ program and describe how they can be designed with reference to two different fisheries. The components described include : number and groupings of species and species aggregations, enforcement and monitoring procedures, initial allocation rules, transferability options, caps on ownership, other required management tools, etc.*

## 1. INTRODUCTION

ITQs are a regulation tool that can simultaneously address the necessary biological aspects of management and avoid some of the problems of traditional management techniques. They can provide operators with the flexibility to increase their profits by lowering their costs (by finding the most efficient way to harvest fish) and by increasing their revenues (by selling their products at those times and in those markets where prices are higher). This flexibility comes from the fact that fishery managers do not have to tell the harvester how to operate. The manager's job can also be easier because he or she does not have to worry about derby openings or about trying to figure out ways of keeping the catching power

* The material in this paper draws heavily on a report prepared under contract to National Oceanic and Atmospheric Administration, National Marine Fisheries Services, U.S.A. I am grateful for helpful comments from Wade Griffin, Daniel Huppert, Wally Milon, Jon Sutinen, and Rebecca Metzner. The views presented are my own and do not necessarily represent those of the above nor the National Marine Fisheries Service.

of a fishing fleet to a level that will not overfish the stock. By facing the allocation decision at the outset, the dual questions of how much to catch and who can catch it are separated. This separation leads to a system which can provide incentives matching the fishing power of the fleet to the productivity of the fish stocks.

This is not to say that ITQs do not have their problems. There are draw-backs, especially in certain types of fisheries. One special issue is that ITQs are a new and fundamentally different way to manage fisheries even though similar concepts are used in other types of resource management. The following sections describe issues which must be faced when designing ITQ programs. How they are faced will partially determine how many of the potential advantages of ITQs can actually be achieved and how potential problems can be addressed.

## 2. THE NATURE OF THE PROPERTY RIGHT

The basic differences between an ITQ program and traditional management tools are the "I" and the "T", the individual ownership and the transferability. Although the basics of the "I" and the "T" have been explained above, their true character is much more complex. The exact nature of the ownership right can have many facets, some quite subtle and others very overt. The nature of the right can be changed or limited to accomplish biological, managerial, or cultural objectives - any of which may be fully within the purview of overall fisheries management. However, it is important to compare what is being gained by meeting these other objectives to what is being lost by the diminished flexibility.

The basic issues concerning the nature of the property right are summarized below. The format will be to describe the issue and then to present a one or two sentence statement summarizing the various points of view. Finally suggested options to address the issues are provided. In some instances there may be legal considerations that will have to be addressed before using some options.

### *2.1 Eligibility To Own*

Should any legal entity be allowed to own ITQ or should ownership be limited to natural persons ? On the one hand, preventing corporations from participating may help maintain industry and community structure. At the same time, the limited flexibility may prohibit ITQ owners the opportunity to organize their activities to their best advantage and this may adversely affect the way the Nation's fish stocks are used to accomplish other management goals.

Options :

- Allow any legal entity the right to own ITQ shares.
- Allow only persons the right to own ITQ shares.
- Establish other restrictions on eligibility such as banning foreign ownership.

### *2.2 Duration Of Ownership Right*

In the U.S.A., should the ownership right be permanent, or should it be for some limited period ? According to current interpretations of the MFCMA, the ownership right at most can be guaranteed only as long as the management plan which implemented the ITQ program is in effect. By allowing the ownership right to be as permanent as current policy allows, the ITQ owner will have the securest possible planning horizon and will have better incentives to make efficient investments in harvesting and processing equipment and to develop market channels. On the other hand, there may be hesitations to make long term plans if the ITQ share may be given to someone else at a later date.

However, councils may wish to set limits on ownership rights to maintain some long term control over the fishery. By setting a term of X years, a council will have the opportunity to reassign rights if it feels current owners are not using them properly. However, doing so would require that the councils face the very difficult distributional task of reallocating the rights at regular intervals.

Options

- Ownership rights can be assigned for the duration of the ITQ program.
- Ownership rights can be assigned for fixed, perhaps renewable, terms.
- Ownership rights can be temporary initially, but after a trial period, made permanent.

*2.3 Transferability I*

A fundamental issue is whether ITQ rights should be transferable at all. Some would argue that an individual quota makes sense because it allows for better biological management, but that making the rights transferable is not appropriate because it is a permanent and free (given the current Magnuson Act) consignment of a public resource to a private individual. If, however, restrictions on transferability are permitted, they would constrain the flexibility of owners, which as described above is one of the potential advantages of ITQs. Additionally, with no transferability, a council must devise a way to reallocate the ITQs once an owner has died or retired from fishing. Without transferability, the allocation question must be faced over and over again.

Options

- ITQs can be fully transferable by sale, lease, gift, inheritance or through joint-harvesting arrangements.
- ITQs can be sold but the rights to catch fish in any one year cannot be leased.
- ITQs can be made non-transferable. The individual who receives the right is the only one that may harvest the fish.

*2.4 Transferability II*

Even if ITQs are to be transferable, limitations on the types of trades that are permitted may be justified in certain circumstances. The initial allocation will likely include individuals who differ by gear type, boat size, firm size, type of final product, home port, etc. Free transferability between all such individuals may result in changes in the industrial or cultural aspects of the fishery which the council may wish to prevent. Restrictions on transfers between specified groups may help prevent such changes. However, they will also limit the flexibility of ITQ owners and in the long term could become a stifling influence on the development and utilization of the fishery as a whole.

Options

- Place no restrictions on the transferability of ITQ between different groups of owners.
- Determine critical groupings of participants and prohibit or restrict purchases, leases, etc. between members of these groups.

*2.5 Ownership Caps and Restrictions*

There is often concern with the potential for creating "excessive shares" when implementing ITQ programs. Although there is no clear definition of what an excessive share is, it likely refers to market power for ex-vessel fish, final product, or even ITQ shares. It could also refer to the general historical, industrial, and cultural make-up of the fishery. Councils can take specific actions to address these issues or they may determine that other applicable laws are sufficient for doing so. For example, current anti-trust law addresses problems of excess market power in any industry including fisheries, and the council may conclude that this is adequate. On the other hand, councils may have an interest in directly addressing such issues in the construction of an ITQ program. If this is done, however, the difficulties of defining market power and of measuring the gains and losses of various actions, such that they can be approved as part of a management plan, should not be underestimated.

Options

- Place caps on the percentage of ITQs for a particular management plan or for a particular stock within a management plan that any one entity can own.
- Place other restrictions on how firms or individuals can combine to harvest the ITQ. For example, limit the percentage of total catch that can be landed by one boat or landed in one port.

## 3. MANAGEMENT UNITS

Defining the management unit or units is an important part of any fisheries regulation program. This is no less true with an ITQ program. A management unit in an ITQ program is the species, stock, or aggregation for which a TAC is specified and for which harvesting rights are distributed. In the Surf Clam and Ocean Quahog ITQ program, there are only two units : Surf Clams throughout their range and Quahogs throughout their range. At the other extreme, the proposed ITQ program for Alaskan Sablefish and Halibut has many management units. Each stock is broken down into several geographic areas.

Selecting and defining the management units for an ITQ program is a very important step. The success of the program can depend critically on how well it is done. There are two types of questions pertaining to the selection and definition of the management units that must be answered.

The first question is : How many species should be included in the program ? If different species are biologically or commercially related, there may be grounds for managing them jointly under the ITQ program. Some of the considerations that need to be addressed are : 1. Are the species caught as a by-catch or a directed catch with the same gear or by the same fleet ? 2. Are there ecological or spawning relationships between the species ?

Care must be taken when selecting the stocks. There are two types of errors that can be made. An error of exclusion occurs when a species that is closely related to those in the ITQ program is left out. This can make it difficult to appropriately manage the species that are in the program and/or the one that is left out. For example, if the catch of a species which is not covered in an ITQ program has a significant by-catch of a species which is included, it may be quite difficult to account for by-catch mortality.

On the other hand an error of inclusion occurs when a minor or unrelated species is included in the program. Determining and enforcing the TAC for such a species can involve more work and managerial repercussions on the major species than the gains from managing the minor stock are worth.

The second question is : How should each of the included species be classified ? There may be several stocks or geographically distinct units of the same species. If so it may be appropriate to have a separate TAC for each. At the other extreme, there may be certain groups which may be treated as aggregations for management purposes even though they are technically made up of separate species. Rockfish in Alaska is a good example. These aggregations can have a joint TAC.

Here again the decisions are critical. An error of conglomeration can occur if biologically distinct stocks are not separated. A single overall TAC on two separate stocks may put too much pressure on one stock if it is closer to port or has a higher catch per unit of effort. On the other hand, an error of specificity may occur if the different species are divided into too many stocks because the program can become unwieldy and difficult to manage.

There is definitely a trade-off in answering these two questions. The larger the number of stocks that are included in the program, the more inclusive the system will be and the lower will be the need for a separate management program to handle species and stocks not included. And, the more finely the quota share stocks are geographically defined, the easier it will be to focus management on more narrowly defined species or species groups if there are biological, technological, or distributional reasons for doing so. However, the larger the number of area divisions, the more complex and difficult it will be to manage the ITQ program. There will be more TACs to set, and the monitoring program will have be able to distinguish landings according to the stock from which they were harvested.

## 4. THE DETERMINATION OF THE TOTAL ALLOWABLE CATCH

Because the TAC is the main biological component of an ITQ program, it is essential that it is set with care. TACs are used in many other types of fisheries management programs, whether as actual binding limits or as implicit or explicit targets to be achieved using gear restrictions, season closures, etc. For the most part, the rules and procedures for developing TACs under other programs can apply under ITQ programs as well. The basic idea is to set a total fishing mortality level that is a balance between what can be taken this year and what should remain to grow and/or reproduce for future years. Application of this principle will vary according to the population dynamics and the current status of the stocks under consideration.

There are some facets of TAC determination under an ITQ program that merit special consideration. One very important issue is the definition of the harvest right especially when TACs will likely vary from year to year. The right to harvest cannot be defined in terms of a constant amount of fish each year. In the extreme case this would mean that the TAC, which by definition is the sum of the individual quotas of all participants, could never change. The right to harvest a particular stock must depend upon the current productivity of the stock. Therefore ITQ programs work better if the individual rights are defined in terms of a percentage of the TAC. As the TAC goes up or down according to biological conditions, the individual right to harvest in terms of actual catch will vary accordingly.

Another issue is how to set TACs in those fisheries which have not previously used them. In newly developing fisheries, the accumulated biological data may not be deemed sufficient. In other fisheries, current management may be based on the notion that biological issues can be addressed without using TACs. With New England scallops, for example, the assumption is that appropriately enforced meat count limits will be sufficient to protect the stock so TACs have not been used. They have not been used with shrimp either because shrimp are essentially an annual crop the size of which can vary depending upon factors other than the number of spawners, and so recruitment overfishing is unlikely.

If ITQs are to be used in these situations, the relevant question is : Are the gains from a reduced race for fish and increased flexibility of participants worth the effort and possible drawbacks of instituting TACs ? In developing fisheries, is the best information available sufficient to draw the balance between setting TACs too high and adversely affecting future catches and setting them too low so that current harvests are not unduly restricted ? With scallops, can TACs be set that achieve the biological objectives as efficiently as meat counts ? With shrimp can a TAC policy be established which can estimate, with in-season adjustments if appropriate, the amount of biomass available for harvest ?

There are two questions relating to TACs in shrimp and other short-lived species. Why set one ? How can one be set ? Shrimp is an annual crop, the size of which is not directly related to the harvesting pressure in previous years. A natural question, therefore, is why should there be a limit on harvest in any given year ? Limiting harvest in one year will reduce benefits that year but will not likely have a positive effect on catch next year. This is a valid point, but framing the question this way ignores many other important considerations. For instance, although total effort in the Gulf Shrimp fishery in the U.S. has been increasing steadily in the recent past, total catch has not increased proportionately. In fact, for the past few years, total catch has leveled off. There are indications that total effort could be substantially reduced without significantly affecting total annual catch.

Although increased effort has not increased catch, it has increased the difficulties of managing the fishery. For example, inshore closures are harder to enforce the more boats there are. In addition, the incidental harvest of turtles and finfish is likely to be proportional to total effort even if total shrimp harvest is not. Put simply, a reduction in total potential effort could reduce many of the fishery's other management problems.

But the issue is more involved than just inshore closures and by-catch. It is also important to look at the problem of waste from a broader perspective. On the one hand, having a system which may allow some shrimp to die unharvested undoubtedly involves a waste of fish. On the other hand, a system which can harvest the very last shrimp even in peak years will also have waste. When average years come, the fleet cannot be fully utilized and that is a waste of fishing capacity.

An advantage of an ITQ system is that it can address both types of waste. If individuals know that they have a right to a share of the available harvest, they will be motivated to build their harvesting capacity such that they can make the most of the good years, and at the same time not suffer large losses in medium or bad years. There will not be a race to catch fish, so ITQ owners can plan where, when, and how to take their share. Concurrently, by-catch problems can potentially be reduced because a smaller amount of effort applied at different times and in different locations will be used to take the allowable catch.

Another consideration pertaining to TAC setting is the relationship between TAC determination and the other components of the ITQ program. As discussed above, there are a wide range of issues to be considered in selecting the number and make-up of the management units, and one that deserves special mention is the basis for determining a TAC. Put simply, there needs to be sufficient theory and data to set a credible TAC for a certain species in a specified geographical area. If the problem is a lack of data, it can potentially be overcome. However, if the management unit is defined purely on political grounds, the problem of a credible TAC will remain. In summary, another drawback to expanding the number of management units is the increased data needs and work load of setting one more TAC.

The setting of TACs can also be related to certain enforcement problems. If it is likely that highgrading and by-catch discards will result in fishing mortality that is significantly different than landings, and if there are no other satisfactory ways of correcting for this, adjustments in TACs may be appropriate. For example, if participants can be expected to discard smaller less valuable fish of a particular species and if the smaller fish normally represent 10 % of the catch, the TAC can be reduced by 10 % of what it otherwise would have been.

## 5. MONITORING AND ENFORCEMENT

A fisheries management program is only as good as its monitoring and enforcement system. This is as true of ITQs as of other types of management. However, there will be some fundamental differences in the formulation and operation of a suitable monitoring and enforcement system for an ITQ program. ITQs are like any other TAC based program in that there must be a way to monitor total harvest and to ensure that it does not surpass the TAC. In addition, however, it is necessary to monitor the harvest of each participant and to ensure that it does not surpass his or her current individual quota level. With transferability, it is also necessary to keep track of the current amount of individual quota owned by each participant. While these extra burdens may seem formidable, it is necessary to evaluate an ITQ management and enforcement system relative to those of other types of management programs and relative to the potential management benefits of an ITQ program. Will overall monitoring and enforcement costs be higher or lower ? Even if the costs are higher, are the accomplishments of ITQ management worth it ?

The successful operation of an ITQ program requires that the monitoring system be seen as being capable of detecting abuse. Participants must be confident that others can not beat the system and thus diminish the value of their rights. In addition the participants must also know that the system will detect any misconduct on their own part so incentives to cheat will be small. However, this does not necessarily mean that every fish brought to the dock and every landings report filed must be personally inspected by an enforcement officer.

In-person inspections will still be important aspects of an ITQ monitoring system, but their ultimate success will require a computerized system of electronic reporting and data management. In addition, there must be at least two sources of information for any transaction. For example, both the harvester and the first fish receiver must fill out independent landing forms that can subsequently be double checked against each other. Similarly a transfer of individual quota from one person to another must be verified in writing by both parties. The computer system should have a series of tests that can be run frequently to verify the accuracy and consistency of reported landings and trades.

The work of monitoring agents will change under an ITQ program. The emphasis will shift from checking the day to day operations of the fleet to monitoring catch levels. It is unclear whether the actual amount of monitoring activity or its cost will increase or decrease with an ITQ program. Depending upon the circumstances, it is likely that at-sea monitoring, which can be very expensive, can be significantly reduced. On the other hand the amount of book-keeping type activities will likely be increased. Concurrently, because participants have a long term interest in protecting their harvest rights, they will be more inclined to adhere to the rules and to assist agents in detecting abuse from others.

Permits for both harvesters and processors will likely be a crucial part of an ITQ monitoring system. These permits should be available to any interested party at a nominal fee. A fisherman would be required to obtain a harvesters permit in order to own or lease ITQs. Any harvesting activity would be recorded against the harvesting permit number. Processors would be required to obtain a fish receivers permit in order to buy fish landed under the ITQ program. All purchasing and processing activity would be recorded against the fish receivers permit number. The idea behind a permit program for processors is two-fold. First, it provides for the double entry system that is necessary to establish proper supervision. Second, it provides for a broader based enforcement program. If processors have to show that fish in their possession was legally harvested, they will be very careful from whom they buy. If they will not buy illegal fish, there will less incentive for ITQ owners and non-owners alike to bring in non-quota fish.

Penalties for non-compliance should be firmly established, rigorously enforced and severe enough to encourage compliance. For intentional and rampant cheating, there should be provision to revoke harvesting or fish receiving permits and even to confiscate the basic ITQ harvesting right.

## 6. OTHER REGULATIONS

The heart of an ITQ program is the TAC. If properly enforced, it will ideally address all conservation issues. However, it is not hard to conceive of instances where conservation issues are not satisfactorily addressed in a basic ITQ program. The following are illustrations.

- A stock may be especially vulnerable to exploitation in a particular location or during a particular season. If this is the case, there may still be incentives for ITQ owners to gear up to make their catches at these times or locations so as to lower their costs. There will still be a race for catch, although it will be limited to fewer participants.
- If the TAC for one species is taken in a particular area, during a particular season, or with a certain type of gear or fishing method, the by-catch or discard mortality of other TAC species may higher than would otherwise be the case.
- Individuals in a particular stock may exhibit high growth rates over a season such that the biomass and value increases if a fish is taken later in the season.
- Fishing in nursery grounds or during spawning periods may have larger effects on future stock sizes than taking equivalent catches at other times or places.

If these or other situations occur, the actions of individuals trying to maximize their profits from their ITQs may result in harvesting patterns which do not optimally utilize the long term productive capacity of the stocks. In short, the TACs will not always address all of the biological concerns, and in such instances, it may be worthwhile to consider supplemental regulations.

The exact additional measures that will be worthwhile to institute, if any, will depend upon the particular circumstances of the fishery. A suggested approach for addressing these problems is :

i) Describe exactly the conservation problem that will not be addressed by a basic ITQ program.

ii) List possible ways in which the ITQ program can be modified so as to solve the problem.

iii) List possible supplemental regulations that will address the problems.

iv) Determine which of the potential solutions derived in Items ii and iii best addresses the problem and specify a modified ITQ program which incorporates these additional rules or procedures.

v) Compare the basic ITQ program with the modified ITQ program to determine which one most adequately addresses the management objectives. If the modified one is judged superior it should be adopted ; if not, the basic program should be used (assuming that an ITQ program is to be used). The basic issue is to make sure that the modifications do not introduce problems worse than those they solve.

Consider the case where there are nursery grounds or spawning periods where harvests can have significant long term effects. If the quality of the flesh or the product recovery rate falls during spawning, this may not be a problem because ITQ owners may not want to use their ITQs on lower valued fish. However, if costs are reduced by fishing spawning aggregations or if the roe is commercially valuable, there may be incentives to harvest spawning fish rather than at other times of the year which may create a potential problem for optimal utilization of the long term productivity of the stock.

The problem could be addressed within an ITQ program by adjusting the TAC level. Or it may be possible to assign coefficients that would transfer catches at different times of the year into equivalent terms with respect to future stock sizes. For example, each ton of fish harvested during the spawning period could count as 1.5 tons of fish harvested during other periods of the year. This would allow individuals the flexibility to operate when they wanted, but it would force

them to consider the long range effect of their decisions. This adjustment would increase management costs. Research would be necessary to calculate the appropriate coefficients, and enforcement would become more complex and perhaps more expensive.

The problem could also be addressed by adding a supplementary regulation that fishing not be allowed in spawning areas or during spawning periods. This would likely be easier to enforce but its inherent lack of flexibility may reduce the potential gains to individual operators that ITQs can provide. It is important to make sure that the gains that are provided in an ITQ program are not taken back by supplemental restrictions unless it can clearly be shown that the overall gains are greater than the costs.

The ultimate questions are which of the two modifications best addresses the problem and if it is adopted, does it provide an overall improvement in the system as a whole ? The answer will depend upon the exact biological, economic, and institutional characteristics of the fishery involved.

## 7. INITIAL ALLOCATION

The initial allocation of quota shares to individuals is obviously very important. It will, for the most part, determine who gets the gains from an ITQ program. It will determine who will be the initial participants in the fishery. How future participants will be determined depends upon the rules for transferability and the duration of the ownership rights. The importance of this decision notwithstanding, for the most part the initial allocation issue is independent of other components of an ITQ program. It is, after all, a once-and-for-all-step. Given flexible transferability rules and non-expiring ownership rights, allocation decisions only have to be made once. In order to maintain a balanced focus when considering ITQs, the independence of the initial allocation question from the other five fundamental issues (sections 2-6) should be high-lighted. Otherwise, it is possible that the distributional issues will unnecessarily cloud or over-shadow the discussions of other important, but basically independent issues.

There are literally an infinite number of initial allocation options. An option that is suitable for a particular fishery can be developed by answering the following questions.

i) Will the rights be sold or given away ? If the rights are to be sold, will it be by an auction, by sealed bids, or by some other means, and will existing participants be given a preference ?

ii) If the rights are to be given away, how will the pool of recipients be selected ?

iii) Once the pool of recipients has been selected, on what basis will the quota shares be distributed among them ?

iv) Will the quota shares be based solely on the definition of quota share stocks, or will they be further sub-divided by vessel category, gear type, or some other classification ?

# Marketing Losses in Regulated Open Access Fisheries

**James E. Wilen[a] and Frances R. Homans[b]**

[a] Department of Agricultural Economics, University of California, Davis, CA 95616 U.S.A.

[b] Department of Agricultural and Applied Economics, University of Minnesota, St-Paul, MN 55108 U.S.A.

ABSTRACT

*Much of the focus of fisheries economists' analysis of common property inefficiencies has been on the production cost side of the ledger. For example, the fundamental problem has often been described as " too many boats chasing too few fish." As a result of this view of the problem, policy recommendations have evolved through gear restrictions, limited entry, and buy-back programs, all aimed at harvesting efficiency and inputs. Ignored in all of this is the impact of common property incentives on the market or revenue side of the ledger. Casual observation suggests that there are widespread losses of revenues associated with common property exploitation that may even swamp the cost impacts. For example, the "race for fish" typical in many regulated open access fisheries often results in poor quality raw products (poor handling, lack of refrigeration, small sizes, no sorting) as well as poor quality wholesale products due to storage and freezing, etc.*

*This paper develops a model of marketing losses due to common property. We then conclude with the examination of the marketing and revenue impacts of recent introduction of ITQ's in the New Zealand groundfish fishery, the Australian Bluefin Tuna fishery, and the British Columbia halibut fishery. These cases verify one of the main hypotheses ; namely, that the gains from revenue improvements associated with higher quality products can be significant and may even swamp the production efficiency gains associated with moving away from open access and common property.*

## 1. INTRODUCTION

The literature in fisheries economics is dominated by a simple theme, namely that open access resource use dissipates the rent potential of fisheries. This theme has roots in the original paper by H. S. Gordon (1954) who analyzed the tendency for additional effort to enter beyond the point where marginal benefits equal marginal costs. A large amount of analysis has been devoted to comparisons of open access systems and various forms of regulated systems designed to correct the common property incentives.

This simple paradigm has been important in several respects to policy making in fisheries. First, by bringing attention to the rent losses inherent in open access resource use, it has resulted in important changes in the goals of regulation, away from reliance on steady-state biomass concepts and towards a focus encompassing economic efficiency and other social objectives. Second, it has fostered a broader set of policy options for consideration, including landings taxes, limited entry schemes, and recent Individual Transferable Quota (ITQ) systems in fisheries.

Although the simplicity of the basic open access paradigm has been mostly a virtue, economists have not paid enough attention to the complexity of real world rent dissipation processes and the implications for policy design. For example, the first limited entry programs were basically guided by a characterization of the rent dissipation problem as "too many boats chasing too few fish." As a result of this simple view, early programs which limited **boats** were quickly found to be ineffective as fishermen increased vessel capacity by altering other inputs. Regulators have responded haphazardly with restrictions on other dimensions of effort (such as length, tonnage, gear type) but without much guidance by economists about the nature of the choice process that fishermen use in selecting these inputs in an open access setting. An obviously important (but not well understood) variable input choice in fishing is **time** , both total fishing time and the split between fishing and searching/traveling time. Most regulatory programs regulate effective fishing time by using season length to reduce the actual impact of fleet capacity on catch. In many important fisheries, the impact of this has been a steady compression of fishing seasons into shorter and shorter periods.

The focus of this paper is on a neglected component of the rent dissipation process, namely the marketing losses associated with open access or regulated open access. Virtually all of the attention devoted by economists to the rent dissipation problem to date has been concerned with production inefficiencies. That is, nearly all analysis assumes that the major effects of open access behavior manifest themselves in inefficient production input choices, specifically, too many boats chasing too few fish, and/or inefficient input combinations in catching technology. This simplistic focus on the cost side of the profit equation runs a danger of leading to more ineffective policy recommendations and miscalculations about how the most significant gains from regulation might be achieved. Marketing losses occur in open access or regulated open access fisheries for several reasons. Foremost among these is poor quality raw product associated with the race to catch fish (gear damaged fish, undersized fish, lack of on board handling). Additional factors include reduced quality wholesale product associated with capacity bottlenecks, freezing deterioration, and inability to market when fewer substitutes are available. All of these translate into lower ex-vessel prices, which in turn affect the process of rent dissipation.

This paper presents a simple model which describes some of the components and consequences of marketing losses due to open access. In the next section, we present a model of a regulated open access fishery which reduces the comparison between an optimized fishery and the open access fishery to a few simple parameters. Then, in the following section, we discuss the implications of marketing losses in terms of the model's parameters and with three real world case studies. The final section summarizes.

## 2. MODEL OF A REGULATED FISHERY

The world has changed considerably since H. S. Gordon's seminal paper which described the process of rent dissipation in a purely open access fishery. The major changes have occurred as a result of the extension of jurisdiction in 1978 by coastal nations after the Law of the Sea negotiations. Since the extension of jurisdiction in 1978, virtually all coastal nations have had the ability, if not the resolve, to avoid the waste inherent in open access. As it has turned out, the evolution towards rationalized systems has been slow. Most fisheries today are neither open access nor anything approaching the sole owner ideal, but rather a hybridized system best called **regulated restricted** (or open) **access**. By this we mean that most fisheries retain vestiges of old biologically-determined effort restrictions within limited entry systems or in systems still open to everyone.

The most commonly observed regulatory instruments are gear restrictions such as net mesh regulations and season closures. Season closures are particularly important because they are in many fisheries the principle means of ensuring that targeted catches are not exceeded. They operate very simply : when potential effort is drawn into a fishery in response to profitability, its use is curtailed by restricting the season length over which the fleet can operate. Thus if effort increases ten percent in response to fishing profitability, we would expect the season length to decrease by a corresponding amount to hold catch constant. In a regulated open access or restricted access fishery, effort restrictions are essentially endogenous and are promulgated to ensure that a targeted catch is achieved.

These ideas can be formalized as follows. Suppose that we have a fishery whose pre-season exploitable biomass is estimated to be $X_0$. We assume for simplicity that natural mortality is insignificant and that there is no stock growth within the season so that the stock declines by the harvest h(t), where the harvest production function is $h(t) = qEX(t)$.[1] In this formulation, E is the effort level which is assumed to be constant and committed at the beginning of the season and q is a catchability coefficient. Costs consist of two components related to E, the first a cost c per unit effort per unit time and the second a cost v per unit effort. Consider first the benchmark case of a profit-maximizing industry facing a fixed price P that chooses E to maximize profit :

$$\max_E \Pi = \int_0^T [Ph(t) - cE]\,dt - vE \tag{1}$$

$$\text{subject to} \quad \dot{X}(t) = -qEX(t)$$

$$X(0) = X_0 .$$

For simplicity we ignore the discount rate. After solving the state equation and substituting, the objective function can be integrated directly to obtain

$$\max_E \Pi = PX_0[1 - e^{-qET}] - cET - vE \tag{2}$$

Under the assumption that the industry takes the season length T as given, the optimal level of E satisfies

$$E^* = \frac{1}{qT} \ln \left[ \frac{PqX_0 T}{cT + v} \right] . \tag{3}$$

To incorporate a model of the regulatory system, assume that regulators have a targeted end-of-season stock level that must be left after the fishery is completed. If this is denoted $X_T$, then the total allowable catch Q is simply the difference between the exogenous beginning stock and the targeted end of season stock[2]. Given that the state equation for the biomass is as in (1) above, the season length that ensures that the targeted stock will be achieved (with a beginning stock $X_0$ and effort level E) is given by

$$T^* = \frac{1}{qE} \ln \left[ \frac{X_0}{X_T} \right] . \tag{4}$$

Equations (3) and (4) together yield a description of a regulated fishery with (arbitrary) end of season stock level $X_T$, assuming that the industry chooses the restricted maximum profit level of E [3]. Solving these in terms of the model parameters yields

$$E^* = \frac{PqX_T - c}{qv} \ln \left[ \frac{X_0}{X_T} \right] \tag{5}$$

as the solution for the optimal level of E, and

1. This is a standard Beverton-Holt assumption which we adopt for simplicity. We are most interested in characterizing the within-season behavior of the industry and regulators in a simple fashion rather than between-season dynamics. This leads quite naturally to a structure where the biomass simply declines with cumulative fishing effort.
2. This is a simple way to capture the regulatory philosophy followed in many fisheries. It also appears objectionable to economists worried about efficiency and optimization. We should emphasize that we are modeling what regulators appear to do, rather than what they might do if they were trying to optimize.
3. Note that we have characterized all of the regulatory options that a management agency might use in a single control, the season length. In practice, regulators use other instruments but the intent is generally the same, namely to reduce the effectiveness of effort operating over the fish stock. Note also that (3) and(4) are structural decision equations. The industry is assumed to take season length as given and then maximize profits by selecting effort whereas the regulators take effort as given and choose season length according to the targeted catch.

$$T^* = \frac{v}{PqX_T - c} \tag{6}$$

as the solution for the optimal regulated season length [4]. These can be inserted into the profit function (2) to yield the maximized profits expressed as a function of the parameters, [5]

$$\Pi^* = PX_0 - PX_T\left(1 + \ln\left[\frac{X_0}{X_T}\right]\right) \tag{7}$$

Now consider the counterpart to the above regulated profit maximizing system, namely a **regulated open access** system. In this case, we assume that effort will enter until profits are driven to zero, or where

$$\Pi_0 = P_0 X_0[1 - e^{-qE_0T}] - cE_0 T - vE_0 = 0\,. \tag{8}$$

Note that we assume the price under open access is $P_0$, which may be different from the P achievable under optimized conditions. In this case we also assume that the regulators choose a season length that ensures the targeted terminal stock is achieved, or

$$T_0 = \frac{1}{qE}\ln\left[\frac{X_0}{X_T}\right]. \tag{9}$$

In this scenario, the rent dissipating effort level E can be determined to be

$$E_0 = \frac{P_0}{v}(X_0 - X_T) - \frac{c}{qv}\ln\left[\frac{X_0}{X_T}\right] \tag{10}$$

and the corresponding season length will be

$$T_0 = \frac{v \ln (X_0/X_T)}{P_0 q(X_0 - X_T) - c \ln (X_0/X_T)}\,. \tag{11}$$

Profits in this system are zero since rents are dissipated. It is easily seen that the effort level in the optimized system is lower than that in the open access system, as would be expected [6]. Since the product of the effort level and season length must be the same in both systems (see (4) and (9)), the season length in the open access system will be compressed, in order to ensure that the targeted catch is not exceeded with the higher level of effort.

## 3. MARKETING LOSSES AND RENT DISSIPATION

The incorporation of marketing losses associated with common property behavior has several impacts on the system modeled above. First note that marketing losses actually mitigate some of the normal effects of common property

4. The end of season stock level is left arbitrary. Once the initial stock is known, selecting the terminal stock is equivalent to selecting a catch target. Note also that we could in principle introduce more complicated optimization (such as between-season dynamics) by choosing the terminal stock as part of some dynamic plan, i.e. the terminal stock could also be the optimal terminal stock.
5. Note that this is a function of prices, the initial stock, and the regulator-chosen terminal stock. Costs are embedded in this equation since variable input costs are essentially determined by the regulatory choice of the terminal stock.
6. This condition is met whenever optimized profits are positive, which is always the case as long as the allowable catch is positive.

incentives because lower prices cause less effort to enter than would be the case otherwise. This allows a relatively longer season, although not as long as would be the case under an optimized system. In Figure 1 we show the combinations of effort and season length that achieve a fixed target catch under various scenarios. This relationship is depicted as a rectangular hyperbola, since $ET=(1/q)\ln(X_0/X_T)$ is assumed fixed by regulators under all scenarios. Under the optimized system at A, rents are maximized with low effort spread over a long season, with prices P. If there were no marketing losses, this same price would induce entry to point B, necessitating a very short season to ensure the targeted catch. With marketing losses reducing price to $P_0$, however, entry proceeds only to C, where a relatively longer season may be allowed.

A second implication of significant marketing losses is that the potential rent gains to be achieved under more efficient regulatory regimes will be underestimated unless the market losses are satisfactorily accounted for. From equation (7), we can calculate the total rents foregone under rent dissipation. Using (5) and (10) to calculate the excess costs $v(E_0-E^*)$, equation (12) shows that true rent losses can be partitioned into

$$\Pi^* = (P - P_0)(X_0 - X_T) + v(E_0 - E^*)\,. \tag{12}$$

Note that the first term is the revenue loss associated with poorer quality raw product and the second term is the excess costs generated with excessive effort. As $P_0$ and P diverge, $E_0$ approaches $E^*$ and the fraction of losses associated with marketing costs rises. Similarly, as $P_0$ approaches P, rent losses are dominated by production inefficiencies associated with excess effort. In evaluating regulatory changes such as limited entry/buyback and ITQ systems, it has been common practice to focus exclusively on production/capital cost savings associated with more efficient input use [7]. Equation (12) suggests two important problems with this procedure. First, by not considering potential marketing gains, the first term will be ignored. Second, by determining optimized effort under the assumption that common property marketing conditions will prevail, the level of the optimal effort $E^*$ in the second term will be underestimated [8]. Since this inflates the production cost saving estimates, these errors will be partially off-setting but the overall effect is still an underestimate of true potential rent gains. Using (5) to calculate $E^*$ with the underestimated common property price $P_0$, it can be shown that true potential rents will be underestimated by :

$$\begin{aligned}\Pi^* - \tilde{\Pi} &= (P - P_0)(X_0 - X_T) + v(E_0 - E^*(P)) - v(E_0 - E^*(P_0)) \\ &= (P - P_0)(X_0 - X_T) - (P - P_0)\,X_T \ln\left[\frac{X_0}{X_T}\right].\end{aligned} \tag{13}$$

As discussed above, this underestimate consists of the ignored marketing gains (the first term) offset partially by the second term representing overestimated production cost savings. An important empirical question which this discussion raises is : how large are the marketing losses associated with rent dissipation ? A rough idea of potential magnitudes can be inferred from three recent adoptions of ITQ systems in the Pacific Halibut fishery, the Southern Bluefin Tuna fishery, and the near-shore New Zealand groundfish fishery. The halibut fishery is a classic example of a fishery fitting the characteristics modeled above. As figure 2 shows, season length in the regulatory area 2A has been used to mitigate the potential impact of effort on the stock, with increased effort matched by decreased seasons. This fishery has pushed this scenario to extremes during recent periods, with seasons lasting for only four or five days of frenzied activity.

During the 1991 season, Canadian fishermen decided to conduct their portion of the fishery under a vessel quota system rather than the usual "fishing derby." The U.S. fishery was conducted in the normal fashion and there were reports that over fifty percent of the catch was landed without ever having been iced and about a third of the fish were not even gutted during the biggest one day opening in the first week of May. The British Columbians, in contrast, mostly chose to hold their quotas over to use after the May opening in the U.S. and before the final closing date of November. As a result significantly higher prices were obtained by Canadians. Fishermen's News (June 1991) reported that ex-vessel prices received during the later part of May by B.C. fishermen averaged $1.10 higher than those received by U.S. counterparts

7. Examples of attempts to compute rent gains from ITQ's include Dupont (1990), Geen and Nayar (1988), and Squires(1990).
8. This effort level is another point on Figure 1, say point D. This is the effort/season length combination associated with profit maximizing choice of effort at common property prices. Since by equation (5) the optimal effort is proportional to prices, this point lies to the right of point A. This in turn suggests that computing cost savings between points C and D will overstate them.

(who received about $1.70). This suggests a price "penalty" due to common property of about forty percent of potential. Similar results have emerged in the Australian Southern Bluefin Tuna fishery which converted to an ITQ system in 1984. Geen and Nayar (1988) report results of some simulations which attribute production cost savings of 25-30 % of the steady state common property fishery costs. More important, however, are the impacts on the revenue side. Significant shifts in fleet effort occurred towards regions where the average size of fish caught was larger due to the incentives to maximize revenues. In only three years of operation, the number of large fish (greater than 15 kg.) increased from 13 to 35 percent of catch This was induced by new marketing opportunities presented by the ITQ system, particularly the ability to serve the lucrative Japanese sashimi market. Significantly, revenues rose from 988 to 2000 dollars per tonne between 1984 and 1987, (in constant dollars) as a result of higher product quality and better marketing opportunities. In the New Zealand fisheries the evidence is even more startling. Early reports are that revenues **tripled** in some groundfish fisheries after the introduction of the ITQ system. This was made possible by a major shift in products marketed, away from mixed batches of small, trawl marked fish caught in compressed seasons, towards long-line caught fish, selected for size and market characteristics and spread over the whole year. Interestingly, this switch to a **costlier** technology was induced by the prospect of the marketing gains made possible by the regulatory change. Thus, in contrast to what most economists would have expected, in this case unit costs actually rose after adoption of a more efficient regulatory scheme but revenue increased more than compensated to increase profits. Needless to say, an *ex ante* analysis which attempted to predict rent gains in this fishery by examining production cost savings would have not only missed the most significant component of the rent gains, but also would have likely been carried out under the assumption that trawl technology would have continued to be in use.

## 4. SUMMARY

This paper discusses the implications of a source of rent losses not normally considered by fisheries economists ; namely losses associated with the marketing or revenue side of the profit equation. A model is developed which captures some important features of regulated restricted and open access fisheries. The model is then used to explore the implications of marketing losses. It is shown that market effects actually may mitigate the tendency towards excessive effort. However, if there are significant marketing losses, they must be accounted for when predicting or evaluating the potential of policy changes. In fisheries where our only experience is with traditional regulation regimes, it may be difficult to foresee the magnitude and kinds of revenue effects that might be induced by more efficient management. In three examples discussed here, the impacts appear to be very significant and potentially high enough to swamp any production cost savings.

## REFERENCES

**Crutchfield J. and A. Zellner** (1962). "Economic Aspects of the Pacific Halibut Fishery," in *Fishery Industrial Research*, Vol. 1, U. S. Dept of the Interior, Bureau of Commercial Fisheries.

**Dupont D. P.** (1990). "Rent Dissipation in Restricted Access Fisheries," *Journal of Environmental Economics and Management*, Vol. 19, No. 1, pp. 26-44.

**Geen, G. and M. Nayar** (1988). "Individual Transferable Quotas in the Southern Bluefin Tuna Fishery : An Economic Appraisal," *Marine Resource Economics* , Vol. 5, No. 4, pp. 365-388.

**Gordon H.S** (1954). "The Economic Theory of a Common Property Resource : the Fishery," *Journal of Political Economy*, Vol. 62, pp. 124-142.

**International Pacific Halibut Commission** (1991). Scientific Reports #67, #74.

**Squires D.** (1990). "Individual Transferable Quotas : Theory and an Application," Administrative Report LJ-90-16, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, Calif.

**Squires D. and J. Kirkley** (1991). "Production Quota in Multiproduct Pacific Fisheries, *Journal of Environmental Economics and Management*, Vol. 21, No. 2, pp. 109-126.

**FIGURE 1.**
**EFFORT AND SEASON LENGTH**

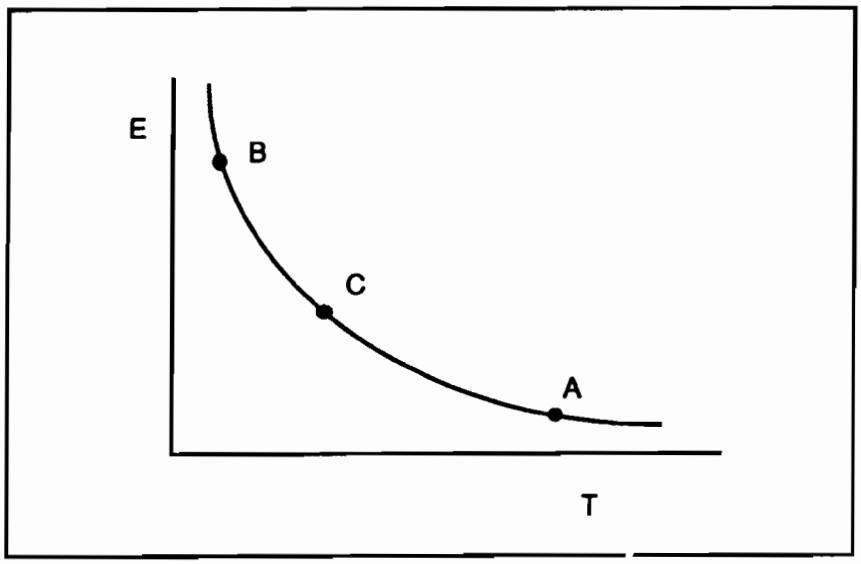
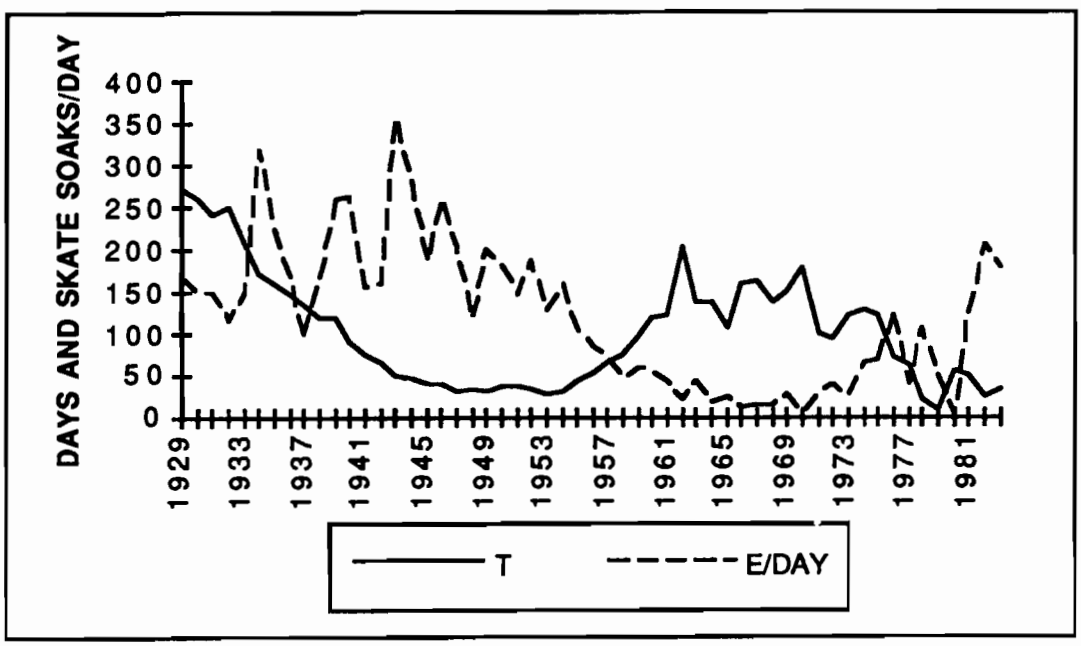



**FIGURE 2.**
**PACIFIC HALIBUT REGULATORY AREA 2A. SEASON LENGTH AND EFFORT PER DAY**



# The Role of Economics in the Development of Limited Entry Programs : Two Examples from Groundfish Fisheries in the Western United States

**James D. Hastie**[a]

[a]National Marine Fisheries Service, Northwest and Alaska Fisheries Center, 7600 Sand Point Way, NE, BIN C15700, Seattle, WA 98115, USA

ABSTRACT

*Fisheries occurring within the Exclusive Economic Zone of the western coasts of the United States have undergone tremendous changes since the implementation of the Magnuson Fishery Conservation and Management Act in 1977. Increases in fleet harvesting capacity have contributed to a growing list of problems facing fisheries managers, including reductions in the net fishery value, gear conflicts and an increasing number of contentious proposals for preferential allocation of the fish resource among various domestic user groups. In many instances, increased capacity has lead to substantial reductions in season length. These shorter seasons not only frustrate industry participants, they often create nightmares for managers, who must guard against excessive removals from the fishery, while at the same time achieving economic and social objectives.*

*Both the Pacific and North Pacific Fishery Management Councils have devoted considerable attention during recent years to proposals which would limit access to all or some of the groundfish fisheries within their jurisdictions. This paper reviews the development of two differing approaches to effort control : a vessel license form of limited entry, recently approved by the Pacific Council for their entire groundfish fishery, and ITQ proposals pending before the North Pacific Council for both sablefish (Anoplopoma fimbria) and halibut (Hippoglossus stenolepis). The paper reviews the limited role which economic analysis played in shaping the final proposals considered by each of the Councils. The availability of economic information for these analyses is discussed along with political and social issues which were influential in the decision-making process. Finally, the anticipated economic efficiency implications of these programs are assessed.*

## 1. INTRODUCTION

The objective of this paper is to describe the development of two very different proposals for limiting entry to U.S. groundfish fisheries, and assess the importance of economic analysis in their evolution. One of these programs would

limit entry to most of the groundfish fishery that occurs off the west coast of the U.S. (Washington, Oregon, California) through the issuance of a limited numbers of licenses. This fishery falls under the policy sphere of the Pacific Fishery Management Council (PFMC). The other effort, which evolved from two parallel proposals, would limit entry to sablefish and halibut fisheries off Alaska, through the issuance of individual transferable quotas (ITQs) for these species. This fishery falls under the policy sphere of the North Pacific fishery Mangement Council (NPFMC).

## 2. RECENT HISTORY OF GROUNDFISH FISHERIES OF THE WESTERN UNITED STATES

These proposals for limiting entry have not emerged from a vacuum. Both fisheries are subject to numerous management and economic problems. In order to place the emergence of the limited entry discussion in proper perspective, I will briefly review the recent history of these fisheries. At the foundation of the current fisheries management superstructure in the U.S. is the Magnuson Fisheries Conservation and Management Act of 1976 (MFCMA). This legislation not only created the regional fishery management councils, who establish much of the policy for managing the fisheries, it also established an exclusive economic zone, between 3 and 200 miles, and set forth a preference for U.S. fishing operations over the activities of foreign parties within that zone.

These actions had a tremendous impact on the development of western U.S. offshore fisheries. Figures 1a and 1b show the annual tonnage landed in west coast and Alaskan fisheries, respectively, since 1981, broken down by the mode of operation : domestic, joint-venture, or foreign. Both regions witnessed a progression from prominent foreign catcher/processor operations, through a period in which the growing domestic catcher-boat fleet supported joint ventures with foreign processing ships, to fisheries that are now wholly domestic. This transformation has been more dramatic in the fisheries off Alaska, in part because of their greater scale, but also because the west coast domestic fishery had already realized a higher degree of its potential by the mid-1970s.

This increase in domestic catching and processing has been accompanied by the entry of more vessels into the fishery. In 1981, fewer than 900 vessels landed groundfish (excluding halibut) off Alaska. By 1991, this fleet had soared to an all-time high of more than 2,200. The Alaskan halibut fleet numbered less than 2,900 in 1981, but reached 4,400 during the 1991 season (NPFMC, 1992b). The increase in fleet size has been less pronounced in the west coast fishery. However, fleet composition in both fisheries has shifted towards larger, more powerful fishing vessels over the past decade. This is particularly true in the Alaskan fisheries, where a substantial domestic factory trawler fleet has emerged.

The growth in domestic fleets has been accompanied by increasing fishery management problems. The west coast groundfish fishery has two major components : a trawl fleet which targets several different assemblages of species and a fixed-gear fleet whose major targets are sablefish and assorted rockfish species. Most west coast species are supplied primarily to domestic markets, with the exceptions of Pacific whiting and sablefish, which are largely exported to Japan. A major PFMC goal of managing the trawl fishery has been to extend the season as long as possible throughout the year, in order to stabilize employment opportunities and provide uninterupted supplies of product to regional domestic markets (PMFC, 1990). This has led to implementation of a complex system of trip landing and frequency limits for many economically desirable species. Even though the council has provided some flexibility for vessels of different sizes to meet the requirements, discarding of fish that exceed the limits has become a major concern. In a fishery that lacks any significant at-sea observer coverage, there is considerable uncertainty regarding the extent to which total removals from the fishery may be exceeding quotas or harvest guidelines. This method of management also imposes significant operating inefficiencies on the groundfish fleet.

Moreover, fishermen have repeatedly testified before the PFMC concerning the bitter irony of having to throw dead fish overboard at a time when allowable catches for many species are declining. The complexity of the regulations produces another nightmare for fishermen : simply complying with concurrent limits on several different species. Recent testimony by one enforcement official indicated that more than half of the landings which were checked for compliance were in violation of some landing restriction. In an effort to reduce some of this problem, the PFMC is experimenting during the 1992 season with a system of monthly limits for some species, which it is hoped will reduce the frequency of discard situations, as well as provide a transition to a system of transferable fishing rights.

In the fixed-gear fishery, where maintaining a steady supply of fish is less of a concern, the problem has been one of dramatically shortened seasons. Because sablefish are often caught in conjunction with other species, the PFMC has

resorted to use of trip limits for fixed-gear sablefish landings throughout much of the year in an effort to reduce discards of sablefish caught unintentionally. Prior to 1985, the only regulations affecting the sablefish fishery were limits on the amount of fish smaller than 22 inches that could be landed. During 1985, the season was closed in early December. By 1988, the season closed before September. During 1991, a 500-lb trip limit was imposed before June, and the fishery was closed entirely by July 1st (PFMC, 1991). After opening the 1992 fishery with a 500- and then 1,500-lb trip limits, unexpected high catch levels led to reduction of the limit to 250 lb prior to the start of the "open" season. The unrestricted season is expected to last less than one month this year, before trip limits are reinstated for the remaining duration of the fishery. This compression of the season has placed greater in-season monitoring demands on managers, and has significantly lowered the average income derived from this mainstay species.

The fisheries managed by the NPFMC utilize vastly larger stocks of fish, and provide a very high percentage of the resulting products, usually in frozen form, to Japanese and other foreign markets. Although steady employment opportunities are a concern of the council, it has not opted for a trip-limit style of management. Instead, both trawl and fixed-gear fisheries are managed principally by quota, with the use of multiple seasons in some cases. The trawl fishery is driven by more than 1.25 million mt of annual pollock catch, along with substantial harvest of Pacific cod and various flatfish species. As recently as 1988, the domestic fishery for pollock operated year-round (Kinoshita, et. al., 1991). By 1991, the open season had been split into two periods which totalled only 150 days of directed pollock fishing. In addition to quotas on groundfish species, harvests are limited by caps on the amount of prohibited species--such as halibut, salmon, and crab--that can be killed through incidental catch and mandatory discard. The mounting problems throughout the fishery have led the NPFMC to initiate analysis of a moratorium on new entrants to its fisheries, while a more comprehensive solution to over-capitalization can be developed.

Using quotas and season closures has also been the chief method of coping with overcapacity in the fixed-gear fisheries of the North Pacific. The halibut season in the Gulf of Alaska has been reduced from 128 days in 1975 to 20 days in 1980 to 2 days in 1991, despite a 3-fold increase in allowable commercial landings over the past decade (IPHC, 1977,1982,1991). The rapid rate of capitalization in the domestic sablefish fishery, reflected in a 50 % annual rate of increase in landings from 1981 to 1988, resulted in a similar decline in season length. During 1984, only one management sub-area had less than a 240-day season for sablefish ; and the season was open there for 6 months. By 1990, 2 of the 6 sub-areas had seasons of less than 3 weeks, while two others had openings of roughly 2 months. Together, those 4 areas accounted for nearly 90 % of the sablefish landed (NPFMC, 1991a).

Both of these management councils have struggled with the effects of overcapitalization, though they have generally appeared unwilling to take steps to remedy the underlying causes of the problem. Both councils have long histories of open access to groundfish fisheries which have engendered considerable philosophical opposition to the notion of selectively limiting access to the fish resource. What follows is a brief discussion of recent proposals for limiting entry to these groundfish fisheries, along with an evaluation of the role which economic analysis, and other factors, played in their development.

## 3. LIMITED ENTRY IN THE PFMC GROUNDFISH FISHERY

The PFMC embarked on its journey towards limiting entry to its groundfish fishery in the spring of 1987 (PFMC, 1992). At that time a group containing supporters and opponents of limited entry was formed, and given the charge to develop proposals for instituting a license limitation plan for the groundfish fishery. Two proposals were submitted to the Council during the summer of 1988. Workshops were held that winter in order to disseminate information and receive further input from the fishing community. A survey was subsequently administered, in order to obtain more input from various segments of the industry. Following deliberation of the industry response, the Council elected to continue the development of a detailed limited entry package, under the guidance of a new committee that would include not only members of the industry, but also state and federal agency representatives. This group provided guidance to a 3-member team of staff having responsibility for analysis of the proposal [1].

Even though the original thrust of the limited entry discussion had been towards a license limitation proposal, the potential for use of individual transferable quotas (ITQs) was discussed within the committee forum. While some

1. The author served as a member of this analytical team from February 1990 through the completion of the project.

segments of the fishery appeared amenable to the use of ITQs, much of the trawl fishery presented some serious problems. Several modes of trawling in this fishery involve the coincident catch of a variety of species, which in many cases have fairly independent market values and stock dynamics. Most committee members harbored serious doubts as to whether an ITQ plan could be devised, in a timely manner, which would overcome highgrading and other discard concerns in a fishery where observers were not likely to become an integral part of most fishing operations. Since the primary objective was to develop a proposal that would encompass the entire fishery, ITQs were eventually included only as a discussion item in the analysis, and were not embodied in any specific alternatives for council consideration.

From the outset, it was clear that the process of defining a limited entry fleet was not tied to the notion of an optimally sized fleet. Members of the industry expressed their displeasure with any system that would attempt to realize reductions in vessel numbers through the use of qualifying criteria. They viewed a buy-back program for permits as the only acceptable method for removing, what they considered to be, reasonably active participants entirely from the fishery. Unfortunately, without Congressional intervention, the opportunities for implementing a buy-back program were not viewed as realistic. The National Marine Fisheries Service (NMFS) lacked the funding to initiate such a program, and provisions of the MFCMA prevented NMFS from imposing an industry-funded program on all fishery participants. This set of political and administrative circumstances led to the delineation of the Council's primary objective for a limited entry program : "to limit or reduce harvest capacity in the West Coast groundfish fishery." This objective was augmented with a dozen secondary objectives, addressing a variety of economic, social, administrative, and enforcement issues. Economic objectives included promoting long-term stability, increasing net returns, maintaining opportunities for vessel flexibility, and ensuring consumers a stable supply of products at reasonable prices.

A qualifying window was established, running from July 1984 through July 1988. Two major options affecting fleet size were considered. In one, any vessel that had caught groundfish with trawl, longline, or pot gear during this window would qualify for a permit. In the other, higher qualifying criteria were set so that the number of qualifiers within each gear group would approximate the size of the active fleet during 1987. These criteria were based primarily on the number of deliveries that were made over the course of the entire window, although vessels whose landed catch was in the top 15-20 % of those using the same gear could also qualify, even if they did not meet the number-of-landings requirement. Under the more restrictive option, other vessels with some window landings that did not meet the qualifying criteria would be granted temporary, non-transferable participation rights, to allow for a period of adjustment to the new system.

It was recognized early in the process that issuing unrestricted permits to vessels or owners would allow fleet capacity to increase considerably, through the replacement of existing vessels with larger, more powerful ones. Various vessel characteristics were considered as candidates for restricting increases in vessel capacity. A vessel-length endorsement was finally chosen as a means of limiting such increases. A vessel intended to replace a qualifying vessel could not exceed the original vessel's length by more than 5 feet. Vessel permits could be combined to accomodate transfer to larger vessels, as long as the total harvesting capacity of the smaller vessels was at least as great as that of the larger one.

Because the Council had limited the scope of the available alternatives to those having at least as many participants as were observed in a recent year's fishery, one normally important economic rationale for limiting entry--namely, gains in fleet efficiency and net national benefits--was more difficult to establish than it would have been with a smaller target fleet-size. Because of the size and profitability of this fishery, relative to others, it seemed unlikely that very many vessels would be newly constructed specifically to participate in it. Thus, in terms of long-run equilibrium fleet sizes, there seemed to be little efficiency advantage from the standpoint of preventing unnecessary investment in vessels. Existing fishery management has relied upon numerous measures aimed at reducing the efficiency of individual operations--foremost among these, trip limits--and the removal of these could yield increases in fleet efficiency, as well. But, conditions that would allow the relaxation of trip limits will not occur without an actual reduction in fleet harvesting capacity. The only scenario in which noteworthy efficiency gains might result from the plan involves the entry of so much capacity into the trawl fishery that trip limits would have to be totally abandoned--because the year-round fishery could not be maintained without limits that are so low that they would create more discards than landings. The resulting compressed fishing season could lead to lower prices through the loss of some markets, and seasonal gluts of product provided to others. On the other hand, the efficiency benefits of a license plan could be enhanced, were a buy-back program to become feasible.

Beyond the matter of efficiency, however, was the question of the economic health of traditional west coast fishery participants. Deteriorating conditions in regional salmon fisheries and increasing overcapitalization in the Alaskan fleet provide some support for the argument that new capacity may be drawn into certain segments of the groundfish fishery

in the near future. In large part, then, economic analysis was left to discuss issues such as firm stability and market power, and whether the permitted fleet would be geographically representative, and of sufficient diversity that available quantities of all species would be harvested.

In March, 1991, following an intensive year of refining alternatives, analysis, and public comment, the PFMC decided that the fate of small west coast vessels, many of whom had fished predominantly for salmon during the window, needed further study. Subsequently, options for extending the end of the window period and creating an exemption for landing small quantities of fish were analyzed. In the final package, a compromise was struck, in which only landings of at least 500 lb counted towards qualifying for a permit, but a portion of species quotas, based on historical performance, would be allocated to an open access fishery for longline and pot gears, and would be managed under very restrictive trip limits. Gears not included in the limited entry program, such as nets and line gear other than longlines would also fish under the open access fishery, but could have different restrictions placed upon them than those fishing with longlines and pots. The qualifying standards for each gear group were also cut in half from the original values selected to approximate the 1987 fleet size. The conjunction of these two new requirements left the number of permanent permits relatively unchanged in the fixed-gear fleet, and reduced the number of temporary permits dramatically. But in the trawl fleet, where very few trips yielded less than 500 lb, the number of permanent permits rose by about 10 %. The proposal in this form was approved by the PFMC in November 1991, and subsequently submitted to the Secretary of Commerce for approval. Federal action on this item is still pending.

As mentioned, the analysis included general comparisons between license and ITQ approaches on several issues. It was hoped that by gradually familiarizing the Council and members of the industry with the strong points of ITQs, some of the fear and uncertainty of this style of management could by defused. In part because of the actions of the NPFMC regarding sablefish and halibut, discussed below, and perhaps also because of the increased dialogue on the subject within the license analysis, the Pacific Council initiated an ITQ scoping process in November 1991. At their April, 1992 meeting they voted to proceed with the development of an ITQ package for sablefish and halibut caught with fixed-gear.

## 4. LIMITED ENTRY IN NPFMC SABLEFISH AND HALIBUT FISHERIES

The issue of limiting entry to NPFMC groundfish fisheries dates back to at least 1982, when discussions addressed the benefits of limiting entry to the halibut fishery (NPFMC, 1992a). In 1983, the NPFMC recommended to NMFS that a moratorium on further entry be imposed in that fishery. Despite the benefits that might have been realized by that proposed action, it was not approved, on the grounds that it did not include a clearly articulated a set of goals and objectives, along with a rationale for how the action would serve those interests. During this period, the NPFMC also received comments from fishermen requesting that action be taken to ensure that the sablefish fishery did not deteriorate along the same path as the halibut fishery. Although discussion of the issue continued, by 1985 the only substantive action that had taken was the allocation of sablefish between the major domestic gear groups. This action began a continuing history of ill-fated council attempts to alleviate problems associated with excess capacity, by allocating fish to politically favored user groups.

In December of 1985, the NPFMC approved a cut-off date of September 26, 1985, which could be used to restrict the future access of those entering the sablefish fishery after the date. Subsequently, a committee was designated to review available options for addressing the fishery's problems and to contract for surveys of industry members, in order to evaluate support for alternative approaches. Following a request for input, the NPFMC received 59 separate proposals addressing sablefish management, reflecting the fragmented political nature of the fishery. Subsequent public workshops in 1988 and 1989 identified some general regional preferences for ITQs, license limitation, or continued open access management. By November, 1989 a draft analysis of 4 major alternatives had been prepared, and was released for public review. At its following meeting the NPFMC voted to move forward with a comparative analysis of ITQs (referred to as IFQs in NPFMC documents) and continued open access.

Although final action was scheduled to be taken on this issue at the June, 1990 meeting, the Council's inability to reach a clear concensus on the issue led to a series of further analyses for modifications to this original proposal. During this timeframe, a related proposal to institute ITQs in the halibut fishery was developed (NPFMC, 1991b), and eventually merged with the sablefish proposal, after some council members expressed a preference for dealing with the related matters in a joint action. Final action had been scheduled on the combined proposal for September, 1991, however the

vote was delayed until the December, 1991 meeting, at which time the proposal passed by a narrow margin. Subsequently, the matter was returned to the council's agenda for its meeting in April, 1992, where it voted not to reconsider its earlier decision, again by a narrow margin.

The evolution of the alternatives in the North Pacific discussion has, like those in the Pacific Council, been greatly influenced by "political realities" and the acceptibility of the alternatives to segments of the industry. Theoretically, ITQs allow for a gradual rationalization of the fleet, with the potential for providing compensation to those members of the fleet who elect to leave the fishery. The economic analysis of the alternatives provided as thorough a discussion as available data allowed of the comparative profitability of various sizes of vessels, in each of the management sub-areas for which quota is assigned. These measures of profitability were used to infer the most likely long-run fleet composition in each area, and the implications for equilibrium fleet size. Sensitivity analysis was conducted to assess the impact of cost reductions or increases in price that might result from implementing ITQs. The analysis also compared the impacts of different weighting schemes on the distribution of individual ITQ holdings, further comparing those values with actual landings amounts in the 1989 fishery.

Throughout the refinement of alternatives, communities supported by small-boat fleets expressed considerable concern over the likelihood of large freezer-longliner vessels buying up area quotas and removing one of their more important means of economic sustainability. This fear persisted even after the analysis indicated that these larger vessels were not likely to generate the highest rate of profit per pound of fish in several of the management sub-areas. Concern was also voiced over the possibility of harvest rights becoming controlled by speculators and other non-participants, in turn, leaving future fishermen to toil as sharecroppers. In yielding to these fears, the Council placed numerous restrictions upon the ownership and transferability of ITQs.

In an effort to prevent outside interests from gaining control of the fishery, the Council required that ITQs could only be owned by individual persons, and that in order to buy quota, an individual would have to have a minimum level of experience in Alaskan groundfish fisheries as a captain or crewman. Another major restriction on transferability limited the future use of ITQs to vessels in the same class as the vessel which landed the qualifying poundage for the person originally issued the ITQ. For this purpose, vessels were divided into three groups for sablefish : catcher-boats under 60 ft, catcher boats over 60 ft (generally under 100 ft), and freezer longliners (generally over 100 ft). The halibut plan further divided the group under 60 ft into two classes with a 35 ft dividing line.

The proposal also included limitations on the amount of quota an operation could control. Individuals could not own more than 1 % [1/2 %] of the overall quota for sablefish [halibut]. Similar percentage restrictions were also included for selected management sub-areas for both species. As a further limit on industry concentration, the percentages of the overall quotas that could be landed with any boat were restricted to the same levels as for ITQ ownership. A significant restriction on the use of ITQs necessitated that an owner of quota be aboard a vessel while it was fishing his ITQ, in order for the fish to be counted legally against his quota holdings at the time of landing. Additionally, quota would have to be held before a trip for the entire amount of the trip. The ability to adjust ITQ holdings while at sea, to avoid the necessity of discarding, was not viewed by the Council as preferable to a 5 % limit on overages for a trip, with a subsequent reconcilliation. The sum of these restrictions may be expected to have a considerable effect on the long-run efficiency of the program.

In fairness, it should be pointed out that both the sablefish and halibut fisheries would benefit greatly from implementation of even the very restrictive proposal that was approved in December, 1991. By increasing the quality of handling and the opportunity to market fresh halibut throughout the year, ex-vessel revenues would be expected to rise by 30 %. Without the pressures of a 1-day opening, harvesting and processing costs would also likely drop, resulting in an even greater net benefit to fishermen and processors. The sablefish fishery provides product predominantly for Japanese consumers, whose demand is largely seasonal, during the winter months. In previous years when Japanese fishing was allowed, harvest was concentrated at the end of the calendar year. The current spring fishery necessitates at least 6 months of storage for most of the product that is exported. Allowing fishermen to schedule sablefish fishing later in the year would reduce the cold-storage holdings, and also have a modest favorable impact on fish quality and size (Hastie). Together, these factors might represent about 10-20 % of the current ex-vessel value of the annual harvest. American fishermen and processors would be in a good position to capture a large share of this savings.

One of the more interesting aspects of this proposal's development has been the extent, and vigor, with which fishery participants objected to an offer that is as close to a compensated pareto improvement as we are likely to experience in fisheries management. People sincerely objected to having the option to sell their interest in the fishery to the highest

bidder. Admittedly, some recent entrants to the fishery may not have qualified for as much poundage as they were expecting, or hoping, to catch in the future. However, with significant increases in net return per pound, even many of the people receiving lower poundage might expect to receive comparable profit from their ITQ holdings. The overriding factor in this dissention appears to be tied intrinsicly to the issue of maintaining the way of life in small coastal communities ; making sure that their residents have at least some continuing access to the fishery. For example, a report prepared for industry interests in southeast Alaska suggested that poor rural fishermen would be "more likely to sell their quota shares (out of necessity) than their high income urban neighbors." Similar concern is expressed in the report over the rural poor's access to capital markets, for acquiring ITQs. One is left to speculate as to whether these people would be better off facing the same necessities during the 11 months of the year when these fisheries are closed, without having the asset of their ITQ holdings. Such concerns over the future viability of rural life in Alaska are important, to be sure. But, none of the ITQ proposals presented for council action over the past two years would prevent the State of Alaska or any municipality from helping, in some way, to underwrite the cost of acquiring quota by people in these communities. Given these concerns, it is interesting that much of the criticism of the ITQ plan also centers around the economic windfall that would be provided to those receiving quota. While an auction-based system for allocating harvest rights would be desirable, from the standpoint of recapturing resource rents from the public resource, such charges are not currently compatible with the MFCMA.

## 5. SUMMARY

Discussion of the need for limiting entry in the fisheries is often spearheaded by economists. Within the arenas of the Pacific and North Pacific Fishery Management Councils, economists have played an important role in stimulating the discussion of various limited entry options as more comprehensive approaches to solving both emerging and mature management problems. Although some segments of the industry have embraced the general concept of limited entry, that support often withers in the face of specific proposals. Furthermore, a large portion of the industry continues to express the belief that competition, within an olympic style fishery, is the appropriate method of determining who belongs in the fishery and who doesn't. These participants often appear to place a higher priority on having the continuing opportunity to race for fish than on generating higher returns, either for the industry, in general, or themselves, in particular. Inevitably, where strong industry support is obtained, it is received only after conditions in the fishery in question degenerate to such an extent that the alternative mangement measures needed to cope with them become unbearable to a majority of the fleet.

One might envision a system of management wherein policy makers would identify problems in the fishery, define a set of objectives for potential solutions to the problems, and then allow a team of technical advisors, including economists, to outline the most effective means of achieving those objectives. In the management of western U.S. fisheries, it is much more common for alternative actions to be delineated by council members, often before a clear and complete statement of the problem has been articulated. As a result, the role of the economist in the development of fishery policies, such as limited entry, is less one of analyzing problem situations, and devising solutions for them, than of analyzing the likely effects of preconceived solutions to ambiguously stated problems.

Throughout the process of transforming western U.S. fisheries into domestic ventures, additional fish could often be transferred from foreign allocations, so that newcomers did not significantly reduce the amount of fish available to existing domestic users. Having exhausted this buffer, and with it the opportunity to continually increase the size of the domestic "pie", the fishery management councils in this region have been asked with increasing frequency to allocate fish between competing domestic users. Even though these allocation issues consume massive amounts of council, committee and research time, the councils are reluctant to bequeath their allocation authority to the marketplace. Some of this hesitence undoubtedly stems from the fact that most council members represent specific interest groups. Agreeing to a market-based solution to allocation would place each member in the position of forfeiting much of his future ability to help his constituency via accustomed political channels. Because no one is certain how the distribution of fishing rights would evolve under ITQs, all members become more cautious. Often, by the time a political concensus can be forged among the various factions participating in the fishery and the management dialogue, a proposal is watered down by concessions to the point where comparatively few of the stated objectives, particularly the economic benefits, can be realized.

An outside observer would surely wonder whether this method of management produces policies that are in the best interest of the general public, to whom the resource rightly belongs. The problems embodied in current management are not new, having been addressed by James Madison at the inception of the United States.

He continues by noting that the only relief from the tyranny of such factions lies in principal of the republic, and its representative form of government. Within the present Council structure, there is neither the effort to insure that those who serve do not have ongoing financial interests in the fishery, nor recourse by the general populace to elect new representatives to such bodies should their decisions, or lack thereof, stray far afield from the common good. Since neither the present Council structure nor existing over-capacity problems are likely to be remedied in the near future, it would appear that management policy in the western U.S. fisheries will continue to be shaped principally by the strongest industry groups, leaving management economists with a narrow and often ineffective role in solving the many problems faced by these fisheries.

The most common and durable source of factions has been the verious and unequal distribution of property... The regulation of these various and interfering interests forms the principal task of modern legislation and involves the spirit of party and faction in the necessary and ordinary operations of the government... It is vain to say that enlightened statesmen will be able to adjust these clashing interests and render them all subservient to the public good. Enlightened statesmen will not always be at the helm. Nor, in many cases can such an adjustment be made at all, without taking into view indirect and remote considerations, which will rarely prevail over the immediate interest which one party may find in disregarding the rights of another or the good of the whole (Hamilton, 1961).

## REFERENCES

**Hamilton A., J. Madison and J. Jay** (1961). *The Federalist Papers.* The New American Library, Inc., New York, 560 p.

**Hastie J.D.** (1989). An Economic Analysis of Markets for U.S. Sablefish. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-171, 71p.

**International Pacific Halibut Commission (IPHC)** (1991). Annual Report, 1990. Seattle, WA.

**International Pacific Halibut Commission (IPHC)** (1982). Annual Report, 1981. Seattle, WA.

**International Pacific Halibut Commission (IPHC)** (1977). Annual Report, 1976. Seattle, WA.

**Kinoshita R.K. et al.** (1991). Economic Status of the Groundfish Fisheries off Alaska. Unpubl. manuscr., 94 p. Northwest and Alaska Fisheries Center, 7600 Sand Point Way, NE, BIN C15700, Seattle, WA 98115.

**North Pacific Fishery Management Council (NPFMC)** (1991a). Longline and Pot Gear Sablefish Management in the Gulf of Alaska and the Bering Sea/Aleutian Islands. Revised Supplement to the Draft Supplemental Environmental Impact Statement/Regulatory Impact Review/Initial Regulatory Flexibility Analysis. Anchorage, AK. May 13, 1991.

**North Pacific Fishery Management Council (NPFMC)** (1991b). Proposed Individual Fishing Quota Management Alternatives for the Halibut Fisheries in the Gulf of Alaska and the Bering Sea/Aleutian Islands. Draft Environmental Impact Statement/Regulatory Impact Review/Initial Regulatory Flexibility Analysis. Anchorage, AK. July 19, 1991.

**North Pacific Fishery Management Council (NPFMC)** (1992a). Supplemental Analysis of the Individual Fishing Quota Management Alternatives for Fixed Gear Sablefish and Halibut Fisheries in the Gulf of Alaska and the Bering Sea/Aleutian Islands. Anchorage, AK. March 27, 1992.

**North Pacific Fishery Management Council (NPFMC)** (1992b). Unpubl. data. Anchorage, AK.

**Pacific Fishery Management Council (PFMC)** (1990). Amendment 4 to the Fishery Management Plan for Pacific Coast Groundfish. Portland, OR. January, 1992.

**Pacific Fishery Management Council (PFMC)** (1991). Status of the Pacific Coast Groundfish Fishery through 1991 and Recommended Accep table Catches for 1992. Portland, OR. October, 1991.

**Pacific Fishery Management Council (PFMC)** (1992). Amendment 6 (Limited Entry) to the Fishery Mangement Plan for Pacific Coast Groundfish. Supplemental Environmental Impact Statement/Regulatory Impact Review. Portland, OR. January, 1992.

FIGURE 1A.
TOTAL WEST COAST GROUNDFISH HARVEST, BY FISHERY MODE, 1981-91.

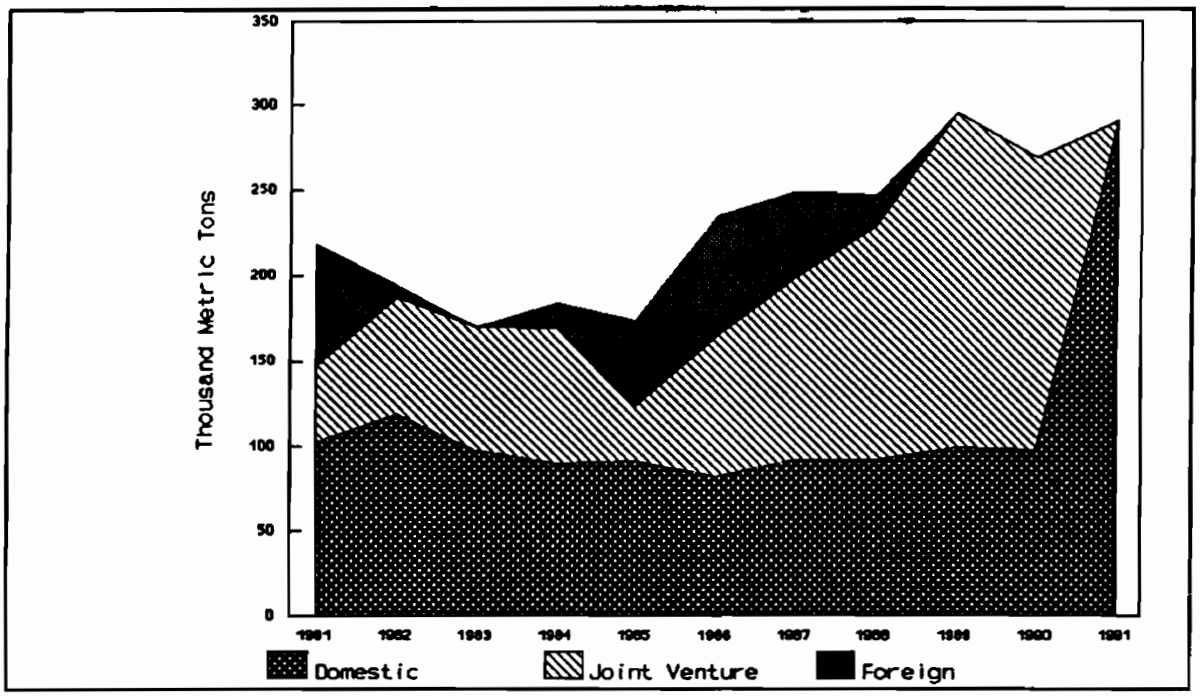
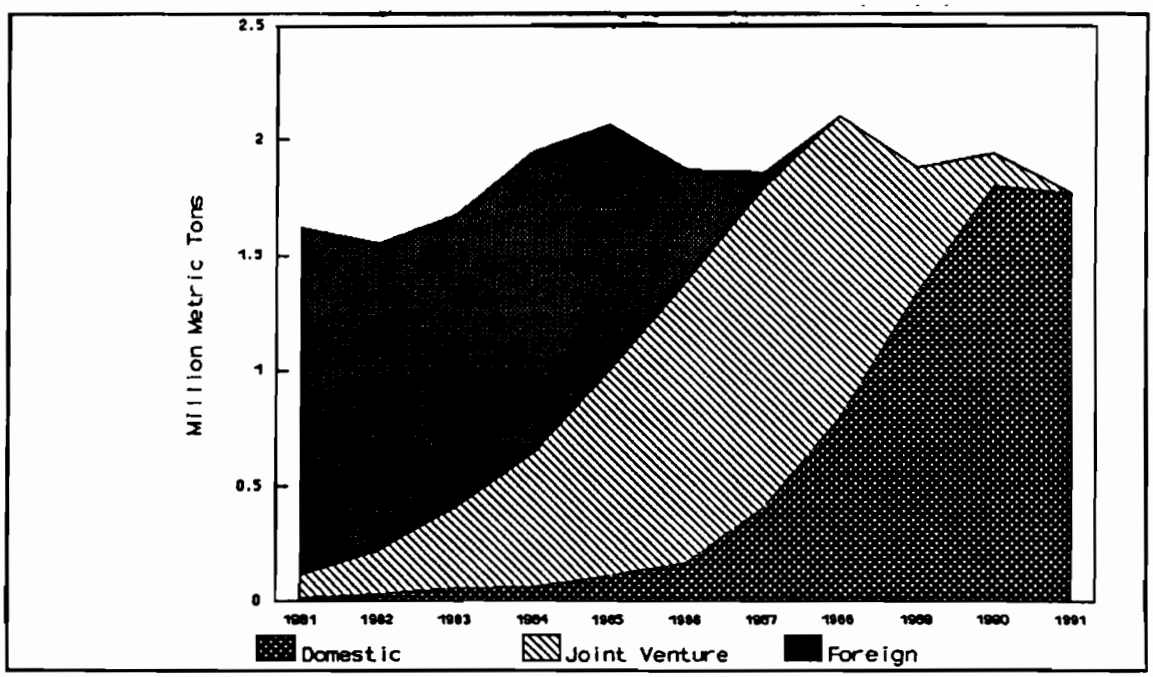



FIGURE 1B.
TOTAL ALASKAN GROUNDFISH HARVEST, BY FISHERY MODE, 1981-91.




Source : Pacific Fisheries Information Network, 76000 Sand Pt. Way, NE, Seattle, WA 98115.

# Exvessel Price Behavior in West Coast U.S. Groundfish : Implications for the Choice of Fishery Management Technique

**Susan Hanna** *

Department of Agricultural and Resource Economics, Oregon State University Corvallis, Oregon 97331, USA

ABSTRACT

*The objective of this paper is to examine the interaction of the exvessel market with the fishery harvest sector and analyze implications of this interaction for the choice of fishery management technique.*

*Historical trends in exvessel prices for several groundfish (demersal) species are illustrated. The structure of the exvessel market is detailed, including price negotiating processes and tie-in sales. Estimates of price flexibilities and elasticities are presented. Major factors influencing the responsiveness of groundfish prices at the exvessel level are identified, including fluctuations in exchange rates and substitution relations with nonseafood commodities. The role played by market factors in driving fishing effort is discussed.*

*Fishery management in West Coast U.S. groundfish is at a juncture. Established management techniques of gear regulations and trip quotas are under reexamination. New management approaches of license limitation and individual fisherman quotas (IFQ's) are being considered. A major concern of industry representatives is to assess the impact of each management technique on the structure and function of the exvessel market. The historical behavior of exvessel groundfish prices carries implications for the impact each type of management technique is likely to have on the harvest sector. These implications are discussed.*

* This publication is the result of research sponsored by Oregon Sea Grant with funds from the National Oceanic and Atmospheric Administration, office of Sea Grant, Department of Commerce, under Grant No. NA85AA-D-SG095 (project no. R/ES-13) and from appropriations made by the Oregon State Legislature. The U.S. Government is authorized to produce and distribute reprints for governmental purposes, notwithstanding any copyright notation that may appear hereon. The provision of unpublished data by Jim Hastie and the review comments of David Brooks are gratefully acknowledged.

## 1. INTRODUCTION

This paper presents an overview of exvessel prices for two major West Coast groundfish species : rockfish (*Sebastes* spp.) and Dover sole (*Microstomus pacificus*). These species are the "bread and butter" species of the mixed groundfish landings, constituting the bulk of the quantity landed in any given year. Price and landings data are available in various sources for various time periods. Major data sources are the PacFIN Management Data Base, state fishery agencies, and the Fisherman's Marketing Association. Data from these sources are summarized in the "Economic Status of the Groundfish Fishery" reports published annually by the National Marine Fisheries Service Southwest Region and in various reports of the Pacific Fishery Management Council.

The discussion is divided into 5 sections : 1. Price series of rockfish and Dover sole ; 2. Exvessel price correlations for major groundfish species ; 3. Price-quantity relationships ; 4. Price response relationships ; 5. Implications of rockfish and Dover sole price behavior for choice of fishery management technique.

## 2. PRICE SERIES

Series of nominal exvessel prices for West Coast groundfish show a marked and continual upward movement since the 1970's for Dover sole and rockfish (Figure 1). Embedded in the nominal time series is a general price inflation which distorts the true direction of change in exvessel prices. Time series adjusted for the effects of inflation reveal a different pattern of change. The series of real prices for Dover sole and combined rockfish (Figure 2) shows a cyclic pattern that is repeated for each species between 1962 and 1988. Real prices for these species rose and fell in four cycles : 1963-1971 ; 1971-1976 ; 1976-1981 ; 1981-1988. In general, each cycle occurred at a slightly higher price level than the previous one, resulting in a slight increase in average real price from one cycle period to the next. The exception to this trend is a $.01 decline in the average real price of Dover sole between the 1976-1981 period and the 1981-1988 period.

West Coast groundfish prices show different degrees of seasonal variability. Trawl gear prices are influenced by negotiations between processors and the Fisherman's Marketing Association (FMA). These negotiations establish market orders specifying minimum exvessel prices to be received by FMA members over a specified time period. As such, prices for most groundfish species tend to be fairly stable within a market order period, typically about six months. However, the stabilizing influence of the FMA price does not always dampen coastwide exvessel price variation over seasons or areas. Current work in progress with data on FMA market order prices is expected to yield insight into the role FMA prices play in influencing price levels and directions of change for all West Coast groundfish prices.

Price differences by size are not an important element in the exvessel price of most West Coast groundfish. Sablefish (*Anoplopoma fimbria*) is the notable exception. In 1987 and 1988, exvessel price ranged from $.33 to $.45 per pound between large and small sablefish caught by trawl gear. In that time period, the price difference by size was even greater for longline caught sablefish, ranging from a $.43 to a $.46 per pound difference between large and small sablefish (Hastie 1989).

## 3. PRICE CORRELATIONS

Correlations between exvessel prices of Dover sole and rockfish and other major West Coast groundfish species are reported in Table 1. As with the nominal price series, correlations of nominal prices show a strong relationship that includes the general inflationary trend in prices over the time period. Adjusting for the inflationary trend reveals interesting differences in the strength of association between various species exvessel prices.

Not surprisingly, the highest correlations between exvessel prices exist for species of similar characteristics. Real prices for flatfish species (Dover sole, English sole, Petrale sole) are strongly related : correlation coefficients (R's) range between 87 and 93. Roundfish species (combined rockfish, widow rockfish, sablefish) show similar strong associations : correlation coefficients range between 62 and 99. An interesting exception to the general pattern of stronger associations among species of similar type is the high correlation between Petrale sole price and widow rockfish price (R =.9).

## 4. PRICE-QUANTITY RELATIONSHIPS

Plots of real prices and quantities landed of rockfish and Dover sole (Figures 3-4) exhibit some interesting patterns. Rockfish exvessel price and quantity were stable between 1971, followed by a period of increase in both exvessel price and quantity landed. Between 1980 and 1985, price and quantity of rockfish showed an inverse relationship : quantity landed peaked in 1982 ; real prices were at their lowest level in 1981 followed by a steady climb until 1988. Between 1982 and 1986 the quantity of rockfish declined, followed by a steady two year period between 1986-1988. The quantity of rockfish landed becomes constrained by regulation to an increasing extent after 1983. By 1986 landings of several rockfish species had been stabilized at equilibrium yield levels.

Real exvessel price and quantity landed of Dover sole generally move in the same direction between 1971 and 1980, changing to an inverse relationship between 1984 and 1987. Unlike rockfish, regulations have not played a direct role in limiting Dover sole landings until very recently. Direct restrictions still do not apply to Dover sole by itself, but beginning in 1991 restrictions were applied to the deepwater complex from which Dover sole is taken in order to limit harvest on sablefish and other associated species (Pacific Fishery Management Council 1991). However, market factors do play an important role in limiting landings. Dover sole are not considered high quality flatfish and as such face limited markets. Limits placed by groundfish processors on size of Dover sole landings remain the most important factor affecting quantities landed.

## 5. PRICE RESPONSE RELATIONSHIPS

A set of fundamental questions regarding exvessel prices of groundfish have to do with the responsiveness of species price to changes in other factors. Of particular interest for policy and market analysis is the responsiveness of species price to changes in the quantity landed, changes in quantities of available substitutes, and changes in prices of substitute species. The responsiveness of prices to changes in quantities landed or other factors is called price flexibility.

Price flexibility equations have been estimated for the two major groundfish species, rockfish and Dover sole. Initial estimations have been made using 26 years of data on landings and prices. The time period covered by these data encompasses a major change in institutional arrangements for the fishery brought about by the passage of the Magnuson Fishery Conservation and Management Act (MFCMA) of 1976. Accordingly, estimations were made for two time periods : the entire 1962-1988 time period and the 1977-1988, post MFCMA, period.

For the longer time period, four equations were estimated using annual observations (Table 2). Two equations each were estimated for Dover sole and rockfish. One set of equations estimated each species' real exvessel price as a function of own quantity landed, substitute species quantity landed, and real per capita disposable income. A second set of equations estimated real exvessel price as a function of own quantity landed in the previous year, substitute quantity landed in the current year, and real per capita disposable income. For the shorter time period, for which data on imports of Canadian groundfish were available, four additional equations were estimated incorporating imports of Canadian cod and flatfish.

Results of the estimations without imports are reported in Table 3. In general, the equations estimated for the 1977-1988 time period (equations with subscripts n) have better fits than those estimated for the longer time period. The rockfish equations have better fits than equations estimated for Dover sole. The rockfish equation with the best fit is, for each time period, rockfish price as a function of own quantity landed in the current time period and other factors (Equations $R_1$ and $R_{1n}$). The Dover sole equation achieved the best fit for the 1977-78 time period when price was estimated as a function of lagged own quantity and other factors (equation $D_{2n}$).

Canadian imports of groundfish are anecdotally identified as substitutes for West Coast groundfish. Price response equations including imports of Canadian flatfish and Canadian roundfish are presented in Table 4. Both current year and lagged year own quantity equations are estimated. The addition of an import variable improves the overall fit of the estimation in all cases, but the coefficients for import quantities do not have the expected negative sign.

Price flexibility to landings measures the sensitivity of a species price to the quantity of that species landed. Price flexibility coefficients are expected to have a negative sign, illustrating an inverse price/quantity relationship. Prices are called flexible if the price flexibility coefficient has an absolute value greater than one : this means that for every 1 % change in quantity landed, prices change by greater than 1 %. Price flexibility coefficients with values less than one indicate an inflexibility of prices to changes in own quantities landed.

Price flexibility to own landings is calculated as :

$$F_{p1} = \frac{\partial p}{\partial q} \cdot \frac{\bar{q}}{\bar{p}}$$

Price-landings flexibility coefficients calculated from regression equation coefficients ($\delta p / \delta q$), mean price ($\bar{p}$), and mean quantities ($\bar{q}$) are displayed in Table 5.

Seven of the eight flexibility coefficients for own price ($R_1$, $R_2$, $D_1$, $D_2$, $R_{1n}$, $R_{2n}$, $D_{1n}$, $D_{2n}$) have the expected negative sign. In contrast, because the coefficients on import quantities have positive signs, import price flexibility coefficients have positive signs. All flexibility coefficients have absolute values less than one, indicating an inflexibility of real exvessel prices of both rockfish and Dover sole to changes in own quantities landed over the two time periods. For example, the flexibility coefficient of -.56 measured for Dover sole ($D_{2n}$) indicates that a 1 % increase in Dover sole landings will result in only a.56 % decrease in Dover sole price.

Import price flexibilities have lower values than own price flexibilities for the same time period, indicating a lower degree of response in domestic groundfish prices to changes in import quantities than to changes in own quantities. The positive sign of the import price flexibilities is counter-intuitive, indicating that changes in quantities of groundfish imports are associated with changes in domestic groundfish price of the same direction. This relationship is in direct contradiction to widespread anecdotal evidence. It is generally accepted that under favorable price conditions Canadian groundfish is substituted in West Coast processing lines for domestic groundfish, leading to lower prices offered to West Coast groundfish fishermen. The degree of acceptance of this general knowledge leads to the conclusion that problems may exist with the equations as currently specified.

Price flexibility values for Dover sole and rockfish are consistent with the range of values reported for other groundfish by Wang (1985), Bockstael (1977), and Crutchfield and Gates (1982). Own price flexibilities are higher for the 1977-1988 period than for the 1962-1988 period, reflecting a period of the fishery with more developed markets and more players in the market. Values of import price flexibilities for 1977-1988 are consistent with those of own price flexibilities for the period 1964-1988.

Price response equations for West Coast sablefish landed by fixed gear (longline and pot) have been estimated by Hastie (1989). The market for sablefish landed by this gear type is primarily a Japanese export market. Nominal fixed-gear exvessel price is estimated to be a function of lagged own price, Tokyo Central Wholesale Market price, and the exchange rate. The importance of the export market for this species caught by fixed gear is reflected in the $R^2$ of.84 for the estimated equation. Price flexibility with respect to the exchange rate has an estimated value of -.8. This value suggests an almost unit flexibility of exvessel fixed-gear price to changes in the exchange rate ; i.e.a 1 % increase in the exchange rate will lead to an almost equivalent decrease in exvessel price. Hastie's results also suggest that over time the Japanese market has played an increasingly influential role in the formation of West Coast fixed gear sablefish prices.

## 6. IMPLICATIONS FOR CHOICE OF MANAGEMENT TECHNIQUE

Work is continuing to establish as full a picture of the West Coast groundfish price structure as the data will allow. Work to date has established several important basic attributes of this price system which have implication for the choice of management technique. Prices show seasonal variations to varying degrees but because of the price negotiating system are relatively stable. Real prices of groundfish have both increased and declined over the past 12 years at the exvessel level. Strong correlations exist between exvessel prices of species of similar type, but weaker correlations exist between exvessel prices of species of different types. Exvessel prices of two major West Coast groundfish species are fairly inflexible to quantities landed and to quantities imported.

Management of the West Coast groundfish fishery has become increasingly complex over time, moving from an olympic system of landings within overall annual quotas to a modified olympic system within trip quotas. "Trip limits" are established for several groundfish species to limit both the quantity and frequency of landings and to space landings throughout the year. Because targeting takes place on multispecies assemblages, trip limits indirectly limit landings of associated species and/or result in discards at sea of limited species when fishing continues in the same biological assemblage.

The exvessel market effect of trip limits is twofold : variability in quantities landed is dampened through upper limits per unit of time placed on certain species ; fishermen control of the timing of quantities landed is diminished. For example, fishermen cannot forego targeting a species until late in the season in order to take advantage of more favorable market conditions because they will face the same or even greater restrictions on landings later in the season than early.

Regulatory trip limits are supplemented by limits placed on landings of certain species by processors. Processors may direct vessel captains before a trip begins to bring in only certain combination of species and may also specify quantity limits of species combinations. The effect of these combined limits is to place the balance of exvessel market power with processors, a further contributor to low flexibilities of price response to quantities landed. Processors are in a position to absorb the effects of favorable market conditions through increases in exvessel-wholesale margins without passing price increases on to fishermen.

Changes in the regulatory system for West Coast groundfish offer the potential for a freer functioning exvessel market which would be reflected in increased price flexibilities. A license limitation program has been developed for the three major groundfish gears : trawl, longline and pot. This program, on the verge of implementation, has the potential to increase market power of fishermen only in the long run as effort reduction strategies slowly take effect. However, in conjunction with the license limitation program, individual quota (IQ) systems are also under consideration for several groundfish species. IQ systems have the potential to place more control over timing and composition of landings in the hands of fishermen. The design and the nature of implementation of IQ systems in this fishery will be critical factors in the extent to which fishermen market power increases. For example, if IQ's are layered over existing trip limit systems, a major benefit of such systems in terms of increased flexibility of fishermen choice in landings will be removed.

## REFERENCES

**Bockstael N.E.** (1977). A market model for the New England Groundfish Industry. University of Rhode Island, Agricultural Experiment Station Bulletin No. 422.

**Crutchfield S.R. and J.M. Gates** (1982). Tariffs, quotas, and U.S. groundfish imports : an applied welfare analysis. Staff Paper, Department of Resource Economics, University of Rhode Island.

**Hastie J.D.** (1989). An economic analysis of markets for U.S. sablefish. NOAA Technical Memorandum NMFS F/NWC-171, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

**Korson C.S. and R.K. Kinoshita** (1990). Economic status of the Washington, Oregon and California groundfish fishery in 1988. NOAA Technical Memorandum NOAA-TM-NMFS-SWR-023, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service Southwest Fisheries Center.

**Pacific Fishery Management Council** (1982). Pacific coast groundfish plan, Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW. First Avenue, Portland, Oregon 97201.

**Pacific Fishery Management Council** (1989). Status of the Pacific coast groundfish fishery through 1989 and recommended accep table biological catches for 1990, Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW. First Avenue, Portland, Oregon 97201.

**Pacific Fishery Management Council** (1991). Status of the Pacific coast groundfish fishery through 1991 and recommended acceptable biological catches for 1992, Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW. First Avenue, Portland, Oregon 97201.

**Wang S.D.H.** (1985). Partial adjustment price models : a study of the impact of fish imports on ex-vessel prices of New England groundfish. pp. 221-232 in Proceedings of the *Second Conference of the International Institute of Fisheries Economics and Trade,* Christchurch, New Zealand, August 20-23, 1984, Volume 1.

**TABLE 1.**
**CORRELATION (R) OF NOMINAL AND REAL EXVESSEL PRICES FOR SELECTED GROUNDFISH SPECIES.**

| Nominal Exvessel Prices | | | | | | |
|---|---|---|---|---|---|---|
| | Dover | English | Petrale | Rockfish | Widow | Sable |
| Dover | 1.00 | .93 | .87 | .88 | .84 | .88 |
| English | | 1.00 | .91 | .84 | .92 | .73 |
| Petrale | | | 1.00 | .90 | .97 | .67 |
| Rockfish | | | | 1.00 | .99 | .84 |
| Widow | | | | | 1.00 | .62 |
| Sable | | | | | | 1.00 |
| **Real Exvessel Prices** | | | | | | |
| | Dover | English | Petrale | Rockfish | Widow | Sable |
| Dover | 1.00 | .87 | .79 | .56 | .36 | .64 |
| English | | 1.00 | .69 | .54 | .37 | .64 |
| Petrale | | | 1.00 | .76 | .90 | .54 |
| Rockfish | | | | 1.00 | .99 | .84 |
| Widow | | | | | 1.00 | .75 |
| Sable | | | | | | 1.00 |

Data Source: Korson and Kinoshita (1990).

TABLE 2.
PRICE RESPONSE EQUATIONS FOR ROCKFISH AND DOVER SOLE.

Eight equations were estimated using annual observations for each time period (1963-88; 1977-88). Equations were specified as:

$$P_{Rt} = b_0 + b_1 Q_{Rt} + b_2 Q_{Dt} + b_3 PCY_t \qquad (R_1)$$

$$P_{Rt} = b_0 + b_1 Q_{R(t-1)} + b_2 Q_{Dt} + b_3 PCY_t \qquad (R_2)$$

$$P_{Rt} = b_0 + b_1 Q_{Rt} + b_2 Q_{Dt} + b_3 Q_{IRt} + b_4 PCY_t \qquad (R_{1im})$$

$$P_{Rt} = b_0 + b_1 Q_{R(t-1)} + b_2 Q_{Dt} + b_3 Q_{IRt} + b_4 PCY_t \qquad (R_{2im})$$

$$P_{Dt} = b_0 + b_1 Q_{Dt} + b_2 Q_{Rt} + b_3 PCY_t \qquad (D_1)$$

$$P_{Dt} = b_0 + b_1 Q_{D(t-1)} + b_2 Q_{Rt} + b_3 PCY_t \qquad (D_2)$$

$$P_{Dt} = b_0 + b_1 Q_{Dt} + b_2 Q_{Rt} + b_3 Q_{IFt} + b_4 PCY_t \qquad (D_{1im})$$

$$P_{Dt} = b_0 + b_1 Q_{D(t-1)} + b_2 Q_{Rt} + b_3 Q_{IFt} + b_4 PCY_t \qquad (D_{2im})$$

where $P_{Rt}$ = price of rockfish in year t

$P_{Dt}$ = price of Dover sole in year t

$Q_{Rt}$ = landed quantity of rockfish in year t

$Q_{Dt}$ = landed quantity of Dover sole in year t

$Q_{R(t-1)}$ = landed quantity of rockfish in year t-1

$Q_{D(t-1)}$ = landed quantity of Dover sole in year t-1

$Q_{IRt}$ = imported quantity of Canadian roundfish in year t

$Q_{IFt}$ = imported quantity of Canadian flatfish in year t

$PCY_t$ = deflated per capita disposable income in year t

TABLE 3.
PRICE RESPONSE EQUATIONS ESTIMATED FOR WEST COAST ROCKFISH AND DOVER SOLE.

| | Coefficients (T Statistics) | | | | | Adjusted $R^2$ | Time Period |
|---|---|---|---|---|---|---|---|
| | Intercept | Own Q | Lag Q | Sub Q | Income | | |
| **Rockfish** | | | | | | | |
| ($R_1$) | -.1668<br>(-1.68)* | -1.314E-06<br>(-2.56)*** | - | 4.042E-06<br>(1.67)* | .416E-04<br>(3.13)*** | .86 | 1964-1988 |
| ($R_2$) | -.1322<br>(-1.75)** | - | -6.582E-07<br>(-1.04) | 1.393E-06<br>(.34) | .401E-04<br>(2.86)*** | .67 | 1964-1988 |
| **Dover Sole** | | | | | | | |
| ($D_1$) | -.0055<br>(-.06) | 6.879E-07<br>(.272) | - | -5.537E-07<br>(-1.067) | .276E-04<br>(2.19) | .57 | 1964-1988 |
| ($D_2$) | -.0285<br>(-.51) | - | -3.400E-06<br>(-1.43)* | -2.076E-07<br>(.56) | .362E-04<br>(3.76)*** | .49 | 1964-1988 |
| **Rockfish** | | | | | | | |
| ($R_{1n}$) | -.3627<br>(-3.42)*** | -1.660E-06 | - | 3.371E-06<br>(1.21) | .671E-04<br>(5.16)*** | .86 | 1977-1988 |
| ($R_{2n}$) | -.436<br>(-3.55)*** | - | -1.718E-06<br>(-2.32)*** | 7.703E-06<br>(1.55)* | .667E-04<br>(4.00)*** | .79 | 1977-1988 |
| **Dover Sole** | | | | | | | |
| ($D_{1n}$) | .0957<br>(.74) | -3.921E-06<br>(-1.15) | - | -1.015E-06<br>(-1.72)* | .275E-04<br>(1.73)* | .47 | 1977-1988 |
| ($D_{2n}$) | -.0084<br>(-.08) | - | -7.510E-06<br>(-3.25)*** | -8.015E-06<br>(-2.03)** | .451E-04<br>(3.53)*** | .73 | 1977-1988 |

* Significant at .10 level
** Significant at .05 level
*** Significant at .01 level

Note: Equations with subscripts 3 and 4 are equivalent in specification to equations with subscripts 1 and 2 respectively, but are estimated for time period 1977-1988.

TABLE 4.
PRICE RESPONSE EQUATIONS WITH IMPORTS ESTIMATED FOR WEST COAST ROCKFISH AND DOVER SOLE.

| | Coefficients (T Statistics) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Intercept | Own Q | Lag Q | Sub Q | Import Q | Income | Adj $R^2$ | Time Period |
| Rockfish | | | | | | | | |
| ($R_{1im}$) | -.2570 (-2.51)** | -1.58E-06 (-4.19)*** | | 6.574E-06 (3.03)** | 2.183E-08 (2.83)** | .462E-04 (3.68)*** | .94 | 1978-88 |
| ($R_{2im}$) | 0.3073 (-2.59)** | | -2.041E-06 (-4.18)*** | .129E-04 (3.91)*** | 1.798E-08 (2.35)** | .393E-04 (2.46)** | .93 | 1978-88 |
| Dover Sole | | | | | | | | |
| ($D_{1im}$) | .385 (1.69) | -4.883E-06 (-1.37) | | -1.514E-06 (-2.23)* | 3.846E-08 (1.371) | -4.500E-06 (-.168) | .52 | 1978-88 |
| ($D_{2im}$) | .320 (3.02)** | | -7.095E-06 (-4.80)*** | -1.562E-06 (-4.75)*** | 2.076E-08 (3.55)*** | 2.076E-08 (.54) | .90 | 1978-88 |

TABLE 5.
OWN-PRICE AND INPUT PROCE FLEXIBILITY COEFFICIENTS : ROCKFISH AND DOVER SOLE.

| | Rockfish | Dover Sole |
|---|---|---|
| 1964-1988 | | |
| Equation ($R_1$) | -.15 | -- |
| ($R_2$) | -.08 | -- |
| ($D_1$) | -- | -.04 |
| ($D_2$) | -- | -.20 |
| 1977-1988 | | |
| ($R_{1n}$) | -.30 | -- |
| ($R_{2n}$) | -.28 | -- |
| ($R_{1im}$) | .08 | -- |
| ($R_{2im}$) | .14 | -- |
| ($D_{1n}$) | -- | -.30 |
| ($D_{2n}$) | -- | -.56 |
| ($D_{1im}$) | -- | .04 |
| ($D_{2im}$) | -- | .15 |

FIGURE 1.
NOMINAL EXVESSEL PRICES OF DOVER SOLE AND ROCKFISH, 1962–1988. DATA SOURCE: PACIFIC FISHERY MANAGEMENT COUNCIL (1982); KORSON AND KINOSHITA (1990).

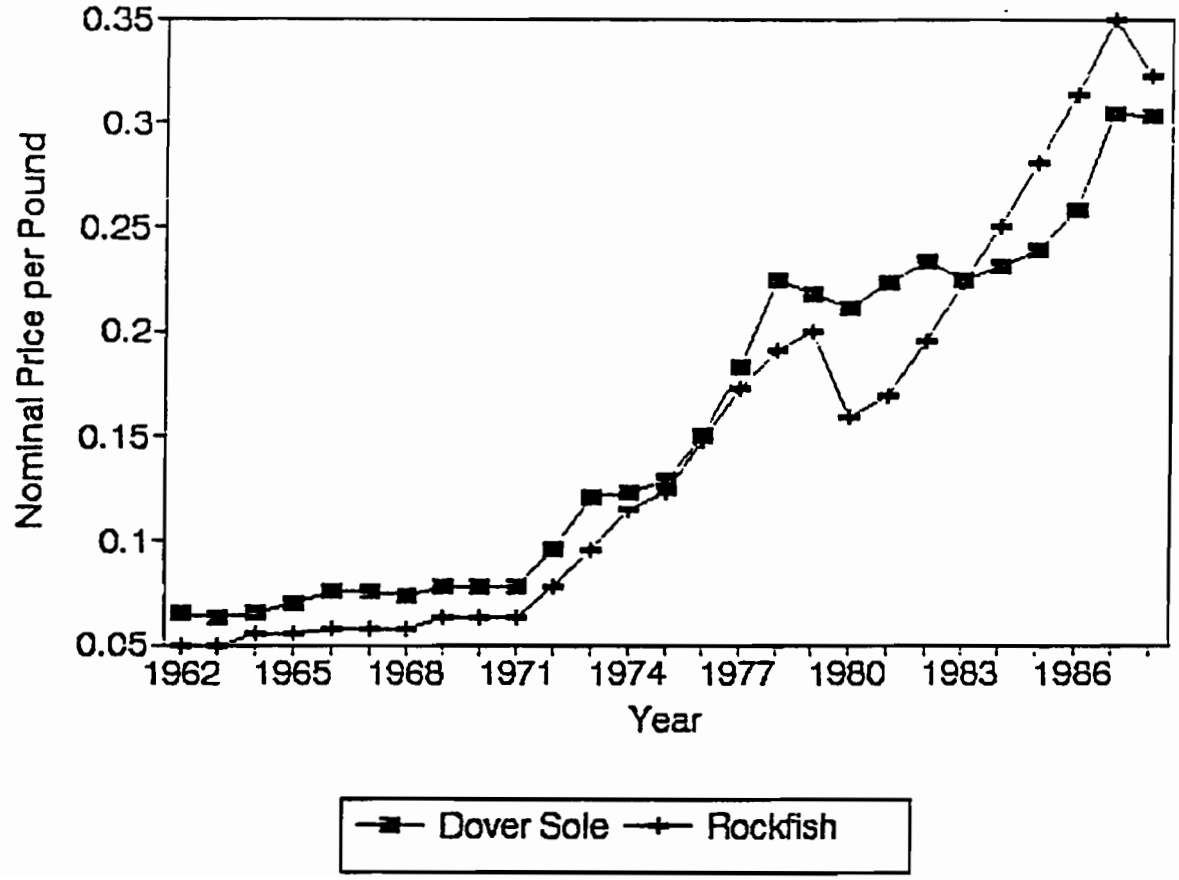


FIGURE 2.
REAL EXVESSEL PRICES OF DOVER SOLE AND ROCKFISH, 1962–1988. INDEX: PPI ALL COMMODITIES, 1980 = 100. DATA SOURCE: PACIFIC FISHERY MANAGEMENT COUNCIL (1982); KORSON AND KINOSHITA (1990).

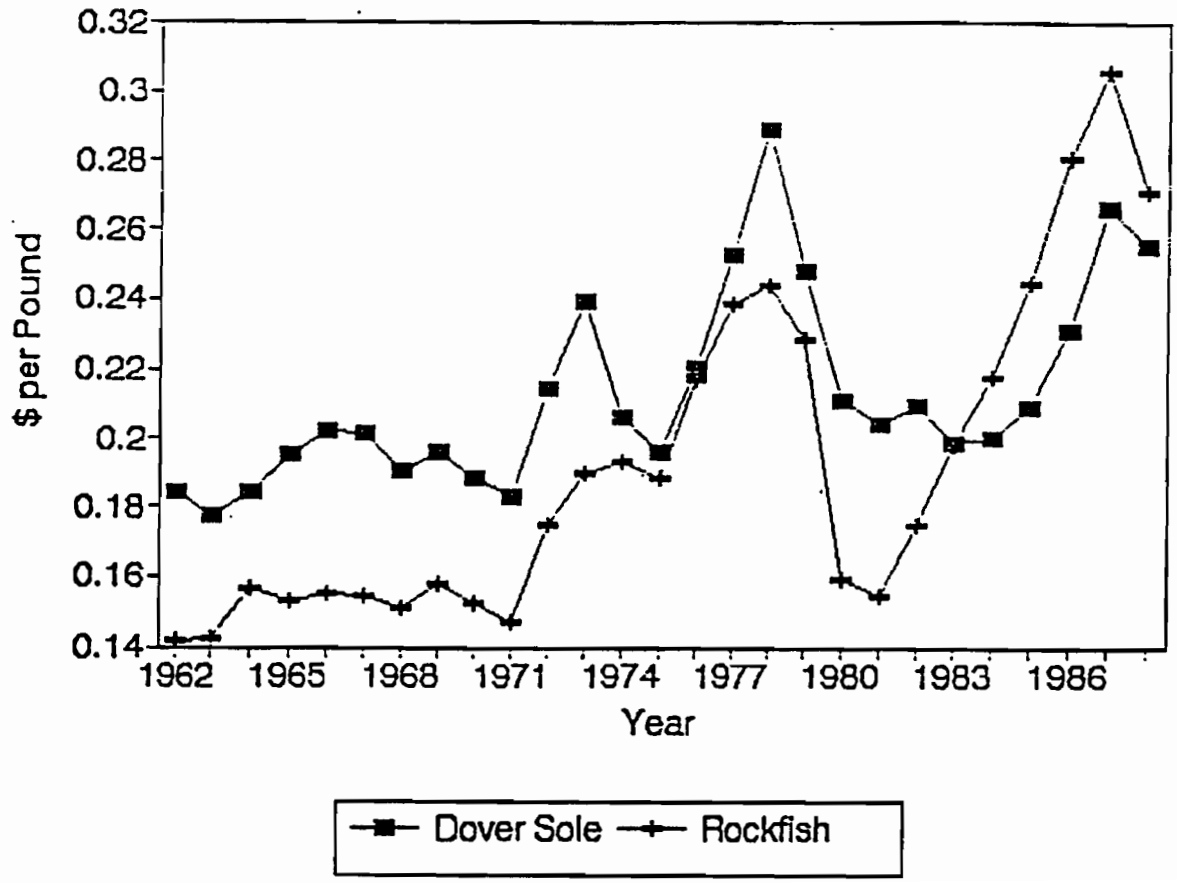


FIGURE 3.
REAL EXVESSEL PRICE AND QUANTITY OF ROCKFISH, 1962–1988. INDEX: PPI ALL COMMODITIES, 1980 = 100. DATA SOURCE: PACIFIC FISHERY MANAGEMENT COUNCIL (1982); KORSON AND KINOSHITA (1990).

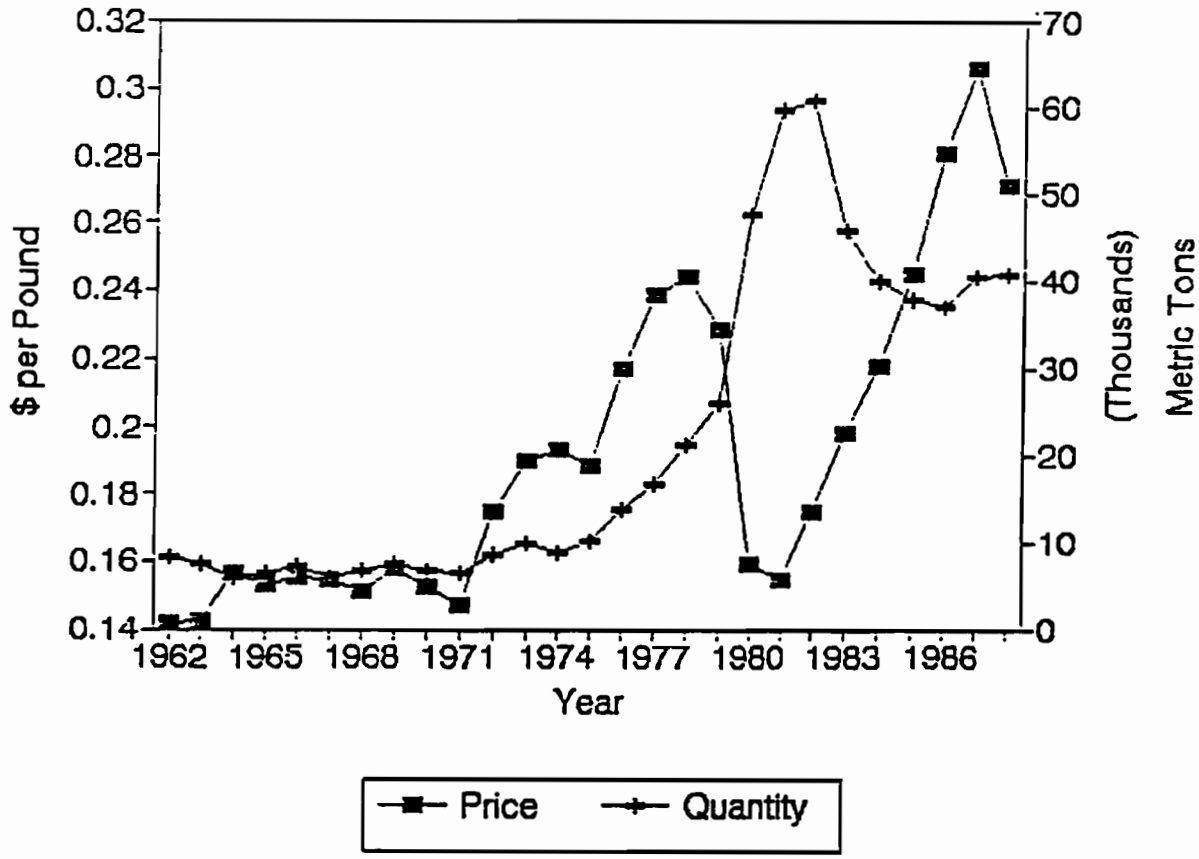
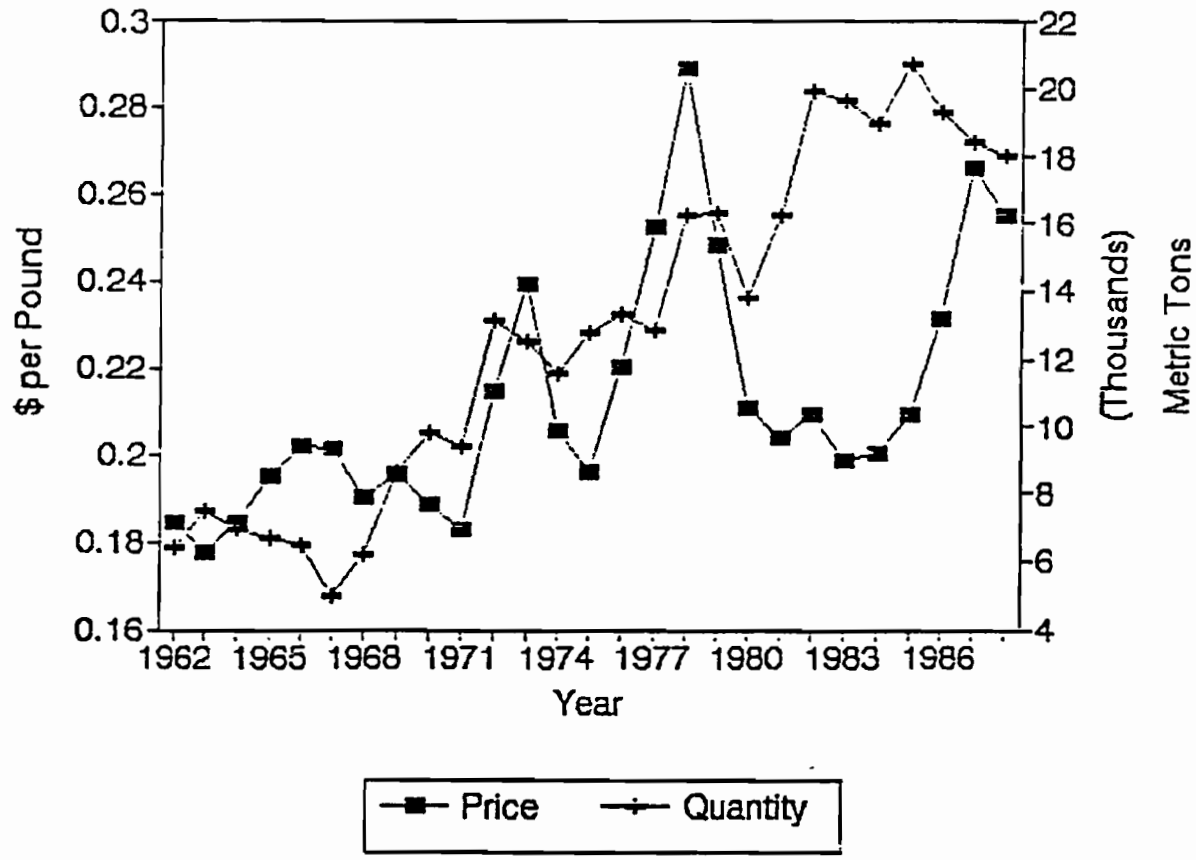


FIGURE 4.
REAL EXVESSEL PRICE AND QUANTITY OF DOVE SOLE, 1962–1988. INDEX: PPI ALL COMMODITIES, 1980 = 100. DATA SOURCE: PACIFIC FISHERY MANAGEMENT COUNCIL (1982); KORSON AND KINOSHITA (1990).



# Multiproduct Supply under Production Quota : an Application to Pacific Fisheries

**Dale Squires** *

National Marine Fisheries Service, Southwest Fisheries Science Center, P.O. Box 271 La Jolla, California 92038 USA

ABSTRACT

*This paper uses the concept of virtual prices to evaluate the competitive multiproduct firm's output supply when faced with production quotas. The properties of the quota-regulated and unregulated output supply functions are related, consistently describing behavior under both regimes. The impacts of quotas upon multiproduct costs, shadow prices of fixed factors, and multiproduct capacity utilization are also analyzed. The effects of imposing production quotas are empirically evaluated for an open-access multiproduct fishing industry and the implications for regulation assessed.*

## 1. INTRODUCTION

Production quotas are a well-established method to regulate output flows in a number of industries. One of the crucial problems facing regulators when designing and implementing a quota scheme is anticipating the multiproduct firm's supply behavior in response to changes in quota levels and market conditions under the new regulatory regime. Over a longer time period, the quota and induced reorganization of the product bundle may also change the firm's investment behavior and ultimately the industry structure.

Neary and Roberts (1980) considered the related problem of household behavior under rationing, and related the properties of rationed demand functions to the properties of the unrationed demand functions with the latter evaluated at the virtual prices. This approach has not been used to analyze firm supply behavior.

* The author is grateful to Stan Metcalfe for helpful discussions and to Mohammed Alauddin, Boris Bravo-Ureta, Christopher Bliss, Larry Jacobsen, Jim Kirkley, Alistair McIlgorm, Ricardo Quiroga, and two anonymous referees for detailed comments and to Pete Leipzig of the Eureka Fisherman's Marketing Association for identifying vessels with high-speed winches. The author alone, however, remains responsible for any remaining errors. The results are not necessarily those of the National Marine Fisheries Service. The author is grateful to the Department of Economics, University of Queensland, where this paper was written.

This paper *ex ante* evaluates the competitive multiproduct firm's supply response facing a production quota. The behavioral hypothesis of revenue maximization and a production quota are applied but the extension to another behavioral hypothesis or an input control is immediate. The framework of Neary and Roberts and virtual prices is used to relate the properties of quota-regulated and unregulated input-compensated (Hicksian) supply functions, consistently describing behavior under both regimes. This framework is also applied to relate the unregulated and regulated firm's investment incentives, as signaled by measures of multiproduct capacity utilization and shadow prices of quasi-fixed factors.

The paper addresses the design of a command-and-control output quota in an open-access multiproduct fishing industry prior to its regulation by a production quota. To curtail excessive production and depletion of sablefish, which has an important export market to Japan, a catch quota for the entire industry is set each year. Year-round production is achieved by limiting the amount of sablefish caught during each firm's fishing trip. Regulators routinely make adjustments during the year to these trip quotas as information accumulates about the actual level of catch as opposed to the target industry quota. Regulators are often unsure about the firm's supply response under the quota, and hence do not know to what extent the proposed adjustments alter production. If firms do not sufficiently curtail production, the industry quota is prematurely exhausted. The fishery is then shut down prior to year's end, causing severe financial hardship. The quota might also induce spillover harvesting onto other threatened resource stocks and perhaps excessive depletion, requiring supplementary quotas.

Markets and prices also change over the year. If the supply response under regulation is sensitive to price changes, sizable product transformations onto unregulated species with threatened resource stocks again could require supplementary quotas.

A quota and its marginal adjustments may also affect the firm's investment behavior. Quota may cause the multiproduct firm to adjust its volume and mix of production, in turn altering incentives for investment or disinvestment (Segerson and Squires, 1993). Evaluating these effects helps to design quota schemes consistent with the overall objectives of the regulatory program. For example, in this fishery, the quota is intended to only spread production throughout the year but not to create investment disincentives severe enough to induce full-time producers to exit the industry. Regulators must also consider these potential problems when adjusting quotas.

In short, regulators must design the quota consistent with the overall limits established by the resource stock and with the currently unregulated multiproduct firm's technology and multiproduct investment incentives when all outputs are decision variables.

The approach used in this paper should be useful not only for fisheries regulation, but also in connection with any multiproduct firm or industry facing output constraints. Production controls are often applied to regulate firms exploiting other common property resources or to limit a particular output for health or environmental reasons. In agriculture, forestry, transportation, and financial and health services, production controls are routinely applied. Market economies emerging from centrally planned economies are a blend of markets and quantity controls. Finally, in the context of international trade and GNP functions, the approach could be used to analyze the effects of export quotas or voluntary export restrictions.

Section II develops the empirical model, Section III examines the empirical results and implications for regulatory policy, and Section IV contains concluding remarks. The Appendix summarizes the main results for multiproduct supply under production quota.

## 2. EMPIRICAL MODEL

### *2.1 Industry background*

The potential effects of a quota upon sablefish production were studied for an open-access multiproduct trawl fishery off Northern California and Southern Oregon of the United States. The three ports are Eureka, Crescent City, and Brookings. This region is one of the centers of the sablefish fishery on the Pacific coast, which is conducted in the deep waters of

the continental slope, beginning at a depth of about 200 fathoms. Vessels harvest two other important species on the continental slope, Dover sole and thornyheads. Several other species are also harvested in shallower waters to utilize excess hold capacity and to enjoy product diversity.

When serious fishing began on the three continental slope species about a decade ago, their stocks were virtually unexploited but were subsequently fished down to about maximum sustainable yield (MSY) levels, at which they currently rest. Overcapitalization of the fleet and growing sablefish export demand from Japan, coupled with the absence of property rights, created harvest pressures sufficient to potentially deplete the stock of this slow-growing and long-lived species. Command-and-control quotas on sablefish for individual fishing trips were considered to maintain stocks close to MSY levels. The goals were to prevent overproduction, conserve the resource stock, maintain a year-round fishery, and increase economic rent.

### *2.2 Production process*

The analysis assumes that the unregulated firm maximizes profit in two stages. In the first stage of production, a fishing trip, a vessel departs port toward a pre-selected fishing ground. The net is released, towed for several hours off the bottom, hauled in, its contents released onto the deck, sorted by species, and then stored in ice in the hold. Species composition can be altered by changing the area fished or depth and speed of net tow.

Vessel operators key production directly to the market (fish brokers or processors), given relative prices and the technological constraints imposed by the vessel, gear, equipment, weather, and resource abundance. The gear type, design, and size of the vessel largely determine the level of other inputs on the trip, including labor and fuel consumption. Moreover, inputs on the vessel are largely fixed because boats are away at sea where input levels cannot be readily altered. The services of some inputs, particularly fuel, may vary with time at sea during an individual fishing trip, but time at sea varies only slightly and the variation is not systematic. The narrow width of the continental shelf and slope (limiting fishing area), limited hold (storage) capacity, and relatively small vessel sizes limit trip lengths to a maximum of about five days. Hence, the input bundle can be specified as a single, composite input, since vessel size or capital stock is fixed over such a short production period and largely determines the level of other inputs. Formally, Leontief input separability is assumed, with input quantities remaining in fixed proportions over time.

Revenue maximization subject to a single quasi-fixed input is the appropriate behavioral objective for a such a short production period once a resource stock area has been determined (Kirkley and Strand 1988 ; Segerson and Squires 1993). The composite input is proxied by vessel size, gross registered tons (GRT).

In the second stage of production, over roughly three to fourteen months, firms adjust the level of their capital stock to minimize production costs by selecting the optimal vessel size.

The analysis studies vessels less than 75 GRT (a segment of the fleet not previously studied) which landed at least 1,000 pounds of sablefish in 1984. The last year without trip quotas was 1984. Only vessels with high-speed winches were considered, where these powerful winches allow vessels to exploit the deep waters of the continental slope.

### *2.3 Unregulated production*

The revenue-maximizing vessel-level production process for an unregulated fishing trip is modeled by the following nonhomothetic generalized Leontief revenue function (Kirkley and Strand) :

$$R[P, Z] = \Sigma_i \Sigma_j \alpha_{ij} [P_i P_j]^{1/2} Z + \Sigma_i \alpha_i P_i Z^2 + \Sigma_i \Sigma_k \beta_{ik} D_k P_i Z + \Sigma_i \Sigma_j \tau_{il} E_l P_i Z, \quad (1)$$

where $P_i$ is the price of species i, Z is the composite input, $D_k$ is the $k^{th}$ of two dummy variables for ports in Brookings and Crescent City, and $E_l$ is the $l^{th}$ of three quarterly dummy variables for winter, spring, and fall. The base case accounts for the port of Eureka in the summer. The area dummy variables $D_k$ account for spatial variations in access to fish stocks, species abundance, and port effects on prices. The quarterly dummy variables $E_l$ account for intertemporal variations in the technological constraints of weather and resource abundance.

The input-compensated supply equations Y[P,Z] for unregulated production obtained by Hotelling's Lemma are (McFadden 1978) :

$$\frac{\delta R\,[P,\,Z\,]}{\delta P_i'} = Y_i[P,\,Z\,] = \alpha_{ii}\,Z + \alpha_i\,Z^2 + \Sigma_k\,\beta_{ik}\,D_k\,Z + \Sigma_l\,\tau_{il}\,E_l\,Z + \Sigma_j\,\alpha_{ij}\,[P_j/P_i]^{1/2}\,Z\,, \tag{2}$$

where $Y_i$ is the quantity harvested of species i. Symmetry is imposed by the econometric restriction : $\alpha_{ij} = \alpha_{ji}$, i not equal to j. Zero homogeneity in prices for the supply equations follows from the generalized Leontief functional form.

### *2.4 Technology Tests*

The effect of an output quota depends upon the final form of the technology, which can be assessed by likelihood ratio tests of parametric restrictions. Input-output separability implies a single aggregate input and output. The marginal rates of transformation between all output pairs are independent of factor intensities when the technology is separable between M outputs and the composite input. Hence, only the overall output, and not the individual outputs, requires a quota. The econometric restriction with the Generalized Leontief revenue function is (Kirkley and Strand) : $\alpha_i = 0$, all i.

A technology joint-in-inputs requires all inputs to produce all outputs. Separate production processes exist for each output as a function only of Z and $Z^2$ and not P when the technology is nonjoint-in-inputs. Because there are no technological or cost trade-offs between outputs, relative price changes or imposition of, or changes in, quota on one output do not spill over onto another output. The econometric restriction for nonjointness-in-inputs throughout the product set is written (Kirkley and Strand) : $\alpha_{ij} = 0$, i not equal to j, all i,j. Nonjointness-in-inputs for a single output, say $Y_1$ , requires $\alpha_{1j} = 0$, all j, j not equal to 1.

Pooling the data over quarters and ports can also be assessed by likelihood ratio tests.

### *2.5 Quota-regulated production*

Neary and Roberts showed, in the context of consumer demand, that the properties of rationed profit, revenue, or cost functions and their derivative demand or supply functions can be related to the properties of the quota-constrained functions, where the latter are evaluated at the virtual prices. Virtual prices, $q^-$, first developed by Rothbarth (1941), are defined as an implicit function of $Y^-$, P, and Z by the restriction that they are those prices which would induce an unregulated firm to produce that quota level $Y^-$ :

$$Y^- = Y[P\hat{}q^-,\,Z], \tag{3}$$

where $P\hat{}$ is the price vector of unregulated outputs and Y is the vector of input-compensated supply functions for the regulated products evaluated at the virtual prices. In single-product production, the virtual price equals marginal cost and the marginal cost curve equals the inverse supply function. In multiproduct production, marginal costs assume all other outputs are fixed in quantity, while the supply curves assume that all other outputs are at their respective optimal levels. Hence, inverse marginal cost curves and supply curves coincide only at the initial optimal point. (Beattie and Taylor 1985) In contrast, virtual prices, because they are a function of $P\hat{}$ and input prices, incorporate all adjustments in the unregulated outputs and inputs to their respective optimal levels at optimal output and input mixes and levels other than the initial. See Neary and Roberts for a formal definition and proof of existence.

The virtual price for the sablefish quota $q^-$ is estimated from the corresponding unregulated supply equation of (2). If sablefish is indexed as 1 and the remaining five outputs (species) are indexed 2 - 6, and the sablefish quota is $Y_1 = Y^-_1$, then the virtual price for sablefish $q^-_1$ is (where $\Omega = \Sigma_k\,\beta_{1k}\,D_k\,Z + \Sigma_l\,\tau_{1l}\,E_l\,Z$) :

$$q_1^- = \left[\frac{\Sigma_{j=2,\,\ldots,\,6}\,\alpha_{1j}\,P_j^{1/2}\,z}{Y_1^- - \alpha_{11}\,Z - \alpha_1\,Z^2 - \Omega}\right]^2. \tag{4}$$

At the quota-regulated production point the rationed and unrationed supply functions are equivalent provided the latter are evaluated at the virtual prices. The quota-constrained input-compensated supply functions for the unregulated outputs (indexed 2,...,6) are derived by substituting (4) into (2) to give :

$$Y_i^- = \alpha_{ii} Z + \alpha_i Z^2 + \Sigma_k \beta_{ik} D_k Z + \Sigma_L \tau_{il} E_l Z + \\ + \Sigma_{j=2,\ldots,6} \alpha_{ij} [P_j/P_i]^{1/2} Z + \alpha_{i1} \left[ \frac{\Sigma_{j=2,\ldots,6} \alpha_{1j} P_j^{1/2} Z}{(Y_1^- - \alpha_{11} Z - \alpha_1 Z^2 - \Omega)} \right] \left[ \frac{1}{P_i} \right]^{1/2} Z . \quad (5)$$

*2.6 Price elasticities of supply*

The input-compensated price elasticities of supply for unregulated production are written :

$$E_{ij} = \frac{\delta \ln Y_i}{\delta \ln P_j} = \frac{Z}{2 Y_i} \alpha_{ij} [P_j/P_i]^{1/2} \quad (6)$$

for i not equal to j, i, j = 1, ..., 6. The own-price elasticities are given by the homogeneity of degree zero of the supply equations : $E_{ii} = -\Sigma_j E_{ij}$, i not equal to j. $E_{ij} > / < 0$ indicates that outputs $Y_i$ and $Y_j$ are net complements / substitutes.

The input-compensated price elasticities of supply for regulated production when quota is binding are written :

$$E_{ij}^- = \frac{\delta \ln Y_i^-}{\delta \ln P_j} = \frac{Z}{2 Y_2^-} \alpha_{ij} [P_j/P_i]^{1/2} + \frac{\alpha_{i1} \alpha_{1j} Z^2}{2 Y_i^- (Y_1^- - \alpha_{11} Z - \alpha_1 Z^2 - \Omega)} [P_j/P_i]^{1/2} . \quad (7)$$

for i not equal to j and i, j = 2, ..., 6. Because of symmetry, $\alpha_{i1} = \alpha_{1i}$. The own-price elasticities of unregulated input-compensated supply when sablefish is under quota are given by the homogeneity of degree zero of the supply equations. $E_{ij}^- > / < 0$ indicates net complements / substitutes. $E_{ij}^- \leq E_{ij}$, i, j = 2, ..., 6 due to the Le Chatelier-type effect of a quota.

Changes in the prices of other regulated or unregulated products or the quantities of quasi-fixed factors do not alter quotas, since the binding quota is a fixed, perfectly inelastic supply curve to the firm. In addition, input-compensated supply for an unregulated product is unaffected by changes in the prices of quota-regulated outputs.

*2.7 Quota elasticity*

The elasticity of input-compensated output supply for the change in unregulated output with a change in quota level is :

$$E_{iY^-}^- = \frac{\delta \ln Y_i^-}{\delta \ln Y_1^-} = - \frac{\alpha_{i1} Y_1^- Z}{Y_i^-} [1/P_i]^{1/2} \left[ \frac{\Sigma_{j=2,\ldots,6} \alpha_{1j} P_j^{1/2} Z}{[Y_1^- - \alpha_{11} Z - \alpha_1 Z^2 - \Omega]^2} \right] , \quad (8)$$

i = j for $Y_i^-$ . $E_{1Y^-}^- > / < 0$ indicates net complements / substitutes.

*2.8 Investment Incentives*

Shadow prices of quasi-fixed factors ($W^*$) are investment determinants ; they represent the firm's implicit marginal valuation of the quasi-fixed factor. The shadow price measures the change in revenue from a marginal change in Z. It is given by :

$$\delta R[P ; Z]/\delta Z = W^* = \Sigma_i \Sigma_j \alpha_{ij} [P_i P_j]^{1/2} + 2 \Sigma_i \alpha_i P_i Z + \Sigma_i \Sigma_k \beta_{ik} D_k P_i + \Sigma_i \Sigma_l \tau_{il} E_l P_i . \quad (9)$$

The quota-constrained shadow price ($W^{*\bar{}}$) is given by substituting (4) into (9) to give :

$$W^{*\bar{}} = \alpha_{11} 2\left[ \frac{\Sigma_{j=2,\ldots,6} \alpha_{1j} P_j^{1/2} Z}{Y_1^{\bar{}} - \alpha_{11} Z - Z - \alpha_1 Z^2 - \Omega} \right]^2 + \Sigma_{i=2,\ldots,6} \alpha_{ii} P_i +$$

$$+ 2 \Sigma_{j=2,\ldots,6} \alpha_{1j} \left[ \frac{\Sigma_{j=2,\ldots,6} \alpha_{1j} P_j^{1/2} K}{Y_1^{\bar{}} - \alpha_{11} Z - \alpha_1 Z^2 - \Omega} \right] P_j^{1/2} + 2 \Sigma_{i=2,\ldots,6} \Sigma_{j=2,\ldots,6} \alpha_{ij} [P_i P_j]^{1/2}$$

$$+ 2 \alpha_1 \left[ \frac{\Sigma_{j=2,\ldots,6} \alpha_{1j} P_j^{1/2} Z}{Y_1^{\bar{}} - \alpha_{11} Z - \alpha_1 Z^2 - \Omega} \right]^2 Z + 2 \Sigma_{i=2,\ldots,6} \alpha_i P_i Z , \qquad (10)$$

where i does not equal j.

Measures of capacity utilization (CU) assess the current state of the economy and any expansionary or contractionary forces on investment that might exist. The cost-based measure of multiproduct CU for the revenue-maximizing firm with a single quasi-fixed factor is (Segerson and Squires) : $CU_C = W^*/W$. Substituting $W^{*\bar{}}$ gives the quota-constrained $CU_C^{\bar{}}$ : $W_*^{\bar{}}/W$.

The elasticity of $W^{*\bar{}}$ for a change in quota is given by :

$$\frac{\delta \ln W^{*\bar{}}}{\delta \ln Y_1^{\bar{}}} = \left[ \frac{-2 \alpha_{11} q_1^{\bar{}}}{Y_1^{\bar{}} - \alpha_{11} Z - \alpha_1 Z^2 - \Omega} - 2 q_1^{\bar{}} - \frac{4 \alpha_1 Z q_1^{\bar{}}}{Y_1^{\bar{}} - \alpha_{11} Z - \alpha_1 Z^2 - \Omega} \right] \frac{Y_1^{\bar{}}}{W^{*\bar{}}} . \qquad (11)$$

The elasticity of $CU_C^{\bar{}}$ for a change in quota is also given by (11).

## 3. EMPIRICAL RESULTS

Six species or outputs were specified : Dover sole, thornyheads, sablefish, other rockfish, other flatfish, and a residual, all others. Other flatfish, other rockfish, and all others were constructed as Divisia indices of other species using revenue shares as weights. There were 585 observations or fishing trips for 17 vessels, with uneven numbers of trips for each vessel. The quantity landed and revenue by species were recorded each time a vessel landed its catch after a fishing trip. Prices were calculated implicitly. Vessel sizes were from the U.S. Coast Guard. These data were from the PacFIN Research Data Base maintained by the National Marine Fisheries Service.

The supply equations (2) were estimated for unregulated production by vessels less than 75 GRT in 1984. Maximum likelihood estimates for parameters were obtained using Zellner's seemingly unrelated regression iterated to convergence. Each supply equation in (2) was divided by Z after heteroscedasticity of the form discussed by Parks (1970) was discovered, in which the error variance was proportional to $Z^2$. The generalized $R^2$ for the system of equations prior to the heteroscedasticity correction was 0.97. The revenue function was concave in Z at the sample mean and satisfied monotonicity over all observations.

The likelihood ratio tests for the final form of the technology, reported in Table 1, indicate that the technology for conventional levels of significance is not input-output separable and is joint-in-inputs over the entire output set. Hence an aggregate output cannot be formed, and supply management cannot simply regulate aggregate output and must consider the technological and cost tradeoffs among individual species.

The quarterly and area dummy variables are statistically significant. Parameter estimates for the final form of the technology are available upon request.

Unregulated product supply price responsiveness, calculated at the sample mean using equation (6), was highly inelastic (Table 2). Difficulties in locating and harvesting an unseen and spatially dispersed resource, particularly at great depths, and the short production period give this result. Sablefish is a net (Hicksian) substitute in unregulated production to all species except thornyheads, for which it is a net complement. Finally, all own-price elasticities were statistically nonnegative, indicating that the necessary conditions for a well-behaved technology were met.

*3.1 Production quota and supply*

The quota is set at 70 % of the unregulated firm's sample mean production of sablefish. The firm's technology does not inhibit the firm meeting the 30 % reduction in sablefish production, since the positively sloped supply curve supports the quota's virtual price. The industry quota can be met from this perspective.

Production quota reduces the supply responsiveness of the unregulated outputs. The price elasticities under quota, calculated by equation (7) for the 70 % quota, are more inelastic than those prior to regulation (Table 3). Because of the highly inelastic notional supply of the regulated output, reductions in the supply elasticities are sizable, often exceeding 50 %.

In three instances, each involving the all others output, a sign reversal was experienced for the price elasticities : (i) Dover sole supply-all others price ; (ii) other rockfish supply-all others price ; (iii) all others supply-other rockfish price. In each case, net complementary became net substitution. Because these switches do not presently involve species with threatened resource stocks, additional management measures are not required.

The price elasticities of supply under quota can help regulators anticipate the regulated firm's response to changes in regulations and markets. The highly inelastic supply responses under quota indicate that substantial changes in the mix and volume of unregulated outputs are unlikely when market prices change. In addition, a rising sablefish price will not alter the production of other species, and hence not threaten their abundance.

Rising prices of unregulated joint outputs complementary to sablefish, in this case thornyheads, will induce additional sablefish production along the notional sablefish supply curve. Since the expanded sablefish catch is unavoidable, exceeds quota, and cannot be landed on shore, the sablefish production in excess of quota is discarded at sea.[1] Mortality is very high among discarded sablefish, so that the original intention of the quota, enhanced mortality, is in large part defeated.

This pattern of at-sea discards of sablefish is precisely what occurs as growing thornyhead export demand from Japan lifts thornyhead prices. Skippers are forced to weigh the higher returns from increased thornyhead production against the sablefish discards (which may be as much as 16 % ; Pikitch et al. 1988). Since the latter is an external cost which is borne by the entire industry over a period of years (due to the dynamic nature of the resource stock and incomplete property rights), the economic incentive is generally for skippers to maximize short-run private returns.

The quota elasticities for supply of unregulated outputs, calculated by (8), are all quite inelastic (Table 4). The positive elasticity for thornyheads follows from the net complementarity between thornyheads and sablefish. The negative elasticities follow from the net substitutability between sablefish and the other unregulated outputs. Hence, adjustments of the sablefish quota directly alter production of thornyheads, but inversely change production of other species.

If sablefish biomass is further cropped to below the optimum level, the sablefish quota will be correspondingly tightened. Fishing vessels will harvest less of the net complementary species, which will reduce pressure on those resource stocks and tend to enhance their abundance. Because thornyheads already face excessive production, tightening the sablefish quota will also lighten pressures on the thornyhead stock. Hence, an additional thornyhead quota may not be necessary, simplifying the regulations. In contrast, tightening the quota will increase production of sablefish's net substitutes. To date, these other species in this region are not excessively harvested, so that supplemental quotas will not be required.

Regulators are also concerned with the effects of quota upon the individual firm's revenues. The initial change is given by : $R[\bar{q}_1, P^0_{-1} ; Z] - R[P^0_1, P^0_{-1} ; Z]$, where $P_{-1}$ denotes prices exclusive of $P_1$ and the superscript 0 (1) denotes the initial (subsequent) state. $P^0_1 = \bar{q}^0_1$ is used for subsequent quota adjustments. This general formula captures adjustments in the mix and volume of production throughout the firm's product set. The \$1217.38 decline in revenue due to the initial quota was a 17.40 % reduction at the sample mean.

The marginal rent effect of a change in quota is the unit quota rent : $\tau = [P_1 - \bar{q}_1]$, which is \$0.054 for the 70 % quota. At about 32 % of the mean sablefish price, marginal quota adjustments substantially reduce unit rent. The total quota rent evaluated at the sample mean, $\tau \bar{Y}_1$, is \$89.99.

1. In contrast to other industries, control over joint outputs is not absolute because of the commingling of species, incomplete discrimination by the net over product mix, and inability to fully detect and differentiate the different, unseen fish. Carlson (1939) called these joint products technically complementary and noted that they are probably technically complementary over all ranges of outputs ; others (but with greater fixity in output proportions) include cotton and cotton seed and gas and coke.

### *3.2 Production quota and capacity utilization*

Quotas not only regulate the output flow but also alter investment incentives, which could eventually affect industry structure. The significance test of Kulatilaka (1985) indicated that vessels were not in full static equilibrium with their quasi-fixed factor prior to quota. Since $CU_C = 2.54$, these vessels faced incentives to increase vessel size. During recent years, vessels increased the harvest of the deep-water species in ever-deeper waters of the continental slope, progressively migrating further offshore to harvest unexploited stocks in response to sablefish prices growing from developing export markets to Japan. This high-volume, open-access strategy favored larger vessels since vessels did not face full economic costs of production, including the marginal user cost of the resource.

Marginal adjustments in the 70 % sablefish quota only minimally reduce $\tilde{CU}_C$ and $\tilde{W}^*$ since their elasticity with respect to the 70 % quota is very inelastic at 0.12 %. Moreover, the 70 % quota reduces the firm's implicit marginal valuation of its quasi-fixed factor ($\tilde{W}^*$) from \$56.68 prior to regulation to \$55.01 and $CU_C$ drops from 2.54 to 2.47 at the sample mean. $\tilde{W}^*$ and $CU_C$ were only marginally altered by the quota. $\tilde{W}^*$ remains well above the market rental rate and $\tilde{CU}_C$ continues strong investment signals. Hence, the 70 % trip quota and subsequent adjustments do not induce industry exit, satisfying one of the regulatory goals. Nonetheless, this regulatory approach fails from a broader perspective because it does not reverse or even retard the longer-term pressures on the resource and depletion of resource rents from the incomplete property right structure of open access and overcapitalization.

## 4. CONCLUDING REMARKS

This paper used the concept of virtual prices to evaluate the competitive multiproduct firm's supply and investment behavior when faced with a production quota. The properties of the quota-regulated and unregulated supply functions were related, consistently describing behavior under both regimes. The results can be used for designing supply or trade management programs by production quota under joint production.

The effects of imposing a nontradable production quota on sablefish supply to regulate excessive production in an open-access multiproduct fishing industry were assessed. The quota reduces responsiveness of an already highly inelastic system of supply. Rising market prices of sablefish's complement, thornyheads, induces at-sea disposal of sablefish overages. The high mortality thwarts the quota's original intention. Tightening the quota generates spillover harvesting onto most of the other species, reducing their abundance. Because they currently do not face excessive production pressures, supplementary quotas are not necessary to prevent depletion. Imposition of quota and subsequent marginal adjustments substantially impact revenues and quota rents, so that fine-tuning is not warranted unless absolutely necessary. Strong investment signals to the private firm continue in this overcapitalized, open-access fishery.

In sum, the sablefish quota may spread production over the year but the surplus sablefish production disposed at sea largely defeats the quota's purpose by only incompletely slowing short-term resource depletion. Moreover, longer-term pressures from overcapitalization and positive investment incentives under open-access property rights are not substantially altered. An alternative regulatory approach seems warranted.

## REFERENCES

**Anderson J.E.** (1988). *The Relative Inefficiency of Quotas*, Cambridge : MIT Press.

**Baxter N. and J. Cragg** (1970). "Corporate Choice among Long-Term Financing Instruments," *Review of Economics and Statistics* **52 :** 225-235.

**Beattie B. and C. Taylor** (1985). *The Economics of Production*, New York : John Wiley & Sons.

**Carlson S.** (1939). *A Study on the Pure Theory of Production*, New York : Augustus M. Kelley, Reprints of Economic Classics, 1965.

**Denny M. and M. Fuss** (1977). "The Use of Approximation Analysis to Test for Separability and the Existence of Consistent Aggregates," *American Economic Review* **67 :** 404-418.

**Diewert W.E.** (1974). "Functional Forms for Revenue and Factor Requirements Functions, " *International Economic Review* **15 :** 119-130.

**Godfrey L.** (1988). *Misspecification Tests in Econometrics*, Cambridge, U.K. : Cambridge University Press.

**Kirkley J. and I. Strand Jr.** (1989). "The Technology and Management of Multispecies Fisheries," *Applied Economics* **20 :** 127-1302.

**Laitinen K.** (1980). *A Theory of the Multiproduct Firm*, Amsterdam : North-Holland Press.

**Lee L. and M. Pitt** (1987). "Microeconometric Models of Rationing, Imperfect Markets, and Non-Negativity Constraints," *Journal of Econometrics* **36 :** 89-110.

**Maddala G.** (1983). *Limited Dependent and Qualitative Variables in Econometrics*, Cambridge, U.K. : Cambridge University Press.

**McFadden D.** (1978). "Cost, Revenue and Profit Functions," *in Production Economics : A Dual Approach to Theory and Applications*, ed. by M. FUSS and D. McFADDEN, Amsterdam : North-Holland Press.

**Neary J. and K. Roberts** (1980). "The Theory of Household Behavior under Rationing," *European Economic Review* **13 :** 24-42.

**Parks R.** (1970) "Price Responsiveness of Factor Utilization in Swedish Manufacturing," *Review of Economics and Statistics* **53 :** 129-139.

**Pikitch E., D. Erixkson and J. Wallace** (1988). An Evaluation of the Effectiveness of Trip Limits as a Management Tool, NWAFC Processed Report 88-27, Seattle : National Marine Fisheries Service.

**Rothbarth R.** (1940). "The Measurement of Changes in Real Income under Conditions of Rationing," *Review of Economic Studies* **8 :** 100-107.

**Sakai Y.** (1974). "Substitution and Expansion Effects in Production Theory : The Case of Joint Production," *Journal of Economic Theory* **9 :** 225-274.

**Segerson K. and D. Squires** (1993). "Capacity Utilization under Regulatory Constraints, *Review of Economics and Statistics* LXXV, 76-85.

**Squires D. and J. Kirrkley J.** (1991). "Production Quota in Multi-product Pacific Fisheries," *Journal of Environmental Economics and Management* **21 :** 109-126.

**Wales T.** (1977). On the Flexibility of Flexible Functional Forms : An Empirical Approach," *Journal of Econometrics* **5 :** 183-193.

TABLE 1.
STATISTICAL TESTS FOR STRUCTURE OF TECHNOLOGY

| Test | Chi-square | No. of independent restrictions | Reject? (Y/N) |
|---|---|---|---|
| No quarterly dummy vars. | 113.6 | 18 | N |
| No area dummy vars. | 117.8 | 12 | Y |
| Input-output separability | 117.6 | 6 | Y |
| Overall nonjointness | 107.6 | 28 | Y |
| Nonjointness for: | | | |
| Dover sole | 27.6 | 5 | Y |
| Thornyheads | 60.8 | 5 | Y |
| Sablefish | 39.4 | 5 | Y |
| Other flatfish | 35.2 | 5 | Y |
| Other rockfish | 57.2 | 5 | Y |
| All others | 25.2 | 5 | Y |

Note: Likelihood ratio tests with degrees of freedom equal to the number of independent restrictions.

TABLE 2.
INPUT-COMPENSATED PRICE ELASTICITIES WITHOUT REGULATION

| | Quantity supplied of: | | | | | |
|---|---|---|---|---|---|---|
| Prices & Effort | Dover Sole | Thorny-heads | Sable-fish | Other Flatfish | Other Rockfish | All Others |
| Dover Sole | -0.027 | 0.237 * | -0.330 * | 0.167 | 0.447 * | 0.071 |
| | (0.035) | (0.080) | (0.146) | (0.097) | (0.110) | (0.363) |
| Thornyheads | 0.032 * | 0.019 | 0.150 * | -0.127 * | -0.456 * | -0.285* |
| | (0.013) | (0.021) | (0.040) | (0.045) | (0.068) | (0.141) |
| Sablefish | -0.081 * | 0.268 * | 0.383 * | -0.184 * | -0.182 * | -0.171 |
| | (0.036) | (0.062) | (0.168) | (0.082) | (0.081) | (0.366) |
| Other | 0.025 | -0.137 * | -0.113 | 0.096 * | 0.068 | 0.026 |
| Flatfish | (0.217) | (0.042) | (0.050) | (0.031) | (0.039) | (0.108) |
| Other | 0.049 | -0.363 * | -0.082 * | 0.046 | 0.108 * | 0.056 |
| Rockfish | (0.214) | (0.048) | (0.036) | (0.026) | (0.037) | (0.075) |
| All Others | 0.001 | -0.025 | -0.008 | 0.002 | 0.005 | 0.303* |
| | (0.085) | (0.012) | (0.018) | (0.008) | (0.007) | (0.072) |

NOTE: * Statistically significant at 1%
Calculated at sample mean for Eureka in the summer.
Linearized standard errors in parentheses calculated by the delta method.

TABLE 3.
INPUT-COMPENSATED PRICE ELASTICITIES UNDER REGULATION

| | Quantity Supplied of: | | | | | |
|---|---|---|---|---|---|---|
| Prices & Effort | Dover Sole | Thorny-heads | Sable-fish | Other Flatfish | Other Rockfish | All Others |
| Dover Sole | - 0.0980 | 0.4286 | 0 | 0.0359 | 0.3179 | - 0.0507 |
| Thornyheads | 0.0323 | - 0.0262 | 0 | - 0.0653 | - 0.3845 | - 0.2271 |
| Sablefish | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Flatfish | 0.0054 | - 0.0707 | 0 | 0.0094 | 0.0312 | - 0.0125 |
| Other Rockfish | 0.0350 | - 0.3119 | 0 | 0.0208 | 0.0327 | 0.0295 |
| All Others | - 0.0007 | - 0.0198 | 0 | - 0.0008 | 0.0027 | 0.2608 |

NOTE: * Statistically significant at 1%. Calculated at sample mean for Eureka in the summer for quota of 70% of sample mean sablefish production.

TABLE 4.
INPUT-COMPENSATED SUPPLY ELASTICITIES WITH QUOTA CHANGES.

| Dover Sole | Thorny-heads | Other Flatfish | Other Rockfish | All Others |
|---|---|---|---|---|
| - 0.0987 | 0.2356 | - 0.1599 | - 0.1457 | - 0.1260 |

NOTE: Calculated at sample mean for Eureka in the summer for quota of 70% of sample mean sablefish production.

# The potential Benefits of Individual Transferable Quotas and their Effects on Industry Structure

**Dale Squires** *

National Marine Fisheries Service, Southwest Fisheries Center, P.O. Box 271 La Jolla, California 92038, USA

ABSTRACT

*This paper ex ante analyzes a potential program of individual transferable quotas for two size classes of vessels in a multiproduct common property fishery. The paper finds only moderate total rents and potential efficiency gains from quota trade and explicitly valuing the marginal user cost of the resource. Evaluating the incentives for disinvestment and industry exit after quota exchange indicated potential for a concentrated industry structure with the larger class. Their quota market would potentially be thin, noisy, and noncompetitive, requiring restrictions on their quota transferability and concentration.*

## 1. INTRODUCTION

Individual transferable quotas (ITQs) are increasingly used to regulate common property fishing industries around the world [1]. Under this system, firms are allocated divisible rights to a quantity of an overall quota. Firms trade these quantitative restrictions and adjust production flows, satisfying the overall quota, resource rents are generated, equilibrium market prices for the individual transferable quota develop, and gains from trade are enjoyed. Industries are reorganized on efficiency grounds, with more efficient firms, rather than government, paying a lump sum to higher-cost firms to exchange fishing rights and lower or cease production.

Three issues are of fundamental concern when designing an ITQ program. First, the potential total rents and gains in arbitrage efficiency should be sufficient to warrant an ITQ program. Second, firms are concerned about the expected

* The discussions with, or suggestions of, Harry Campbell, Jon Conrad, Gary Hamer, Larry Jacobson, Jim Kirkley, Anthony Scott, Clem Tisdell, Geoff Waugh, David Wesney and 1990 seminar participants at the Universities of Queensland and Tazmania and Purdue University are gratefully acknowledged. The author is grateful to the Department of Economics, University of Queensland, where this work was completed while the author was a Visiting Lecturer. Pete Leipzig of the Eureka Fisherman's Association identified vessels with high-speed winches. Any errors remain the responsibility of the author. The results are not necessarily those of the National Marine Fisheries Service.

1. See Muse and Schelle (1989) for a review. Scott (1986) notes that ITQs are a right to the resource flow not to the stock itself.

equilibrium market price of a unit quota, which forms a production cost and barrier to entry. Third, regulators are concerned about the expected industry structure (particularly possibilities for quota and industry concentration), competitiveness and thinness of the quota market, and expected rent and efficiency gains. In short, both firms and regulators face considerable uncertainty prior to an ITQ program, and resolution of this uncertainty would eliminate perhaps the chief barrier necessary to gain industry acceptance and cooperation to implement such a program if it is justified.

The purpose of this paper is to *ex ante* analyze a potential ITQ program in a fishery to address the concerns of firms and regulators about the probable consequences. Incentives for disinvestment and industry exit after quota exchange, and subsequent structure of the industry and ITQ market, receive close attention. The prospective gains in economic rent from explicitly valuing the user cost of the resource and arbitrage efficiency created by quota exchange are assessed. The approach builds upon recent advances in the use of virtual prices to model the effects of quantity constraints (Neary and Roberts 1980) and multiproduct capacity utilization to assess firms' investment incentives (Segerson and Squires 1990, 1993).

The approach should be useful for analyzing potential programs for other industries currently or potentially regulated by ITQs. These programs include marketable emission permits for pollution and ITQs for waste management, agriculture, water resources, development rights, oil, and other common property resources. The approach can also shed light on transferable quotas in programs of voluntary export restrictions.

Section 2 develops a generalized ITQ model for use in the empirical analysis. Section 3 gives a background to the fishing industry and introduces the empirical model. Section 4 reports the empirical results and considers the implications for an ITQ program, and the last section contains concluding remarks.

## 2. TRADABLE QUOTA AND THE FIRM

This section examines the problem of applying an ITQ to a revenue-maximizing multiproduct firm facing competitive prices in the absence of prior regulation[2], although the results can be immediately extended to profit-maximization. The problem assumes a certain and static environment and does not allow banking of quota for future use. The quota is assumed to be issued without charge, freely transferable, and denominated in units sufficiently small to contribute to an active and competitive market for quota.

A revenue-maximizing firm facing a binding quota on the first of M outputs, $Y_1$, adjusts both the production levels and quota holdings to maximize revenues. Formally, the Lagrangian is :

$$\max_Y L = \Sigma P_i Y_i + \Theta T(Y ; E) - \tau(Y_1 - y_1) = 0,$$

where $T(Y ; E)$ represents the firm's technology, $\Theta$ and $\tau$ are Lagrange multipliers, Y is a vector of outputs with competitive prices P, E is a vector of quasi-fixed or fixed factors, and $y_1$ is the firm's quota.

The first-order condition with respect to $Y_1$ for an interior solution is : $\delta L/\delta Y_1 = P_1 + \Theta\delta T(Y ; E)/\delta Y_1 - \tau = 0$, where $\delta T(Y ; E)/\delta Y_1 < 0$. $\Theta\delta T(Y ; E)/\delta Y_1$ is the implicit marginal cost of quota. This virtual price, $\phi_1$, is the implicit marginal valuation of an additional unit of quota, the firm's implied opportunity cost of production[3].

The firm's unit quota rent, $\tau = P_1 - \phi_1$, is the difference between the marginal revenue from production, $P_1$, and the virtual price $\phi_1$. $\tau$ is thus the firm's unit producer surplus, and the price which firms are willing to pay for a unit license at that level of quota. A firm m will then demand (supply) quota when $\tau^m > (<) \tau^n$ for another firm n[4]. $P_1$ is constant over all production levels. $\phi_1$ varies with the level of quota held, so that with upward-sloping supply of $Y_1$, quota purchase (sale) monotonically lowers (raises) $\tau$ in the market. The equilibrium market price $\tau^*$ is formed by the Walrasian tatonnement.

2. Exogenous and competitive prices is the small country assumption of international trade. It is appropriate for internationally traded products, in competitive markets, or with very elastic cross-price demand elasticities. This section builds upon Anderson (1988), Maloney and Pearse (1979), and Montgomery (1972).

3. No firm will retain quota in excess of the revenue-maximizing level for Y given a binding and enforced quota and $P_1 > \phi_1$ since revenue is maximized by sale of excess. Hence, $\phi_1$ is evaluated at the quantity of quota held.

4. When markets are thin, price signals are noisy and firms will directly bargain and exchange quota (with high transactions costs and perhaps strategic price behavior), but firms in well-developed auction markets will compare $\tau$ with the existing bid price.

The efficient outcome after competitive exchange of $y_1$ is given by equalizing the net returns from a unit license, $\tau$, across the N heterogeneous firms. Quota exchange amongst firms gives arbitrage efficiency by maximizing producer surplus [5]. The quota rent gained from exchange between firms m and n is :

$$\tau^m - \tau^n = (P_1{}^m - \phi_1{}^m) - (P_1{}^n - \phi_1{}^n),$$

or the producer surplus gain from firm m's greater efficiency, where $\tau^m > \tau^n$. Initial distribution of the quota only affects the distribution of rents, not the efficiency after exchange (Montgomery 1972).

The formal static problem adjusts (through trade) each firm m's initial quota endowment $y_1{}^m$ to maximize returns from quota for each firm and the industry, subject to the constraint that all quotas are used in production. Hence,

$$\max_y L = \Sigma_m \tau^m y_1{}^m + \Gamma(\Sigma_m Y_1{}^m - Q)$$

with N first-order conditions : $\tau^m - \Gamma = 0$, m = 1, ..., N - 1, and $\Sigma_m Y_1{}^m - Q = 0$, where Q is the aggregate quota. The Lagrange multiplier $\Gamma$ is the marginal net benefit of a one unit increase in the overall quota. Rearranging the first N-1 first-order conditions gives $\tau^1 = \tau^2 = ... = \tau^N$. In practice, $\tau^*$ differs between firms by an amount equal to transactions, information, and transport costs[6].

The equilibrium unit rent $\tau^*$ is equivalent to a tax uniform across firms or the competitive market price of the quota initially allocated by auction, except for the distribution of revenue.

A specific tax, $t < \tau$, reduces competitive P and $\tau$ by t.

Over a longer time period, when a firm has time to adjust its quasi-fixed factor E, quota trade may lower the firm's rate of capacity utilization (CU), creating disinvestment incentives[7]. If a firm's implicit marginal valuation of E, i.e. its shadow value, is W*, then the cost-gap multiproduct CU measure for the revenue-maximizing firm is : $CU_C = W^*/W$ (Segerson and Squires 1990, 1993), where W is the market rental rate. $CU_C$ contains information on the implicit costs of divergence from long-run equilibrium. If quota sufficiently reduces W*, CU will also decline. Purchase (sale) of quota will increase (decrease) W * and $CU_C$, and for firms selling quota, $CU_C$ and W* may decline enough to prompt industry exit.

## 3. EMPIRICAL ANALYSIS

### *3.1 Industry background*

The potential benefits and effects of ITQs were studied for an open-access multiproduct trawl fishery off Northern California and Southern Oregon harvesting thornyheads, a fish with an important export market to Japan. This region is the center of the thornyhead fishery on the Pacific coast, and the fishery is concentrated in the deep waters of the continental slope. Overcapitalization of the fleet and growing thornyhead export demand, coupled with the absence of property rights, have placed sufficient pressures upon the biomass to require command-and-control quotas on thornyheads in 1991 for each fishing trip of each vessel.

Quotas without ownership or trade, however, do not tackle the fundamental problem, the absence of property rights. A program of ITQs, in contrast, directly addresses this problem. ITQs also generate arbitrage efficiency and price signals

5. Consumer surplus is constant with competitive price $P_1$ . Assume that any option exercises (allowing for uncertainty) are too small to the total spot quota market volume to affect price.
6. This might inhibit trade, but arbitrage agents would fill part of the gap if the potential market in ITQs is sufficiently large. Thin markets, expectations over property rights and uncertain quota supply raise transactions costs. Lower transactions and information costs can be expected with well-developed markets.
7. Economic efficiency over both the short and long runs has two requirements when controlling an externality : (1) the marginal value of the firm's output must equal marginal cost (both private and external) ; (2) the total value of the firm's output must not be less than total costs (both private and external) (Schulze and d'Arge 1974). The ITQ ensures the satisfaction of the first (short-run) condition for economic efficiency. For the long-run condition, this paper applies recent developments in evaluating firm investment and exit decisions by assessing multiproduct capacity utilization.

formed through market activity. Production and investment decisions are then formed considering all costs. ITQs also allow the most efficient firms to remain in the industry and less efficient firms to lower or cease production induced by a lump sum payment from quota sale.

*3.2 Empirical model*

The industry is comprised of many multiproduct firms. During each fishing trip, vessel operators key production directly to the market, given vessel and resource abundance constraints and fixed competitive prices. Vessels apply inputs to the resource stock for a product flow in a stock-flow technology. Revenue maximization is the objective for the short production period of a fishing trip once a resource stock area has been selected (Kirkley and Strand 1988, Segerson and Squires 1990). Inputs on the vessel are largely fixed because boats are away at sea where inputs cannot be readily altered. Since vessel size or capital stock is fixed at the trip level and largely determines the level of other inputs over this time period of one to four days, the input bundle can be specified as a single, composite input, called effort[8].

The revenue-maximizing production process for each vessel's fishing trip can be modeled by a nonhomothetic generalized Leontief revenue function (Kirkley and Strand) :

$$R[P ; E] = \sum_i \sum_j \alpha_{ij} [P_i P_j]^{1/2} E + \sum_i \alpha_i P_i E^2 + \sum_i \sum_r \alpha_{ir} D_r P_i E + \sum_i \sum_s \alpha_{is} S_s P_i E , \quad (1)$$

where E represents the capital stock or effort, measured by a vessels gross registered tonnage (GRT). The competitive price of product $Y_i$ is $P_i$ and R[P ; E] represents maximum revenue given E and the vector of prices P. $D_r$ is the $r^{th}$ of two home port dummy variables for Brookings and Crescent City and $Q_s$ is the $s^{th}$ of three quarterly dummy variables for winter, spring, and fall. The intercept is used for the port of Eureka in the summer. The area dummy variables account for spatial variations in access to resource stocks, species abundance, and port effects on prices. The quarterly dummy variables account for intertemporal variations in the technological constraints of weather and resource abundance.

Input-compensated supply equations Y*(P ; E) are given by Hotelling's Lemma (McFadden 1978) :

$$\delta R[P ; E]/\delta P_i = Y_i^*(P ; E) = \sum_j \alpha_{ij} [P_j/P_i]^{1/2} E + \alpha_i E^2 + \sum_r \alpha_{ir} D_r E + \sum_s \alpha_{is} Q_s E . \quad (2)$$

Symmetry is imposed by the following econometric restriction : $\alpha_{ij} = \alpha_{ji}$, where i is not equal to j. The Generalized Leontief form automatically imposes linear homogeneity in prices.

**3.2.1 Unit quota rent**

The unit quota rent of a license for $Y_1$, in pounds per trip per vessel, with the Generalized Leontief revenue function is calculated by :

8. Formally, Leontief separability is assumed.

$$\tau = P_1 - \left\{ \frac{E\left[\sum_{2}^{M} \alpha_{1j} P_j^{1/2}\right]}{Y_1 - \alpha_{11} E - \alpha_1 E^2 - \sum_r \alpha_{ir} D_r E - \sum_s \alpha_{is} Q_s E} \right\}^2 , \quad (3)$$

where the term $\{.\}^2$ is the virtual price, $\phi_1$.

### 3.2.2 Market quota price

The equilibrium market quota price after trade, $\tau^*$, can be solved by first finding the trip demand curve from the inverse demand curve (3) and then summing over all firms and trips to give the market demand curve for the annual overall quota. Equating this market demand curve to the perfectly inelastic industry supply of overall quota, Q, gives for $Y_1$ :

$$Q = \sum_k^K \left\{ \sum_j \alpha_{1j} [P_j/(P_1 - \tau)]^{1/2} E + \alpha_{11} E + \alpha_1 E^2 + \sum_r \alpha_{ir} D_r E + \sum_s \alpha_{is} Q_s E \right\} , \quad (4)$$

where j = 2, ..., M, the quota is denominated in one pound units, and K is the observed total number of firm-trips or observations with a binding quota. $\tau^*$ was numerically solved for each value of Q considered. The new "domestic" price vector faced by firms is $\phi_1 = P_1 - \tau^*$. The individual demand curves allow estimation of the equilibrium allocation of quota by vessel and trip.

### 3.2.3 Gain from trade

All thornyhead rents are capitalized in $\tau^*$. Hence $\tau^* Q$ is the full economic rent generated by the resource and the gain in producer surplus compared to open access. $\tau^*$ is the marginal user cost of the unit resource for optimal Q (Maloney and Pearse 1979). $\tau^* Q$ is also the revenue government receives if quota licenses were initially auctioned at a single price or were placed under a uniform tax. Total industry producer surplus under the command-and-control quota equals $\Sigma_k[\tau^k + \frac{1}{2} \varnothing^k] y^k$, where $\Sigma y^k = Q$. The total gain in arbitrage efficiency, or producer surplus, due to exchange at the competitive equilibrium market price, $\tau^*$, is $[\tau^* + \frac{1}{2} \varnothing^*]Q - \Sigma_k[\tau^k + \frac{1}{2} \varnothing^k]y^k$.

### 3.2.4 Data

The data were from the PacFIN Research Data Base maintained by the National Marine Fisheries Service. Landings and revenues were recorded by species at the port of landing after each vessel's fishing trip. The Eureka Fishermen's Marketing Association identified vessels with the high-speed winch required to fish in deep contintental slope waters. Vessel size was from the U.S. Coast Guard and costs were from federal income tax returns.

## 4. EMPIRICAL RESULTS

The model was estimated using data for a year without regulation, 1984. Vessel size affects trip length, hold capacity, weather capabilities, and area and depth fished. These factors, in turn, affect product mix and levels. Hence, the fleet was divided into vessels less than 75 GRT (gross registered tons) and those 75 GRT or more. There were a total of 585 observations or fishing trips on the 16 smaller vessels and 444 observations on the 14 larger vessels, with unequal observations for vessels. Six outputs were specified : Dover sole, thornyheads, sablefish, other flatfish, other rockfish, and a residual category, all others.

The system of input-compensated supply equations, equation (2), was initially estimated by ordinary least squares. Heteroscedasticity was found, in which the error variance was proportional to the squared input level, $E^2$ (Parks, 1971).

Each equation was subsequently divided by E. Maximum likelihood estimates for parameters were obtained using Zellner's seemingly unrelated regression iterated to convergence [9].

The parameter estimates for the smaller vessels are not reported here for brevity, while those for the larger vessels are reported in Segerson and Squires (1993). The generalized $R^2$ for the entire system of equations (Baxter and Cragg 1970) has a value prior to the heteroscedasticity correction of 0.97 for the smaller vessels and 0.99 for the larger vessels. The own- and cross-price input-compensated supply elasticities evaluated at the observed sample mean for the smaller vessels are not reported here for brevity while those for the larger vessels are reported in Segerson and Squires (1993). The own-price elasticities are all nonnegative except for Dover sole for smaller vessels and sablefish for larger vessels, both of which are negative but statistically insignificant. In addition, the revenue function is increasing and concave in E at the sample mean in both cases. Applying the significance test of Kulatilaka (1985) for the shadow value of effort, t-ratios of 0.06 and 4.73 were found at the sample means, indicating that effort was at its full static equilibrium value for large group vessels but that vessels of the small group faced incentives to increase vessel size.

Transferable user rights were initially allocated, without charge, in equal amounts of one pound to each vessel for each trip. This allocation, in effect, gave firms transferable ownership of the 1991 command-and-control trip quota and allowed explicit contrast of the potential gains in economic rent and arbitrage efficiency which would be created by exchange. Firms producing less than permitted by quota were not allowed to retain the quota and banking was not allowed [10]. Inter-group trade was prohibited to spatially distribute production and protect resource stocks.

### *4.1 Distribution of unit quota rent*

The thornyhead unit quota rent prior to exchange, $\tau$, was computed following equation (3) for each trip of each vessel group covering the entire year. Each vessel of the small (large) size class was assigned a quota of 1200 (2100) pounds per trip unless production fell short of this value. A wide range of $\tau$ was observed : 0.0015 to 0.3481 for small vessels and 0.00085 to 0.2488 for large vessels. The standard deviations of $\tau$ were 0.0821 for small vessels and 0.0747 for large vessels.

To assess the distribution of $\tau$ among firms and the factors affecting the size of unit quota rent, $\tau$ was regressed upon an intercept, the area and quarterly dummy variables, vessel size (GRT), and measures of : product-specific economies of scope and scale for thornyheads, multiproduct economies of scale, and $CU_C$. Product-specific economies of scale and scope were for shadow costs and were calculated following Squires and Kirkley (1991). Multiproduct economies of scale were calculated as : $W^* Z/\Sigma_i P_i Y_i$, i.e. total shadow cost divided by total revenue (Laitinen 1980).

The sample was censored and required Tobit analysis, since not all vessels were bound by quota. For the small vessel group, $\tau$ was statistically different by port (Table 1). Seasonal variation in $\tau$ was indicated for both groups. Vessels already facing high CU were also those with economic incentives, through $\tau$, to expand production by quota trade. Vessel size (GRT) reduced $\tau$ for smaller vessels but increased $\tau$ for larger ones. Expanding the short-run overall scale of production lowered $\tau$ for smaller but not larger vessels. Hence, vessels of the smaller group could gain from quota trade and increased production, which would exploit overall scale economies and raise CU. Expanding only thornyhead's scale of production did not affect $\tau$ for either group. Product-specific economies of scope raised $\tau$ for smaller but not larger vessels. In sum, vessels in both groups with high CU had the strongest economic incentives to trade for quota.

9. The functional form is assumed to be exact rather than an approximation, and the errors are from optimization rather than approximation and apply only to the input-compensated supply equations. The problem of zero outputs also arose in a some instances, creating a limited-dependent variable problem, which may cause bias and non-normality of the residuals. The procedure of Lee and Pitt (1987) solves this problem using virtual prices, but is not computationally feasible with the number of variables in this study. A Box-Cox transformation could be used, but was rejected on the grounds that a particular form of non-normal disturbances is assumed prior to transformation. The small value of 0 1 was substituted for zero when necessary. A sensitivity analysis for the large vessel group used values of 0.01 and 0.001 ; the log-likelihood function changed by 0.099 % and 0.246 %, respectively. A few parameter values (particularly those for effort) changed by as much as 5 %, but price elasticities appeared to be robust.

10. Quota allocated when not binding would simply increase Q and K in (4) and lower $\tau^*$, unless smaller amounts were initially allocated. In this case, because the opportunity cost (revenue foregone) of holding quota is zero, $\tau$ is the output price.

*4.2 Market equilibrium quota price*

The equilibrium market prices of quota, $\tau^*$, was solved for each vessel size group :

(i) at the overall sample mean ;
(ii) using mean prices and GRT for four GRT size classes ; and
(iii) over all binding observations[11].

The models were well-behaved at the sample mean, but performance of these second-order approximations deteriorated at some sample observations. These trips were not incorporated in the third approach to calculating $\tau^*$ (otherwise, there was a tendency for equation (4) to slope upwards). Hence, gains in arbitrage efficiency were assessed only for well-behaved binding observations, and some bias was undoubtedly introduced. Values of $\tau^*$ were assessed for a wide range of initial quota allocations.

Fairly close values of $\tau^*$ were found for the three methods with the large vessel group except at the highest quota sizes (Table 2). Values of $\tau^*$ could not be calculated with sample means for large quotas with the small vessel group, since these quotas were not binding. The $\tau^*$ values were similar for the more restrictive quotas.

For both groups, $\tau^*$ was comparatively close to the mean product price per pound of 0.25 dollars, indicating high producer surpluses. The high $\tau^*$ values reflected the steeply sloped supply curves and a high marginal user cost of the resource. In turn, the high marginal user cost relative to price suggests the extent of resource rents potentially gained under rights-based management in comparison to open-access conditions.

Proportional gains in arbitrage efficiency compared to the command-and-control quota were calculated using the binding observations for each group. Fairly similar results (except at large quotas) were found for the large vessel group when using mean values, but model performance deteriorated significantly using means for the four GRT classes of the small vessel group. (These results are available upon request.) The gains in producer surplus, reported in Table 2, were moderate for most of the possible initial allocations of quota for both vessel groups. These moderate gains reflect the relatively small intervessel differences in allocative efficiency.

$\tau^*$ increased for both groups as the quota further restricted production, but the mean quota rent per vessel per trip declined. At high quota levels, only the most efficient vessels (with lower $\phi_1$) traded for quota, while at a lower quota, increasingly inefficient vessels began trade, so that inter-vessel differences in producer surplus narrowed. Hence, proportional gains in arbitrage efficiency tapered off with tighter quota, although total potential gains in producer surplus rose.

Total rent for the small vessel group, beyond the largest quotas, declined at a fairly slow rate as quota tightened (Table 2). Market quota demand was thus somewhat elastic over most of its range. Total rent for large vessels first rose rapidly then continued to rise but at a very slow rate as the quota declined when calculated using all binding observations. When calculated using mean values, total rent slowly declined. Hence, market demand for the large group was either inelastic but almost unit elastic or slightly elastic. In sum, for both vessel groups and for all methods of calculation, market demand was not strongly inelastic, reflecting the large number of substitute species in production.

A broad range of overall quotas is thus available to maximize the fishery's static optimum rent. This result, however, must be tempered by considerations of resource conservation, i.e. the dynamics of the resource stock. Because calculations of optimum stock size generally have a wide confidence band, relatively conservative stock estimates can be used without a large opportunity cost of rent foregone. This conservative strategy protects the resource stock and insulates the industry against abrupt and large reductions in the overall quota if new stock assessments show a sudden population decline or that previous resource assessments were in error.

11. Certain regularity conditions (particularly convexity) are often violated over large sample regions with a flexible functional form (FFF). These violations can be for reasons other than failure to satisfy the model's behavioral assumptions. For example, Wales (1977) showed that estimates of a FFF may violate regularity conditions even if the data came from a well-behaved technology. Functional forms that *a priori* satisfy all regularity conditions sacrifice flexibility and impose restrictive assumptions (homogeneity and separability). Imposing convexity, either globally or over a region (see Diewert and Wales (1987) and Roller (1990)), is convenient for simulation work and is consistent with economic theory, but also obscures economic responses. Eliminating troublesome parameters can also give convexity but imposes unknown structure and bias upon the model and reduces flexibility. Eliminating observations causing violations also creates biased results. Evaluating results at a point more likely to be well-behaved, such as the sample mean or point of approximation, is useful, but masks results for individual firms. In short, all methods obscure economic relations. This paper blends an analysis of the well-behaved individual observations and analyses at sample means with extensive knowledge of the industry and data to spark insights into the most probable economic relationships.

Total rents, for each of the three methods of calculation, were relatively small for each vessel group. These limited total rents reflected the small size of the industry and an ITQ program regulating a single species in a multispecies fishery. The rents could be smaller than the regulatory costs of planning, implementing, monitoring, and enforcing an ITQ program for thornyheads.

Extending the ITQ program to additional species would expand the resource rents, giving a more favorable benefit-cost ratio. Expansion, however, would face the marked inability of vessels to make substantive changes in the mix and volume of their optimal product mix. In this fishery, at least, the technology and shadow cost structure prohibit such adjustments (Squires and Kirkley, 1991). Hence, as a response to microregulation of the individual multiple products, vessels discard excess production, causing unnecessary mortality and countering many of the expected beneifits of an ITQ program.

A variety of remedies have been proposed (see Schelle and Muse and Copes 1986 for reviews), but they all rely upon some combination of complex trading or taxation schemes, large and well-functioning markets with minimal transactions and information costs, or fairly obedient firms. These proposed solutions all fly in the face of one of the chief lessons learned from over a decade of deregulation in a wide range of industries : the limits to complex microregulation.

### *4.3 Quota and capacity utilization*

ITQs induce less efficient firms to lower or even cease production. Firms disinvest and exit the industry if, after exchange, $\tau^*$ and the amount of quota retained after trade lower $\phi_1$, and hence the firm's implicit marginal valuation of effort (W*), by a sufficient amount below its market rental rate (W). Equivalently, the equilibrium allocation of quota might sufficiently reduce the firm's CU to induce disinvestment and industry exit. That is, an ITQ program creating property rights over the resource flow forces firms to explicitly confront the user cost of the resource, $\tau^*$, and reevaluate investment decisions in light of full costs.

The changes in CUs were evaluated for both $\tau$ and $\tau^*$ for each vessel's trip to assess these possibilities. Calculations used all of the binding (and well behaved) observations. Quota prior to exchange reduced CUs by a sizable amount in all cases[12]. After $\tau^*$ was formed through exchange, CUs climbed for firms buying quota and further dropped for firms selling quota.

Mean W* and CU per vessel per trip for the small vessel group usually became negative with quotas before exchange but climbed to positive values after trade. Because of the high initial CU values prior to quota, CUs after exchange declined for only a few vessels by such a visible amount as to suggest disinvestment and industry exit. The sizable CU declines were for some of the larger vessels in the small group, as noted from the Tobit analysis.

Most vessels in the larger vessel group, in contrast, experienced a marked decline in the mean CU per vessel per trip after quota exchange. The shadow price of effort, W*, and hence CU, frequently became negative, giving strong signals for disinvestment or exit from the fleet, each vessel receiving a lump sum payment $\tau^* y_1$. These vessels tended to be the smaller ones in the larger vessel group, as noted from the Tobit analysis.

Several vessels in the larger group with strong disinvestment incentives also had cost incentives (lower $\phi_1$) to trade for quota, but had low CU even prior to quota. Purchase of quota raised $\phi_1$ and W*, but it was insufficient to give positive values of W* and $CU_C$ because the quota seriously lowered CU for these vessels.

In short, tradable property rights in this common property fishery created a uniform price signal $\tau^*$ and forced firms to explicitly account for the resource's user cost and restructure accordingly. Prior to the ITQ program, vessels mined the resource stock in ever-deeper waters of the continental slope, progressively migrating farther offshore to harvest unexploited stocks. Because this high-volume, open-access production strategy favored larger-sized vessels, vessels of the smaller group had high rates of CU and economic incentives to expand effort. In contrast, open-access effort of larger vessels was in full static equilibrium. The ITQ program, however, confronted firms with full social costs. This, in turn, lowered the firm's implicit marginal valuation of effort (W*) and CU. Smaller-sized vessels in the small vessel group remained, but only a few of larger-sized vessels of the larger vessel group were suited to produce at the socially optimal rate. $\tau^*$ is sufficiently small to not pose a prohibitive entry barrier. Finally, this prospective analysis suggests that ITQs can provide considerable impetus to reduced capitalization in a fishery.

12. Primarily due to the steep thornyhead supply curve, so that even a moderate quota seriously lowered $\phi_1$, and hence W * and CU.

*4.4 Concentration of quota*

Exchange of a quota may be unwelcome if it facilitates the concentration of quota in the hands of a limited number of producers (Scott 1986). The full equilibrium cost and technological determinants of multiproduct industry structure, prior to ITQs, did not favor extensive horizontal or vertical integration of vessels into multivessel firms (Squires and Kirkley). However, ITQs would potentially generate such sharp disinvestment and exit incentives for so many firms in the larger vessel group as to suggest that quota will become concentrated in the hands of the few remaining firms. Hence, for the larger vessel group, the quota market risks becoming thin, noisy, and hampered by noncompetitive forces, potentially requiring limits to quota transfer and concentration.

## 5. CONCLUDING REMARKS

This paper evaluated a prospective program of individual transferable quotas for two vessel groups in a common property fishery. Explicitly accounting for the user cost of the common property resource by the ITQs created strong disinvestment and exit signals for the large vessel group, so that a concentrated industry structure was possibly favored. Their quota market is potentially thin, noisy, and noncompetitive, and may require limits to transferability and concentration of quota. The small vessel group, however, appeared to have close to the appropriate vessel numbers and sizes with ITQs.

The quota created strong disinvestment and exit incentives for a surprisingly large number of firms, even for those purchasing quota, by weakening the firm's implicit marginal valuation of capital and lowering capacity utilization. That is, a tradable quota remains a quota, and not just inefficient firms may face serious disinvestment incentives, but also a number of more efficient firms with low initial economic capacity utilization.

Finally, in contrast to the current command-and-control quota, explicitly valuing the user cost of the resource and allowing quota trade created economic rents and moderate gains in arbitrage efficiency. In contrast to open-access, resource rent can be enjoyed under rights-based management.

These gains were nonetheless limited, calling into question the efficacy of an ITQ program as a rent generator for a single species in a multispecies fishery. Extending ITQ coverage to other species encounters the problem of microregulation of multiple products when the technology and cost structure preclude sizable changes in the mix and volume of products without at-sea disposal. Complex trading rules or taxation schemes are a possible solution, but simple and robust regulations seem to have the greatest chance of success.

The primary regulatory alternative of license limitation with a vigorous vessel buy-back program has fallen out of fashing in favor of ITQs. Yet, given the limits to microregulation of joint products (Kirkley and Strand, Squires and Kirkley 1991, Squires 1987), this alternative should reexamined in this light. A supplementary ITQ might then offer protection to the most threatened species and provide a strong complementary impetus to vessel reductions.

C.E.D.I.D. - IRD

**TABLE 1.**
**TOBIT ANALYSIS PARAMETERS OF QUOTA RENT INCIDENCE.**

| Variable | Coefficient | |
|---|---|---|
| | < 75 GRT | 75+ GRT |
| Intercept | 0.171 * | -0.640 * |
| | (0.023) | (0.066) |
| Brookings Dummy | 0.059 * | -0.010 |
| | (0.014) | (0.022) |
| Crescent City Dummy | 0.163 * | 0.012 |
| | (0.012) | (0.023) |
| Winter Dummy | -0.017 | -0.062 * |
| | (0.013) | (0.024) |
| Spring Dummy | -0.029 * | 0.015 |
| | (0.012) | (0.020) |
| Fall Dummy | 0.016 | 0.032 |
| | (0.014) | (0.025) |
| Gross Registered Tonnage of Vessel | -0.283E-2 * | 0.446E-2 * |
| | (0.389E-3) | (0.318E-3) |
| Thornyhead-Specific Economies of Scale | 0.129E-3 * | 0.226E-4 |
| | (0.604E-4) | (0.701E-4) |
| Thornyhead-Specific Economies of Scope | 0.664E-4 | -0.305E-2 |
| | (0.336E-3) | (0.471E-2) |
| Multiproduct Economies of Scale | -0.804E-4 * | -0.737E-2 |
| | (0.244E-3) | (0.753E-2) |
| Economic Capacity Utilization | 0.061 * | 0.036 * |
| | (0.006) | (0.015) |

NOTE: Estimated for Summer Quarter with Eureka as intercept.
Standard errors in parentheses.
* indicates statistically significant at 1%.

TABLE 2.
EQUILIBRIUM QUOTA MARKET PRICE, TOTAL RENT, AND GAINS FROM TRADE SMALL VESSELS.

| No. Trips Binding Quota | Trip Quota (lbs) | Market Price (dl/lb) (1) | (2) | (3) | Trade Gains (%) | Total Rent (dl) (1) | (2) | (3) |
|---|---|---|---|---|---|---|---|---|
| 168 | 1700 | 0.1839 | - | 0.1056 | 3.67 | 52,522 | - | 30,159 |
| 175 | 1600 | 0.2088 | - | 0.1884 | 5.14 | 58,464 | - | 52,752 |
| 184 | 1500 | 0.2176 | 0.0788 | 0.19526 | 3.85 | 60,058 | 21,748 | 53,892 |
| 193 | 1400 | 0.2226 | 0.1857 | 0.19578 | 2.45 | 60,147 | 50,176 | 52,900 |
| 205 | 1300 | 0.2276 | 0.2015 | 0.19588 | 2.79 | 60,655 | 53,700 | 52,202 |
| 211 | 1200 | 0.2323 | 0.2066 | 0.19592 | 5.24 | 58,818 | 52,311 | 49,607 |
| 223 | 1100 | 0.2352 | 0.2089 | 0.19593 | 3.83 | 57,695 | 51,243 | 48,062 |
| 230 | 1000 | 0.2370 | 0.2101 | 0.19594 | 4.82 | 54,510 | 48,323 | 45,066 |
| 245 | 900 | 0.2371 | 0.2108 | 0.19595 | 3.35 | 52,281 | 46,481 | 43,207 |

NOTE: (1) $\tau$ calculated using all binding observations
(2) $\tau$ calculated at overall sample mean
(3) $\tau$ calculated at means of 4 vessel size classes
Gains from trade calculated using all binding observations.

TABLE 3.
EQUILIBRIUM QUOTA MARKET PRICE, TOTAL RENT, AND GAINS FROM TRADE LARGE VESSELS.

| No. Trips Binding Quota | Trip Quota (lbs) | Market Price (dl/lb) (1) | (2) | (3) | Trade Gains (%) | Total Rent (dl) (1) | (2) | (3) |
|---|---|---|---|---|---|---|---|---|
| 151 | 2500 | 0.0730 | 0.2041 | 0.2071 | 2.85 | 27,558 | 77,048 | 78,180 |
| 154 | 2400 | 0.1276 | 0.2171 | 0.2080 | 4.26 | 47,161 | 80,240 | 76,877 |
| 160 | 2300 | 0.1674 | 0.2231 | 0.2086 | 6.73 | 61,603 | 82,101 | 76,765 |
| 164 | 2200 | 0.1890 | 0.2264 | 0.20902 | 12.05 | 68,191 | 81,667 | 75,414 |
| 169 | 2100 | 0.2024 | 0.2283 | 0.20933 | 10.90 | 71,832 | 81,024 | 74,291 |
| 174 | 2000 | 0.2112 | 0.2296 | 0.20955 | 5.87 | 73,498 | 79,901 | 72,923 |
| 180 | 1900 | 0.2174 | 0.2305 | 0.20973 | 7.84 | 74,351 | 78,831 | 71,728 |
| 190 | 1800 | 0.2220 | 0.2311 | 0.20987 | 3.56 | 75,924 | 79,036 | 71,776 |
| 198 | 1700 | 0.2253 | 0.2316 | 0.209981 | 2.44 | 75,836 | 77,957 | 70,680 |

NOTE: (1) $\tau$ calculated using all binding observations
(2) $\tau$ calculated at overall sample mean
(3) $\tau$ calculated at means of 4 vessel size classes
Gains from trade calculated using all binding observations.

# Productivity and Efficiency of the Fishing Fleet : the Case of the Small Scale Fishing Enterprises in Boulogne

**Chris Ioannidis [a] and Frédéric Lantz [b] ***

[a]Cardiff Business School, University of Wales, Aberconway Building, Colum Drive, Cardiff CF1, 3EU-Wales

[b]Institut Français du Pétrole, 1 & 4 avenue de Bois-Préau, 92506 Rueil-Malmaison, France

ABSTRACT

*The estimation of productivity and efficiency provides a useful tool to evaluate the economic consequences of the regulation policy on the fishing enterprises. The purpose of this paper is to examine some measures of productivity and efficiency of the fleets. The theoretical background of this methodology is the multi-input and multi-output firm behaviour. We use the "production-frontier" function definition to measure input or output inefficiency through a cross-section data analysis. We apply this methodology to the artisanal fleet of Boulogne-sur-mer which is the first French landing port. We have constructed a data base from the daily log-book statistics and we have selected a homogenous sample of 74 trawlers. This example shows how the adoption of different criteria can lead to diverse classifications of the ships.*

## 1. INTRODUCTION

The exploitation of the North Sea fisheries by the French Fishing Fleet, was marked by the relative decline in the importance of 'industrial' vessels and the growing influence of small scale fishing enterprises (Lemoine, 1988).

Because of the risks of over-exploitation of the principal species of the North Sea the European Community took an array of measures aimed at limiting catches. These measures include the total banning of herring fishing during the end of the 70's, a number of temporary suspension of fishing for certain species and various regulations concerning the capturing equipment used by trawlers, mainly the mesh size.

* This study has been prepared with IFREMER. The authors wish to acknowledge the helpful comments of Alain Laurec (EEC-DG XIV) and Alain Maucorps (IFREMER).

In parallel the Community introduced the MAGP's in 1988 in an attempt to reduce permanently the capacity of the fishinng fleets both in terms of tonnage and horse power. A critical and comprehensive survey of these measures can be found in Weber (1990).

The set of these regulatory instruments employed by the Community correspond to their theoretical counterparts cited in the theoretical bio-economic models (Clark, 1985). The usefuleness and limits of such measures have been the objects of several studies (Meuriot, 1987).

An important problem which arises by the application of such instruments of fisheries management is their impact on the profitability of the fishing enterprise. It was noticed that the fleet of the 16-25m trawlers has shown a strong tendency to invest in capital equipement during the mid 1980's as the value of their landings increased. Was such move justified in the presence of this regulatory apparatus ?

The analysis of the different profitability ratios and their indebtness which was established by the examination the accounting information from a sample of 27 among 88 vessels between 1985 and 1989, has revealed that their profitability has shown some decline as their gross margins were squeezed and at the same time their debt burden increased regularly.

Such trends make the analysis of the productivity and efficacy along with the study of their rate of capacity utilisation to be essential in order to appreciate the economic situation of these fishing enterprises and measure the impact of the regulatory measures on their functions.

## 2. PRODUCTIVITY AND EFFICIENCY : SOME THEORETICAL CONSIDERATIONS

Productivity is the relationship between production and inputs, normally capital and labour. It is a measure used frequently to quantify the economic performance of the firm. However, productivity is as it requires the calculation of several ratios between each of the inputs to output. Furthermore such measure does not indicate whether the enterprise is using its utilised inputs optimally.

In an effort to construct the appropriate indices which can measure the degree of 'efficiency', the concept of the 'frontier production functions' has been developed. The literature in this area is quite extensive and we site the work of Tulkens (1988) as a more recent survey of the theoretical concepts involved and Simar anf Deprins (1988) for the relevant econometric applications.

The frontier production function defines, for any given quantity of inputs the maximal output possible, or for any given level of output the minimal quantities of inputs required. Therefore the enterprise will be considered efficient if the appropriately constructed index of its performance, places it on the frontier. Enterprises which do not belong to the frontier are said to be inefficient. If we were to observe an increase in output for the same level of inputs, that is a shift of the frontier, we then talk of technical progress.

The construction of such an index of efficiency requires the definition of a absolute scale. To avoid this problem we will measure the efficiency of each enterprise in terms of the others and utilise a measure of relative efficiency. Thus an enterprise will be judged inefficient and dominated in output if one were to find that other firms produce the same of more output using less of the same levels of inputs. A convinient starting point will the construction of the simpler index of relative efficiency as the ratio between the output of the enterprise and the maximal productions previously encountered.

## 3. MEASURES OF PRODUCTIVITY OF THE TRAWLERS IN BOULOGNE SUR MER

In the light of the previous discussion we set to examine the performance of the 'small scale' fishing trawlers. Our sample consists of a number of fishing units whose log-books were obtained (Allard, 1991). The log books contain information of captures per species, number of days fishing and the number of hours fishing during. In Boulogne there are in excess of 250 fishing vessels which land their catch, but here we concen trate exclusivelly on boats between 16-25, for two main reasons :

(i) they constituted a fishing fleet having access to the the same fishing technology, thus they can be said to technologically homogeneous and

(ii) the accounting information available can be statistically analysed in the context of the concepts used in fisheries economics. The totality of their landings are auctionned a set up which allows to verify the data on captures and the information on time spend fishing can be translated to a measure of fishing effort which is of importance in the literature.

We have constructed a data base of boats using the motor's power and time fishing as factors of production and turnover as a mesure of output. The utilisation of time fishing as a factor of production has eliminated some of the boats from the sample, as they did not report it. We have finally retained 62 boats from the 88 available.

The calculation of the fishing time productivity (Y/TIME) and the motor power productivity (Y/HP) show the median measures of 263 FF/hour and 1610 FF/hour respectively. There was however a great deal of dispersion between the most and least productive boats as the following table (Table 1)

Therefore the calculation of the boat's characteristics following that their productivity is above or below the median does not always allow for the same values for these criteria and consequently the same fishing units, as the classification in Table 2.

Here we remark that the boats which are most productive in terms of motor power (Y/HP>Median) have the same characteristics than the most productive ships in terms of Y/Time. However, the boats with the lowest values of Y/HP have a fishing time which is lower, by 3.5pc, and have turnovers which are higher, by 4 pc in comparison to those whose Y/TIME productivity is low : the ships with the lowest productivity in terms of Y/Time or in terms of Y/HP are not the same.

## 4. MEASURES OF EFFICIENCY OF THE TRAWLERS IN BOULOGNE SUR MER

The application of the concept of efficiency, as defined in the second paragraph, allows us to define 20 boats, considering the inputs and output and classify them as 'efficient'[1] Figure 1 presents the production function frontier. The 'efficient' ships are on the envelop of the production function.

The identification of these vessels as the most productive in terms of Y/TIME and the Y/HP criteria, makes evident that are only one half of the boats common to the intersection of the set of these boats which are deemed efficient in terms of the Y/HP and as thus classified using Y/TIME as a measure of productivity. In consequence the characterisation of the fishing units interms of turnover, fishing time and engive power is quite different following the criretion of efficiency used, as it can be seen of Table 3.

This example shows that how the adoption of different criteria can lead to diverse classifications. In effect the vessels which are more productive in terms of Y/TIME have obviously lower average value for fishing time. Thus the advantages of the use of the criterion of efficiency which combines both inputs are been made clear. Finally, this example points out some undesirable effects of fisheries management tools : the reduction of the global horse power of the fishing fleet does not involve an homothetic decrease of the catches.

1. We have used a criteria in terms of output efficiency : a fishing unit is dominated in output terms if an other boat has both an higher turnover and input factors which are lower or equal. In this case the fishing unit is 'non efficient'. The output efficiency index is defined as the ratio of the turnover divided by the turnover of the closest efficient ship.

## REFERENCES

**Allard M.O.** (1991). *"Analyse du comportement des flottilles de Boulogne-sur-mer"*, Mémoire ENSAE, IFREMER, Marine Economic Service, April 1991.

**Clark C.** (1985). *Bioeconomic modelling and fisheries management*, Wiley, New York.

**Deprins D. and L. Simar** (1988). Mesures d'efficacité de réseaux de chemin de fer, in *Gestion de l'Economie et de l'Entreprise*, CORE, Balise, Bruxelles, 1988.

**Lemoine M., L. Reynal and A. Souplet** (1988). Les flottilles de pêche boulonnaises, *Equinoxe*, IFREMER, Hors Série n° **1 :** 21-32.

**Meuriot E.** (1987). *Les modèles d'exploitation des pêcheries*, IFREMER, Collection Ressources de la mer, Nantes.

**Tulkens H., A. d'Aspremont and C. Nollet** (1988). Mesures de la performance productive d'une entreprise publique, in *Gestion de l'Economie et de l'Entreprise*, CORE, Balise, Bruxelles, 1988.

**Weber J., D. Leviel and E. Grimbert** (1990). La Décision CEE 4028/86 et la gestion des pêches en France, EAFE Annual Meeting, INIP, Lisboa, in *Pesca e Navegacao*, n° **101-102 :** 51-52.

TABLE 1.
PRODUCTIVITY OF FISHING TIME AND HORSE POWER.

| | Y/Time | Y/HP |
|---|---|---|
| Median | 0.263 | 1.610 |
| Average | 0.502 | 2.996 |
| Mode | 0.208 | 1.407 |
| Lower Quart. | 0.053 | 0.370 |
| Upper Quart. | 0.964 | 6.143 |

Unit : 1000 FF

TABLE 2.
SHIP'S CHARACTERISTICS ACCORDING TO THE LEVEL OF PRODUCTIVITY.

| | Y/Time (Lower than the median) | Y/HP (Lower than the median) | Y/Time (Greater than the median) | Y/HP (Greater than the median) |
|---|---|---|---|---|
| Gross earnings (1000 FF) | 183 | 190 | 2371 | 2364 |
| Fishing Time (Hours) | 2247 | 2193 | 2662 | 2716 |
| Horse Power (KW) | 361 | 369 | 442 | 434 |
| Length (m) | 19.9 | 20.0 | 21.3 | 21.1 |
| Year of constr. | 1979 | 1979 | 1984 | 1984 |

Gross earning, Fishing Time, Horse Power, Length : average; Year of construction : median

TABLE 3.
CHARACTERISTICS OF THE 20 MOST PRODUCTIVE VESSELS.

| | Efficiency | Y/Time | Y/HP |
|---|---|---|---|
| Gross earnings (1000 FF) | 1822 | 3037 | 3016 |
| Fishing Time (Hours) | 1921 | 2680 | 2673 |
| Horse Power (KW) | 364 | 435 | 428 |
| (Length (m) | 19.4 | 20.8 | 20.6 |
| Year of constr. | 1979 | 1984 | 1982 |

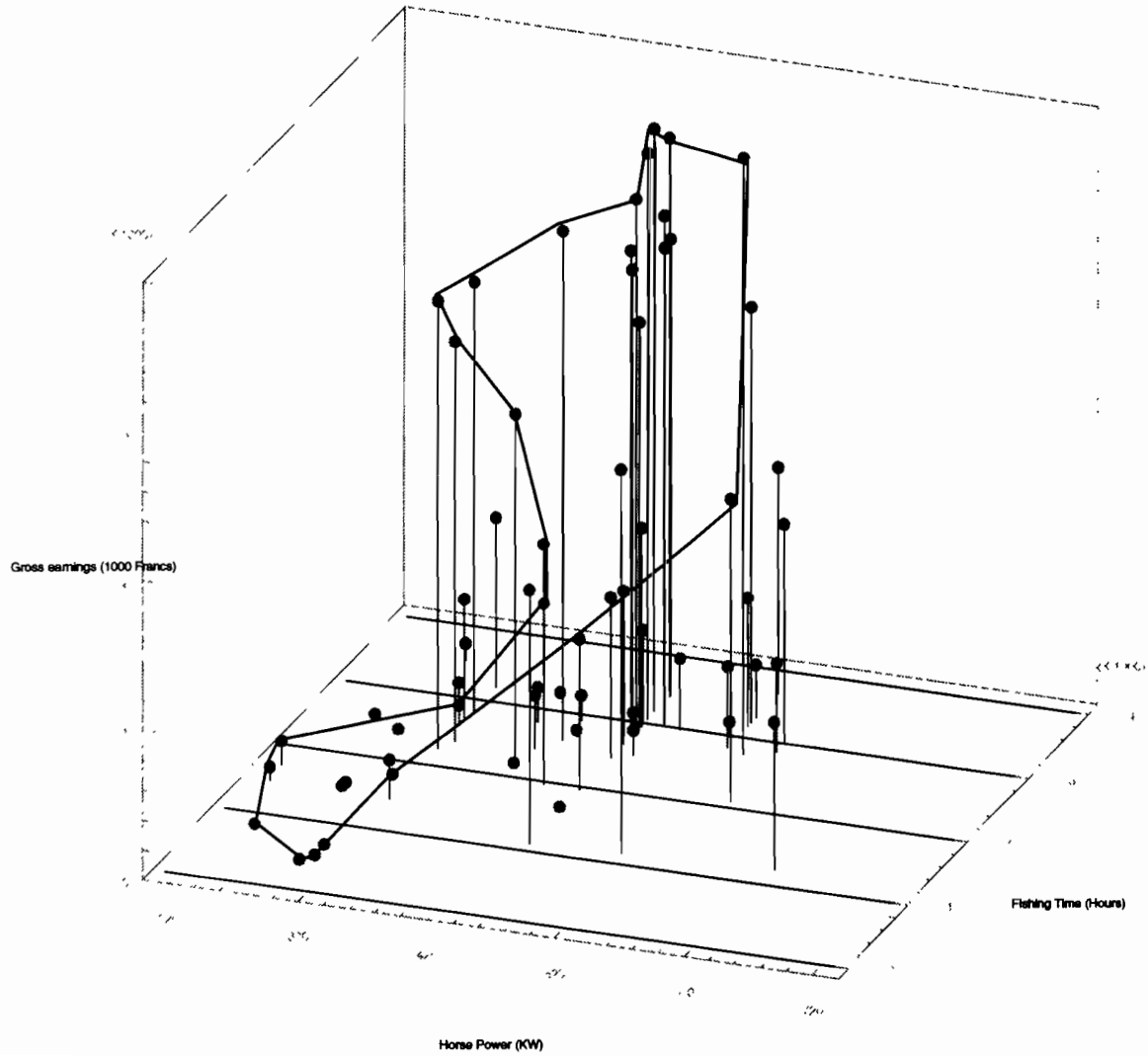
Gross earning, Fishing Time, Horse Power, Length : average; Year of construction : median

## APPENDIX : PRODUCTIVITY AND EFFICIENCY OF FISHING SHIPS (16-25 meters trawlers in Boulogne-sur-Mer in 1989

**Year : Year of construction**
**Efficient : 1 if efficient, 0 otherwise**
**Ef. Index: Index of efficiency (in output terms)**
**Y/Time : Gross Earning/Fishing Time**
**Y/HP : Gross Earnings/Horse Power**

| Length | GRT | Year | HP | Time | Earnings | Efficient | Ef.Index | Y/Time | Y/HP |
|---|---|---|---|---|---|---|---|---|---|
| 17.98 | 49.99 | 1980 | 316 | 2243 | 2989.59 | 1 | 100.00 | 1.33 | 9.46 |
| 20.45 | 49.88 | 1973 | 316 | 2841 | 2862.05 | 0 | 95.73 | 1.01 | 9.06 |
| 14.00 | 102.00 | 1988 | 440 | 3184 | 3896.33 | 1 | 100.00 | 1.22 | 8.86 |
| 23.00 | 70.00 | 1984 | 441 | 3063 | 3783.42 | 0 | 97.10 | 1.24 | 8.58 |
| 20.50 | 49.95 | 1980 | 397 | 2605 | 3402.36 | 1 | 100.00 | 1.31 | 8.57 |
| 20.45 | 49.80 | 1975 | 441 | 3423 | 3732.87 | 1 | 100.00 | 1.09 | 8.46 |
| 16.75 | 29.86 | 1979 | 323 | 2370 | 2672.11 | 1 | 100.00 | 1.13 | 8.27 |
| 21.00 | 84.78 | 1986 | 441 | 2870 | 3557.29 | 1 | 100.00 | 1.24 | 8.07 |
| 20.80 | 100.00 | 1987 | 530 | 2765 | 3986.87 | 1 | 100.00 | 1.44 | 7.52 |
| 20.48 | 58.65 | 1985 | 455 | 3037 | 3394.04 | 0 | 99.76 | 1.12 | 7.46 |
| 20.50 | 49.00 | 1980 | 441 | 2789 | 3246.03 | 1 | 100.00 | 1.16 | 7.36 |
| 20.50 | 59.46 | 1986 | 455 | 3041 | 3175.45 | 0 | 93.33 | 1.04 | 6.98 |
| 24.00 | 102.21 | 1986 | 442 | 3423 | 3057.12 | 0 | 94.18 | 0.89 | 6.92 |
| 21.00 | 49.45 | 1984 | 421 | 3237 | 2905.92 | 0 | 97.20 | 0.90 | 6.90 |
| 20.45 | 49.85 | 1974 | 378 | 2210 | 2324.17 | 1 | 100.00 | 1.05 | 6.15 |
| 21.00 | 59.46 | 1986 | 441 | 2925 | 2709.26 | 0 | 79.63 | 0.93 | 6.14 |
| 23.25 | 103.17 | 1983 | 515 | 3214 | 2777.38 | 0 | 92.90 | 0.86 | 5.39 |
| 16.46 | 40.00 | 1981 | 510 | 1157 | 2560.80 | 1 | 100.00 | 2.21 | 5.02 |
| 19.00 | 49.88 | 1978 | 412 | 1963 | 1598.73 | 1 | 100.00 | 0.81 | 3.88 |
| 20.50 | 47.69 | 1978 | 441 | 1108 | 1691.68 | 1 | 100.00 | 1.53 | 3.84 |
| 24.44 | 120.00 | 1988 | 552 | 2091 | 2016.87 | 0 | 78.76 | 0.96 | 3.65 |
| 20.60 | 49.90 | 1978 | 316 | 3211 | 1128.46 | 0 | 37.75 | 0.35 | 3.57 |
| 24.95 | 109.93 | 1984 | 442 | 2944 | 1326.74 | 0 | 78.43 | 0.45 | 3.00 |
| 22.40 | 76.69 | 1986 | 515 | 3666 | 1515.56 | 0 | 89.59 | 0.41 | 2.94 |
| 24.40 | 110.00 | 1947 | 551 | 3000 | 1460.11 | 0 | 86.31 | 0.49 | 2.65 |
| 17.67 | 49.99 | 1980 | 316 | 2677 | 806.41 | 0 | 26.97 | 0.30 | 2.55 |
| 19.37 | 49.85 | 1978 | 441 | 2461 | 1063.27 | 0 | 62.85 | 0.43 | 2.41 |
| 24.00 | 102.00 | 1988 | 441 | 2672 | 1017.98 | 0 | 60.18 | 0.38 | 2.31 |
| 22.40 | 116.95 | 1988 | 441 | 1947 | 1006.32 | 0 | 59.49 | 0.52 | 2.28 |
| 19.80 | 49.90 | 1982 | 368 | 2909 | 745.74 | 0 | 24.94 | 0.26 | 2.03 |
| 23.52 | 108.82 | 1988 | 515 | 3163 | 854.39 | 0 | 50.51 | 0.27 | 1.66 |
| 23.60 | 102.00 | 1987 | 626 | 1232 | 978.22 | 0 | 38.20 | 0.79 | 1.56 |
| 20.45 | 49.88 | 1974 | 441 | 2985 | 620.57 | 0 | 20.76 | 0.21 | 1.41 |
| 20.50 | 49.95 | 1980 | 551 | 2870 | 587.98 | 0 | 19.67 | 0.20 | 1.07 |
| 23.00 | 76.46 | 1987 | 515 | 2826 | 538.62 | 0 | 31.84 | 0.19 | 1.05 |
| 20.40 | 100.00 | 1984 | 470 | 2981 | 472.85 | 0 | 15.82 | 0.16 | 1.01 |
| 20.40 | 90.35 | 1986 | 383 | 2435 | 350.98 | 0 | 15.10 | 0.14 | 0.92 |
| 20.60 | 49.99 | 1980 | 316 | 1450 | 259.11 | 1 | 100.00 | 0.18 | 0.82 |
| 20.35 | 69.47 | 1954 | 220 | 1714 | 154.97 | 1 | 100.00 | 0.09 | 0.70 |
| 24.40 | 120.00 | 1986 | 515 | 3304 | 347.12 | 0 | 21.71 | 0.11 | 0.67 |
| 18.23 | 45.43 | 1966 | 307 | 2780 | 198.70 | 1 | 100.00 | 0.07 | 0.65 |
| 20.40 | 49.07 | 1983 | 368 | 2807 | 229.55 | 0 | 88.59 | 0.08 | 0.62 |
| 18.98 | 48.57 | 1964 | 316 | 2593 | 139.11 | 0 | 89.77 | 0.05 | 0.44 |
| 20.50 | 49.95 | 1980 | 397 | 2916 | 165.02 | 0 | 83.05 | 0.06 | 0.42 |
| 20.45 | 49.88 | 1972 | 278 | 3511 | 112.40 | 0 | 72.53 | 0.03 | 0.40 |
| 21.00 | 46.84 | 1964 | 222 | 1472 | 86.31 | 1 | 100.00 | 0.06 | 0.39 |
| 24.00 | 102.21 | 1986 | 455 | 2529 | 168.37 | 0 | 84.74 | 0.07 | 0.37 |
| 18.99 | 49.62 | 1979 | 441 | 2826 | 141.05 | 0 | 91.02 | 0.05 | 0.32 |
| 23.00 | 76.46 | 1986 | 508 | 3008 | 82.77 | 0 | 53.41 | 0.03 | 0.16 |
| 16.05 | 46.08 | 1974 | 305 | 444 | 58.19 | 1 | 100.00 | 0.09 | 0.13 |
| 20.00 | 48.73 | 1963 | 278 | 1472 | 29.67 | 0 | 34.37 | 0.02 | 0.11 |
| 20.67 | 49.85 | 1975 | 404 | 2687 | 38.69 | 0 | 24.97 | 0.01 | 0.10 |
| 16.50 | 33.98 | 1982 | 278 | 1532 | 26.14 | 0 | 30.28 | 0.02 | 0.09 |
| 20.50 | 49.00 | 1983 | 368 | 3185 | 33.58 | 0 | 87.91 | 0.01 | 0.09 |
| 16.00 | 29.67 | 1979 | 242 | 794 | 19.10 | 1 | 100.00 | 0.02 | 0.08 |
| 20.50 | 49.85 | 1975 | 442 | 1598 | 34.06 | 0 | 89.19 | 0.02 | 0.08 |
| 16.20 | 46.48 | 1967 | 303 | 647 | 20.63 | 1 | 100.00 | 0.03 | 0.07 |
| 16.28 | 43.21 | 1972 | 252 | 2571 | 8.66 | 0 | 45.35 | 0.00 | 0.03 |
| 17.20 | 49.98 | 1984 | 278 | 2408 | 8.62 | 0 | 45.13 | 0.00 | 0.03 |
| 20.50 | 49.05 | 1968 | 303 | 1780 | 5.94 | 0 | 31.07 | 0.00 | 0.02 |
| 20.45 | 49.85 | 1974 | 378 | 2185 | 1.97 | 0 | 10.32 | 0.00 | 0.01 |
| 19.00 | 46.00 | 1962 | 294 | 430 | 0.89 | 1 | 100.00 | 0.00 | 0.00 |

**FIGURE 1.**
**PRODUCTION FUNCTION OF THE 16-25 TRAWLERS IN BOULOGNE-SUR-MER**



# Setting Total Allowable Catches based on Market Conditions : Economics of Atlantic Herring Roe Production

**Robert Nowak**

Department of Fisheries and Oceans, Scotia-Fundy Region, P.O. Box 550 Halifax, Nova Scotia, B3J 2S7, Canada

ABSTRACT

*For many years fishery biologists, economists and resource managers have struggled to define some "optimal" criterion to set the amount of maximum harvest or total allowable catch (TAC). Many reference points have been suggested. Biologists used objective biological criteria to establish maximum sustainable yields (MSY). Economists have proposed the maximum economic yield (MEY) concept which maximizes a stream of net revenues. Meanwhile, pragmatic fishery managers have used a combination of political, biological and economic factors to determine TACs to address a multitude of conflicting "socioeconomic" objectives (Optimal Sustainable Yields).*

*In recent years, a new term has appeared : a "market-determined" TAC. Specifically, the Atlantic Canada herring industry has argued that the abundance of herring, the dominance of the Japanese herring roe market by Canadian exports and limited alternative markets for other herring products constitute required conditions to introduce a market TAC.*

*This paper presents a framework for evaluation of the market-determined TAC concept based on the Scotia-Fundy (4WX) herring purse seine fishery. Although the term implies some relationship between the amount of fish allowed to be caught/sold and market conditions, it is not an ambiguous concept. At best, it could be defined as an initiative that prevents oversupplying market segments currently occupied by Canadian products. The paper describes the program's potential design, its effectiveness and distributional consequences. It is shown that a strategy of limiting catches might be the wrong strategy to pursue for the 4WX herring fishermen. A simple quantity-dependent model is used to estimate the price elasticity of final demand for flavoured herring roe products. These policy implications, however, may be misleading given a speculative and non-competitive nature of the Japanese market. Thus, the paper considers other methods of market manipulation particularly, the possibility of "designing" a different market structure in order to ensure a more favourable outcome. The inherent instability and difficulty in distribution of potential gains also disqualifies this approach.*

## 1. INTRODUCTION

Market considerations have recently been suggested as a potential reference point in determining the amount of maximum herring harvest. Specifically, the Atlantic Canada herring industry has argued that the abundance of herring, the dominance of the Japanese herring roe market by Canadian exports and limited alternate markets for other herring products constitute required conditions to introduce a "market-determined" total allowable catch (TAC). Although the term implies some relationship between the amount of fish allowed to be caught or sold and market conditions, it is not an unambiguous concept. At best, it could be vaguely defined as an initiative that "prevents oversupplying market segments currently occupied by Canadian products" (Kirby, 1982, p.289).

This paper consists of four main sections. First, a short history of the herring roe market is presented. Second, various reference points used to establish TACs are discussed. Third, a simple demand model is used to estimate the price elasticity of demand for flavoured herring roe products. Finally, it is shown that a strategy of limiting herring catches in Atlantic Canada might be the wrong strategy to pursue for reasons other than those implied by the elasticity estimates.

## 2. AN OVERVIEW OF THE HERRING ROE FISHERY

Consumption of herring roe (kazunoko) is deeply rooted in Japanese tradition. For decades it has played an integral part of Christmas, New Year and wedding celebrations in Japan. The name itself (prolific eggs as opposed to herring eggs) confirms kazunoko's special position in the Japanese culture. Japan is also the principal market for kazunoko in the world.

Japanese fishing fleets used to satisfy most of the domestic demand for herring. Subsequently Japanese catches gradually declined, but herring import quotas effectively prevented a market penetration by foreign producers. In 1972 trade restrictions were relaxed and for the next few years Chinese fleets supplied most of the Japanese herring market with the residual being supplied by Canadian British Columbia catches. Subsequent depletion of Chinese herring stocks allowed the B.C. production to become the dominant supplier (Alley, 1982).

In Japan, herring roe products fall into two distinct groups. The traditional product is salted roe (shio kazunoko). It is consumed mostly during Christmas holidays or given as a year-end gift. Pacific herring is predominantly used for this product. It is estimated that less than 20 % of Atlantic herring roe is salted (less than 10 % of Atlantic Canada herring roe). Consumption of salted roe has reached a maturity stage with static consumption patterns (Anderson et al, 1989). The other class of products, flavoured herring roe (ajitsuke kazunoko), was developed in the 1980s. It is believed that this range of products was developed to utilize herring roe unsuitable for salted roe production. Flavours include soya sauce, brandy, hot peppers and wine. Over 90 % of Atlantic Canada herring roe exports goes into production of flavoured roe. Unlike salted herring roe, these products are promoted as snacks for consumption throughout the year.

The emergence of a market for flavoured herring roe has been rapid. Atlantic Canada herring roe production increased from 400 tonnes in 1983 to almost 8,000 tonnes in 1990. Two Canadian regions export roe to Japan : the Atlantic part of the province of Nova Scotia (Scotia-Fundy Region) and the Gulf of St. Lawrence (Gulf Region). In Scotia-Fundy most herring is caught using purse seines. Fishing for herring roe has become the most important activity for about 40 purse seine vessels. In 1988, about 70 % of all purse seine landings were for roe extraction. In the Gulf Region, fishing for herring has also become an increasingly important income supplement to cod, crab, and lobster for about 600 fishermen employed on 200-300 boats. In Gulf, herring for roe extraction are caught using gillnets.

While Canadian herring fishermen and processors are becoming more dependent on herring roe sales, there have been continuous reports of "unsatisfactory" pricing and grading methods by Japanese buyers. The Atlantic Canada industry believes that the Japanese use discriminatory (monopsonistic) pricing to their advantage. For example, Japanese buyers have been reported to use information on the number of weeks the plant workers needed to qualify for Unemployment Insurance in price and volume negotiations. These negotiations frequently continue for weeks after the roe has been shipped to Japan. Although no specific proposals have been posited, some segments of the Atlantic Canada herring roe industry believe the same marketing arrangement is necessary to counteract this unfavourable market structure. It has been suggested that a market-determined total allowable catch (ie., limited roe sales) would strengthen the weak bargaining position of Canadian sellers and increase their revenues.

## 3. TOTAL ALLOWABLE CATCH

For many years fishery biologists, economists and resource managers have attempted to define some criterion to set the amount of maximum harvest or total allowable catch. Many reference points have been suggested. Originally, biologists used objective biological criteria such as maximum sustainable yields (MSY). Subsequently, this reference point was declared *not sustainable*, not operational and thus unacceptable (Larkin, 1977). The concept of maximum sustainable yield is the simplest biological management objective that aims at the maximum harvest (in perpetuity) without altering the stock level. The concept is based on the assumption that the exploitable population of each stock has an optimum size which could be maintained if the annual catches are equal to the annual natural increases in the stock size.

The concept relies crucially on the assumption that catches are the only factor influencing fish populations ; it completely ignores natural fluctuations in stock abundance. Given the presence of stock fluctuations, it is clear that constant-yield policies cannot be optimal and/or sustained (Clark, 1985). In addition to natural stock fluctuations, the TACs based on MSY do not prevent further stock declines because of incomplete catch statistics, overfishing, and lags in scientific advice. Furthermore, the MSY concept completely ignores economic costs of exploitation of the resource while the single most important objective of fishing is earning money and not fish removal per se. Fishermen operate in the world of fluctuating fish stocks and are confronted with changing prices, exchange rates, interest rates, fuel costs and shifting tastes. To account for these factors, economists have proposed the maximum economic yield (MEY) concept.

The static MEY point represents the point where economic rent is maximized (without intertemporal considerations and fishermen are price takers). This is the point where the difference between revenues and costs of fishing is largest. In economic jargon, this happens where incremental revenues (marginal revenue) obtained through adding a small amount of input costs (marginal cost) are just equal. This useful reference point, however, is rarely observed in practice as most fisheries employ redundant capital and labour relative to the available supply of fish.

The employment of redundant capital and labour is well-documented in economic literature. Fishermen collectively are not economic profit maximizers (and fish at effort levels beyond MEY) not because of irrationality, but due to the undesirable aggregate outcome of their individual actions. In case of unrestricted entry fisheries, the new entrants are not worried about their effect on other fishermen. They are concerned with their own revenues. As long as average revenue is greater than marginal cost new fishermen will be attracted to the fishery until the open-access equilibrium is reached. In case of restricted (limited) entry fisheries, fishing effort (cost of fishing) increases through more "intensive" fishing practices by the existing boats (input stuffing). This is usually accomplished by the use of more powerful, bigger vessels, more efficient fish finding technology or any other efficiency increasing method allowed by fishing authorities.

In an intertemporal setting, the dynamic MEY maximizes a stream of net revenues. This concept, however, may be burdened by the difficulty in choosing the appropriate social discount rate and time horizon. The choice of a discount rate is crucial as the most desirable point of economic exploitation may fall anywhere between the static maximum economic yield and open-access points depending on society's time preference (Cunningham and Whitmarsh, 1981).

The significance of the magnitude of discount rate in determination of optimal TACs has been established. In fact, Clark (1973) showed that given no preference between present and future income (a zero discount rate), static and dynamic MEY points coincide. In case of an infinite discount rate (when future income has no value), the dynamic MEY is equivalent to the open-access point. Subsequent research has, however, complicated this intuitively simple solution. For example, Farzin (1984) and Hannesson (1987) illustrated, for exhaustible and renewable resources respectively, that the discount rate has an ambiguous effect on the optimal rate of resource extraction. This happens because a higher discount rate may increase extraction-harvesting costs (by raising opportunity cost of capital), thus forcing a lower level of exploitation. This effect may or may not outweigh an incentive to catch more the higher the discount rate (ie., the time preference effect).

Both MSY and MEY concepts serve as useful reference points but have been criticized for pursuing single objectives. There exist, however, other reference points which attempt to trade off various biological, economic and ecological factors. For example, the $F_{0.1}$ fishing mortality strategy, officially adopted as the management criterion by Canada in 1977, recognized explicitly the need for stock rebuilding. The $F_{0.1}$ strategy is based on the concept of the marginal yield from fish stocks (Gulland, 1968). The $F_{0.1}$ fishing mortality criterion is defined to be that fishing mortality which is derived from application of "a marginal yield equal to one-tenth of the original catch per unit of effort in the very lightly exploited fishery" (Gulland and Boerema, 1972).

The theory of $F_{0.1}$ predicts larger biomass over time consistent with the task of stock rebuilding. Other benefits of this strategy include larger fish and more year classes in spawning biomass. Biologists claim that the $F_{0.1}$ fishing mortality

may use less than two-thirds of the effort maximizing yield (Canada, 1988). The $F_{0.1}$ is also supposed to embrace practical concerns. The 10 % "safety buffer" (although completely arbitrary) addresses uncertainty. However, the $F_{0.1}$ strategy may be outdated and its usefulness questionable under the current exclusive 200-mile fishing jurisdiction (Canada, 1987). In addition, biological and economic premises on which this approach is based may also require a closer examination (Lane, 1989).

The choice of an appropriate reference point implicitly reflects the return maximizing strategy by fishing authorities. For example, the MEY emphasizes cost minimization while the $F_{0.1}$ recommends more and bigger fish (higher revenues). Naturally, a strategy suggesting higher per unit fish prices (ie., market TAC) belongs in the same class of reference points. In addition, while the $F_{0.1}$ strategy entails efficiency, equity, biology and employment trade-offs, the market-TAC approach would also involve a similar compromise[1].

## 4. MARKET DEMAND FOR HERRING ROE PRODUCTS IN JAPAN

Typically, common property characteristics and particularly competition for the fixed supply of fish among fishermen causes the desired catch to exceed the level established by fishing authorities. In economic terms, this occurs because each fisherman faces a perfectly elastic (horizontal) demand curve. As a price taker he cannot influence prices. Thus, increases in his revenues can only be obtained through increased catches while a port market is most likely to absorb available supply at prevailing prices.

In contrast, the market final demand curve is usually downward sloping. This implies higher prices can be obtained by lowering quantities (and vice versa). Accordingly, sellers could act as price makers, as opposed to price takers facing a horizontal demand curve, provided that they are "dominant" suppliers (between 1980 and 1990 Canadian exports of frozen herring roe had on average 85 % of the frozen herring roe market share in Japan). The greater the market share, the higher the chances of successful price setting by sellers. This market mechanism is, in fact, well recognized. For example, a fishermen's union spokesman was recently quoted : "Japan, the main buyer of herring roe, had a surplus from last year and is controlling prices." He also added that "if a limit was set to 2,000 tonnes in the Bay of Chaleur and 2,000 in Fundy, supply would be limited and the Japanese buyers would no longer be in a position to keep prices down."[2]

The quote, of course, implicitly assumes that reduction in quantities sold will be outweighed by increased prices resulting in higher revenues. In fact, a ratio of a percentage change in quantity over a percentage change in price (or price elasticity of demand) measures the magnitude of such changes. If the demand is inelastic (less than one), a change in price causes a less than proportionate change in quantity demanded. Thus, lower quantities lead to higher revenues when an industry operates on the inelastic portion of the market demand curve. If the demand is elastic (greater than one), a change in price causes a more than proportionate change in quantity. Thus, total revenue rises when price falls and falls when price rises.

Although there have been no market demand estimates for flavoured (or frozen) herring roe, the elasticity for salted herring roe has been estimated to be inelastic or close to one (Table 1). Of particular importance is the fact that the calculated estimates vary depending on the season or market segment studied. The estimates of Anderson et al (1989) along with economic theory may assist in predicting the price elasticity of demand for flavoured herring roe. For example, the more the possible uses of a commodity the more elastic the demand for a commodity is expected to be, and if the commodity has close substitutes, the more elastic it should be. In general, luxury goods are price elastic, while necessities are price inelastic. Demand is also more elastic in the long run. Because flavoured herring roe has many substitutes (it is consumed as snacks competing with other snacks) and cannot be classified as a necessity, one would expect it to be price elastic.

Table 2 illustrates a rough test to indicate the relationship between frozen herring roe prices and quantities. It also measures approximate price elasticities evaluated at a Canadian plant level, ceteris paribus. In Scotia-Fundy, the data

1. In general, the presence of economic, biological and social compromises inevitably leads to a concept of Maximum Social Yield (Anderson, 1977). In essence, sometimes, it may be necessary to move away from economic and biological paradigms in order to satisfy other objectives. For example, promotion of fishery underemployment in economically disadvantaged areas with few employment alternatives might be such a different objective.
2. "Fishermen looking for herring limit", *The Telegraph-Journal*, August 23, 1991.

indicate a negative relationship between quantity sold and price received for frozen herring roe in 1983-1990. On three occasions, however, an increase (decrease) in quantities sold coincided with an increase (decrease) in corresponding prices. In contrast, in the Gulf Region, this unorthodox relationship seems to have been prevalent for all, but two years. It is clear that this method based on ex-plant Canadian data is neither conclusive nor rigorous (ie., an identification problem) with respect to the hypothesized relationship between quantities traded and prices and the estimate of price elasticity. Thus, a formal demand model has been formulated and estimated.

## 5. THE MODEL

The model tested in this paper is of the form :

$$Q = aP^b P^c Y^d$$

All coefficients were determined from the following log-log, static equation (ignoring dummy variables, time subscripts and error terms) :

$$\ln Q = a + b \ln P + c \ln P_s + d \ln Y$$

where :

| | |
|---|---|
| Q = quantity demanded | a = intercept |
| P = own price | b = price elasticity of demand |
| $P_s$ = price of substitutes | c = cross price elasticity |
| Y = income | d = income elasticity of demand |

and the expected signs of coefficients are $b < 0$, $c > 0$, $d > 0$

Wholesale Sapporo auction monthly price data for years 1984-1990 were used as a proxy for retail data (the Sapporo market is considered to be the price setter for flavoured herring roe in other Japanese markets). Average monthly prices were available therefore differences in quality and size could not be taken into account. The quantity variables were calculated as traded auction quantities prorated by Japanese domestic consumption. The income data were given by a per capita Gross National Expenditure. A substitute price index was chosen arbitrarily and proxied by food price index. All nominal variables were deflated by the Japanese Consumer Price Index. Some equations employed dummy variables to distinguish between the November/December demand and the rest of the year demand (auction data strongly suggested a structural break in November). Data were obtained from a variety of sources : OECD Main Economic Indicators ; Economic Statistics Annual, 1990, The Bank of Japan ; Japanese Fisheries Market Report, August 1991, Department of External Affairs ; Bill Atkinson's News Report (Issue 410) ; and Annual Report of Sapporo Central Wholesale Market.

Ten different equations were tested (Table 3). The first five equations had "quantity-dependent" specifications. In this case economic theory suggests prices set by the "Walrasian auctioneer" which together with income and substitute effects determines quantities demanded. The other five equations were of "price-dependent" type. Price-dependent specifications conveniently allow for the supply of fish to be exogenously determined (variations in supply cause variations in prices not vice versa). It is worthwhile to note that fishery products demand studies have created a debate among economists with respect to proper approaches, functional forms, specifications and included variables (see Nash and Bell, 1969 ; DeVoretz, 1987 ; Schrank et al., 1988).

The quantity-dependent specifications (equations 1-5) performed fairly well. Equation 4 supplied the best fit :

$$\begin{matrix} \text{Ln } Q_t = & 22.39 & - 2.43D_t & + (0.2D_t & - 1.09)\ln P_t & + 3.55 \ln Y_t \\ & (3.25) & (-0.49) & (0.29) & (-1.63) & (4.13) \end{matrix}$$

where :

t-statistics in parentheses

$Q_t$ = per capita quantity demanded

$P_t$ = deflated price

$Y_t$ = per capita real income

$D_t$ = binary (dummy) variable

$D_t$ = 0 for November and December, $D_t$ = 1 otherwise

Given the logarithmic functional form, coefficients represent respective, constant elasticities. (The linear specifications did not produce satisfactory results and are not reported). The income coefficient was statistically significant and positive (greater than unity) indicating that flavoured herring roe is a normal and luxury good. (3.55 is the value of income elasticity of demand). The price variable had the expected sign. Price elasticity of demand (for November and December) was -1.09 ; and price elasticity for the months January through October was -0.89. The hypothesis of unitary price elasticity of demand in November/December could not be rejected at a 1 per cent level of significance. The price elasticity of -1.0 for January-October was statistically significant at a 1 per cent level.

The price-dependent specifications (equations 6-10) did not perform satisfactorily. The key quantity variable displayed the wrong sign in most cases and was not statistically significant. All equations were corrected for autocorrelation (AR1). High coefficients of determination and statistically non-significant t-statistics suggested presence of multicollinearity. The estimated elasticities of both income and own price were extremely high. It is interesting to note that these results confirm other fish demand studies where results are sensitive to the choice of the functional forms (linear or logarithmic) and the choice of the dependent variable.

The results of equation 4 indicate that the demand for flavoured herring roe is unit elastic at the auction level. This has interesting implications. First, it indicates that sellers of flavoured roe obtain maximum revenues. Second, assuming a competitive distribution chain, revenues of Canadian fishermen and processors are also maximized. Adjustments in fishing effort will not produce higher revenues and there exist no double maxima revenue curve (Anderson, 1973). Third, if employment considerations are important, Canadian sellers should not attempt to reduce the quantities offered. This means that contraction of output destined for the Japanese herring roe market could be the wrong strategy to pursue. On the contrary, expanding frozen herring roe sales to Japan would increase domestic employment. In addition, the estimated coefficients are for "total" flavoured herring roe. The demand for herring roe of Atlantic Canada origin would be more elastic (due to the possibility of substituting roe from other countries or even British Columbia). The more elastic the demand, the greater will be gains from expanded sales.

The major shortcoming of the model proposed here is lack of explicit consideration given to inventories. Specifically, a consistent carry-over of inventory could imply a non-competitive market structure which should be modelled appropriately. In addition, the impact of exchange rates should be taken into account. In many cases exchange rate fluctuations play a more important role than price changes in revenue determination.

## 6. MARKET STRUCTURE : THEORETICAL AND EMPIRICAL EVIDENCE

If sellers were to act as a monopoly, the profit maximizing strategy would require setting output (or prices) at the point where marginal costs equal marginal revenues (price > marginal revenue). Because monopolist must operate on the positive portion of the marginal revenue curve (on the elastic portion of market demand curve), the profit maximizing price would be higher than that maximizing total revenue. Thus herring roe sellers would benefit if they could act as a monopoly (conditional on the position of average cost curve)[3].

However, establishing a monopoly may be costly and/or unsuccessful. This section evaluates pragmatic and qualitative factors which may disqualify the market TAC approach in this fishery. Moreover, because some economists believe that

3. Maximization of profits and consumer surplus would result in a greater social benefit than maximizing profits alone. Because all herring roe is sold abroad thus foreigners would bear reductions in consumer surplus and deadweight losses.

"to date the empirical results in the area of fish products demand have been too diverse to permit strong policy recommendations to be based on them" (Schrank et al., 1988), empirical evidence is provided to illustrate some typical responses of fishing industry to government-imposed market structures.

Market structure plays an extremely important role in determining prices and output produced. On the one hand, a monopolist is able to set a higher than purely competitive price and reduce his output, thus increasing his overall profits. This particular market structure raises distributional issues : a redirection of income from consumers to producers and deadweight losses. On the other hand, a bilateral monopoly provides an indeterminate outcome : the equilibrium in such a market cannot be determined by the traditional economic tools of demand and supply (Fellner, 1947). Economic analysis can only define the range within which the price will eventually be settled. The precise level of the price (and output) will depend on the bargaining power, skills and other strategies of the participants.

Table 4 illustrates a selective survey of theoretical literature describing various market structures in fisheries, but provides no unambiguous basis for favouring one market structure over the other. In essence, socially efficient outcomes are determinate only under specific conditions. Moreover, provided all Atlantic Canada herring roe is exported, a socially efficient solution would not be sought by a profit-maximizing monopolist or export cartel.

According to economic theory, the main condition for a successful export cartel is that the elasticity of demand for imports must be low in the relevant price range. This condition can be extended into two others : (1) the elasticity of supply for the "cartelized" good must be low and (2) the cartel must control a large share of the world market for the commodity.

The previous section has shown that demand for frozen herring roe imports is unit elastic. (Demand for *Canadian* exports, as discussed above, could be even more elastic.) Conditions (1) and (2) above are also violated confirming the reasonableness of the previously calculated estimates. First, effective barriers to entry into the Japanese herring roe market do not exist. In fact, the number of countries exporting roe to Japan tripled in the 1980s. Canadian roe exports have been increasing, but at a lower rate than competitors, particularly the Europeans (Anderson et al, 1987).

Second, although Atlantic Canada exports satisfy between 75 and 97 per cent of the Japanese demand, herring roe products have numerous substitutes not only among other roes. As previously mentioned flavoured herring roe competes in the "snack" market. Moreover, the product substitution takes place not only at the retail level, but also at the intermediate input level (ie., lower quality Pacific roe is used in production of flavoured roe and the highest quality frozen roe is salted for the Christmas gift market). In conclusion, the market-TAC approach for Atlantic Canada exports of frozen herring roe may reduce total revenues even in the short-run.

There exists other evidence suggesting that export cartels rarely achieve maximum joint profits. Cartels are unstable because individual firms do not have identical costs ; market demand must be correctly estimated for the price demanded to be the monopoly price ; each individual firm has a strong incentive to present low-cost figures during cartel negotiations and cheat on their subsequent output. Finally market conditions usually change faster than the cartel's ability to negotiate new agreements.

Moreover, different skills and motivations, different levels of profitability, different attitudes toward risk-taking, the long tradition of competitive spirit among fishermen and technological progress are variables influencing the behaviour of fishermen. The imposition of a central planner would certainly introduce a conflict among private firms (of unequal capabilities and differing interests), in addition to the bureaucratic rigidities, reduced innovation and entrepreneurial drive[4]. Specifically, distribution of relative gains and losses between domestic fishermen and processors would be difficult to accomplish (Kirby, 1982)[5].

These economic predictions have been tested empirically. For example, White and Mace (1988) show that cooperative arrangements among fishermen seldom persist. In Scotia-Fundy, a herring fishermen's co-op, created with the assistance

4. Hayek (1989) argues that competition, not cooperation is the only way to discover what resources we have and which uses of these resources would add most to its total product. In short, it is not possible to design an order in which participants interact through some sort of central authority. Any such a deliberate arrangement would deny itself information (prices) necessary for its profit maximizing approach.
5. "It has been suggested that Canadian processors could take advantage of their large share of some market segments to extract higher prices by restricting the flow of product to a given market and charging customers higher prices. In practice, however, the absence of a practical way of restricting the flow of Canadian products to a particular market or buyer, while compensating those firms whose products would be diverted to less profitable markets or left in the sea, largely eliminates the possibility of attempting to exercise this kind of market power" (Kirby, p.294).

of government in the 1970s, broke down fairly quickly. Despite the cartel collectively bargaining over the price of herring with buyers and allocating catch quotas among its members, individual arrangements between fishermen and buyers undermined the cartel's activities. Low cost producers (highliners) felt their individual quotas were not as high as they were capable of catching. In economic terms, foregone rents to intramarginal fishermen were greater than the total gains from this cooperative arrangement.

In Norway a sales cooperative created to maintain order in the salmon marketplace recently filed for bankruptcy (Seafood Leader, 1992). Of particular interest were reports of circumvention (or outright cheating) of minimum export prices by farmers and exporters of fresh salmon. The natural tendency to overproduce is shown by the "mountains" of frozen salmon in the cooperative's freezers.

If neither cheating nor expensive accumulation of unsold products, destroy cartels division of perceived gains may. For example, Chinese authorities set farmed shrimp prices which when disregarded lead to standoffs between shrimp farmers and buyers. As a result processors handle most of the harvest in a short time leading to poor quality product and lost revenues for exporters. This price setting system is largely ineffective : "The Chinese will tell farmers how much they can grow and what prices they can charge, and they will tell processors how much they can charge. But someone forgot to tell the outside world how much they should pay" (Seafood Leader, 1991).

Finally, international trade theory predicts that an export restriction would cause a shortage of herring roe in Japan creating an additional profit margin between price and costs. This profit would most likely accrue to Canada (depending on the method used to limit exports). In other words, while an export restricting strategy may be beneficial to Canada as a supplier of the large world market share, the Japanese as the principal world demander of that commodity may retaliate through tariffs capturing that profit margin. The final outcome of such herring roe trade war may not be beneficial to Canada. It should be noted that the Japanese used tariff revenues to compensate herring fishermen after the domestic herring stocks collapsed in the 1960s (Alley, 1982).

## 7. CONCLUSIONS

1. Market TAC constitutes a valid concept in the family of reference points used to determine total allowable catches.

2. Preliminary estimates suggest that price elasticity of final demand for flavoured herring roe is unit elastic. This result does not satisfy the necessary condition for implementation of market TAC for the Atlantic Canada herring roe fishery.

3. Theoretical considerations show no conclusive evidence that the existing "regulated competitive" structure is inferior to any other regulated market structure. This is further supported by other countries' experience with minimum export prices or cartel-like arrangements. Furthermore the costs of setting up such institutions and enforcing the optimal economic behaviour would likely be prohibitive.

5. The success of implementing a market TAc is doubtful because of the existence of many international herring roe suppliers and substitutes for herring roe.

6. The "market" TAC approach can work well if its main function is distributional and not profit maximization. For example, allowable catches of capelin in Atlantic Canada are limited to approximate Japanese market demand. The capelin management plan is designed to prevent gear conflicts and allow all licensed capelin fishermen to have fair access to the resource. (Capelin migrate northward and it is possible to satisfy market requirements before all fishermen have had a chance to fish it.)

## REFERENCES

**Alley A.G.** (1982). "Speculation, Risk and Consumer Demand in Japanese Markets for Herring Roe", in *Proceedings of the International Seafood Trade Conference*, Anchorage, Alaska, Alaska Sea Grant Report No. 83-2.

**Anderson J.L., J.T. Gledhill and Y. Kusakabe** (1989). "The Japanese seafood market : Herring roe", A report prepared for Department of Fisheries and Oceans, J.L. Anderson & Co.

**Anderson L.G.** (1973). "Optimum economic yield of a fishery given a variable price of output", *Journal of the Fisheries Research Board of Canada*, **30 :** 509-518.

**Anderson L.G.** (1977). *"The Economics of Fisheries Management"*, The Johns Hopkins University Press.

**Canada** (1987). *"A study of trends of cod stocks off Newfoundland and factors influencing their abundance and availability to the inshore fishery"*. A report to the Honourable Tom Siddon, Minister of Fisheries and Oceans, submitted by the Task Group of Newfoundland Inshore Fisheries.

**Canada** (1988). *"Resource prospects for Canada's Atlantic fisheries, 1989-1993"*. Department of Fisheries and Oceans, Ottawa.

**Clark C.W.** (1973). "Profit maximization and the extinction of animal species", *Journal of Political Economy*, **81 :** 950-61.

**Clark C.W.** (1985). *Bioeconomic Modelling and Fisheries Management*, John Wiley and Sons.

**Clark C.W. and G. R. Munro** (1980). "Fisheries and the processing sector : some implications for management policy", *Bell Journal of Economics*, **11 :** 603-616.

**Crutchfield J.A. and G. Pontecorvo** (1969). *"The Pacific Salmon Fisheries : A Study of Irrational Conservation"* , The John Hopkins University Press, Baltimore.

**Cunningham S. and D. Whitmarsh** (1981). "When is overfishing underfishing ?", *Environmental Management*, **5** (5) : 377-384.

**DeVoretz D.** (1982). "The Uses and Abuses of Econometric Models in Seafood Industry : A Case Study of the B.C. Roe Herring Industry", in *Proceedings of the International Seafood Trade Conference*, Anchorage, Alaska, Alaska Sea Grant Report No. 83-2.

**DeVoretz D.** (1986). "Japan's import demand for a key Canadian fish export : Manipulation of kazunoko inventories", Discussion Paper Series, No.2/86, Institute of Fisheries Economics, Norwegian School of Economics and Business Administration.

**DeVoretz D.** (1987). "A Review of Some Econometric Fish Demand Literature", unpublished manuscript.

**Farzin Y.H.** (1984). "The effect of the discount rate on depletion of exhaustible resources", *Journal of Political Economy* **92 :** 841-851.

**Fellner W.** (1947). "Prices and wages under bilateral monopoly". *Quarterly Journal of Economics* **61 :** 503-32.

**Gulland J.A.** (1968). "The concept of marginal yield from exploited fish stocks". *Journal de conseil international de l'exploration de la mer* **32 :** 256-261.

**Gulland J.A. and L.K. Boerema** (1972). "Scientific advice on catch levels". *Fishery Bulletin* **71** (2) : 325-335.

**Hamalainen R.P., J. Ruusunen and V. Kaitala** (1990). "Cartels and Dynamic Contracts in Sharefishing". *Journal of Environmental Economics and Management*, **19 :** 175-192.

**Hannesson R.** (1985). "The effects of a fishermen's monopoly in the market for unprocessed fish". *Marine Resource Economics* **2** (1) : 75-85.

**Hannesson R.** (1987)."The effect of the discount rate on the optimal exploitation of renewable resources", *Marine Resource Economics* **3** (4) : 319-329.

**Hayek F.** (1989). *The Fatal Conceit : The Errors of Socialism*, The University of Chicago Press, Chicago.

**Kirby M.** (1982). *Navigating Troubled Waters : A New Policy for the Atlantic Fisheries*. Report of Task Force on Atlantic Fisheries, Supply and Services Canada.

**Larkin P.A.** (1977). "An epitaph for the concept of maximum sustainable yield". *Transactions of the American Fisheries Society* **106** (1) : 1-11.

**Lane D.E.** (1989). "Economics of $F_{0.1}$". *Economic and Commercial Analysis Report* No.18, Department of Fisheries and Oceans, 36p.

**Meany T.F.** (1979). "Limited entry in the Western Australian rock lobster and prawn fisheries : an economic evaluation". *Journal of the Fisheries Research Board of Canada* **36 :** 789-798.

**Munro G.R.** (1982) "Bilateral monopoly in fisheries and optimal management policy", in *Essays in the economics of renewable resources*, ed., L.J. Mirman and D.F. Spulber, North Holland Publishing Company.

**Nash D.A. and F.W. Bell** (1969). "An Inventory of Demand Equations for Fishery Products", Working Paper No. 10, Bureau of Commercial Fisheries, Division of Economic Research.

**Schrank W.E., E. Tsoa, N. Roy and B. Skoda** (1988). " Data Problems in the Analysis of Markets for Fish Products", in *Proceedings of the 4th Biennial Conference of the International Institute of Fisheries Economics and Trade* , Esbjerg, Denmark.

**Schworm W.E.** (1983). "Monopsonistic control of a common property renewable resource". *Canadian Journal of Economics* **16** (2) : 275-87.

**Seafood Leader** (1991). "China's Gift to the World", vol. 11, No. 6, November/December.

**Seafood Leader** (1992). "Norway's Salmon Industry Shatters into Chaos", vol. 12, No. 1, January/February.

**Stollery K.R.** (1987). "Monopsony processing in an open - access fishery". *Marine Resource Economics*, **3** (4) : 331-351.

**White III, G. N. and P. Mace** (1988). "Models for cooperation and conspiracy in fisheries : changing the rules of the game". *Natural Resource Modeling*, **2** (3) : 499-530.

TABLE 1.
ELASTICITY ESTIMATES FOR TWO TYPES OF HERRING ROE PRODUCTS.

| | FLAVOURED | SALTED |
|---|---|---|
| A. Alley (1982) | | |
| New Year | --- | -0.24 |
| Off-season | --- | -1.34 |
| D. DeVoretz (1982) | | |
| Ex-vessel | --- | -1.4 |
| Can. wholesale | --- | -0.51 |
| Japanese auction | --- | -0.5 |
| D. DeVoretz (1986) | --- | -0.56 to -0.89 |
| J.L. Anderson et al (1989)* | Elastic | Inelastic |

* Based on qualitative and quantitative data.

TABLE 2.

SCOTIA–FUNDY REGION PRODUCTION AND VALUE: HERRING ROE

| YEAR | QUANTITY (Q) in kg | TOTAL REVENUE in $ | PRICE (P) $/kg | % CHANGE IN Q | % CHANGE IN TR | % CHANGE IN PRICE | ARC ELASTICITY |
|---|---|---|---|---|---|---|---|
| 80 | 3,933 | – | – | – | – | – | – |
| 81 | 0 | – | – | – | – | – | – |
| 82 | 15,619 | – | – | – | – | – | – |
| 83 | 169,884 | 1,226,562 | $7.22 | | | | |
| 84 | 1,470,877 | 10,336,086 | $7.03 | 765.8% | 742.7% | -2.7% | -58.6 |
| 85 | 3,916,793 | 29,252,488 | $7.47 | 166.3% | 183.0% | 6.3% | 14.9 |
| 86 | 2,470,927 | 26,283,992 | $10.64 | -36.9% | -10.1% | 42.4% | -1.3 |
| 87 | 3,508,288 | 31,101,135 | $8.87 | 42.0% | 18.3% | -16.7% | -1.9 |
| 88 | 4,672,959 | 39,962,925 | $8.55 | 33.2% | 28.5% | -3.5% | -7.9 |
| 89 | 1,276,564 | 7,401,121 | $5.80 | -72.7% | -81.5% | -32.2% | 3.0 |
| 90 | 5,374,262 | 43,404,780 | $8.08 | 321.0% | 486.5% | 39.3% | 3.8 |

Source: Statistics Unit, Scotia–Fundy Region, Department of Fisheries and Oceans, Halifax.

GULF REGION PRODUCTION AND VALUE: HERRING ROE

| YEAR | QUANTITY (Q) in kg | TOTAL REVENUE in $ | PRICE (P) $/kg | % CHANGE IN Q | % CHANGE IN TR | % CHANGE IN PRICE | ARC ELASTICITY |
|---|---|---|---|---|---|---|---|
| 80 | 498,000 | 632,558 | $1.27 | | | | |
| 81 | 108,000 | 579,203 | $5.36 | -78.3% | -8.4% | 322.2% | -1.0 |
| 82 | 238,000 | 2,429,831 | $10.21 | 120.4% | 319.5% | 90.4% | 1.2 |
| 83 | 230,000 | 1,655,602 | $7.20 | -3.4% | -31.9% | -29.5% | 0.1 |
| 84 | 401,000 | 2,341,484 | $5.84 | 74.3% | 41.4% | -18.9% | -2.6 |
| 85 | 1,177,000 | 8,289,529 | $7.04 | 193.5% | 254.0% | 20.6% | 5.3 |
| 86 | 2,003,000 | 17,492,111 | $8.73 | 70.2% | 111.0% | 24.0% | 2.4 |
| 87 | 3,062,000 | 28,323,367 | $9.25 | 52.9% | 61.9% | 5.9% | 7.3 |
| 88 | 2,008,000 | 18,175,030 | $9.05 | -34.4% | -35.8% | -2.1% | 19.2 |
| 89 | 1,797,000 | 6,212,530 | $3.46 | -10.5% | -65.8% | -61.8% | 0.1 |
| 90 | 2,557,000 | 18,040,094 | $7.06 | 42.3% | 190.4% | 104.1% | 0.5 |

Source: Statistics Unit, Gulf Region, Department of Fisheries and Oceans, Moncton.

TABLE 3.

| EQUATION NUMBER | DEPENDENT VARIABLE | CONSTANT | OWN PRICE | QUANTITY | INCOME | OTHER PRICE | DUMMY CONSTANT | DUMMY | ADJ. R SQUAR | DW STAT. | F STAT. | AR(1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Q | -7.84<br>(-2.61) | -0.63<br>(-1.52) | - | - | - | - | - | 0.35 | 1.96 | 23.5 | YES |
| 2 | Q | 31.47<br>(3.61) | -0.05<br>(-0.13) | - | 5.92<br>(4.34) | - | - | - | 0.46 | 1.88 | 24.17 | YES |
| 3 | Q | 40.61<br>(3.87) | (-0.11)<br>(-0.27) | - | 6.99<br>(4.58) | -6.0<br>(-1.67) | - | - | 0.47 | 1.91 | 19.18 | YES |
| 4 | Q | 22.39<br>(3.25) | -1.09<br>(1.63) | - | 3.55<br>(4.13) | -<br>- | -2.43<br>(-0.49) | 0.20<br>(0.29) | 0.67 | 1.87 | 42.62 | NO |
| 5 | Q | 22.97<br>(2.80) | -1.09<br>(-1.63) | - | 3.62<br>(3.64) | -0.29<br>(-0.13) | -2.49<br>(-0.5) | 0.21<br>(0.3) | 0.66 | 1.87 | 33.7 | NO |
| 6 | P | 7.15<br>(19.8) | - | -0.007<br>(-0.23) | - | - | - | - | 0.59 | 2.37 | 59.7 | YES |
| 7 | P | -4.99<br>(-1.51) | - | 0.002<br>(0.067) | -1.67<br>(-3.59) | - | - | - | 0.61 | 2.12 | 43.8 | YES |
| 8 | P | -3.04<br>(-0.81) | - | -0.006<br>(-0.18) | -1.41<br>(-2.72) | -1.23<br>(-1.09) | - | - | 0.61 | 2.14 | 33.2 | YES |
| 9 | P | -2.33<br>(-0.70) | -<br>- | 0.02<br>0.55 | -1.36<br>(-3.01) | - | -1.55<br>(-1.93) | -0.12<br>(-1.79) | 0.64 | 2.06 | 30.0 | YES |
| 10 | P | -0.95<br>(-0.25) | - | 0.03<br>(0.56) | -1.18<br>(-2.31) | -0.77<br>(-0.7) | -1.57<br>(-1.95) | -0.12<br>(-1.83) | 0.64 | 2.09 | 25.0 | YES |

TABLE 4.

| | Crutchfield& Pontecorvo (1969) | Meany (1979) | Clark & Munro (1980) | Munro (1982) | Schworm (1983) | Hannesson (1985) | Stollery (1987) | H-R-K* (1990) |
|---|---|---|---|---|---|---|---|---|
| Processors' monopsony | Socially efficient even if vert. unintegr. | No resource rent dissipation | Socially efficient only under special conditions | | Efficient outcome depends on the existence of a large number of firms with identical convex technologies | | Socially efficient outcome depends on the speed of entry/exit in the harvesting sector | |
| Processors' monopoly | | | | | | Socially efficient under some conditions | | |
| Fishermen's monopoly | | | | | | Efficient if the monopolist discriminates perfectly among plants and proc. alternatives | | Cartel-like arrangement among vessel owners is not socially efficient. The cartel is not stable unless its membership and policies are binding. |
| Bilateral monopoly | | | | The solution will likely not be socially optimal. | | | | |
| Main conditions/ assumptions/ notes | Conclusions asserted | Full processing capabilities on some boats providing sufficient bargaining power | Holds only if social discount rate = monopsonist's discount rate and both sectors vert. integrated otherwise ambiguous outcome | Cooperative outcome, however, could be expected (division of rents from the fishery) | Unless harvesting firms have identical technologies the monopsonist cannot charge a single price | Fishing costs= social costs (including equality of discount rates) fish products are sold abroad and MC of proc. are constant | Instantenous fleet size adjust. will force the monopsonist to behave optimally; with slow adjust. the monopsonist overconserves | |

* Hamalainen, Ruusunen and Kaitala (1990).

# Fisheries Regulation and the Incentives to Overfish

**R.L. Mazany[a], A.T. Charles[b] and M.L. Cross[a] ***

[a]Department of Economics, Dalhousie University, Halifax, Nova Scotia, B3H 3J5 Canada

[b]Department of Finance & Management Studies, Saint Mary's University, Halifax, Nova Scotia, Canada

ABSTRACT

*A variety of regulations have been imposed on marine fisheries, often with results that were neither intended nor anticipated. Most of the literature on fisheries regulation looks at the implications for the size of the optimal biomass. In this paper, we focus instead on the individual fisherman and analyze the conditions under which the fisherman will engage in illegal fishing. We consider two forms of regulation : output controls and input controls. We find there is a difference in the behavior of the fisherman depending on the type of regulation imposed. We also examine the management implication for the two regulatory regimes under the assumption that enforcement is costly. This allows us to examine what happens to the optimal management if there are differing enforcement costs for each form of regulation.*

## 1. INTRODUCTION

A variety of regulations have been implemented on marine fisheries, often with results that were neither intended nor anticipated. These regulations arise from biological, political, economic and social concerns. Regardless of motivation, regulations are often changed because new vessels appear that are equipped to exploit loopholes in the regulations or to evade them. The idea of individual transferable quotas (ITQs), a reform designed to improve economic efficiency, has arisen at least in part because other policies have failed. Copes (1986) has argued that ITQs may yet prove subject to similar regulatory problems, and several other authors at least entertain this possibility (Pearse, 1988 ; Scott, 1988 ; Smith, 1985). Furthermore, several authors argue that the failure of regulations to control fishing effort shows not enough work on the microeconomics of fisheries has been done (Anderson, 1989 ; Anderson and Lee, 1986 ; Wilen, 1985).

* This research was supported by the Social Sciences and Humanities Research Council of Canada under grant 410-87-0329, the Natural Sciences and Engineering Research Council under grant A6745, and the Department of Fisheries and Oceans' Science Subvention Program. Helpful comments were received from A.D. Scott and W.R.S. Sutherland. The typing efforts of Monique Comeau and Heather Lennox are also greatly appreciated.

The microeconomic analysis of fisheries has proceeded on two fronts. The first approach assumes that fishermen will attempt to influence regulatory policy in a self-interested fashion. Thus Karpoff (1987) shows that restrictions on tonnage or length, mandated use of obsolete gear, and seasonal or area closures, though ostensibly intended to control fishing effort, can be used to secure distributional shares for groups that are at a competitive disadvantage. Similarly, Dupont (1990) argues regulation of British Columbia's salmon fisheries provides implicit quotas to types of gear that are inefficient. Thus, rent-seeking behavior on the part of different groups of fishermen offers one explanation as to why inefficient regimes persist.

The second body of literature examines the response of self-interested fishermen to regulations that are not perfectly enforced. If enforcement is costly, it is not optimal to ensure complete compliance. Evasion will occur on the basis of marginal returns to individual decisionmakers (Becker, 1968 ; Stigler, 1971). Efforts to control externalities in marine fisheries present such a situation. Optimal enforcement policies have been analyzed by Sutinen and Anderson (1985), who adapt Becker's (1968) framework. Sutinen and Gauvin (1989) examine evasive behaviour in the lobster fishery of Massachusetts. New Zealand recently implemented individual transferable quotas on its fisheries with careful attention to enforcement. Detailed records of fishing activity must be kept and are subject to audit. Violations are treated as commercial fraud (Clark et al., 1988).

This work notwithstanding, questions concerning the design and enforcement of regulations remain. Assuming that enforcement is costly, are there circumstances when restrictions of inputs are preferable to control of output or vice versa? In this paper, we compare the effects of input restrictions on the behavior of individual fishermen with the effects of output controls.

In the next section, we derive a short-run profit-maximizing model of an individual fisherman operating in an environment of no regulation and compare this with the case of imperfect input regulation and imperfect output regulation. In the third section, we examine the implications of the models for management policy.

## 2. A MODEL OF FISHERMEN'S BEHAVIOR

Consider the situation of a limited entry fishery, in which the number of fishermen, the size of each fisherman's vessel and the initial biomass available in the fishery are taken as given. We assume that there are two variable inputs, x and x′. These variable inputs can be thought of as bundles of inputs, with some inputs the same in each bundle. For example, x could be a given configuration of electronic gear, labor, fuel, and nets of a certain mesh size. The bundle x′ would then be a bundle with the same electronic gear, fuel, and labor, but with nets of a different mesh size. The fisherman then decides how much of each bundle he will use, according to the usual profit-maximizing rules.

The harvest level, $h_j$, of the jth fisherman is given by the short-run production function

$$h_j = h_j(x_j, x_j' ; K_j, B) \tag{1}$$

where $x_j$ and $x_j'$ are the amounts of the variable input bundles; $K_j$ is the capital stock, for example, measured by the size of the boat, and B is the biomass of fish available. Each fisherman is assumed to be a price-taker in the market for the variable inputs and pays w and w′ for them, respectively.

### *2.1 No regulation*

Each fisherman is assumed to maximize short-run restricted profits by choosing the optimal combination of $x_j$ and $x_j'$. In the case where there is no regulation of the fishery, the fisherman's single-year optimization problem is given by

$$\max_{x_j,\, x_j'} \{ph_j (x_j, x_j' ; K_j, B) - wx_j - w'x_j' : h_j \in T\} \tag{2}$$

where p is the unit price of output, assumed parametric to the fisherman, and T represents the technology set. Solution of this optimization problem results in the standard condition that the fisherman uses each variable input up to the point where the value of the marginal product equals the marginal cost of the factor (in this case, the parametric w and w') :

$$ph_x = w \tag{3a}$$

$$ph_{x'} = w' \tag{3b}$$

where $h_x = \partial h_j/\partial x_j$ and so forth.

The optimal harvest level for the fisherman, $h^*_j$, is then determined from the production function by evaluating it at the optimal levels of $x_j$ and $x'_j$ chosen.

$$h_j^* = h_j(x_j^*, x_j^{*'}; K_j, B) \tag{4}$$

where $x^*_j$ and $x^{*'}_j$ are the optimal level of inputs determined from equations (3).

### 2.2 *Regulation with imperfect enforcement*

Now assume the fisherman faces a regulatory constraint on harvesting activities, either in terms of inputs (e.g., days of fishing, mesh size) or output (e.g., catch quotas), but that enforcement is imperfect. In the case of output controls, let $h_j$ be the fisherman's allowable quota. Illegal harvest in the case of output control is then defined as $h'_j = h_j - \bar{h}_j$ for $h_j > \bar{h}_j$[1]. In the case of input regulations, we define $x'_j$ as the illegal bundle of inputs (for example, involving illegal mesh size or fishing in a closed area or season) and $x_j$ as the legal bundle of inputs.

We assume the fisherman can fish illegally, but faces a probability, $\theta_j$, of being caught and convicted if he does so. This probability is a positive function both of the level of enforcement and the amount of illegal fishing that occurs. We assume that, if caught, the fisherman is convicted and assessed a fine, $F_j$, thus increasing the costs of fishing. We assume the fishermen are risk-neutral, and do not engage in rent-seeking behavior ; that is, they do not incur variable costs specifically to have the regulations changed. Finally, we assume the fishermen do not incur variable costs to avoid detection of any illegal activities[2].

We specify the probability and fine functions as follows. The probability of fisherman j being caught fishing illegally is given by

$$\theta_j = \theta(h'_j, E) \tag{5a}$$

$$\theta_{j'} \geq 0, \quad \theta_E > 0, \quad \theta_j \equiv 0 \quad \text{if } h_j < \bar{h}_j$$

$$\theta_j = \theta(x'_j, E) \tag{5b}$$

$$\theta_{x'} \geq 0, \quad \theta_E > 0, \quad \theta_j \equiv 0 \quad \text{if } x_j < 0$$

where E is some measure of the level of enforcement, $h'_j$ and $x'_j$ are defined above, and $\theta$ is a suitable function whose range is [0, 1]. The probability of being caught in both cases depends positively on the level of enforcement and on the level of illegal activity, where illegal activity is defined according to whether input controls or output controls are imposed.

The fine paid by the jth fisherman if caught is also determined by the amount of illegal activity that occurred, and is limited by the assets of the fisherman, as proxied by the capital stock K.

$$F_j = F(h'_j ; K_j)$$

$$F_{h'} > 0, \quad F_j \equiv 0 \quad \text{if} \quad h_j < \bar{h}_j \tag{6a}$$

1. In the absence of transferable quotas, it is likely $h'_j \geq 0$ ; that is $h_j \geq \bar{h}$. Our analysis, however, holds for $h_j < \bar{h}$. We assume the quotas are not transferable and that they have been allocated on the basis of past activity. While there is an extensive literature on the optimal allocation of quotas, we do not address the question here, so as to focus the discussion on the impact of input and output regulations on fishermen's behavior.
2. See Milliman (1986) and Anderson (1987) for models that incorporate the cost of avoidance activities.

$$F_j = F(x_j' ; K_j)$$
$$F_{x'} > 0 , \quad F_j \equiv 0 \quad \text{if} \quad x_j' = 0 \tag{6b}$$

The expected value of the fine for the jth fisherman is $\theta_j F_j$. An ideal enforcement policy would set the expected value of the fine equal to the social opportunity cost of the illegal behavior at the margin (Posner, 1977 ; Becker, 1968, among others). Although in theory this could result in a very large fine, in practice, it is reasonable to assume that the fine does not exceed the assets of the fisherman, as represented by $K_j$.

### 2.2.1 Imperfect enforcement with output regulations

With a given individual quota of $\bar{h}_j$ and some probability of being caught if the catch is greater than $\bar{h}_j$, the fisherman's optimization problem in equation (2) becomes

$$\max_{x_j, x_j'} \{ph_j(x_j, x_j' ; K_j, B_t) - wx_j - w' x_j' - \theta_j F_j\} \tag{7}$$

where both $x_j$ and $x'_j$ are legal inputs and where the expected fine for illegal fishing is an additional cost of operations, penalizing that portion of the fisherman's harvest above the allowed catch.

The first-order conditions yield the profit-maximizing solution

$$[p - (\theta_{h'} F + \theta F_{h'})] h_x \leq w \tag{8a}$$

with equality if $h' > 0$

$$[p - (\theta_{h'} F + \theta F_{h'})] h_{x'} \leq w' \tag{8b}$$

with equality if $h' > 0$

Equations (8) are similar to equations (3), except that the effective unit price for fish received by the fisherman has been reduced by the additional opportunity cost of being fined if fishing occurs beyond the legal quota. This opportunity cost is the marginal expected fine, which is equal to the increase in probability of being caught, for a given level of fine ($\theta_{h'} F$) plus the increase in the size of the fine for a given probability of being caught ($\theta F_{h'}$). The fisherman will thus exceed his prescribed quota as long as the marginal value of the catch net of the expected fine exceeds marginal factor cost. In the absence of illegal fishing ($h_j \leq \bar{h}_j$), $\theta = F \equiv 0$, and equations (8) collapse to equations (3).

### 2.2.2 Imperfect enforcement with input regulations

What happens when the regulations are on inputs? The fisherman now faces the choice of fishing illegally by using illegal inputs. The optimization problem is the same as in equation (7), except $x_j'$ is now illegal input. We again are concerned not with the optimal level of input regulations, but rather with the fisherman's behavior in the face of a given set of input regulations. The first-order conditions are similar to equations (8) except $\theta$ and F are now assumed to be functions of x′.

$$ph_x = w \tag{9a}$$

$$[ph_{x'} - (\theta_{x'} F + \theta F_{x'})] \leq w' \tag{9b}$$

with equality if $x' > 0$

Equation (9a) is the standard first-order condition when there is no regulation. In equation (9b), the second term on the lefthand side is again the marginal expected fine. Equation (9b) differs from equations (8) in that the marginal expected fine is not multiplied by the marginal product of x′. This is because in equation (8), where output is regulated, the penalty

feeds back indirectly to the variable input through the production relationship; hence the extra term $h_x$·. In equation (9b), where input is directly regulated, the effect of the penalty is more straightforward. But again the interpretation is that illegal fishing will occur if the marginal value of the catch net of the expected fine exceeds the marginal factor cost.

## 3. MANAGEMENT IMPLICATIONS

In this section, we address the intertemporal optimization problem faced by the fishery manager, who is assumed to be charged with the task of maximizing resource rents. We consider two possible scenarios:

(i) a situation of perfect and costless enforcement, undertaken for comparative purposes, in which an omnipotent manager is able to control completely the inputs used by each fisherman to obtain a "first-best" solution, and

(ii) a more realistic case in which the only means available to regulate the fishery is through the choice of an enforcement level E (assuming a fixed definition of what constitutes illegal fishing activity).

In both cases, the resource manager is assumed to maximize the discounted present value of net economic rents, given the population dynamics of the biomass. These are specified as follows :

$$dB/dt = g(B) - H \tag{10}$$

where g(B) represents the natural growth rate of the biomass and the total harvest is $H = \Sigma h_j = \Sigma f_j(x_j, x_j', K_j ; B)$.

### *3.1 Perfect and Costless Enforcement*

In this case, the values of each fisherman's inputs $x_j$ and $x_j'$ are determined not by the behavioral models discussed above, but rather by a global optimization in which $x_j$ and $x_j'$ are treated as decision variables for the manager rather than for the fisherman. Furthermore, there are no costs of enforcement since no enforcement is necessary. The manager's objective can be written simply as :

$$\text{Max} \int_{x_j,\, x_j'} e^{-\delta t}(pH - C)\, dt \tag{11}$$

where $H = \Sigma h_j$ as above, $C = \Sigma(wx_j + w' x_j')$ represents the total variable cost of fishing for the industry as a whole, and the optimization is subject to the dynamics of equation (10). Applying the Maximum Principle, and assuming for simplicity that an internal solution determines each fisherman's input levels, the optimal equilibrium conditions are as follows :

$$g(B) = H \tag{12}$$

$$g'(B) + \left[\frac{p - \mu}{\mu}\right] H_B = \delta \tag{13}$$

$$(p - \mu)(\partial h_j/\partial x_j) = w \quad \text{and} \quad (p - \mu)(\partial h_j/\partial x_j') = w' \qquad j = 1, \ldots, N \tag{14}$$

where $\mu$ is the shadow value of the fish stock. These 2N + 2 equations determine the 2N controls $\{x_j, x_j' ; j = 1, \ldots, N\}$, the state variable B and the shadow value $\mu$. Note that in equation (13), the lefthand side represents the marginal productivity of the stock, g'(B), adjusted by the "marginal stock effect" (Clark and Munro, 1975), which measures the effects of changes in the biomass on harvest levels and costs. This is equated to society's rate of discount $\delta$, representing the opportunity cost to society of the resource stock.

### *3.2 Imperfect and Costly Enforcement*

We turn now to the case of intertemporal optimization in which the fishery manager can control only the level of enforcement effort over time, while decisions concerning desired inputs are left to the individual fisherman. The results

of the behavioral modelling presented earlier indicate that each fisherman j will select a pair of inputs $x_j$ and $x_j'$ to optimize profits, given specified biomass B, enforcement activity E, capital stock $K_j$, and individual production function $h_j = f_j(x_j, x_j', K_j\ B)$. From here on, the resulting inputs desired by fisherman j will be written as $x_j = x_j(E, B)$ and $x'_j = x'_j(E, B)$, suppressing the dependence on $K_j$ for simplicity. Note that these behavioral response functions differ for the cases of input and of output regulation ; in both cases, however, they combine to produce a harvest level $h_j$. As above we denote the total harvest and the total variable cost by $H = \sum h_j$ and $C = \sum(wx_j + w' x_j')$, respectively.

Given this instantaneous behavioral response by fisherman to enforcement effort E(t) at any time t, the intertemporal optimization problem can be written :

$$\underset{E}{\text{Max}} \int e^{-\delta t}(pH - C - c_E)\, dt \tag{15}$$

where now the fishery manager has only the enforcement activity E as a regulatory instrument. Total societal costs now include the cost of the enforcement effort, $c_E = c_E(E)$, which is assumed to increase with E, so that $c'_E(E) > 0$. While in reality the precise nature of the enforcement activity will differ under input versus output control, we assume here that E is measured in comparable physical units, and represents a "pre-optimized" mix of enforcement options.

This optimization problem is again subject to the stock dynamics in equation (10). However, the harvest H and total costs C now involve input *functions* $x_j(E, B)$ and $x_j'(E, B)$, which are behavioral responses to enforcement activity and biomass levels, rather than being decision variables to be chosen by the fishery manager :

$$H = \sum f_j(x_j(E, B), x_j'(E, B), K_j ; B) = H(E, B)$$

$$C = \sum [wx_j(E, B) + w' x_j'(E, B)] = C(E, B).$$

Using the Maximum Principle, we find that the following equations, combined with either (8) or (9) in the cases of output or input controls, respectively, completely determine the optimal equilibrium :

$$g(B) = H \tag{16}$$

$$g'(B) + \frac{\left(\frac{dH}{dB}\right)\left(\frac{dC}{dE} + c_E'\right) - \left(\frac{dH}{dE}\right)\left(\frac{dC}{dB}\right)}{p\left(\frac{dH}{dE}\right) - \frac{dC}{dE} - c_E'} = \delta \tag{17}$$

As above, the lefthand side of (17) represents the marginal productivity of the stock, g'(B), adjusted by the "marginal stock effect". It is equated to the opportunity cost of the resource stock δ. In this case, the marginal stock effect can be written explicitly in terms of the total derivatives dH/dE, dC/dE, dH/dB and dC/dB. The latter terms can be expressed explicitly in terms of the production functions and the response functions $x_j(E, B)$, $x'_j(EB)$. That is $dH/dE = \sum(h_x x_E + h_x x'_E)$, $dC/dE = \sum(wx_E + w' x'_E)$, and so on. In particular, it should be noted that the total derivative, dH/dB, in equation (17) is quite different from the partial derivative $H_B = \partial H/\partial B$ in equation (13), since in equation (17) the total harvest H depends on the biomass not only directly, but also through the response functions $x_j$ (E, B) and $x_j'(E, B)$.

### *3.3 Interpretation*

The next logical step in this analysis might be a comparison of imperfect regulation using output and input controls, as given by equations (16) and (17) combined with equations (8) or (9), with the optimal first-best equilibrium in the case of "perfect costless" enforcement, as indicated in equations (12)-(14). The goal would be to determine the relative merits of input versus output controls, and the incentive gap produced by these methods of imperfect regulation.

However, the results of the above analysis demand a quite different interpretation. We find that in the present relatively complex multi-dimensional model, the structure of the sole-owner optimum in equations (12)-(14) is not comparable with the case of imperfect regulation. Indeed, the very different behavioral response functions obtained under output and input controls makes a direct comparison of these methods impossible (except under drastic simplifying assumptions).

This result should not be surprising, since the present model reflects, first, the complexity of the real-world situation, in which input and output controls must be "fine-tuned" to specific circumstances, rather than being viewed as artificial constructs, and, second, the nature of behavioral models, which focus on attempts to mimic actual fishermen behavior, however complex, rather than on the use of simple assumptions to produce tractable analyses.

While not surprising, the findings here are nevertheless of considerable importance in policy analysis. They point to the impossibility of determining *theoretically* the relative merits of the various regulatory instruments, and the resulting critical need for more empirical analysis to compare such instruments in particular cases.

## 4. CONCLUSIONS

This paper has presented and analysed a unified model of illegal fishermen behavior under imperfect enforcement of input or output regulations. As in past studies, it has been shown that fishermen will fish illegally (exceeding their quotas or using illegal gear) if the marginal value of the catch, net of the expected marginal fine, exceeds the marginal factor cost.

We have also examined the optimal societal equilibrium in the case of imperfect enforcement and in the sole-owner case of perfect costless enforcement. In each case, we obtained a clear depiction of the optimal equilibrium as a set of simultaneous equations. However, these equations cannot be directly compared, a fact which highlights the complexity of real-world regulatory environments, the impossibility of determining *theoretically* the relative merits of regulatory instruments, and the corresponding need to determine the merits of regulatory options in specific cases, by applying the present results in detailed empirical studies[3].

3 Our results differ from the standard results (e.g., Clark (1976)) both because we specify the harvesting and cost functions as explicit functions of the biomass and because we do not assume linear homogeneity of the cost function.

## REFERENCES

**Anderson L.G.** (1987). "A Management Agency Perspective of the Economics of Fisheries Regulation," *Marine Resource Economics*, **4**(1) : 123-131.

**Anderson L.G.** (1989). "Enforcement Issues in Selecting Fisheries Management Policy", *Marine Resource Economics*, **6** (2) : 261-277.

**Anderson L.G. and D.R. Lee** (1986). "Optimal Governing Instruments in Natural Resource Regulation : The Case of the Fishery", *American Journal of Agricultural Economics*, **68** (4) : 679-690.

**Becker G.S.** (1968). "Crime and Punishment : An Economic Approach," *Journal of Political Economy*, **76** (2) : 169-212.

**Clark C.W.** (1980). "Towards a Predictive Model for the Economic Regulation of Commercial Fisheries", *Canadian Journal of Fisheries and Aquatic Sciences*, **37** (6) : 1111-29.

**Clark I.N., P.J. Major and N. Mollett** (1988). "Development and Implementation of New Zealand's ITQ Management System", *Marine Resource Economics*, **5** (4) : 325-349.

**Copes, P.** (1986). "A Critical Review of the Individual Quota as a Device in Fisheries Management", *Land Economics,* **62** (3) : 278-291.

**Crutchfield J.A.** (1979). "Economic and Social Implications of the Main Policy Alternatives for Controlling Fishing Effort", *Journal of the Fisheries Research Board of Canada*, **36** (7) : 742-752.

**Dupont D.** (1990). "Rent Dissipation in Restricted Access Fisheries", *Journal of Environmental Economics and Management*, **19** (1) : 26-44.

**Karpoff J.M.** (1987). "Suboptimal Controls in Common Resource Management : The Case of the Fishery", *Journal of Political Economy*, **95** (1) : 179-194.

**Milliman S.R.** (1986). "Optimal Fishery Management in the Presence of Illegal Activity," *Journal of Environmental Economics and Management*, **13** (3) : 363-81.

**Pearse P.H.** (1988). "Property Rights and the Development of Natural Resource Policies in Canada", *Canadian Public Policy*, **14** (3) : 307-320.

**Pearse P.H. and J.E. Wilen** (1979). "Impact of Canada's Pacific Salmon Fleet Control Program," *Journal of the Fisheries Research Board of Canada*, **36** (7) : 764-769.

**Posner R.A.** (1977). *Economic Analysis of Law* , Boston : Little, Brown and Company.

**Scott A. and P.A. Neher**, eds. (1981). *The Public Regulation of Commercial Fisheries in Canada*, Ottawa : Supply and Services Canada.

**Scott A.** (1983). "Property Rights and Property Wrongs," *Canadian Journal of Economics*, **26** (4) : 555-74.

**Scott A.** (1988). "Development of Property in the Fishery", *Marine Resource Economics*, **5** (2) : 289-311.

**Stigler G.J.** (1971). "Theories of Economic Regulation," *Bell Journal of Economics* , **2** (1) : 3-21.

**Sutinen J. and P. Andersen** (1985). "The Economics of Fisheries Law Enforcement," *Land Economics* , **61** (2) : 387-397.

**Wilen J.G.** (1985). "Towards a Theory of the Regulated Fishery" *Marine Resource Economics*, **1** (2) : 369-388.

# Fixed or Variable Catch Quotas with Irreversible Investments

**Stein Ivar Steinshamm**

Institute of Fisheries Economics, Norwegian School of Economics and Business Administration

ABSTRACT

*The objective of this paper is to compare two different management strategies for a long-lived fish stock with stochastic recruitment, namely constant catch quotas (TACs) versus variable catch quotas based on a constant level of fishing effort. The analysis is based on a simple aggregated biomass model. The first part of the paper considers some theoretical aspects of the problem with irreversible investments, and identifies expected a priori outcomes from the model compared to a model where investments are reversible.*

*In the second part Monte Carlo simulations are used to quantify the differences in profitability between the strategies. One of the main conclusions of the paper is that the profitability of fixed catch quotas is highly dependent on the degree of investment irreversibility such that the difference in profitability between the strategies becomes greater, the more irreversible investments are.*

## 1. INTRODUCTION

Optimal schemes for fisheries management based on mathematical programming models may be hard to carry out in practice. It is difficult to make an exact and complete specification of the objective function and the side constraints in such models. The more detailed this formulation is, the harder it is to solve the optimization problem. Even when a solution is found, the parameter estimates used in the model are often subject to uncertainty or may be error prone in other ways. The resulting optimum is often a complex strategy with a high degree of pulse fishing. This is the reason why fisheries managers are often inclined to resort to so-called reference points or rules of thumb in managing real fisheries. Advanced mathematical models are often only used for theoretical and educational purposes.

Examples of reference points used in fisheries are $F_{max}$, $F_{0.1}$, constant escapement, constant effort (CE) or constant catch (CC) quotas[1]. In this paper it will be concentrated on the last two alternatives.

Constant effort and constant catch have been shown to perform about equally well with respect to economic return under a variety of circumstances (Steinshamn, 1991). Constant catch, however, has had a reputation of increasing risk and instability in the fish population. This is certainly true if the catch is adjusted to maximize yield biomass but it needs not be the case if the catch is kept at a moderate level. A constant catch adjusted to maximize the net economic return will in many cases imply a moderate rate of harvest. It has been shown that an optimally adjusted constant catch in many respects compares to the $F_{0.1}$ strategy (Murawski & Idoine, 1989).

If the question about irreversible investments and fixed capital is taken into account, things may change. It is the purpose of this paper to compare the economic performaces of constant effort and constant catch under such circumstances. It is also interesting to see how this depends on the degree of irreversibility. These comparisons will be performed both with an aggregate biomass model and a multi-cohort model. First of all a description of the model and a reference to the case without irreversible investments will be given.

## 2. THE MODEL

The model is an aggregate biomass model where the dynamics is given by

$$B_{t+1} = s\xi_t + w_t \tag{1}$$

$B_t$ is biomass, $\xi_t$ is escapement and $w_t$ is recruitment, all at time t, and s is the survival parameter. In the basic model the following production function is assumed :

$$u_t = E_t Bt \tag{2}$$

where $E_t$ is the effort level at time t. The objective function to maximize is given by

$$V = \sum_{t=0}^{T} \alpha^t \pi(u_t, B_t) \tag{3}$$

where $\pi$ is the net revenue function and $\alpha$ is the discount factor $(1+r)^{-1}$, r is the discount rate. The net revenue function can be written

$$\pi(u_t, B_t) = pu_t - C(u_t, B_t) \tag{4}$$

where p is the price per unit harvest and C() is the cost function. The cost function is defined as

$$C(u_t, B_t) = cE(u_t, B_t) \tag{5}$$

where c is the cost per unit effort, and effort is here written as a function of u and B. Given Eq. (2) above, this function is simply $E_t = u_t/B_t$ The net revenue function can therefore be rewritten

$$\pi(u_t, B_t) = (p - c / B_t)u_t \tag{6a}$$

or

1. $F_{max}$ is the fishing mortality maximizing yield per recruit and $F_{0.1}$ is the fishing mortality corresponding to the point on the yield per recruit curve that has a slope which is 10% of the slope through the origin.

$$\pi(E_t,B_t) = (pB_t - c)E_t \tag{6b}$$

$\delta\pi/\delta B > 0$ whereas $\delta\pi/\delta u$ and $\delta\pi/\delta E$ are only greater than zero if $(p - c/B) > 0$, that is when the biomass level is higher than the level that results in an open access fishery.

To start with the simplest possible model as a reference, assume constant recruitment, $wt = w\forall t$ and no discounting, $r = 0$ (i.e. = 1). The objective is first to derive the optimal equilibrium by maximizing

$$V = \sum_{t=0}^{\alpha} \pi(u_t,B_t) \tag{7}$$

It is obvious that with a constant recruitment the optimal equilibrium will imply both constant effort and constant catch. In other words, the three optimal solutions, unconstrained optimum, optimal constant effort and optimal constant catch will coincide. However, with zero discounting it is clear from Eq. (7) that the objective function will not converge, and it will therefore be replaced by the long-term average

$$V = \frac{1}{T} \sum_{t=0}^{T} \pi(u_t,B_t) \tag{8}$$

see e.g. Clark (1976 : p.386). This has to be maximized subject to the dynamic constraint, Eq. (1), and subject to $B_t - u_t \geq \zeta_{min}$ for all t where $\xi_{min}$ is the minimum escapement level required to secure future recruitment. Assuming that an equilibrium solution exists, this problem can be solved as a non-linear programming problem using the method of Lagrange multipliers. The Lagrange expression is given by

$$L = (p - c/B)u + \lambda_1[s(B - u) + w - B] + \lambda_2[B - u - \xi_{min}] \tag{9}$$

where B and u now represent equilibrium levels. The Kuhn-Tucker conditions are

$$\frac{\delta L}{\delta B} = \frac{c}{B^2}u + \lambda_1 s - \lambda_1 + \lambda_2 = 0 \tag{10}$$

$$\frac{\delta L}{\delta u} = p - \frac{c}{B} - \lambda_1 s - \lambda_2 = 0 \tag{11}$$

$$\frac{\delta L}{\delta \lambda_1} = s(B - u) + w - B = 0 \tag{12}$$

$$\frac{\delta L}{\delta \lambda_2} = B - u - \xi_{min} \geq 0, \qquad \frac{\delta L}{\delta \lambda_2}\lambda_2 = 0 \tag{13}$$

From the dynamic constraint the equilibrium catch is given by

$$u = \frac{w - (1 - s)B}{s} \tag{14}$$

Substituting this into Eq. (13) and rearranging it is seen that

$$B > w + \xi_{min}s \tag{15}$$

with $\lambda_2 = 0$, or

$$B = w + \xi_{min}s \tag{16}$$

with $\lambda_2 > 0$. This is the minimum escapement constraint stated only with the biological parameter w, s and $\xi_{min}$. Assuming $\lambda_2 = 0$, i.e. assuming an interior solution, the optimal catch and biomass level can be found from the Eqs. (10), (11) and (12), and they are

$$B^* = \sqrt{\frac{cw}{p(1 - s)}} \tag{17}$$

and

$$u^* = \frac{w - \sqrt{(1 - s)cw / p}}{s} \tag{18}$$

Substituting B* and u* into Eq. (13), it is seen that this interior solution is only in effect if

$$\frac{c}{p} > \frac{(w + \xi_{min}s)^2 (1 - s)}{w} \tag{19}$$

otherwhise $B - u = \xi_{min}$, implying

$$B^* = s\xi_{min} + w \tag{20}$$

and

$$u^* = w - (1 - s)\xi_{min} \tag{21}$$

In other words, the escapement level will only be larger than the required minimum if the cost/price ratio is smaller than some value depending on the biological parameters w, s and $\xi_{min}$ [2]. In particular, if $\xi_{min} = 0$, condition (19) can be rewritten

$$\frac{c}{p} > w(1 - s) \tag{22}$$

The optimal equilibrium effort level will be given by E*= u*/B* which implies that

$$E^* = \frac{1}{s}\left[\sqrt{\frac{p(1 - s)\, w}{c}} - (1 - s)\right] \tag{23}$$

from Eqs. (17) and (18) when the minimum escapement is not binding, and

$$E^* = 1 - \frac{\xi_{min}}{s\,\xi_{min} + w} \tag{24}$$

when the minimum escapement constraint is binding.[3] However, for the purpose in this study the optimal equilibrium with constant recruitment is not of interest in itself, and is only meant to serve as a reference.

Comparing constant effort with constant catch will only be interesting if the fish stock biomass varies for some reason, and in this section the assumption will be that this variation is due to stochasticity in recruitment. The dynamics are still given by Eq. (1), but now the recruitment wt is a stochastic variable with expectation . However, if recruitment is a stochastic variable

and there is no stock – recruitment relationship at all, the optimal policy will be given by the optimal solution from the determinictic equivalent of the model. This is rather obvious since in this cas recruitment will be an additive stochastic variable in the dynmaic equation. The objective is to maximize the expected net present value of future income, and the dynamics can be written

$$\epsilon B_{t+1} = s(\epsilon B_t - u_t) + \mu \tag{25}$$

2. This value will be increasing with $\xi_{min}$, increasing with w given that $w > \xi_{min}s$ and decreasing in s given that $s > (2\,\xi_{min} - w)/3\,\xi_{min}$
3. These optimality conditions can also be found by maximazing the Lagrange expression
$L = (pB - c)E + \lambda_1[s(1 - E)B + w - B] + \lambda_2[1 - E)B - \lambda min]$ with respect to E and B.

$\epsilon$ is the expectation operator. The minimum escapement constraint may play a role here. If the constraint on minimum escapement is

$$\epsilon(B_t - u_t) \geq \xi_{min} \tag{26}$$

the optimal solution will be equivalent to the constant recruitment case with the constant recruitment w replaced by the expected recruitment . Adjustment in the initial and final period is not regarded here. In other words, it is assumed that the initial biomass is at the optimal equilibrium level B*. The optimal approach to this level, e.g. from a severly depleted stock level, is usually a so-called bang-bang approach when we are dealing with linear models. The above constraint on minimum escapement is simply that expected escapement in any period shall not be less than $\xi_{min}$. If this is replaced by the stronger condition that actual escapement in each period shall not be less than $\xi_{min}$, a more cautious policy is required. In this case the worst possible recruitment pattern must be taken into account, although the probability that such a recruitment pattern will in fact occur may be infinitely small. The expected recruitment, $\mu$, has to be replaced by the minimum recruitment, $w_{min}$. A policy based on $w_{min}$ will yield a much lower income than a policy based on since this policy probably will overshoot the minimum escapement goal. It will of course also yield a lower income than a policy based on this condition but where the catch and effort is free to vary from period to period. In this case knowledge about the stock level in each period may be used to assure that optimal effort is applied and at the same time the escapement level is not jeopardized.

Another way to put this is to say that a constant policy with respect to the control variable will only be optimal if knowledge about the current state of the resource is not available beyond period 0. In all other cases such knowledge may be used to improve the performance of the system.

Although the optimal solution is the same in the stochastic model as it is in its deterministic equivalent, the expected performances of the constant catch and the constant effort strategy may be different in the stochastic case. If expected recruitment is $\mu$, the expected biomass in each period will be . Suppose that the actual $B_t$ lies in the range [] which is symmetric around . Then the expected net revenue with constant catch will be

$$\epsilon\pi(CC) = \int_{B_L}^{B_U} (p - c / x)\, uf(x)dx \tag{27}$$

and with constant effort

$$\epsilon\pi(CE) = \int_{B_L}^{B_U} (px - c)\, Ef(x)dx \tag{28}$$

It can easily be shown (see appendix to this section) that $\epsilon\pi(CE) > \epsilon\pi(CC)$ when and the density function f(x) is a constant.

Another way the model above will show a difference in performance between the two strategies considered here is in the approach to the long term equilibrium given by Eqs. (17), (18) and (23). If there were no constraints on the adjustment to the equilibrium, a bang-bang approach would be optimal in this kind of model, meaning that zero harvest is applied if the biomass is below the level given by (17) and maximum harvest is applied if it is above this level, until B* is reached. However, here the problem is to find either the constant catch or the constant effort that is the best substitute for the bang-bang solution. If the time horizon tends to infinity, the optimal constant effort will approach E* given by (23) and the optimal constant catch will approach u* given by (18) for any c/p ratio satisfying (19) and any initial population satisfying the minimum escapement condition. E* and u* may, however, be zero if the c/p ratio is high enough.

With a relatively long but finite time horizon, T=100, numerical calculations confirm that constant effort yields better profitability than constant catch for all relevant values of c/p. In other words, with a long time horizon and stochastic recruitment constant effort is the better alternative. This also indicates that a constant effort policy is the best way to approach the long term equilibrium. This conclusion, of course, depends upon the assumption that all economic and biological parameters remain constant

Non-malleable capital and irreversible investments.

Another factor that may be of importance in the stochastic analysis is the role of investment in fixed (non-malleable) capital. There are two types of fixed capital ; namely perfectly irreversible investment decisions on the one hand and so-called quasi malleable capital on the other hand. In this paper it will be concentrated on the latter since perfectly irreversible investment implies a depreciation rate equal to zero which is not very realistic. Further, it is important to distinguish between fixed (capital) cost and variable (harvesting) costs. Analysis of optimal strategies in the presence of irreversible investments are made by Charles (1983a and 1983b) and Clarck et al. (1979). Some simplifying assumptions are made here, e.g. that the size of the stock is perfectly known at the beginning of each season eand that the necessary non-negative investments can be made immediately according to this knowledge.

In the model applied here the net revenue can be written :

$$\pi_t = pu_t(E_t, B_t) - VC(E_t) - FC(E_t^{max} - IC(I_t) \tag{29}$$

where VC denotes the variable cost function, FC the fixed cost function and IC the investment cost function. The news terms introduced here are $E_t^{max}$ which is the maximum capacity and $I_t$ which is the gross investment in period t.

There are two kinds of dynamics in the model ; the dynamics of the resource stock and the dynamics of the capital stock. Another way to put this is to say that the two types of capital, the resource and the conventional capital, are both included as state variables and the investment in both stocks, the catch rate and capital investment, are included as control variables. In each period

$$0 \leq E_t \leq E_t^{max}$$

where

$$E_t^{max} = (1 - \delta) E_{t-1}^{max} + I_t \tag{30}$$

and the gross investment, $I_t$, is defined as

$$I_t = \max(0, E_t(u_t, B_t) - (1 - \delta)E_{t-1}^{max}) \tag{31}$$

It is not possible to have negative investments in any period ; i.e., there is no second-hand market for capital (fishing vessels).

Assuming a particular model of the same kind that has been used earlier in this section, i.e., dynamics given by Eq. (1) and the production function given by Eq. (2), it is possible to derive some analytical results based on a deterministic version of the model. In particular it is possible to find the optimal equilibrium catch, effort and biomass level. In the optimal deterministic equilibrium there will never exist excess capacity nd hence fixed costs will play no role. The net revenue function can be rewritten

$$\pi_t = pEB_t - (c_v + c_i\delta)E \tag{32}$$

and optimal biomass, catch and effort will be given by Eqs. (17), (18) and (23) with c substituted by $(c_v + c_i\delta)$ where $c_v$ is the variable cost per unit of effort and $c_i$ is the investment cost per unit of capital. These values will be calculated and used as inputs in the stochastic model. The total net revenue from this model will also serve as a reference for the stochastic model. In the stochastic model the updating of fish-stock biomass can be given by

$$B_{t+1} = s\xi_t + w\epsilon_t \tag{33}$$

where is escapement and is a uniformly distributed random variable with expectation 1. That is, recruitment is a completely random, uniformly distribued variable with expectation w. Introducing irreversible investments and fixed costs will not after the situation under the constant effort strategy but will serve to decrease the profitability of constant catch. The interesting question then is how sensitive the profitability of the constant catch strategy is to changes in parameter values like $c_i$, $\delta$ and $c_f$ which is the per unit cost of excess capacity. These results are reported in Table 1. In

the initial model the economic parameter values are p = 1, $c_v$ = 6, $c_f$ = 3 and $c_i$ = 12. The depreciation rate, , is assumed to be 0.1 and the survival parameter s = 0.8. The optimal biomass, catch and effort from the deterministic equivalent of the model are reported as B*, u* and E* respectively. J denotes the accumulated net revenue over a time periodof 50 years. When stochasticity is introduced, 100 different recruitment patterns are drawn with expected recruitment 4 and standard deviation 2. The 95% confidence interval for the average accumulated net revenue with these recruitment patterns can be calculated as $J \pm 2s / \sqrt{n}$ where n = 100 and is the standard deviation for J (Rubinstein, 1981). These intervals and the average J are reported in the rightmost column in Table 1.

$c_f$ is supposed to be significantly less than $c_v$ since it is less costly to have idle fishing vessels than it is to actually use these fishing vessels. In the initial model $c_f = 0$ and $c_f = c_v$ is applied. The deterministic optimum and the profitability of CE is independent of $c_f$.

If $c_i$ and $\delta$ are changed in a way that $c_i\delta$ remains unchanged, this will not have any effect on the deterministic model or on the profitability of the CE strategy, but the profitability of the CC strategy may be affected by the mix of $c_i$ and $\delta$. In the simulations reported in the table $c_i$ and $\delta$ is reduced by 50%, one at a time. The profitability of CC increases faster when $c_i$ is reduced than when $\delta$ is reduced. That is, the constant catch strategy is more sensitive to a change in the cost of investment than to a change in the depreciation rate. It is not intuitively clear why this is so. Part of the explanation is that higher increased $c_i$ will either reduce the profitability due to higher costs when investment takes place or have no effect at all when no investment takes place. An increased depreciation rate will reduce profitability when investment takes place simply because higher $\delta$ implies higher investment. On the other hand, when the level of fixed capital is already too high, increased will reduce fixed costs because it implies some degree of disinvestment and thus it will increase $\delta$ the profitability.

It is also of interest to compare these results with the result of using the alternative production function given by $u = u = B(1 - e^{-E})$. The effort requirement function, which is the inverse of the production function, becomes

$$E = \ln\left(\frac{B}{B - u}\right) \tag{34}$$

The escapement in the case of constant effort is now written :

$$\xi_t = B_t e^{-E} \tag{35}$$

With this production function the optimal equilibrium effort, E*, in the deterministic model is given by

$$E^* = \ln\left[\frac{-s^2c}{\sqrt{p^2w^2M^2 + 4scpwM - 2sc - pwM}}\right] \tag{36}$$

$M \equiv (1 - s)$ and $c = (c_v + c_i\delta)$. This value can be substituted into the production function in ordrer to find u* and into

$$B^* = \frac{w}{1 - se^{-E^*}} \tag{37}$$

in order to find the optimal equilibrium stock. The parameter values are changed such that $c_v$= 5 and $c_i$ = 10. It is interesting to note that the introduction of this production function does not make any big difference compared to the other results reported in the table.

It is common for all the results that the regions (95% intervals for average net revenue) are not overlapping. Further, the regions with constant catch do not in any case include the net revenue resulting from the deterministic model whereas the regions with constant effort do not onlu include this value, but the average J is higher in all cases. In other words, there is a positive cost of stochasticity with constant catch, and this cost increases with fixed costs but it is positive even when $c_f = 0$. With constant effort the cost of uncertainty is not significantly different from zero.

It may be even more interesting to combine irreversible investments with the presence of a spawning stock / recruitment relationship. A Beverton-Holt recruitment function is applied for this purpose. This function is given by

$$w_t = \frac{\alpha \xi_t}{1 + \beta \xi_t} \tag{38}$$

In this case it is not easy to find an analytical expression for the deterministic optimum. The optimal equilibrium can, however, be calculated using numerical methods. With the same economic parameter values as in the initial model and = 1 and = 0.1 in the B-H recruitment function, the result is : E* = 0.139, B* = 20.55 and u* = 2.85. Net revenue in each period is 1.85. The problem now is that in 12 out of 100 simulations, the CC strategy is not feasible bacause the stock ultimately becomes smaller then the allowable catch. In other words, the stock will get extinct if this strategy continues. Higher costs will reduce the optimal catch rate and increase the probability that CC is a feasible strategy. The result reported here is calculated using the following values : $c_v = 10$, $c_f = 10$, $c_i = 20$ and in this case the stock does not get extinct. Now E* = 0.107, B* = 23.84, u* = 2.55 and J* = 63.21.

The confidence intervals are

| | |
|---|---|
| CC [57.45, 60.70] | J = 59.07, |
| CE [61.47, 63.94] | J = 62.71. |

The only noticable difference from the results reported earlier is that the average J with the CE strategy is less than J* from the deterministic optimum.

Another interesting aspect of including non-malleable capital is that it is no longer obvious that the argument about risk aversion being in favour of constant catch holds true. This argument is based on the assumption that net revenue with constant catch will have less variance than net revenue with constant effort, but when there are fixed costs pertaining to investments and the biomass is varying stochastically, this assumption may be false. The argument above is only valid if it is plausible that a low variance of net revenues outweighs a lower value of the average net revenue. Calculations of the average variance of net revenue based on 100 different stochastic recruitment patterns with the initial model mentioned above, show that whereas . It is important to note that the increased variance of the CC strategy is entirely caused by the investment costs and not by the fixed costs of having excess capacity. The fixed costs of excess capacity actually work in the opposite direction ; that is to reduce the variance. This can be explained as follows. In a period when the biomass level is lower than the equilibrium, there is a need for new investments in fishing effort in order to take the constant catch which will make the already low profit in this period even lower, thus increasing the variance of net revenues. In such a period there will be no excess capacity costs. On the other hand, when the biomass level is higher than the equilibrium level, there will be no need for new investments but the excess capacity costs will reduce the net revenue which already is higher than average, and therefore the variance of net revenues will be reduced. It is clear from this that the higher ci and the lower $c_f$ is, the higher the variance with the CC strategy will be. It seems reasonable to suggest that $c_i$ is high relative to $c_f$, or in other words, that the buying cost per unit effort is higher than the per unit fixed cost of idle effort.

## 3. CONCLUSIONS

In general one would expect the constant effort strategy to be more profitable than constant catch. There are, however, many factors that can modify this and make constant catch more desirable. Such factors include everything that makes net revenue concave in catch, e.g. risk-aversion on behalf of fishermen or economies of scale (decreasing marginal cost).

The conclusion when there are irreversible investments in fixed capital is, not unexpetedly, that this will significantly reduce the profitability of the constant catch strategy. Even an —assumption of strong risk aversion will not be able to reverse this conclusion. The analysis above assumes somewhat unrealistically that new investments can be made almost instantaneously. This of course is not true, but it makes it easier to illustrate the main effects of having non-malleable capital.

## REFERENCES

**Charles A. T.** (1983a). "Optimal Fisheries Investment : Comparative Dynamics for a Deterministic Seasonal Fishery", *Can. J. Fish. Aquat. Sci.* n° **40** :.2069-2079.

**Charles A.T.** (1983b). "Optimal Fisheries Investment under Uncertainty", *Can. J. Fish. Aquat. Sci.* n°**40** : 2080-2091.

**Clarck C.W.** (1976). "A delayed recruitment model of population dynamics, with an application to baleen whale populations", *J. Mathematical Biology* n°**31** : 381-391.

**Clarck C.W., F.H. Clarke and G.R. Munro** (1979). "The optimal exploitation of renewable resource stocks : Problems of irreversible investments", *Econometrica* n° **47** : 25-47.

**Murawski S.A. and J.S. Idoine** (1989). "Yield Sustainability under Constant-Catch Policy and Stochastic Recruitment", *Trans. Am. Fish.Soc.* n° **118** :.349-367.

**Rubinstein R.Y.** (1981). *"Simulation and the Monte Carlo Method"*. New York, John Wiley & Sons

**Steinshamn S.I.** (1991). *"On Optimal Harvesting of Fluctuating Fish Stocks : The Case of the Arcto-Norwegian Cod"*. In Essays on the Economics of Migratory Fish Stocks by Arnason & Bjorndal (Eds.) (Berlin, Springer Verlag)

# Renewable Resource Market Obeying Difference Equations : Stable Points, Stable Cycles, and Chaos

**C. Costa Duarte**[a]

[a]Department of Economics, Universidade Nova de Lisboa, Travessa Estevo Pinto, 1000 Lisbon, Portugal

ABSTRACT

*In this paper, the basic principles of chaos theory are applied to dynamic systems involving renewable resource and harvest. The results of simulations are presented regarding harvested resource stock time path. It is shown that stationary steady-state is only one of many different possible outcomes of bioeconomic equilibrium. The varying impacts that different management policies have on an unstable dynamic system are also studied. It is shown that in unstable resource systems, the effects of some policy measures will be very different from the ones obtained through traditional resource analysis. It also shows that policies which induce a stabilizing effect in stock time series will generally provide greater welfare gains. the results are illustrated by two market examples.*

## 1. INTRODUCTION

In renewable resource analysis the main focus has been to first identify and characterize stationary states. A totally different approach comes from Chaos Theory. Basically it shows that simple deterministic but nonlinear relationships are able to generate complex time series behavior that ranges from stable trajectories to a form of instability known as deterministic chaos. A clear description of Chaos Theory and its relevance to economic analysis is presented in Baumol and Benahabid (1988). Its most revealing feature is demonstrating that the source of instability can be within the dynamic system itself, depending on the values of certain parameters.

To apply this framework to renewable resource analysis seems an obvious step, as nonlinearity is one of its more important characteristics. Simulations of time series behavior of an unexploited resource stock, using chaos theory, were first presented by May (1975). Here, the usual assumption of a stable carrying capacity for a unexploited is questioned. However, since then no further analysis on this subject has been published.

The main purpose of this work is to extend May's analysis to a harvested resource stock, i.e try to establish how harvest affect the time path of a resource stock. When harvest is introduced, the dynamic system that rules stock time series is altered. Previous stable trajectories can become unstable or vice versa. Notice, that total harvest each period is determined by market forces and/or by policy regulations. Hence, market parameters and regulation measures in the harvest industry do affect stock behavior. In return, the induced stock behavior can alter the effectiveness of certain policy measures.

The paper is organized in the following way : in section 2 the results for simulations of different harvest conditions are presented and the impact of some regulatory measures is shown. In section 3 two different market examples illustrate the possible implication for policy effectiveness of this new approach, and finally section 4 presents some concluding remarks.

## 2. DYNAMICS OF A RESOURCE STOCK

### *2.1 Dynamics of an Unexploited Resource Stock*

To illustrate the chaos phenomenon (as reported in Conrad & Clark(1987) following the work of May(1975)), let the Logistic function represent the dynamics of an unexploited resource. If written as a differential equation, it takes the form :

$$\dot{X} = rX_t(1 - X_t/K)$$

where $X_t$ is the stock in period t, r is called the intrinsic growth rate and K represents the environmental carrying capacity. In the absence of catch $X_t \rightarrow K$ from any $X_0 > 0$ as $t \rightarrow \infty$, and K is a globally stable equilibrium. If written as a difference equation :

$$X_{t+1} - X_t = r\,X_t\,(1 - X_t/K)$$

one might expect the discrete time analog to exhibit the same properties. However, this nonlinear difference equation is capable of producing much more complex behavior depending on the value of r. For this equation specifically :

If, $0 < r < 1$ - The population steadily approaches K.

If, $1 < r < 2$ - The population overshoots but undergoes dampened oscillation as it approaches K.

If, $2 < r < 2.449$ - The population settles down in a two point cycle.

If, $2.449 < r < 2.570$ - The population achieves a stable cycle with $2^n$ points.

If, $r > 2.570$ - The population behavior is referred to as dynamic chaos.

In dynamic chaos, time series have an appearance of disturbance by random shocks and undergo abrupt qualitative changes. Chaotic time paths are very sensitive to initial conditions and to small changes in the values of the parameters.

A variety of functional forms can be used to specify the resource growth function. Two different functions will be analyzed in order to illustrate the sensitivity of some results.

Logistic Function

$$X_{t+1} - X_t = rX_t\left(1 - \frac{X_t}{K}\right)$$

Gompertz function :

$$X_{t+1} - X_t = rX_t \ln\left(\frac{K}{X_t}\right)$$

Both generate the same kind of time paths as the ones described above for the logistic function.

*2.2 Dynamics of a harvested resource stock*

We will, now, address the following questions : What would be the behavior of a harvested resource stock ? How can harvest intensity affect the time path of the resource ?

With harvest, stock time series are given by the following equation :

$$X_{t+1} = X_t + H(X_t) - C_t$$

where $H(X_t)$ is the resource growth function, and Ct is total harvest in period t.

It is reasonable to assume that harvest in period t also depends on the stock level, either because of induced changes in harvest intensity or because of changes in harvest productivity. Simulations were carried out for different catch stock relationships, and for different levels of harvest intensity. Different market and institutional conditions can support all of the case studied Some examples will be presented at the next section.

### 2.2.1 Linear catch-stock function

Assuming a linear catch-stock function means that variations in catch are proportional to variations in stock levels. In this case, stock time series are calculated from the equation :

$$X_{t+1} = X_t + H(X_t) - C_t$$

where c is a constant [1]and represents the level of harvest intensity.

In this case the following results apply : for the Logistic function any catch level will produce a stabilizing effect in stock time series. On the contrary, with the Gompertz function, stock instability is maintained. To illustrate these results let us look at the two extreme cases : a stable unexploited stock(r=0.8), presented in Fig 1, and a chaotic unexploited stock (r=2.7), presented in Fig 2(a) and Fig 2(b) [2].

In the first case, stock will more or less rapidly stabilize at long run equilibrium level. Here, a stable unexploited stock remains stable. If we look at a chaotic unexploited stock, the result is not the same for the different growth functions. As shown in Figure 2(a), harvest stabilizes the time path of the resource stock when resource growth is represented by the Logistic function. In addition, the stabilization effect is greater, the greater the catch level [3]. On the contrary, as shown in Figure 2(b), for the Gompertz function, a chaotic unexploited stock remains chaotic when catch is introduced.

### 2.2.2 Convex catch-stock function.

A convex catch-stock function assumes that the variation in catch is more than proportional to variations in stock ; here, the resource time path can be represented by :

$$X_{t+1} = X_t + H(X_t) - cX_t^{\delta} \text{ with } \delta \geq 1$$

The simulation results can be summed up as follows : a convex catch-stock relationship will de-stabilize stock time series, the greater the degree of convexity, and the greater catch intensity. Qualitatively, the results are similar for the two specified functions, but the de-stabilizing effects are stronger in the Gompertz function.

1. The value of c can be greater than 1, if r is also greater than 1. Catch can not exceed initial stock plus growth during that period.
2. Catch intensity, in each case, is the level corresponding to the continuous time analog equilibrium for X=20,000.
3. For a small catch intensity (c=.54) the stock stabilizes in a two point cycle ; but for a greater catch intensity (c=1.62) the population rapidly approaches an equilibrium value.

Figure 3 represents stock time path simulated by the Logistic function, for r=2.7. It compares the linear catch-stock function with a convex catch-stock function and as shown, harvest no longer induces a stable stock trajectory. For greater levels of catch stock elasticity ($\delta > 2.3$), the stock time path becomes cyclical [4] or explosive. Also, for different levels of catch intensity time paths remain chaotic, as illustrated in Fig 5.

Even if unexploited stock is stable, a convex catch-stock function is able to produce chaotic behavior, although for higher levels of stock convexity. It is shown in Figure 4, for the Gompertz function The Logistic function also produce similar patterns but for much higher levels of convexity.

Also, the stock time path becomes less stable, the greater the catch intensity. In Figure 6, this result is illustrated for the Gompertz function.

### 2.2.3 Concave catch-stock function

A concave catch-stock relationship assumes that the variations in catch are less than proportional to variations in stock. Here, stock time series will be generated by the equation :

$$X_{t+1} = X_t + H(X_t) - cX_t^{\delta} \text{ with } \delta \leq 1$$

In general, a concave catch-stock function has a stabilizing effect in stock time series, for all growth functions. However, the steady path can either be to equilibrium or to extinction. The range of initial value of the stock level that induce a steady decrease to extinction is enlarged.

With the Logistic function, a concave relation implies an asymptotic approach towards long-run equilibrium, and this is true even for a chaotic unexploited stock (r=2.7). For the Gompertz function the general stabilizing effect is qualitatively the same but less intensive. In Figure 7 a linear catch is compared with a slightly more concave catch, and this is sufficient to change a chaotic time path into a two point cycle trajectory. In all cases the stabilizing effects are greater, the greater the catch intensity.

### 2.2.4 Constant catch

Assume now that total catch is constant. In this case, the stock time series will be determined by the equation :

$$X_{t+1} = X_t + H(X_t) - \mathbf{C}$$

where C is a constant catch level.

In all the examples studied a constant catch will induce a stabilizing effect in the stock time series, and this effect is greater, the closer the catch is to the Maximum Sustainable Yield (MSY). These results are illustrated in Fig 8,9, and 10.

Going through all these cases, has shown that harvest can in fact change stock time path behavior. It can augment, maintain or diminish resource time series fluctuation, and it depends not only on the harvest parameters but also on the specific underlying growth function.

In spite of the sensitivity of the time path, to the model structure, to the values of the parameters and to the initial starting points, some order exists behind all the results of the simulations. For the same values of growth function parameters we can say that the more concave the catch- stock relation, the more stabilizing the harvest is. Also, the more skewed to the right the underlying resource growth function is, the more stabilizing the harvest is, for high levels of catch intensity. In addition, the more stabilizing the harvest is, the smaller the range of initial stock values that produce positive time series.

## *2.3 Dynamics of a Regulated Resource Stock*

Most commercial renewable resource systems are presently subject to some form of regulation, so in this section, we will try to give an answer to the following questions : How do management regulation instruments affect resource stock behavior ? Does it affect policy effectiveness ?

4. This cyclical pattern occurs only if the simulation negative values are changed to arbitrary small values. Alternatively one can assume stock extinction.

In a deterministic context the evaluation of different policy measures is traditionally based on time continuous analysis. It is then generally assumed that, whatever the policy implemented, stock would in any case grow asymptotically towards the new equilibrium. Policy evaluation is then based on comparative static analysis. In the present context, it will be shown that different policy instruments, will affect the dynamics of the system in different ways, either enlarging or reducing the previous stock instability. This will have to be taken into account when evaluating policies from a welfare point of view.

### 2.3.1 Policy 1- Proportional Quota

If a resource stock is managed through annual catch quotas the catch-stock relation is no longer determined by market conditions but by some pre-determined rule. A constant fishing mortality implies that catch is a fixed proportion of stock.

Let us then consider that the annual catch quota is fixed each period according to the following rule : $TAC_t = f\ X_t$, where f represent a constant fishing intensity. If such is the case, all of the results of section 2.2, for the linear catch-stock case, apply.

However, what usually happens is that the TAC for each season is established before the season opens. Suppose it is based on stock surveys of t-1 period, in this case, the annual catch quota is given by : $TAC_t = f\ X_{t-1}$. Stock simulations will be derived from the equation :

$$X_{t+1} = H(X_t) - X_t - f\ X_{t-1}$$

If unexploited stock is unstable, this small change can have a significant impact in simulation results. In Figure 13(a), the stock time series in simulation map called "Prop. TAC" assumes that the TAC is ruled by the first equation and the one named "Lagged TAC" assumes it is ruled by the second equation [5]. In such circumstances this policy will not have the stabilization effect that could be found in the linear catch case.

If unexploited stock is stable, a lagged policy, compared to a linear TAC, will have a minor effect on stock time series. In case of the logistic function, it will even speed up stock adjustment to long run value. However, in general terms, lags in the regulatory process can have de-stabilizing effects in stock time series, and in some cases even result in stock extinction.

### 2.3.2 Policy 2 - Constant Catch Quota

As seen in section 2.2. a constant catch will always have a stabilizing effect on stock time series. For levels of catch near M.S.Y. the time path of the stock level is a stable one. However, high levels of constant catch are not possible if initial stocks are low, in which case time trajectory will drive stock to extinction. This is not a serious policy limitation because lower catch level can be set initially and augmented as stock recovers.

The stabilizing effect of a constant catch is one of the most surprising results [6] of the present analysis. This aspect establishes some advantages in relation to the proportional TAC as the stabilizing effects are independent of the specific growth function used. In addition, the problems derived from the lags in the regulation process are, in this case, irrelevant ; stock surveys are no longer necessary. Also, in all of the cases studied, welfare gains from this policy are always equal to or greater than the ones resulting from a proportional TAC. In addition, they are also always greater than the ones resulting from a lagged TAC.

### 2.3.3 Policy 3 - Licenses

Assume now that a limit is imposed on the number of units allowed to harvest the resource stock. In this case, the policy instrument does not by itself establish a particular catch-stock relationship. The impact depends on the underlying fleet-catch function.

5 In addition, it assumes that the market has a corrective effect, allowing that in bad stock years the TAC will be left unfulfilled if catch is not profitable. Otherwise this rule would drive resource to extinction.

6. Surprisingly from a policy evaluation point of view, because mathematically it is quite obvious.

If the boat catch function is linear in stock, entry restriction will maintain a linear catch-stock relationship, but at a lower level of catch intensity. The results presented for the linear case apply.

If boat catch function is concave in stock, then boat licensing does not change the degree of concavity of the catch-stock relation. In this case the stabilizing effect will be maintain.

### 2.3.4 Policy 4 - Tax on catch.

In the present framework, a tax on catch is the most unpredictable instrument, as it rely on market mechanisms.

Consider first the case where the number of harvest units is fixed. Here, a tax will impose heavy losses in the first periods. If resource price is constant, it will in most cases stop harvesting for one or two periods. If price varies according to a given demand function, a rise in price will maintain some harvest in the initial periods, as long as marginal revenue is greater than or equal to marginal cost. What happens next is always uncertain because it depends on how many boats remain active and for how long. Assuming that all units are identical, there exists no market mechanism to determine the intensity of the industry reaction. After the adjustment, the catch-stock relation will be determined by the underlying boat catch function.

If, on the contrary, the fleet in each period is determined by market equilibrium, a tax on catch will lower the market producer price, and catch intensity is immediately adjusted. The effect on stock time path behavior will, in this case, depend on market characteristics. It generates a totally different outcome whether the tax is a unit tax or an ad valorum tax.

To conclude, except for the constant TAC policy, all the other studied policies will have variable effects on stock behavior depending on both on unexploited resource behavior and market conditions.

## 3. POLICIES EFFECTIVENESS : MARKET EXAMPLES

In order to illustrate some of the above results, and clarify the way markets and regulation affect resource growth behavior, we present two numerical examples. Before proceeding, it should be recalled that one of the characteristics of chaotic dynamic systems is their sensitivity to parameters and initial point values, so the particular values of the simulation results presented have a limited significance. However, as pointed out in Baumol et al. (1988), "despite their sensitivity, they can be effective instruments for disproving the universal validity of some propositions and so *provide warnings to policy designers*". Some of the more interesting results will be presented, first, to point out some cases were policy regulations do not afford the desired welfare gains, and second to show that some apparently equivalent instruments may not be equivalent at all.

Simulations of the industry evolution, in both markets, for different regulation measures, were carried for a twenty-five year horizon, and welfare gains and losses were added using a 1 % discount rate. The results are presented in Figures 12 and 13 for example 1 and Figures 15 and 16.for example 2. The examples assume chaotic growth functions because this case provide the greatest variety of possible situations [7]. Also, the specific values of each regulation measures have a common objective : the continuous time analog, that induce stock and catch to stabilize at :

Logistic function : $X = 30\,000$ ; $C = 32\,400$ ("c" in Figure 11)

Gompertz function : $X = 33\,000$ ; $C = 36\,200$ [8] ("d" in Figure 11)

Aggregate welfare gains or losses will depend on the specific market conditions as summarized in Table 1.

### *3.1 Example 1- Linear catch-stock relation*

Suppose an open access fishing industry characterized by the following relationships :

$$C_t = N.C_{it},\ C_{it} = q.E_{it}.X_t,\ \pi_i = P.C_{it} - wE_{it} - F \quad i = 1,.....,N$$

7. As seen, stable unexploited stocks will generally, remain stable, except when catch-stock relation is convex.
8. This is equivalent to a catch intensity of c = 1.08

where N represents a fixed number of boats, Cit is the catch per boat, q is a constant catchability coefficient, Eit is effort per boat, Òi is the profit per boat, P represents the resource market price, w is constant cost of effort and F is a fixed cost. As catch function per boat is linear in relation to stock level, harvest from this particular industry can be represented by a linear catch stock in active years. Being N = 100, $E_{i\ Max}$ = 200, q = 0,000108, P = 25, w = 2 0, F = 1400, the constant capture coefficient c will be 2.16.

If the system is globally stable, continuous time analysis assumes that resource stock will tend asymptotically to long run equilibrium, as represented in Figure 11. Long-run equilibrium values for the two growth functions would be respectively :

Logistic function : C = 21,600, X = 10,000, $\pi_i$ = 0 ("a" in Figure 11)

Gompertz function : C = 48,526, X = 22,466, $\pi_i$ = 6,731[9] ("b"in Figure 11)

With the Logistic function, the result of the industry simulations in a discrete time context is the same,(Figure 12(a)), with the resource stock, total catch, and profits approaching asymptotically the above equilibrium values [10]. Most policies will imply the same results as continuous time analysis. However, two exception occur, with the tax on catch and the lagged linear TAC (see Figure 13(a)).

Here market equilibrium is a stable equilibrium and a proportional TAC will also maintain a stable stock, profits will grow and rapidly stabilize at 4,700. If there is a lag in establishing the quotas for each harvest season, the scenario will be quite different. As can be seen the de-stabilizing effect on stock time distribution, induce profits instability. For the case studied, average profits are now lower, at 2,266. Compared to the open-access equilibrium where profits are zero, a lag in the regulating process will still have a positive welfare gain [11], although smaller than the one resulting from a linear TAC. However, if agents are risk averse, the certainty equivalent [12] value of profits can be negative. To conclude, if agents individually are risk neutral, this policy can produce some welfare gain, but if they are risk averse, the increase in expected profits can be offset by the increase in profits uncertainty.

The tax case presented assume that the entire fleet will be active for the first four periods. From then on the fleet is adjusted to the level necessary to perform the policy objective (f = 1.08). We choose this particular solution as a reference point, but it should be clear that there is no market mechanism that would induce this specific outcome. This policy produce an unstable catch path, whenever the entire fleet remains active. Once the assumed fleet adjustments are completed, stock will stabilize only after seven periods of time. From a welfare point of view, and if agents are risk neutral this particular simulation will result in a welfare gain : profit losses are smaller than tax revenue.

If we look at the same market conditions but with a different underlying resource growth function, the simulation results will be quite different. As can be seen in Figure 12(b), a linear catch-stock relation does not stabilize stock. The market stock time trajectory is unstable [13]. For the same reason, all policies except the constant TAC will result in unstable time series (Figure 13(b)).

This fact will imply different welfare considerations on the impact of some policy measures. Here, all policy measures will result in welfare losses except the constant TAC policy. Only in this case the actual value of the stream of profits is greater than in market equilibrium

With the proportional TAC the actual value of the stream of profits is smaller than in market equilibrium, so if agents are risk neutral there will be a loss in welfare. However, if agents are risk averse, the certainty equivalent value of profits

9. This case is not an open-access equilibrium, because profits are stable and positive, creating an incentive for new agents to enter this industry.
10. In fact according to section 2, a linear catch stock relation stabilizes stock time series.
11. As price is constant, variations in industry profits represent all possible welfare gains
12. By certainty equivalent we mean the constant value of profits that would generate in twenty five years the same level of utility as the actual profit distribution, that is :
$\pi$ such as $\Sigma\ U(\pi t) / (1 + r)^t = \Sigma\ U(\pi) / (1 + r)^t$
with $U(\pi) = (1 - e^{-\sigma\pi}) / (1 - e^{-\sigma})$ being $\sigma$ a measure of risk aversion.
If agents are risk neutral $U(\pi t) = \pi t$, and $\pi$ is given by :
$\pi$ such as $\Sigma\ (\pi t / (1+ r)^t) = \pi\ \Sigma\ 1 / (1+ r)^t$
13. In this particular simulation, average profits are still positive although lower than the continuous time equilibrium value. Unless agents are risk averse, this simulation does not represent an open-access equilibrium. If agents are risk averse, the certain equivalent value of that particular profits distribution is zero for a constant risk aversion equal to 0,00086885.

is positive ($\pi = 52$) and greater than the certainty value of market equilibrium($\pi \approx 0$). So, from a welfare point of view, the TAC regulation is worse if agents are risk neutral, but can have some welfare gains if agents are risk averse. This can be explain by the fact that while maintaining stock instability, the TAC has, in this case, reduced profits variance.

If a lag exits in the establishment of the TAC, it will enlarge stock instability. In this case the welfare loss that result from this policy will even be greater.

The licensing will produce a time series stock behavior similar to the proportional TAC. From a welfare point of view the result is also similar, there will be higher profits per boat but less number of boats.

A tax will also produce a cyclical catch, whenever the entire fleet remains active. But after the assumed fleet adjustments stock will still remain unstable. In this case a tax will produce a welfare loss, here loss in profits are bigger than tax revenue.

### *3.2 Example 2 - Convex catch-stock relation*

Suppose now an open-access fishing industry characterized by the following parameters :

$$C_t = N.C_{it},\ C_{it} = q.E_{it}.X_t,\ \pi_i = P_t.C_{it} - wE_{it} - F,\ P_t = a(C_t)^{-\beta}$$

Let us also, assume that an unlimited number of boats can enter this fishing activity at a fixed cost F, so that, the number of active boats is in each period determined by market equilibrium. Specifically :

$$\pi_t = 0 \Rightarrow N = (a/(wE_t + F))^2\ qE_iX_t$$

In this context, market clearing will maintain profit per boat and industry profits near zero, but this market is characterized by a fluctuating fleet, price and catch. Welfare gains from the different policy measures will be measured by industry profits plus the change in consumer surplus.

If $E_{i\ Max} = 200$, $w = 20$, $F = 1{,}400$, $a = 3674$, $\beta = 5$ the catch-stock relation is convex and given by :

$$C_t = (aqE_i/(wE_i + F))^2\ X_t^2 = 0.00021597242\ X_t^2$$

Figure 14 represents market equilibrium derived from time continuous analysis. Long-run equilibrium values for the two growth functions would be respectively :

Logistic function : $N = 100$, $P = 25$, $C = 21{,}600$, $X = 10{,}000$. ("a" in Fig.14)

Gompertz function : $N = 150$, $P = 16.(6)$, $C = 48{,}000$, $X = 15{,}000$ ("b"in Fig.14)

However, as could be expected from section 2.2, a convex catch-stock relation market equilibrium will in both cases provide an unstable stock time series.(see Figure 15).

With the underlying Logistic function most policies will change the market convex catch-stock relation in a linear catch-stock relation. This will stabilize stock time trajectory and produce the same results as continuous time analysis. Again, two exception occur, with the tax on catch and the lagged linear TAC as can be seen in Fig 16(a).

Under these market conditions, a tax interfere in the fleet adjustment process, and the choice between a unit tax and a percentage tax will have very different results. The reason being that with a unit tax the catch-stock relation becomes concave, on the contrary, the percentage tax maintains a convex-catch stock relation [14]. This way, a unit tax can have a

14. With a unit tax, market equilibrium catch will be given by :
$C_t = (a/wE_t + TqE_tX_t)^2\ (qE_tX_t)^2$
and the degree of convexity is smaller. Catch-stock relation can even become concave at high stock levels. With an ad valorem tax, market equilibrium catch will be :
$C_t = ((1 - t)a/wE_t)^2\ (qE_tX_t)^2$
which maintains the convexity of the catch-stock relationship, although at a lower level of catch intensity.

stabilizing effect on stock behavior, which will not occur in an equivalent ad valorem tax. It results that, from a welfare point of view, a unit tax will always present higher welfare gains than a percentage tax. The difference in welfare gains between the two instruments is enlarged if agents are risk averse.

With the Gompertz function, these particular market conditions will drive stock to extinction in three periods of time. Alternatively, it can be assumed that stock is never extinct but only severely depleted. In this case, market simulation results in a three-period cyclical harvest, as shown in Fig 15(b). In this case, all policies except the constant TAC and the unit tax will result in unstable time series (see Figure 16(b)).

The establishment of a proportional TAC, will result in a more stable time path, but will also eliminate the occasional profits that occurred in open access. As on the consumer side the TAC will produce a small loss in consumer surplus, the TAC will be worse than market equilibrium. With the lagged TAC welfare loss will be even bigger.

The licence scheme, although producing the same effect on stock and catch time series as the proportional TAC has a different result from a welfare point of view. In this case, some profits are generated in the industry, and in spite of the small loss in consumer surplus there will be a welfare gain from this policy.

Again, a unit tax have a stabilizing effect on stock behavior, which will not occur in an equivalent ad valorem tax. In this case a unit tax will produce a four period cycle behavior in stock time series while the percentage tax will maintain a unstable stock. It results that, from a welfare point of view, a unit tax will also present higher welfare gains than a percentage tax.

Most actual management policies are implemented to preserve resource stocks from extinction, however, within the present framework and looking from a conservation point of view, some policies will not have the desired effect.

## 4. CONCLUSIONS

First of all, it should be clear that all of the results derived from this study depend on the validity of the Chaos theory to explain real resource stocks behavior. Notice however that in many scientific fields, including biology and economics, chaos theory has played a growing role as an alternative approach to understanding reality.

In general terms, this approach enlarges the theoretically possible impacts of harvest in the resources time series behavior. As shown, harvest can augment, maintain or diminish resource time series fluctuations.

In spite of the sensitivity of the time path to the model structure, to the values of the parameters and to the initial starting points, some order exists behind all the results of the simulations. For the same values of growth function parameters we can say that the more concave the catch- stock relation, the more stabilizing the harvest is. Also, the more skewed to the right the underlying resource growth function is, the more stabilizing the harvest is, for high levels of catch intensity. In addition, the more stabilizing the harvest is, the smaller the range of initial stock values that generate positive time series.

From all that has been said we may also conclude, that policy design in renewable resource markets is much more complex than could be expected from traditional deterministic analysis. Although generalizing results are somehow contradicted, some insights are gained which will help in the choice of policy when confronted with a particular real situation.

The most interesting result here is that, in unstable resource systems, the effects of some policy measures will be very different from the ones obtained through traditional resource analysis. It also shows that policies which induce a stabilizing effect in stock time series will generally provide greater welfare gains.

In relation to specific policy measures, a surprising result is the argument in favor of the most criticized management policy in economic literature : the Maximum Sustainable Yield (MSY). As has been shown a constant catch policy in all cases induces a stable stock for values of catch near the MSY. Under certain market conditions this instrument generates the highest welfare gains if compared to equivalent policy measures.

This argument can also bring an additional insight to the recent theoretical discussion over the management policy options : Constant Catch Quota or Constant Effort (see Hanesson (1988)). The choice between these two options is seen

as a choice between stability in catch, necessary for the processing industry and stability in fishing industry profits. Here, a constant catch quota will in all cases stabilize stock time series, stabilizing at the same time total catch and individual fisherman profits. If alternatively a constant effort policy is chosen, it can no longer be insured that it will stabilize stock.

Also, it was shown that, taxes and lags in the regulating process can be an additional source of instability in stock time series. In some cases, those policy have opposite effects than the expected, both from an economic and a conservation point of view.

## REFERENCES

**Andersen P. and J. Sutinen** (1984)."Stochastic Bioeconomics : A Review of Basic Methods and Results", *Marine Resource Economics*, **1**, 117-136.

**Baumol W. and J. Benahabid** (1989). " Chaos : Significance, Mechanism, and Economic Applications." *The Journal of Economic Perspectives* , Winter , Vol. **3(2).**

**Conrad J. and C. Clark** (1987). *Natural Resource Economics : Notes and Problems,* Cambridge University Press.

**Gleik J.** (1987). *Chaos : Making a new science* . Viking.

**Hannesson R.** (1988). "Fixed or Variable Catch Quotas ? The Importance of Population Dynamics and Stock Dependent Costs", *Marine Resource Economics,* **5,** 415-432.

**May R.M.** (1975). " Biological populations obeying difference equations : stable points,stable cycles, and chaos. *J. Theo.Biol.*, **51 :** 511-524.

**Table 1.**
**Social welfare gains from different policy measures**

| Welfare Gains | Ex 1 | | Ex 2 | | |
|---|---|---|---|---|---|
| | Logistic | Gompertz | Logistic | Gompertz | |
| Prop.TAC | 9685113 | -2174875 | 5015 | -822901 | |
| Lagged TAC | 5056908 | -7443641 | -1716 | -1404555 | X |
| Constant TAC | 9680746 | 1101546 | 5182 | -820969 | 1 |
| Licenses | 11242150 | -617838 | 8929000 | 5557718 | |
| UnitTax | 7992456 | -5090678 | 8214586 | 6668118 | |
| % Tax | | | 7839513 | 4127601 | |

**Figure 1.**
**Stable unexploited stock and linear catch-stock function - Both growth functions**

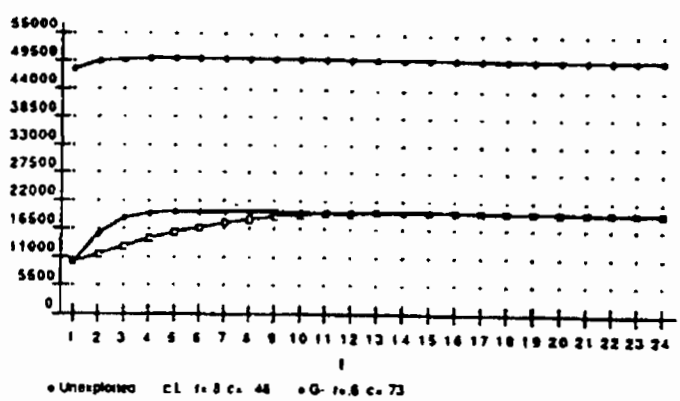


**Figure 2(a). Chaotic unexploited stock and linear catch-stock function - Logistic function**

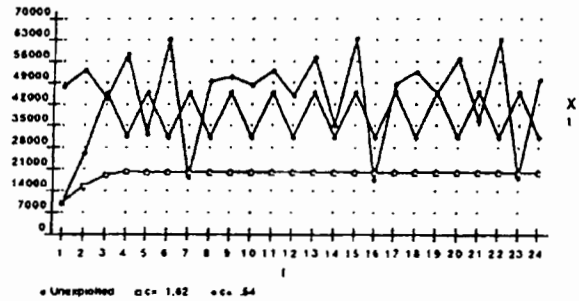


**Figure 2(b). Chaotic unexploited stock and linear catch-stock function - Gompertz function**

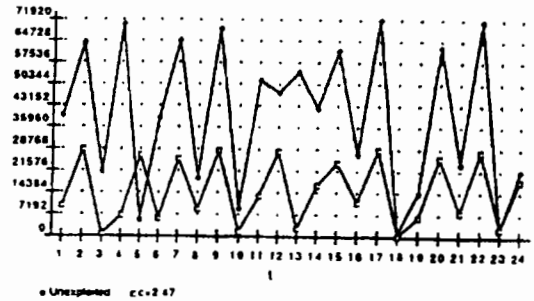


**Figure 3. Chaotic unexploited stock and convex catch-stock function - Logistic function**

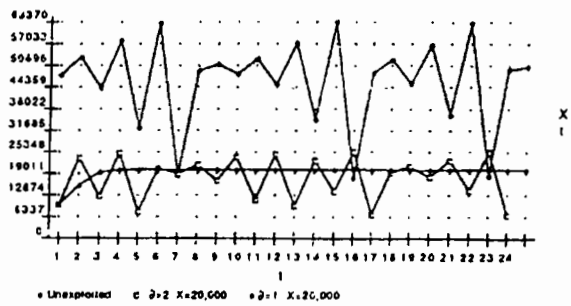


**Figure 4. Stable unexploited stock and convex catch-stock function - Gompertz function**

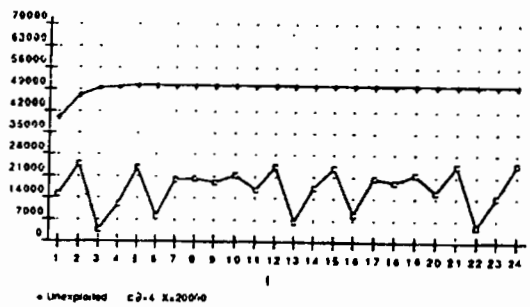


**Figure 5. Chaotic unexploited stock and curvex catch-stock at different levels of catch intensity - Logistic function**

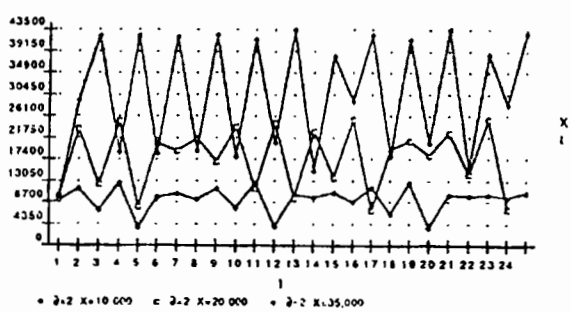


**Figure 6. Stable unexploited stock and convex catch-stock function at different levels of catch intensity - Gompertz function**

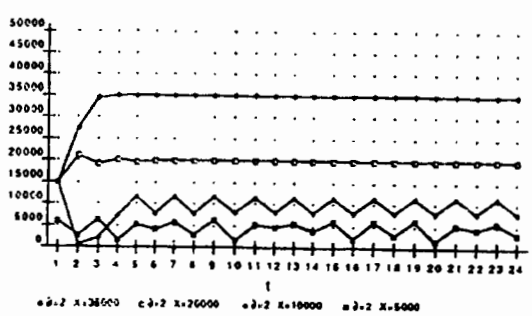


**Figure 7. Chaotic unexploited stock and concave catch-stock function - Gompertz function**

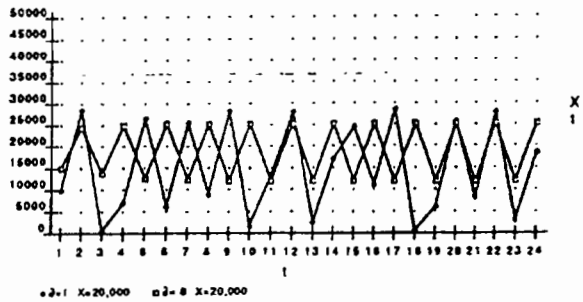


**Figure 8. Stable unexploited stock and constant catch - Both growth function**

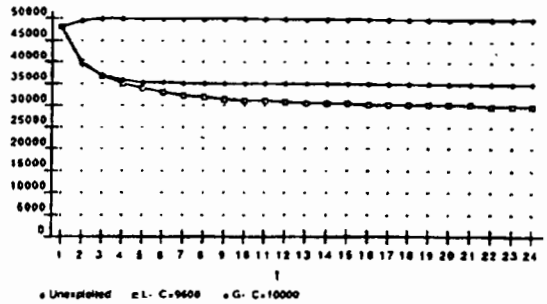


**Figure 9. Chaotic unexploited stock and constant catch - Both growth function**

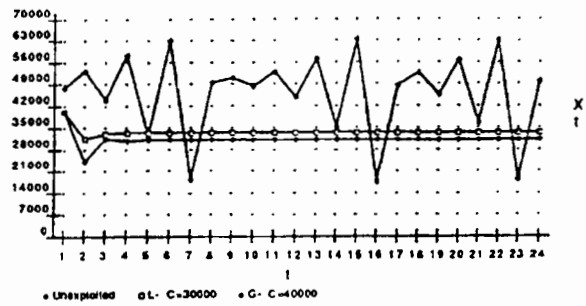


**Figure 10. Chaotic unexploited stock and constant catch at different levels of catch intensity - Logistic function**

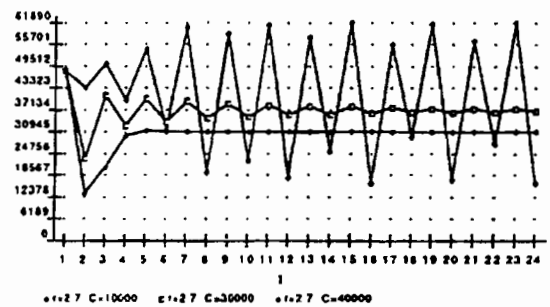


**Figure 11. Bioeconomic equilibrium - Example 1**

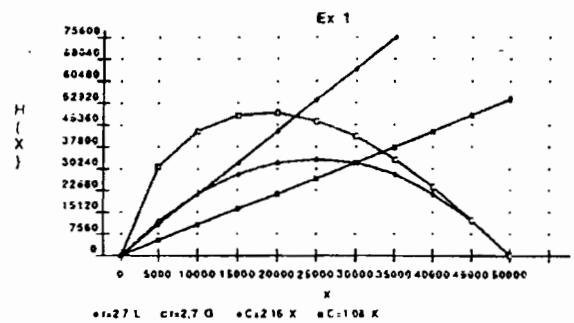



**Figure 12 (a). Ex 1- Market simulation - Logistic function**

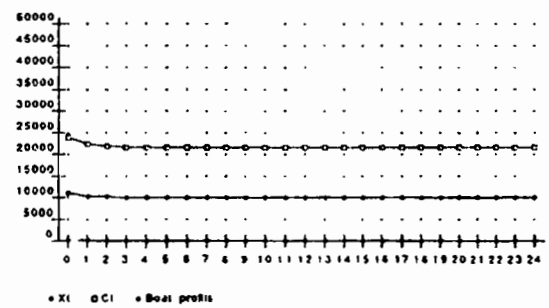


**Figure 12b.Ex 1- Market simulation - Gompertz function**

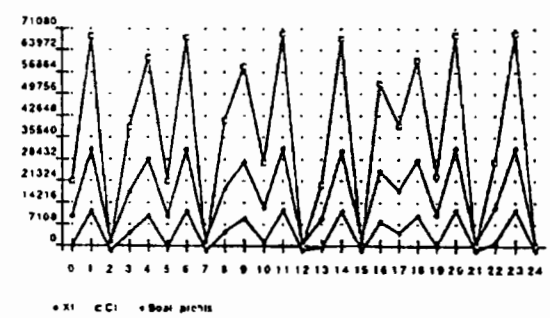


**Figure 13(a). Ex 1- Simulation results of the policy measures - Logistic function**

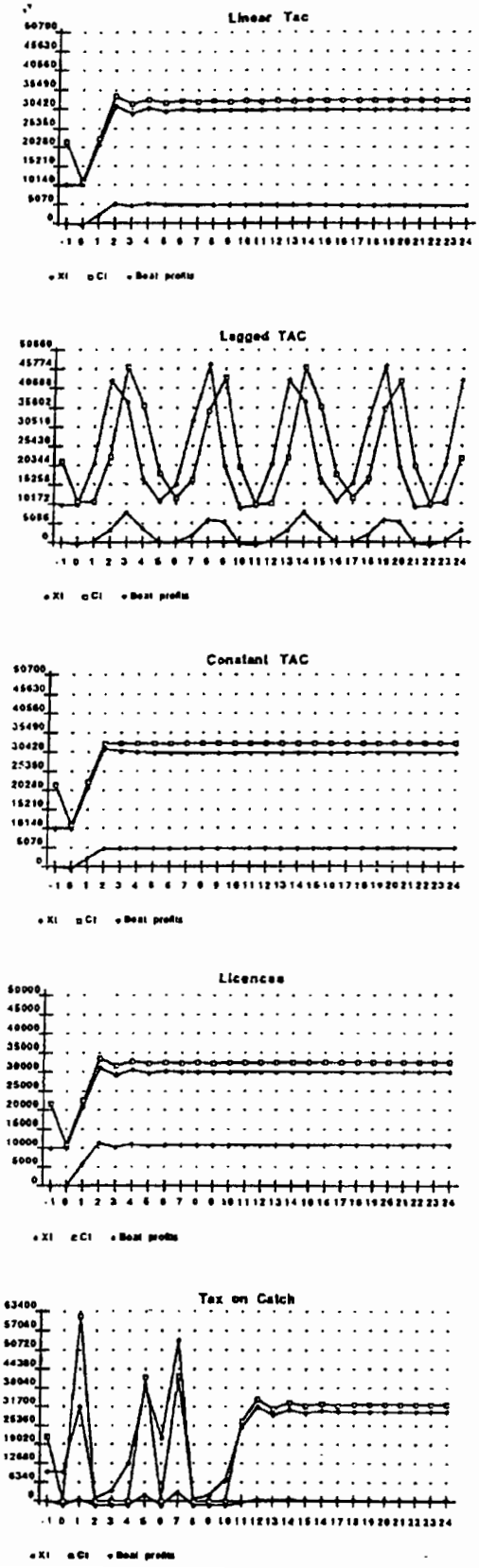



**Figure 13(b). Ex 1- Simulation results of the policy measures - Gompertz function**

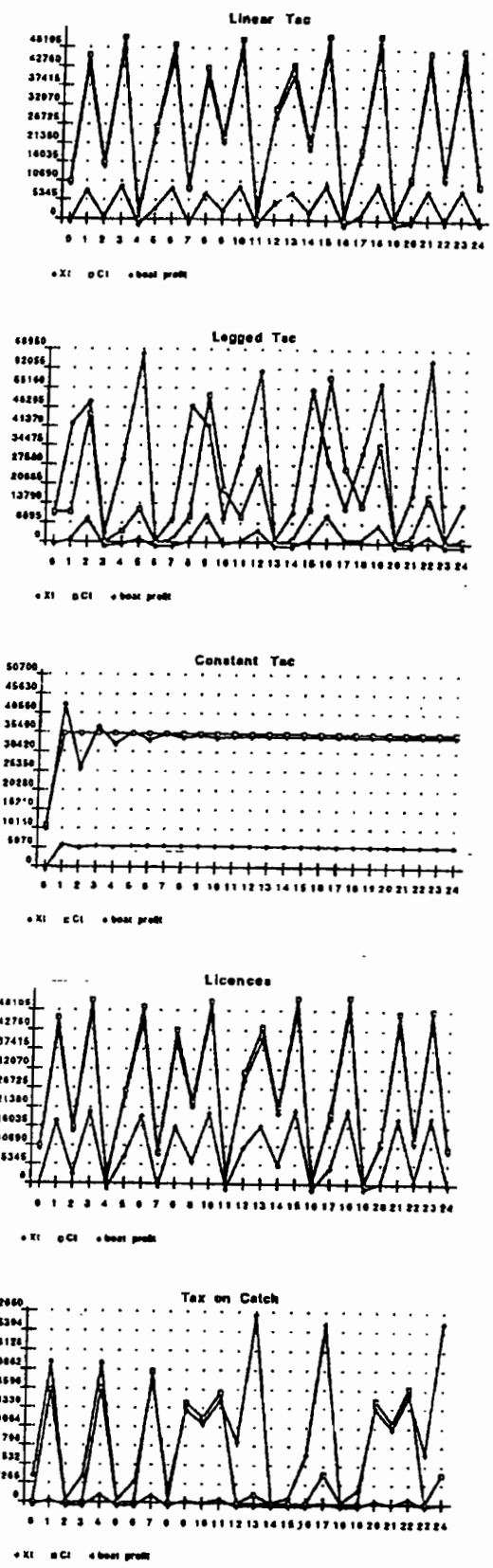


**Figure 14. Bioeconomic equilibrium - Example 2**

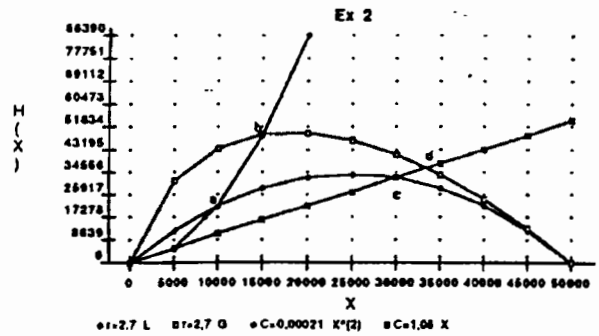



**Figure 15 (a). Ex 2- Market simulation - Logistic function**

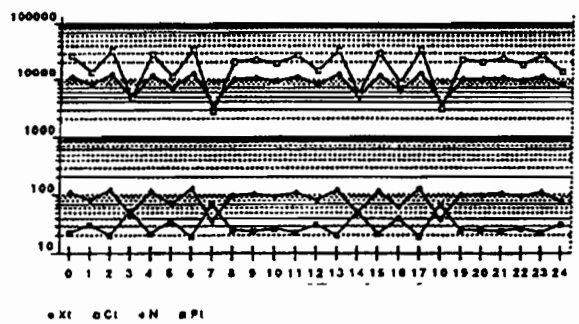


**Figure 15b.Ex 1- Market simulation - Gompertz function**

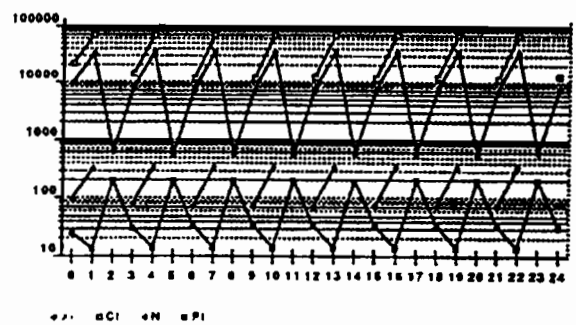


**Figure 16(a). Ex 2- Simulation results of policy measures - Logistic Function**

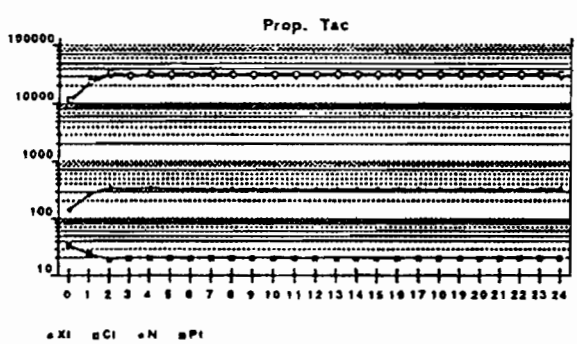



**Figure 16(b). Ex 2- Simulation results of policy measures - Gompertz Function**

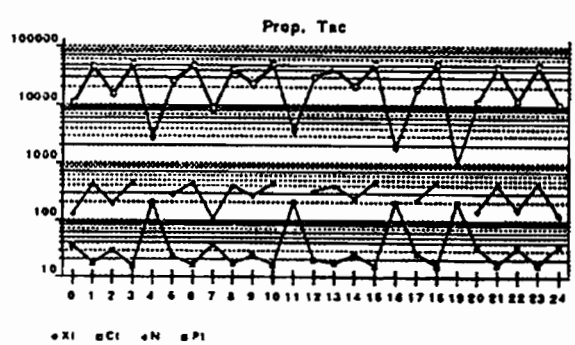


**Figure 16(a) (cont.) : Ex 2- Simulation results of the policy measures - Logistic function**

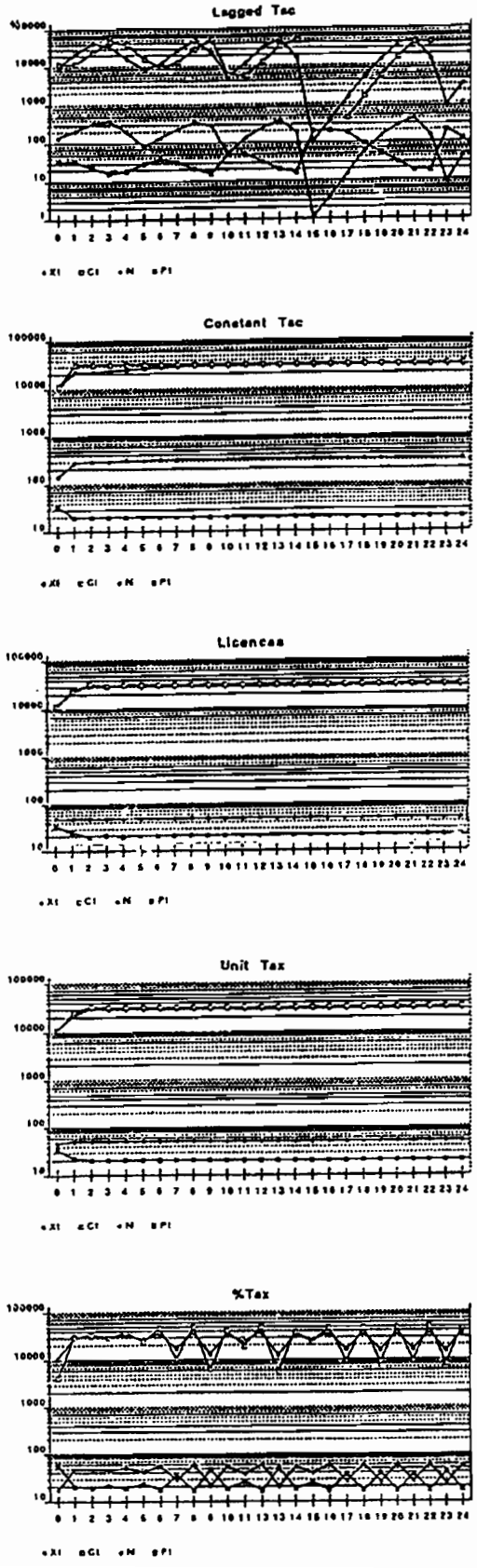
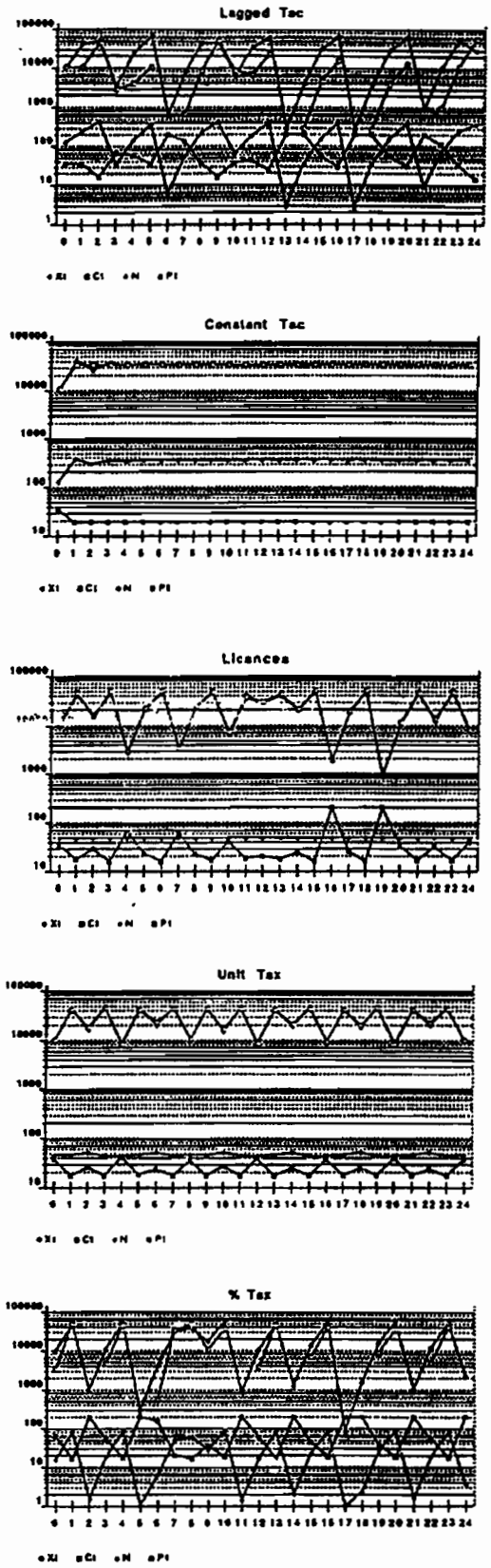



**Figure 16(b) (cont.) : Ex 2- Simulation results of the policy measures - Gompertz function**



# Individual Fishing Rights : Some Implications of Transferability

**Parzival Copes** *

[a]Institute of Fisheries Analysis and Department of Economics, Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada

ABSTRACT

*This paper analyzes the differential impacts of transferable (i.e. freely marketable) and non-transferable (i.e. granted for lifetime or limited term) individual fishing rights in respect of two interacting features : 1) the process of fisheries rationalization and 2) the achievement of a lasting improvement in fishing incomes. It traces the probable impact of transferability both for limited entry and individual quota regimes, noting similarities and differences.*

*With respect to rationalization, the paper concludes that transferability, by comparison with non-transferability, generally hinders implementation in the case of a limited entry regime, but helps it in the case of an individual quota regime. However, in the case of both regimes transferability leads to a "transitional gains trap", thereby impacting negatively on the prospects for a lasting improvement in fishing incomes.*

*The paper also comments on the particular merits of limited-term fishing rights in the case of both regimes.*

## 1. INTRODUCTION

Historically, most fish stocks have been exploited as common property resources under conditions of open access. Almost invariably this has involved excessive inputs of capital and labor in relation to output, resulting in dissipation of available resource rents (Gordon 1954). To restore such rents, and thereby improve economic performance, economists in recent decades have brought forward proposals for fisheries rationalization. These usually have involved either limitations on fishing inputs through limited entry licensing, or limitations on access to fishing outputs through the allocation of individual quotas (Scott and Neher 1981).

* In writing this paper the author has benefited from financial support provided by the Social Sciences and Humanities Research Council of Canada and from valuable research assistance by Don Reddick.

There are examples to be found of fishing operations that obtain good returns and of some that generate spectacularly high incomes. But it has been widely recognized that fishing communities throughout the world more often have suffered from low incomes relative to other groups in the same society (Copes 1987). For that reason the real problems of the fishing industry are socioeconomic as much as they are economic. An improvement in fishing income levels typically has a high priority in programs of economic reform for the fishing industry.

It is debatable to what extent low fishing incomes may be attributed directly to common property resource problems (Copes 1987). However, it is evident that a successful program of fisheries rationalization to remove or attenuate these problems could generate rents which might be used to alleviate the low incomes of fishers.

Economists have emphasized that the common property problems of the fishery are related to the nonspecification of property rights. Limited entry licenses and individual quota allocations represent forms of partial property rights, designed to overcome some of the misallocation of resources inherent in common property fisheries. However, the specific conditions qualifying the application of these rights may have considerable bearing on the success of any scheme of rationalization in meeting the dual objectives of a lasting regeneration of rents and a lasting improvement of income levels in the fishery. This paper will concern itself, specifically, with the crucial difference between the effects of transferable and non-transferable rights in this matter. It will also explore the application of limited-term fishing rights as a further alternative.

## 2. THE OBJECTIVES OF RATIONALIZATION

In the preceding section two major problems were identified that could be addressed by the rationalization of common property fisheries, viz., the regeneration of resource rents and the raising of low fishing incomes. Many economists, particularly among those devoted to formal theoretical analysis, have been preoccupied with the efficiency problem to the exclusion of distributional considerations, and accordingly have focused their attention on the maximization of resource rents. Johnson and Libecap (1982) captured this predilection in their observation that the "... inefficiencies of common property fisheries are of continuing concern to economists."

Not surprisingly, fishers, and the politicians representing them, have been more sensitive to the raising of income levels in the fishing community. The decision to introduce a management regime designed to rationalize a fishery is taken by politicians on the basis of their own priorities. Politicians may be more or less cognizant of, and sensitive to, the efficiency arguments for rationalization advanced by economists. They may also be appreciative of the circumstance that resource rents generated through fisheries rationalization are capable of providing the means for income improvement. But many of them, as a first priority, will wish to resolve once and for all the problem of chronically low fishing incomes and thereby remove the importuning pressures that many fishing communities have learned to apply very effectively.

For the reasons indicated, the politician's decision to rationalize the management of a fishery is likely to hinge in whole or in large part on the prospects of income improvement offered by the rationalization scheme. In the industrially advanced western countries where fisheries rationalization is being practiced, it is almost inconceivable that a rationalization scheme would be introduced without substantial support from the fisheries sector involved. That support will be lacking unless the scheme offers a clear promise of improved fishing incomes.

Observant economists involved in fisheries management have acknowledged the reality of the political imperative of income improvement in fisheries rationalization. Thus Moloney and Pearse (1979) have affirmed that "... in all cases we are aware of where governments have intervened to improve the economic performance of fisheries, an important objective has been to raise chronically low incomes of fishermen." They continue with the acknowledgement that "any regime that precludes fishermen from sharing in resource rents is not likely to be acceptable...."

Economists should be cognizant of the intellectual and practical shortcomings of their "efficient" solutions when they rely on simplifying assumptions to overcome the limitations of a welfare-theoretic framework that abstracts from many aspects of income distribution. There can be no unique efficiency solution where optimal factor allocation will be different for each distribution of income [1].

1. This question has been explored in a fisheries context by Bromley and Bishop (1977).

When economists ignore distributional effects in putting forward "solutions" to fisheries rationalization problems, they are advancing a questionable implication of superiority for whatever distribution of income that happens to occur in the scenario they prescribe. This is particularly unsatisfactory in the domain of fisheries, where the prevailing social and political objectives almost always have distinct distributional content. If economic solutions are to be relevant, they must be at least compatible with important distributional objectives, if not actually instrumental in their achievement.

## 3. IMPLEMENTING RATIONALIZATION PROGRAMS

In fisheries rationalization the practical choice generally is between two categories of schemes, limited entry licensing and individual quota allocation. Depending on circumstances, schemes in either category may be made more effective by various supplementary regulations, such as area and time closures, gear and vessel specifications, etc. The relative merits of limited entry and individual quota allocation depend very much on the specific characteristics of the fishery in which application is being considered. Despite some superior features, the individual quota is inherently unsuited for application under conditions characteristic of several fisheries (Copes 1986).

The possibilities of individual quota management of late have drawn much attention. While individual quota schemes have now been introduced in several fisheries, there still are many more limited entry schemes extant. In this paper the effects of transferability will be traced first with an example of limited entry licensing. Subsequently, a discussion will be presented on the consequences of transferability under individual quota management, where these differ from those present under limited entry licensing.

The first major attempt at fisheries rationalization based on the newly developed theories of fisheries economics was introduced in Canada in 1968, expressly "to increase the earning power of British Columbia salmon fishermen and to permit more effective management of the salmon resource by controlling the entry of fishing vessels into the fishery...."[2] A brief review of the structure and operation of the British Columbia salmon fishery rationalization program will serve to illustrate some important problems of rationalization and will help to explain the significance of the issue of license transferability.

The program was based on limited entry licensing (Fraser 1977). Active fishers were "grandfathered" into the fishery, while no further licenses were issued. The existing fleet, however, represented already a greatly excessive fishing capacity in relation to the available catch. In order to shrink the fleet and reduce aggregate operating costs, so that rents could be generated, a "buy-back" plan was included in the rationalization program.

Under the buy-back provision fishermen were offered the assessed value of their vessel plus a bonus for the surrender of their vessel along with its license. By not reissuing the surrendered licenses it was expected that the fleet could be reduced to an optimal size. The buy-back scheme was financed by increased license fees levied on fishing vessels continuing in the fishery. Presumably, owners would be able to pay the higher fees from the benefits accruing to them as a result of increased returns, representing restored resource rents.

## 4. TRANSFERABILITY

When the salmon rationalization program was introduced, the authorities decided to offer vessel owners transferable licenses, meaning that they were allowed to sell their vessel with license attached to any successor at any price they were able to obtain [3]. Licenses were made transferable despite a recommendation in the expert report on which the program was based (S. Sinclair 1960) that non-transferable licenses be used, at least initially. A non-transferable license would be one that a fisherman could not pass on to a successor. It would revert to the management authority after a defined period of time or on retirement from the fishery of the license holder.

2. Press Release. Minister of Fisheries. Ottawa. September 6, 1968.

3 Administratively, licenses were tied to vessels and had to be sold together. To simplify the narrative in the anlysis of this paper, much of the discussion will be couched in terms of the value of the license by itself.

Most economists involved in fisheries management appear to have accepted as self-evident the superiority of transferable over non-transferable fishing rights, be those rights in the form of limited entry licenses or individual quota allocations. Indeed, examples of proposals by economists to use non-transferable rights are scarce[4]. The uncritical acceptance of the purported superiority of transferable rights was succinctly stated in a key article reviewing the main policy alternatives for controlling fishing effort, where Crutchfield (1979 :745) dismissed any consideration of non-transferable rights with the comment : "Even less purpose is served by debate over transferability. Efficiency in use, continuity of operation, and ease of administration are eloquent arguments for relatively free and costless transferability of limited fishing rights."

This ready acceptance of the superiority of transferability seems to rest on an (uncontroversial) estimation that transferability represents an increase in the extent of property rights specification together with a (contestable) corollary that this will allow market forces to bring about a superior factor allocation, leading to an improvement in welfare. There are distinct weaknesses in the assumption of the superiority of transferable rights. First of all, transferable fishing rights do not amount to a full specification of property rights. Each particular system of fishing rights involves an unique set of complementary externalities, the effects of which can not be predicted from the extent of its property rights specification. It may be noted that Johnson and Libecap (1982) have demonstrated the possibility that the introduction of transferable licenses will lead to a reduction in aggregate wealth. What is of greater importance for this paper, however, is the implicit assumption by the proponents of transferability that the distributional effects of rationalization are irrelevant.

As argued above, this assumption conflicts with what is perhaps the most common practical objective of rationalization. What is particularly contradictory, is that many economists explicitly recognize the need for rationalization to raise chronically low fishing incomes, while at the same time advocating transferability of fishing rights as a superior means of rationalization [5]. It is the purpose of this paper to demonstrate the incompatibility of these two positions.

## 5. LICENSE VALUES AND THE EXPECTATIONS TRAP

It is instructive now to explore what happened with the implementation of the British Columbia salmon rationalization program, which had as a major objective the raising of fishing incomes and which operated with transferable licenses. It may be noted that in order to obtain the cooperation of the industry for rationalization, it had been necessary to explain in advance the advantages of the program, including in particular the prospects of much higher returns from the fishery once surplus fishing capacity had been removed by buy-back.

A fortuitous period of good prices and catches confirmed fishers in their high expectations. Obviously, their limited entry license had a substantial value if it offered privileged access to large net returns over and above those prevailing under the previous regime of open access to the fishery. And with their license having been made transferable, vessel owners had the option of collecting a windfall gain by selling it for a substantial amount to an aspiring new fisher tempted by the predictions of generous earnings.

The buy-back authority was constrained by a limited budget drawn from license fees, which was designed to make the buy-back program self-supporting. Soon the authority found that license values had escalated to the point where it was impossible for them to make further purchases of significant numbers of vessels. In consequence, they suspended their operations, at which time vessels responsible for only five percent of the fleet's harvest had been removed by buy-back (Copes 1992), when full rationalization would probably have required half or more of the fleet to be removed. The program had fallen into an "expectations trap". The expectation of large benefits had led to an escalation of license values, which in turn had caused a suspension of the vessel buy-back program on which the generation of increased benefits through rationalization depended. By this process the promise of benefits from the regeneration of resource rents was threatening to become largely a self-defeating prophecy.

As economists should foresee, expected future benefits would be discounted at an appropriate rate and capitalized in the value of a limited entry salmon license. Indeed, the license values that emerged when limited entry was introduced soon

4. Non-transferable licenses have been proposed by S. Sinclair (1960) and by W.F. Sinclair (1978). Copes (1978 and 1980) has argued for non-transferable licenses in direct comparison with transferable license alternatives.
5. A good example is Moloney and Pearse (1979), where the authors advance both of these positions in the same article.

escalated to very substantial sums. License values are known to have fluctuated considerably over the years, though no official data have been collected on license values. Unofficially, license values reaching to over $100,000 for the largest vessels (seiners) were reported in 1984, at a time of relatively depressed conditions in the fishery[6].

The presence of a license value is too easily taken to be an indication of rent that has been capitalized. The continuing presence of license values after implementation of the British Columbia salmon rationalization program has indeed been interpreted as evidence that at least a modicum of success was achieved and that resource rents have been and are being earned in the fishery (Pearse and Wilen 1979). It should be noted, however, that a license value in truth represents *expected future benefits*, not *actual current benefits*, though the latter may have more or less influence on the former. Nevertheless, it is clear that a value may attach to a license even when current fishing operations are yielding no rents or may even be suffering losses.

The estimation by potential buyers and sellers of salmon licences of future benefits to be generated in the salmon fishery is highly speculative, given the many uncertainties involved. The substantial sums that continue to be paid for salmon licenses may in fact rest largely on a dubiously grounded optimism on the part of fishers.

## 6. INPUT STUFFING

A second significant phenomenon that emerged in the salmon fleet soon after limited entry was imposed should now be noted. It appears that the unusually good prices and harvests that were in evidence during the early phases of the limited entry program, generated at least some short term rents. In an attempt to increase their individual shares of the catch and thus of the available rents, vessel operators sought to expand the harvesting capacity of their vessels.

At an early time in the salmon rationalization program regulations had been implemented to prohibit any increase in the net tonnage of replacements for licensed vessels. However, by installing additional and more advanced equipment (i.e., by investing in unconstrained factors), vessel owners succeeded in expanding the harvesting capacities of their vessels. This process has become known as "capital stuffing" (Crutchfield 1979), though it might appropriately be called "input stuffing"[7]. It reduced fleet efficiency on two counts. In the first place it caused a distortion in factor allocation, biased towards unconstrained factors. Secondly, it increased aggregate capacity in the fishery. This meant higher costs for the industry as a whole in relation to the available harvest, resulting in an erosion of rents generated initially by rationalization.

Input stuffing has been strongly in evidence in the British Columbia salmon fishery. Fraser (1977 :52) estimated that real capital inputs in the fishery increased 36 percent over the period 1969-1975, offsetting and greatly exceeding the reduction in capital inputs resulting from the abortive attempt at buy-back. It should be noted, however, that before limited entry was introduced capital inputs in the salmon fishery were already increasing steadily, probably under the influence of a rising trend in real prices for salmon.

Pearse and Wilen (1979) estimated that real capital inputs were growing at an annual average rate of 5.7 percent before 1969, as compared to a rate of 3.7 percent in the period thereafter until 1977. They concluded that while this had eroded much of the potential gain from rationalization, it had not removed all of the gain, so that some resource rent was being generated and reflected in license values.

## 7. THE TRANSITIONAL GAINS TRAP

One further problem area in the salmon rationalization program will now be discussed, namely that of the "transitional gains trap", which has been described by Tullock (1975) in a different context. While this is perhaps the most important of the problems that beset the program, given its objective of income improvement, it is one that has been almost entirely ignored by most analysts.

6. Nonofficial figures obtained from industry sources through the Department of Fisheries and Oceans.
7. Generically, the process might more appropriately be referred to as "factor stuffing" or "input stuffing", as the same effect may be generated in relevant cases by adding to the labor factor through additional inputs of crew members.

As indicated earlier, raising the level of fishing incomes almost invariably is an important objective of rationalization. It has also been an almost universal practice for governments to make the initial distribution of limited entry licenses free of charge to those "grandfathered" in — at least no contrary instance is known to this author. After all, if current fishing incomes are considered inadequate, it would hardly do to place a new and additional charge on fishers before the promised improvement in income was in evidence.

It is clear that the first generation of British Columbia salmon fishers to hold limited entry licenses has been able to benefit therefrom. They have had a double advantage. In the first place, they have been able to share in what limited rents have been generated in the fishery. In the second place, and perhaps more importantly, on retirement from the fishery they have been able to sell at handsome prices the licenses that they acquired at no cost. In respect of this first generation of license holders the objective of improved incomes clearly has been met.

But what about subsequent generations of license holders ? Standard theory suggests that they will have to pay in advance for any benefits (rents) they are expected to derive from the acquisition through purchase of a limited entry license. For the price of their license is the present value of the stream of the anticipated future benefits obtainable from that license. Unless an exogenous change has taken place to increase opportunity cost incomes in the fishery, there is no reason to expect that their net incomes will be improved over the levels previously obtaining in the nonrationalized fishery. If that level of income was considered socially and politically to be too low, then the generations of fishers subsequent to the first license holders will continue to have inadequate incomes.

While there are no studies comparing fishers' incomes in the salmon fishery before 1968 with those of post-first generation fishers after the introduction of limited entry, there is casual empirical evidence of severe financial difficulties suffered by successor generations of fishers. During 1983-1985 about 300 salmon license holders (from a fleet of about 4250 vessels) had their vessels along with their licenses seized by creditors for failure to meet payments on loans taken out to finance purchase of their licensed vessels [8].

The financial strain on fishers undoubtedly was exacerbated by the high value of new vessels affected by input stuffing and by relatively high interest rates. Nevertheless, it seems evident from the extraordinary rate of failure that the net incomes of many successor fishers fell well short of the level needed for viable participation in an industry that was subject to the annual variation in fortunes typical of the salmon fishery.

By providing the benefits of rationalization to the first generation of license holders in the form of transferable rights, the government frustrated its own apparent intention to bring about a lasting improvement of income levels in the fishing industry. The transferable licenses brought on the transitional gains trap. Income improvements that were meant to be lasting, were in fact transitional, i.e. they benefited the first generation of license holders only.

## 8. THE BENEFITS OF NON-TRANSFERABILITY

This section will focus on an analysis of the different scenario that one might have expected had non-transferable, rather than transferable licenses been used in the rationalization of the salmon fishery. The discussion will focus on the differences that would apply in respect of the expectations trap, the input stuffing problem and the transitional gains trap.

A non-transferable license would make it possible to avoid the expectations trap entirely. As fishers retired, their licenses could be withdrawn from the fishery. The number of licensed vessels in the fishery could thus be reduced by attrition to any lower number compatible with the rationalization program. If a faster pace of withdrawal was desired, a supplementary buy-back program could be introduced. As a fisher would not have the option of selling the license to a successor, the premium necessary to induce an offer of the boat for buy-back would be determined only by the net benefits the fisher could expect to reap during the remaining years of fishing before retirement.

One may expect the premium necessary to buy out a fisher approaching retirement to be quite modest by comparison with the premium necessary to buy out a license to which perpetual rights were attached. Clearly, a non-transferable license could make reduction in the number of fishing licenses quite easy. An example may be found in the California abalone

8. Unofficial data obtained from industry via the Department of Fisheries and Oceans.

fishery, where a non-transferable limited entry license scheme succeeded in reducing the number of vessels by attrition from over 500 to about 150, while curbing overfishing and improving incomes in the fishery [9]. Another example is provided by the non-transferable license system in the abalone fishery of the Australian state of Victoria, where the number of divers was reduced by attrition from about 200 to 100 over the period 1968-1979, leaving the industry in an economically healthy condition (Stanistreet 1982).

A non-transferable license will not prevent input stuffing, but is likely to reduce its extent and will make it easier to deal with. Fishers with non-transferable licenses will benefit from input stuffing only in respect of any rents they may thereby capture during their remaining years in the fishery, unless the management authority agreed to compensate them for their investment in stuffing at the time of their retirement. The opportunities for profitable input stuffing may therefore be limited in the case of a non-transferable license.

More significant, perhaps, is the ability of a non-transferable limited license system to offset the capacity-increasing effects of input stuffing, simply by allowing the withdrawal of a few more licensed vessels by attrition. It should also be noted that input stuffing is not necessarily all bad. New technology frequently has features that cut the cost per unit of a vessel's catch. A non-transferable license system may gain advantage in adopting new technology : it may benefit from the cost-reducing aspects of innovation, while avoiding the fleet-level losses associated with capacity-increasing aspects, because it can easily shed surplus capacity as it develops (Copes 1978). In contrast, a transferable license system has proven difficulties in attempting to shed the excess capacity added by input stuffing.

If a permanent improvement in fishing incomes is an important objective, then the avoidance of the transitional gains trap by the non-transferable license is perhaps the greatest advantage that it offers. In treating all generations of fishers equally, allowing no generation to charge its successors for any rents they will earn, the non-transferable license applies a standard of intergenerational equity. If income levels in the fishery need to be raised, the management authority may distribute licenses free or at annual fees that do not fully absorb the rents generated in a rationalized fishery.

## 9. THE INDIVIDUAL QUOTA

It is possible to have either transferable or non-transferable rights in an individual quota regime, with the distinction between the two being much the same as in the case of limited entry licensing. However, the impact of transferability on efforts to reduce harvesting capacity in a fleet is quite different in the two cases. As was demonstrated above, transferability tends to hamper rationalization of effort considerably in the case of limited entry licensing. With individual quota management transferability may serve as a major means of reducing fleet capacity, if such is necessary.

In an individual quota regime (Moloney and Pearse 1979) fishermen are given harvesting entitlements to specific quantities of fish, with the aggregate of the individual quotas in a fishery equalling a total allowable catch determined on the basis of bioeconomic considerations. An initial allocation of these quantitative rights among individual operators in a fishery is likely to be related to historical performance or some other aspect of equity. With quotas divided into small enough units and transferability providing for a free market in these units, rationalization can proceed without any need for further regulatory intervention.

Presumably, in a free market for quota units, the most efficient operators will be able and willing to buy up enough harvesting entitlements from less efficient operators to ensure that the total of their entitlements match the harvesting capacity of their vessels optimally. Less productive operators may remain in the fishery if they wish, but have the option of selling out at the best prices thay can get for their harvesting entitlements, vessels and equipment. It should be noted that those who stay in the fishery, despite low productivity (i.e. small harvests per person-year), should probably not be regarded as "inefficient". If they continue to fish despite small catches, they presumably also have low opportunity costs, making it worth their while to stay.

In the case of the individual quota, transferability also helps to avoid or reduce the input stuffing problem. With an individual transferable quota regime there is no serious need for controls on the number or size of vessels in the fishery, as operators generally have the freedom and the incentive to acquire the most efficient factor combinations. There are

9. Personal communication from E.C. Fullerton, Regional Director of the Southwest Region, U.S. National Marine Fisheries Service.

some circumstances, however, in which an incentive remains for some input stuffing (Copes 1986). This may be the case, for instance, when there are seasonal or spatial concentrations of fish that are particularly profitable to exploit. Operators may then contrive to build in extra harvesting power (distorting optimal factor combinations) to compete more effectively in a race for the most profitable catches.

It is in the area of the transitional gains trap that transferability may remain a serious problem in the case of individual quota management. Of course, it is a problem only if there is a recognized need to provide for a lasting increase in the level of fishing incomes. If that is the case the problem of transferability, generally, is of the same nature and severity as between a limited entry regime and an individual quota regime. With transferability, expected future benefits of rationalization will be capitalized in the trading value of harvesting entitlements. Successor generations of fishers will have to pay for their expected benefits in full in advance and cannot expect to secure any improvement in income levels as a result of rationalization.

## 10. LIMITED-TERM FISHING RIGHTS

An option that needs to be considered seriously in fisheries management is that of issuing limited-term rights, rather than perpetual rights. This is worth considering, whether one is dealing with a limited-entry regime or an individual-quota regime, and whether one is issuing transferable or non-transferable rights. A pervasive feature of the many experiments in fisheries management and rationalization that have been attempted in recent decades is the uncertainty of their outcome and the high probability of new and unforseen problems cropping up. The above account of the attempt at rationalization in the British Columbia salmon fishery serves as a cogent example.

Fisheries managers need to be prepared for "Murphy's Law" : if anything can go wrong with a new fisheries management regime... it will ! The issuing of limited-term rights avoids irrevocable commitments to management systems that may prove both seriously flawed and difficult to undo if perpetual rights have been issued. It provides the opportunity for a fresh start, keeping alternative options open.

Limited-term rights will also help to reduce the effect of the transitional gains trap where these rights have been made transferable. If, for instance, a transferable limited-entry license has been issued for ten years, of which four more years remain, its transfer value will be much reduced by the fact that it offers an entitlement to any future benefits for four years only. At times of reissue there is a fresh opportunity to allocate licenses to successor generation fishers on the same conditions as were enjoyed previously by the first generation of fishers to benefit from a newly implemented limited-access regime. In this fashion most of the enhanced income benefits of rationalization may be spread over successive generations of fishers, serving the purpose of intergenerational equity.

It may be noted that a system of life-time, non-transferable fishing rights also provides a hedge against the contingency of unanticipated difficulties in a new fisheries rationalization program. Rights that are incompatible with changes that need to be made in the management regime may be phased out as fishermen retire. However, a system of limited term rights may be more effective, at least if the maximum term of the rights is reasonably short. In that case there will probably be less delay in phasing out existing rights than in the case of non-transferable rights, where the maximum life-term still running at any one point in time may be quite long.

## 11. CONCLUSION

A question that inevitably suggests itself when non-transferable rights are proposed for the fishing industry is : "Why should rights in the fishing industry be non-transferable when they are not so in other industries ?" Rhetorically, the question may be reversed, suggesting that there may be other industries for which non-transferable rights should be considered. But that is not the topic of this paper, in which the case is being made specifically for the fishing industry – or, as will be explained, for part of the fishing industry only.

If we are looking for reasons to treat the fishing industry differently, we may find it in part in the peculiar nature of a fugitive common property resource. For most fishery resources it is impossible or impractical to contain the resource and

divide it into discrete units to be put under the ownership and control of individual fishing enterprises. Even if fish stocks could be suitably divided amongst enterprises, they could not be separated from their habitats, which form part of a multiple-use marine environmental resource. The government, as custodian of the public marine resource complex, inevitably must assume responsibility for its overall management.

As the discussion in this paper has indicated, the reason for proposing non-transferable fishing rights is to allow for an effective way of dealing simultaneously with the two common policy objectives of fisheries rationalization programs : the generation of resource rents and the permanent raising of the level of fishing incomes. The paper rests therefore on the assumption that there are fishing industry sectors in which incomes are distinctly and chronically low.

To most observers who have been widely involved with fishing matters the casual evidence of low fishing incomes is clear. An analysis of the facts and circumstances behind the assumption has been given elsewhere (Copes 1987). At the same time, it should be emphasized that this paper makes no suggestion that low fishing incomes are universal. In particular, "industrial" fisheries undertaken by corporations typically fall outside the analysis of this paper. The low income problem is more widely present in the small-scale fisheries of individual owner-operators – but these fisheries do accommodate the great majority of fishers.

If by the nature of the fishery governments must assume responsibility for biological and economic management, and if it is acknowledged that there is a serious income problem in the fishery to be remedied, then it appears logical enough that governments should seek to solve the income problem through their management plans. It may therefore be considered a legitimate and responsible undertaking of governments to include as a primary objective in their fisheries rationalization plans, a lasting remedy for chronically low fishing incomes. When they do so and call upon economists to provide them with advice appropriate to this objective, it behooves economists undertaking to provide that advice to consider the implications carefully and craft designs for management regimes that will clearly meet the objective. In that circumstance economists should be careful to set aside any proclivity to work to a more narrow professional agenda that focuses solely or primarily on "efficiency" objectives that are detached from their distributional consequences. The analysis of this paper suggests that in this regard economists, on important occasions, have not served well their patrons in government and have not contributed effectively to the implementation of public policy.

## REFERENCES

**Bromley D.W. and R.C. Bishop** (1977). "From Economic Theory to Fisheries Policy : Conceptual Problems and Management Prescriptions." In L. G. Anderson (ed.), *Economic Impacts of Extended Fisheries Jurisdiction*. Ann Arbor : Ann Arbor Science Publishers.

**Copes P.** (1978). *Resource Management for the Rock Lobster Fisheries of South Australia*. Adelaide : Committee for the Review of Fisheries of the South Australian Government.

**Copes P.** (1986). "A Critical Review of the Individual Quota as a Device in Fisheries Management." *Land Economics* **62 :** 278-291.

**Copes P.** (1987). "Why are Fishing Incomes Often Low ? A Critical Review of Conventional Wisdom." Working paper. Simon Fraser University.

**Copes P.** (1993). "The Attempted Rationalization of Canada's Pacific Salmon Fisheries : Analysis of Failure." *Proceedings of the Fifth Conference of the International Institute of Fisheries Economics and Trade*. Santiago, Chile.

**Crutchfield J.A.** (1979). "Economic and Social Implications of the Main Policy Alternatives for Controlling Fishing Effort." *Journal of the Fisheries Research Board of Canada* **36 :** 742-752.

**Fraser A.G.** (1977). *Licence Limitation in the British Columbia Salmon Fishery*. Vancouver : Canada Department of the Environment, Economics and Special Industry Services Directorate, Pacific Region.

**Gordon H.S.** (1954). "The Economic Theory of a Common Property Resource : The Fishery." *Journal of Political Economy* **62 :**124-142.

**Johnson R.N. and G.D. Libecap** (1982). "Contracting Problems and Regulation : The Case of the Fishery." *American Economic Review* **72 :** 1005-1022.

**Moloney D.G. and P.H. Pearse** (1979). "Quantitative Rights as an Instrument for Regulating Commercial Fisheries." *Journal of the Fisheries Research Board of Canada* **36 :** 859-866.

**Pearse P.H., Commissioner** (1982). *Turning the Tide : A New Policy for Canada's Pacific Fisheries* . Vancouver : Commission on Pacific Fisheries Policy.

**Pearse P.H. and J.E. Wilen** (1979). "Impact of Canada's Pacific Salmon Fleet Control Program." *Journal of the Fisheries Research Board of Canada* **36 :** 764-769.

**Scott A. and P.A. Neher** (1981). *The Public Regulation of Commercial Fisheries in Canada*. Ottawa : Economic Council of Canada.

**Sinclair S.** (1960). *License Limitation – British Columbia : A Method of Economic Fisheries Management*. Ottawa : Department of Fisheries of Canada.

**Sinclair W.F.** (1978). "Management Alternatives and Strategic Planning for Canada's Fisheries." *Journal of the Fisheries Research Board of Canada* **35 :** 1017-1030.

**Stanistreet K.** (1982). "Limited Entry in the Abalone Fishery of Victoria." In N.H. Sturgess and T.F. Meany (eds.), *Policy and Practice in Fisheries Management*. Canberra : Department of Primary Industry.

**Tullock G.** (1975). "The Transitional Gains Trap." *Bell Journal of Economics* **6 :** 671-678.

# Considerations for an Individual Transferable Quota Program for the South Atlantic Mackerel Fishery

**Katharine F. Wellman[a], J. Walter Milon[b] and John Gauvin[c] ***

[a] National Oceanic and Atmospheric Administration, Office of the Chief Scientist , 1825 Connecticut Ave. NW, Suite 625, Washington D.C. 20235, USA

[b] Department of Natural Resource and Environmental Economics, University of Florida, Natural Resource and Environmental Economics, 6129 Mc Garty Hall, Gainsville, FL 32611, USA

[c] South Atlantic Fishery Management Council, 1S Park Circle, Charleston, SC 29407, USA

ABSTRACT

*In order to solve difficult management problems, many U.S. Fishery Management Councils are considering Individual Transferable Quotas (ITQs) as a limited access option. Regulation by ITQ offers the potential to control effort without inducing adverse increases in the costs of production. All of the existing ITQ systems are designed to manage fisheries that are dominated by commercial fishing. There is no reason, however, why ITQs should not be considered in recreational or combined commercial/recreational fisheries.*

*The focus of this paper is the south Atlantic king and Spanish mackerel fishery. This fishery is unique in that a large percentage of total annual harvest is landed by the recreational sector. This creates particular problems when dealing with allocation and transferability issues of the ITQ design and additional uncertainty as to ultimate consequences of ITQ implementation. The objective of the study is to consider the potential application of an ITQ to the south Atlantic mackerel fishery, including options for structuring an ITQ system and the constraints of ITQ management in a mixed fishery.*

*Information and data used in this analysis are from the South Atlantic Fisheries Management Council, National Marine Fisheries Service Southeast Regional Office and Fisheries Science Center, and state divisions of natural resources.*

* This paper is based on a report prepared under contract to the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD. The views presented herein are those of the individual authors and do not represent those of their institutions nor of the National Marine Fisheries Service.

## 1. INTRODUCTION

The south Atlantic mackerel fishery[1], like most other fisheries in the U.S., is managed as an open-access resource. Open-access means that anyone is allowed to enter the fishery as long as they comply with basic eligibility requirements. Open-access in the mackerel fishery has led to increased competition between recreational and commercial users of the mackerel stocks and between gear types, geographic areas and full-time and part-time commercial fishermen. Open-access has also led to excess fishing pressure on the stock resulting in the reduction of the benefits from commercial and recreational uses of the stock.

South Atlantic federal and state fishery managers have attempted to ameliorate the negative impacts of open-access by restricting participants' fishing activities (see Milon et al, 1992). User group quotas, bag limits, and gear limitation/prohibitions are all management devices which have been considered as a means to control the level of harvests and reduce competition between users. These management devices have successfully reduced total harvests from the south Atlantic mackerel fishery. However, as in many other fisheries, success has come at the price of inefficient harvesting practices by users of the stock and misallocation of the resource to different user groups. In addition, success in preventing depletion of the stock has encouraged additional fishermen to enter the fishery so that more restrictive management measures are required to maintain the stock.

A potential solution to this problem is an Individual Transferable Quota management system. Individual Transferable Quotas (ITQs) are a means of creating rights in a fishery and limiting the number of participants while meeting biological stock management objectives. Under an ITQ system, fishermen receive "shares" of a fishery stock based on criteria set by fishery managers. Share owners may then harvest as many fish as their share allocation allows using any gear and at any time during the fishing season. This allows the fishermen to make decisions that maximize their return from fishing effort. The stock is protected because the total number of shares issued does not exceed the management's desired harvest level.

Under an ITQ system the efficient utilization of the resource is encouraged through the sale, or transfer, of shares from one ITQ owner to another or to a new entrant into the fishery. Even with the new entrant, however, total fishing effort is limited because the seller of the ITQ shares no longer can harvest that share of the stock. ITQs differ from standard license limitation programs in that the share owner has no incentive to overcapitalize to harvest his/her share of the resource. In addition, ownership of a personal quota reduces the incentive to "race" other fishermen to capture the allowable catch. ITQ systems have been implemented in many fisheries around the world, and recently in the U.S., as a means to limit entry and reduce the inefficiencies of open-access fishing. Muse (1991) provides an overview of these ITQ systems.

The advantage of ITQs are that they create a secure consumptive use, or harvest, right in the fishery and they help allocate the fishery resources to users with the highest value. The consumptive use right is not a complete property right like land ownership. The public still owns the resource and can revoke the right to use the resources. The consumptive use right assures the individual fisherman that his/her share of the resource can be harvested. The harvest right becomes part of the inputs necessary to participate in the fishery so that the fisherman does not view access to the fishery as a free good as with open-access regulation. The harvest right is valuable because right holders can determine their own harvesting practices and scheduling allowing them to obtain maximum value from their share of the resource. If another fisherman offers to buy their right, they can determine whether the sale proceeds are greater than expected future returns from exercising their harvest right. Theoretically this should lead to greater efficiency in utilization of the fishery.

All of the existing ITQ systems are designed to manage fisheries that are dominated by commercial fishing. There is no reason, however, why ITQs could not be used in recreational or combined commercial/recreational (or mixed) fisheries such as the south Atlantic mackerel fishery. As in commercial fisheries, problems of unlimited entry and inefficient allocation to low valued users can be overcome through the transfer of catch rights in the recreational fishery. Theoretically, recreational fishermen who have a high value for the resource could buy catch rights from other recreational fishermen or from commercial fishermen. Similarly commercial fishermen could increase their individual share of total allowable catch by buying catch rights from recreational fishermen. These sales of catch rights could be for part or all of a year or for the duration of the ITQ system. Although each group has a different motive for participating

1. There are two migratory groups of king and Spanish mackerel ; a Gulf of Mexico and an Atlantic Group. This study focuses solely on the potential for ITQ management in the Atlantic Group of the U.S. king and Spanish mackerel fishery.

in the fishery, transfers of shares between different user groups would direct the share of rights to the most valued use. As a result, all harvest shares could be owned by either commercial or recreational fishermen if they are willing to buy the harvest rights. If fishery managers decide that they want to preserve some portion of the total catch for a particular group of users then some of the catch shares can be exempt from trading.

The objective of the following paper is to consider the potential application of an ITQ to a combined commercial/recreational fishery such as the Atlantic Group of the south Atlantic mackerel fishery. In Section 2 the objectives of fishery management under ITQs are outlined. Section 3 describes options for structuring an ITQ system in a mixed fishery. Finally, by way of conclusion, the constraints of ITQ management in a mixed fishery are considered in Section 4.

## 2. OBJECTIVES OF FISHERY MANAGEMENT BY ITQS

### *2.1 Efficiency in Harvesting*

One of the primary objectives of ITQ management is to create economic efficiency. Harvesting under an ITQ system can be more efficient than with traditional approaches due to several factors. First, fishermen are free to choose the most efficient gear and scheduling to harvest their shares so there is no incentive to invest in unnecessary capital and equipment or to fish when market or weather conditions are not favorable. Second, incentives to overharvest are reduced since fishermen own harvest rights that give them a stake in the long-run health of the fishery. Third, commercial harvesters can schedule their effort to provide steady landings during the season thereby making it easier for processors to market the product and avoid short-term gluts. Finally, fishermen are free to choose the level of commitment that they want in the fishery by their purchase of harvest shares. Those that want to be part-time or casual fishermen can hold just a few shares while others who want to specialize full-time in the fishery can purchase as many shares as other share owners are willing to sell.

Efficient harvesting under an ITQ system also implies that Total Allowable Catch (TAC) is allocated to different user groups based on their value for the catch. This means that it is not necessary to continuously decide how much one group of users (such as net fishermen) are allowed to harvest relative to other users (such as hook and line fishermen). As long as individual quota shares are fully transferable, fishermen themselves can determine the highest valued use of the allowable catch.

The above principle also applies to allocations between commercial and recreational fishermen. If charter boat captains want to offer their customers the opportunity to harvest more mackerel than allowed under bag limits, they can buy mackerel ITQ shares. A captain can offer this harvesting opportunity to his/her customers as long as the captain's total catch during the year does not exceed his quota. If he/she wants to increase his/her total catch, he/she could buy more shares from other charter boat captains or from commercial captains. The charter boat captain would be willing to buy mackerel ITQ shares as long as his/her customers are willing to pay for the increased cost of the harvest rights for mackerel. Thus, the recreational charter boat customer determines charter boat captains' willingness to pay for ITQ shares.

The relationship between recreational value and mackerel harvest rights is more direct in the case of the recreational fisherman who wants to personally hold ITQ shares. The recreational fisherman could buy shares from charter boat captains, commercial fishermen, or other recreational fishermen as long as the fisherman is willing to pay the seller's asking price [2].

2. It is not entirely clear that ITQ management will lead to complete efficiency in a mixed commercial/recreational fishery. While similar production and market conditions drive both the commercial and recreational charter/headboat sectors, this may not hold for individual recreational fishermen who, rather than attempting to maximize profit in a standard production theory framework, is interested in maximizing the quality of the fishing experience, catch rate, or time fishing. For example, if under ITQ management stocks increase, it is hypothesized that the willingness to pay for shares will increase in the commercial and charter/headboat sectors. Transfers would occur resulting in shares held by users with the highest value.

### *2.2 Economic Rents*

A second objective of ITQ systems is the creation of economic rents. Open-access regulation leads to excess competition and rent dissipation while ITQ systems limit competition and make it possible for share owners to earn rents. Whether these rents should accrue to the ITQ share owners or to the public through the federal government is a matter of public policy.

If it is decided that rents should accrue to the public, there are several ways that this can occur, each with differing implications for commercial and recreational classes of fishermen. First, the initial allocation of shares can be by public auction whereby each share owner pays for the harvest right. The amount each bidder would be willing to pay to own shares is a measure of their expected rents from owning the shares. In this case, commercial and recreational fishermen would be treated equally since they would express their personal value for a share of the total catch. Since shares would be allocated to the highest bidders, the public would collect the full expected rents under the ITQ system. These rents would not be collected if shares are allocated by a lottery or are given to fishermen. This type of auction system is currently used by the federal government for mineral mining and timber harvesting rights but has not been used for fisheries due to restrictions in the Magnuson Act.

A second way rents can be collected by the public is through income taxation. Profits earned by commercial fishermen or charter boat operators under an ITQ system could be taxed at prevailing individual or corporate tax rates. This allows the federal government to recover part of the ITQ rents. If ITQ shares are treated as productive assets like stocks, bonds and other property, part of the rents would be taxed as capital gains when ITQ shares are sold. However, individual recreational fishermen who own ITQ shares would not be taxed since these rents accrue directly to the individual. These rents would not accrue as income but would be capitalized in the market value of the ITQ shares. Part of these rents would be taxed when the ITQ shares are sold if recreational shares are also treated as productive assets.

Another way ITQ rents could be taxed is with a flat tax per unit of fish harvested or per share owned. The disadvantage of the per share approach is that rents are not uniform across share owners so the tax may over-tax some share owners and under-tax others. Alternatively, a tax on fish harvested creates an incentive to under-report actual landings. This would be especially true in the case of recreational fishermen who might have increased incentive to high-grade. This approach generally would make it more difficult for fishery managers to monitor the stock. As a practical matter, the flat tax per share would be less harmful since it does not encourage cheating and could be imposed as part of annual permit fees.

### *2.3 Stock and Environmental Considerations*

A third objective of ITQ management is to maintain consistency with biological and environmental objectives such as species conservation and maintenance of critical habitat.

Concern for stock levels under ITQs is no different than biological concerns under traditional fisheries management based on TAC. It is important to note, however, that unlike traditional fisheries management an ITQ system creates incentives for share owners to comply with TAC and consider stock conservation explicitly. Since the value of ITQ shares is based on expected harvest in the future, over-harvesting that jeopardizes future harvest can only reduce the value of shares. Although a single fisherman, either commercial or recreational, may still perceive some advantage to quota-busting, other share owners have a proprietary incentive to insure that this does not happen [3].

In addition to target species conservation, it is hypothesized that the ITQ mechanism will lead to a reduction in gear on the fishing grounds. The removal of redundant gear will subsequently lead to a reduction in habitat degradation and by-catch. Other environmental objectives related to specific gears can also be addressed in ITQ management. For example, if a specific gear causes excessive by-catch of other species or degrades important spawning habitat, it can be prohibited from use under an ITQ system. As long as fishermen can select from other gears and determine their own scheduling and harvesting rates, the ITQ system will encourage more efficient harvesting while realizing environmental objectives.

---

In the case of a small-scale recreational fisherman, however, though he/she may perceive an increase in the quality of their fishing experience as a result of increased stock size, he/she may be constrained by gear type or fishing range. In this case the benefits of the increased stocks will not be realized and incentives to trade over the long run diminished.

3. Compliance incentives are particularly strengthen if the initial ITQ share allocation is denominated in terms of a percentage of TAC.

## 3. OPTIONS FOR STRUCTURING AN ITQ SYSTEM FOR THE MACKEREL FISHERY

### *3.1 Scope of Quota Share Ownership*

An ITQ system can be designed to operate for one group of fishermen within a fishery or across all fishermen. Trading and transferability of shares would be determined by the number of share classes and the rules governing conversion from one class to another. In the context of a joint commercial/recreational fishery this means that ITQs can be created for :

(i) the commercial fishery only with recreational harvest regulated through bag limits and season closures ;

(ii) a single class of ITQ shares for both commercial and recreational sectors with no restrictions on transfers between commercial and recreational fishermen ; or

(iii) two separate classes of ITQ shares - one for the commercial sector and one for the recreational sector.

While the administrative and enforcement costs of the first option would be relatively low given the small number of commercial participants involved, transferability of ITQ shares would be limited and there would be no control on entry into the recreational fishery. Option 2 would provide the maximum amount of transferability among fishermen and promote efficient allocation. However, administrative and enforcement costs could be high given the large number of recreational fishermen involved. In addition, recreational fishermen may object to ITQ reporting requirements for small quantities of fish, while commercial fishermen and processors may object to the market uncertainty caused by highly variable supplies from ITQ owners.

The third option is the most desirable from an efficiency point of view as it provides for a high degree of ITQ share transferability yet allows part of the recreational sector catch to be regulated by bag limit/seasonal closures. Commercial shares could be transferred and/or converted to recreational shares, or vice-versa, at specific times such as the first month of the fishing year. The total shares allocated as commercial ITQs, recreational ITQs, and recreational bag limit shares would never exceed 100 percent of the TAC. This system would promote efficient allocation between users while helping to reduce administrative and enforcement costs. Retaining bag limits for part of the recreational sector catch would eliminate direct reporting for anglers who only want to keep their bag limit thus reducing enforcement costs. Recreational fishermen who want to keep more than the bag limit could purchase ITQ shares and harvest their shares according to regulations governing recreational harvest.

### *3.2 Commercial Share Classifications*

There are many ways that ITQ shares could be subdivided within a general commercial classification. For example, separate subgroups (by gear type and/or vessel size) of ITQ shares within the commercial class could be created with restrictions on transfers to trading within each subgroup. Alternatively, subgroup classifications within the commercial sector could be used in the establishment of the initial allocation of ITQ shares with full transferability between the subgroups allowed once the system is operational. It is necessary in either case to include classes of shares that confer with the different motives for using the fishery.

While subgroup share classifications and restricted transferability may have social or political justification, these features of commercial shares would limit the potential efficiency gains that could be expected from an ITQ system. If the Council wishes to consider the interests of certain groups of commercial fishermen, it is argued that these concerns should be addressed only in the initial allocation. If a certain subgroup receives quota shares, they should be free to decide whether they want to continue fishing or to sell out to other fishermen. In either case the individual fisherman makes the choice and is not dependent on decisions of the Council beyond the initial allocation.

### *3.3 Recreational Share Classifications*

In addition to subgroups within a commercial class of ITQ shares, it may also be desirable to create subgroups within a recreational share class. This would extend beyond the basic distinction between recreational ITQ share fishing and bag limit fishing discussed earlier. Separate subgroups within a recreational share class for certain groups of recreational

fishermen such as charter boats, party boats or other identified recreational groups could be established. The rationale for these subgroups would be similar to that for the commercial subgroups : to protect certain recreational groups such as charter boats or to protect stocks in specific areas. Subgroups may also be useful if the costs of enforcement differ between recreational groups. Alternatively, the initial allocation of ITQ shares could be used to address specific distributional concerns about recreational share ownership and allow full transferability to determine the most desirable pattern of share ownership.

While it may be desirable to create subgroups of ITQ shares for certain recreational groups where the costs of enforcement are lower, such as for charter or party boats, the creation of the subgroup shares with restricted transferability essentially "locks-up" a share of the resource for a particular group with no consideration of whether the resource is being allocated to its highest valued use. This could perpetuate inefficient use of the resource since other groups that might have a higher value for that share of the resources could not purchase the harvest rights. One way to avoid locking-up shares of the resource, while still recognizing certain recreational subgroups is to use the initial allocation to give shares to these subgroups and then allow all other users to decide if they want to buy-out the share owner's rights. Full transferability with other recreational harvesters or with commercial harvesters allows the users to continuously determine the best allocation of the stocks rather than relying on the Council to make these decisions.

### *3.4 Total Allowable Catch and ITQ Management Units*

Both king and Spanish mackerel are jointly managed by the South Atlantic and Gulf of Mexico Fishery Management Councils under a TAC limitation (see Milon et al, 1992). Each species and migratory group has a TAC. Annual TACs are defined to account for population changes and/or management objectives. An ITQ system would divide annual TAC into individual shares. The initial share allocation would be denominated in specific units such as pounds or number of fish or as a percentage of TAC. The latter approach is preferable since allocating a specific quantity of fish may cause problems if TAC is revised upward or downward in the future. Shares defined in terms of percentages of TAC could be converted to specific individual catch allocations, or quotas, as TACs are revised over time. The percentage shares approach does introduce some uncertainty about the actual amount of catch allowed by an individual fisherman, but this is necessary to reflect the biological variability of the stock and possible changes in the Council's objectives for the stock. Percentage shares of TAC could be denominated in terms of the total weight of fish that could be harvested under an individual quota or in terms of the total number of fish that could be harvested under an individual quota.

Since TAC can be specified as either total weight (pounds) or total number of fish harvested, the choice between options depends on how the catch measurement unit influences incentives to utilize the fishery resources and the costs of monitoring individual catch. Individual quota defined in terms of weight would encourage commercial fishermen to land all of their catch since there is little price variation for mackerel of different weights. If commercial individual quotas were denominated in terms of numbers, there would be an incentive to discard smaller, less valuable fish. Excessive high-grading would jeopardize the Council's stock management objectives.

On the other hand, denominating recreational individual quota in terms of weight makes it more difficult to monitor recreational catch and enforce quotas and bag limits. Since most recreational catch is likely to be less than 100 pounds per trip, it would be difficult to measure the weight of each catch and monitor quota. Therefore, it is more appropriate to denominate recreational individual quota in terms of number of fish.

An alternative is to initially denominate all shares in terms if weight. If the share is used as a commercial class ITQ share, the shareholder's allocation would be given in units of weight (e.g. 1000 pounds of mackerel). If the share is used as a recreational class ITQ share, the share holder's allocation would be converted to a specific number of fish based on conversion ratio set by the Council (e.g. 100 pounds of mackerel = 10 fish). Similarly, shares set aside for recreational catch under the bag limit would be converted from weight to numbers using the same conversion ratio. This is the procedure that is used under the current south Atlantic mackerel TAC allocation system.

### *3.5 Initial Allocation of ITQ Shares*

The initial allocation of shares depends, in part, on the classes of shares created for the ITQ system and the relative importance given to fairness and historical participation considerations suggested in the Magnuson Act. The initial

allocation of ITQ shares is important because it establishes which groups will have quota shares to use and/or transfer. It would be possible for the Council to : (1) create one class of shares and leave the allocation decision to a lottery or auction (The lottery or auction could be open to anyone who wishes to participate or it could be limited to individuals who meet specific eligibility criteria.) ; (2) allocate ITQ shares to individuals based on historical participation as determined by average catch records and/or some other indicator during some prior specified time period ; or (3) allocate ITQ shares according to different criteria for each class of shares created. In the latter instance, commercial shares could be allocated based on historical catch records or some other historical participation indicator while recreational shares could be allocated via a lottery after some portion of the TAC is assigned to recreational bag limit fishing.

The first option would make it possible for anyone to be allocated ITQ shares if they were lucky enough to win them in a lottery or to purchase them in an open auction. This option is appealing from a fiscal point of view because it provides the Federal government with a means to collect the rents that would accrue to ITQ share recipients through a lottery. The primary short coming is that the Magnuson Act does not currently authorize auctions [4].

The second option is desirable if only commercial ITQ shares are created. Since most recreational fishermen do not have historical catch records to document participation, there would be no way to allocate recreational shares. Thus, any trading of ITQ shares could only involve commercial ITQ shares which may not be convertible into recreational shares. The advantage of the third option is that it allows the historical participation criteria to be used to initially allocate commercial ITQ shares and provides a method to allocate recreational ITQ shares. The recreational allocation could be used to create tradable ITQ shares within the recreational sector depending on the extent of the Council's interest in promoting recreational sector trading. The lottery is a simple way for the Federal government to fairly and equitably allocate ITQ shares to the recreational sector while maintaining consistency with the current Magnuson Act.

### *3.6 Initial Eligibility Criteria*

The eligibility criteria for the initial allocation of ITQ shares depends on the types of ITQ shares created and the initial allocation mechanisms. ITQ share ownership could be made open to anyone regardless of the class of shares a fisherman wanted to obtain or based on specific eligibility criteria for each class of ITQ shares to reflect certain Council priorities for ITQ share ownership. Criteria based on demonstrated participation in the fishery will tend to limit the number of fishermen eligible for initial ITQ share allocations but these criteria would reward fishermen who have been most active in the fishery. On the other hand, if eligibility was open to anyone who wished to receive ITQ shares there would be considerable opportunities for share trading. But, fishermen who have actively participated in the past may have to give up part of their historical catch to accommodate new entrants. Open eligibility may also make ITQ shares so small that it would not be economical for an individual to hold an ITQ share and comply with permitting and reporting requirements.

While the first option would make it easy for anyone who wished to own ITQ shares to participate and would allow ownership of multiple classes by a single fisherman, it creates the possibility of speculation by individuals who do not wish to participate in the fishery but want to receive an ITQ share allocation for future sale. Ownership of multiple classes of ITQ shares may also make enforcement more difficult since each class of shares may have different reporting requirements.

The second option, on the other hand, gives the Council the latitude to identify certain priorities for initial ITQ ownership to facilitate the success of the ITQ system. For example, the Council may decide that commercial ITQ shares should be allocated to long-time mackerel fishery permit holders with certifiable catch records and no history of permit violations. Similarly, recreational ITQ shares may be allocated to long-time charter vessel permit holders with no record of violations. The Council may also decide that individual fishermen should not hold more than one class of ITQ shares so that a fisherman who held both commercial and charter permits would only be eligible for one class of shares. This would aid in enforcement since each class of shares could be monitored under a separate system of reporting.

4. It is clear that in the context of a joint commercial/recreational fishery any lottery process (if it were authorized) must include protocol unique to the mixed nature of the fishery. For example, in the south Atlantic mackerel fishery there are more recreational than commercial participants. Therefore, if the intention of the Council is to provide for an equitable allocation, the lottery must include some weighting mechanism that adjusts for this imbalance.

### *3.7 Duration of Rights*

The duration of ITQ ownership rights is an important issue because it influences the relative value of share ownership. The duration of the ITQ ownership of shares could be limited to a short period of time such as 1 or 2 years to determine whether the system is workable and the Council's desired share allocations continue to exist or defined as indefinite pending subsequent amendment. In the latter case, the market for share transfers is left to determine whether the system is working and the allocation of shares correct.

While it could be argued that limiting the duration of ITQ rights gives fishery managers more flexibility to adjust share allocations or to terminate the system if desired, the first option would create considerable uncertainty about the future status of the ITQ system and discourage investment in share ownership. Uncertainty about the Council's future intentions could undermine the ITQ system and cause it to fail. While the Council would have some flexibility to redefine and reallocate rights, it is not clear that the ITQ system would accomplish much more than the current management system and would tend to perpetuate current problems. The second option, on the other hand, would be more likely to encourage share investment and trading. The market for shares both within and across shares classes could help to allocate mackerel stocks to the users with the highest value and eliminate the need for the Council to reallocate harvest rights. The Council would always have the option of eliminating the ITQ system by amendment if they perceived that management objectives were not being met.

### *3.8 Permit Requirements*

Under a joint commercial/recreational ITQ system a fisherman could not legally harvest mackerel unless he/she held ITQ shares or he/she fished under the bag limit. As in any ITQ there will always be some incentive to cheat by fishing without ITQ shares or by trying to harvest more than the quota owned by the fisherman (quota-busting). Therefore, it may be desirable to require fishermen to possess individual permits. Permitting could include a general purpose permit to fish with ITQ shares regardless of the class of shares owned or a special permit for each class of ITQ shares with an exemption for recreational fishing under the bag limit. Under the second option, permits would be issued for each type of ITQ share to help distinguish those who are fishing for the purpose of selling their catch from those who wish to keep fish solely for their own use.

The first option would impose some costs on ITQ participants but would help to overcome incentives to cheat under the ITQ system. Each share owner, regardless of the class of shares owned, would be required to possess an annual permit that would allow the owner to harvest his/her shares during the fishing year. New buyers or lessors of ITQ shares would also have to possess a permit. Penalties could then be tied to permit renewal since the Council could deny permits to anyone found in violation of ITQ system operating procedures. The main shortcoming of this option is that it is not tied to specific classes of ITQ shares.

The second option would help to reinforce a system of separate classes of ITQ shares. Fishermen who wished to use their ITQ shares for commercial purposes could be required to have a "harvest and sale permit" that would allow them to sell their catch to licensed dealers. Those who wished to use their ITQ shares for recreational purposes could be required to have a "harvest and possession permit" to allow them to keep their catch. Penalties could be imposed for selling catch under a possession permit. This sharp distinction between commercial and recreational harvesters of mackerel may be necessary due to the potentially high costs of monitoring recreational catch. A "no sale" condition on recreational ITQ quotas would minimize incentives to exceed quota. The enforcement effects of dual permits could be reinforced by making it illegal to possess both harvest/sale and harvest/possession permits concurrently. The two types of permits would make it easier to monitor individual quotas since each type of permit could require different reporting mechanisms (see *Reporting Requirements* below). This dual permitting approach may be necessary because most states in the south Atlantic region do not have a fish sale reporting system to monitor individual fishermen sales. Penalties for violating permit restrictions could be tied to annual permit renewal. NOAA general counsel could then penalize violators who have reduced their exposure to enforcement by leasing shares to associates. Recreational fishermen who fished under the bag limit would not be required to have a permit since their catch is restricted by the bag limit. This would help to reduce the administrative and compliance costs for the ITQ system.

*3.9 Reporting Requirements*

The benefits from ITQ management depend, in large measure, on effective monitoring and enforcement. This means that a system to track and monitor individual quota harvests is a necessary first step. The design of this catch monitoring system should take into account differences between commercial and recreational catch and the broad geographic dispersion of mackerel harvesting activities in order to reduce monitoring and enforcement costs. A reporting system could be based on catch "coupons" or an electronic "credit card" required for all ITQ share holders including all recreational fishermen. Alternatively, a separate system of individual catch reporting could be required for commercial and recreational ITQ share holders with recreational fishing under the bag limit monitored by the existing Marine Recreational Fishing Survey.

While the first option provides a feasible means of monitoring individual catch for commercial harvesters, it is likely to be costly and difficult to administer for recreational harvesting. Given the large number of landing ports along the south Atlantic coast it is unlikely that enough agents could be designated to make the system effective. In addition, many recreational fishermen may find the system burdensome and decide not to comply. The second option, on the other hand, tailors the reporting system to the unique aspects of each user group. Individual commercial quotas could be monitored with a coupon and "double-entry" system. The double-entry system could consist of designated agents (fish houses, marinas, etc) who collect coupons equivalent to landings under each quota and file reports on quota landings with the National Marine Fisheries Service. A similar system could be set-up with an electric credit card that would track each individual quota account through a computer network.

Recreational fishermen who hold ITQ shares could be issued non-reusable tags in conjunction with a harvest and possession permit. The tags issued would be equivalent to the number of fish the share holder was entitled to for the share held and the Council's weight-number conversion ratio. All mackerel landed by a recreational fishermen holding ITQ shares must be tagged. Recreational ITQ share owners could also be required to keep a logbook of mackerel catch and return used tags to the National Marine Fisheries Service. The share holder's quota would be filled when the tags are exhausted. Penalties could be imposed for fish landed without tags. Recreational fishermen who do not own ITQ shares would not be required to tag their fish as long as they complied with the bag limits. Total catch by recreational fishermen fishing under the bag limits would be monitored with the Marine Recreational Fishing Survey as it is now done. Recreational ITQ share owners may attempt to harvest their mackerel quota quickly and then land mackerel under the bag limit until the season closes. It may be necessary to prohibit such actions. Restricting recreational ITQ share owners would reduce uncertainty about the number of fishermen fishing under the bag limit and make it easier to set bag limits to keep the season open as long as possible. This approach to reporting recreational ITQ catch would reduce the administrative cost of the ITQ system and help to provide better data on mackerel harvests than with the current system.

*3.10 Gear Restrictions*

A majority of king mackerel landed commercially in the south Atlantic is harvested by hook and line, while Spanish mackerel is primarily harvested by gill net. The recreational fishery is almost one hundred percent hook and line. It is assumed that under an ITQ, Councils would continue to regulate against gear types which result in undesirable side-effects to the environment (such as by-catch by drift nets). However, one of the goals of an ITQ is to promote efficiency of harvest and production. Therefore, it is necessary to consider carefully whether a fishery should be allowed to operate under no gear restrictions or whether the benefits (both environmental and economic) outweigh the costs of regulation. Options for gear restriction in the south Atlantic mackerel fishery include : (1) no gear restrictions on commercial or recreational harvest ; (2) all gear approved by the South Atlantic Fisheries Management Council would be allowed ; or (3) all approved gear would be allowed for the commercial harvest of king and Spanish mackerel under the ITQ system while recreational harvest would be restricted to hook and line.

The first option is clearly questionable under the Magnuson Act which emphasizes a policy of fish resource conservation and protection of related habitat. The second option would allow fishermen freedom to choose cost minimizing, efficient gear types to harvest their quota. This is desirable unless there is some concern that certain gear types could lead to individual catches that could significantly exceed individual quotas. In addition, the possibility that recreational harvests may exceed allowable catch is raised. Recreational use of gillnets or seines, for example, could lead to catches in excess of the quota or the bag limit and potential problems of high-grading, illegal discards, and increased fish mortality rates. The third option would allow any gear approved by the Council to be used to harvest mackerel under a harvest/sale permit. This would lead theoretically to cost minimizing behavior by commercial fishermen and uphold the

environmental and conservation objectives of the Magnuson Act. Recreational fishermen fishing for mackerel under a harvest/possession permit or the daily bag limit could be limited to hook and line. This gear restriction could decrease the mortality rate for mackerel released after catch.

### *3.11 Penalties*

Because the benefits obtained from any ITQ management scheme depend on compliance with individual quotas, gross violations (such as commercial quota busting, harvesting above the bag limit, or failure to report landings) warrant strict penalties. Experience suggests that exceeding individual quotas or "quota busting" has been one of the most frequent problems with ITQ systems. Quotas are exceeded by either not canceling coupons, not turning in tags so that they can be used again, or fraudulent use of coupons. An ITQ system is not likely to succeed if individuals can exceed their quotas without a reasonable probability of detection, or without severe penalties when violations are detected. Because quota share ownership involves a type of long term investment on the part of the fishermen, individuals may be more willing to report violations they observe than under traditional open access fishing. In order to address this issue infractions such as quota busting, non-reporting or fraudulent use of coupons or tags could be penalized with temporary permit sanctions. Alternatively, infractions could be penalized by forfeiture of ITQ shares and harvest/sale or harvest/possession permit sanctions.

Under the first option the National Marine Fisheries Service could only revoke a share owner's permit to penalize non-compliance with ITQ rules. Given that permits would be obtained on an annual basis, this temporary sanction would have little long term impact on developing incentives to comply. The second option allows for penalties for non-compliance to include both forfeiture or sanction of annual harvest/sale or harvest/possession permits, as well as ITQ share holdings within a given year. In this case NOAA general counsel would have two effective means of penalizing violators. The individual who has reduced his "exposure" by dividing total shares among family members can be sanctioned and kept from fishing by removing or suspending their permit.

Neither of these two options address the problem of fishermen harvesting without ITQ shares in excess of the bag limit. Undoubtedly some fishermen will attempt to catch more mackerel than legally allowed without owning ITQ shares. Under the catch reporting system described above, this illegal catch could not be sold legally because fish houses would be required to buy mackerel only from ITQ share owners with harvest/sale permits and they would be required to report all mackerel purchases. It is possible, however, for "black market" sales to occur directly off a boat to an unauthorized buyer. To make ITQ share ownership meaningful, it will be necessary to have sufficient policing to assure that illegal catch does not become a significant part of total harvest. These violations of the ITQ system would need to be sanctioned under general enforcement provisions of federal fishery law. It should be recognized, however, that the geographic distribution of the mackerel fishery may make it very expensive for the National Marine Fisheries Service to provide sufficient policing of illegal catch.

### *3.12 Transferability*

Transferability is of paramount importance in an ITQ system of management. Theoretically, transfer of allocated shares, or the sale or lease of individual quota, allows for greater efficiency in utilization of the fishery. Transferability includes the sale of percentage shares and the sale or lease of all, or a fraction of, individual quota. Sale or lease of individual quota could be accomplished by selling or leasing individual quota coupons for the quantity of mackerel denominated by the face value of the coupons. The Council could allow percentage shares to be sold to anyone within a share class, whether they hold a percentage share or not, during any part of the fishing year, but require that the sale or lease of individual quota be to share holders only. Alternatively, the sale or lease of percentage shares and individual quota could be open to anyone within a share class whether they hold a percentage share or not.

Restricting the sale of individual quota to vested share holders might increase incentives for compliance and simplify monitoring and enforcement of the ITQ program. However, limiting the quota transfers to share holders would restrict the ability of new entrants to enter the fishery during the fishing year and thereby limit fishermen's responses to seasonal variations.

The second option, on the other hand, would allow for the free movement of quota during the fishing year within all share classes. Unrestricted transfer within each share class lets the market work unimpeded. The potential for quota busting and non-reporting of catch is increased if all entrants can exceed quota during the year. However, the monitoring and enforcement associated with the permitting process should help to minimize these problems.

### *3.13 Convertibility*

Convertibility is an element that is unique to an ITQ system involving both recreational and commercial classes of share owners. Convertibility between commercial and recreational shares can be allowed to occur at any time during the fishing year or be restricted to the time of permit renewal during the first month of the year fishing year. The choice depends on the potential for market instability and enforcement problems with unrestricted conversions.

Allowing conversion at any time of year would provide maximum flexibility in the movement of quota shares between users. However, it may result in erratic movement into and out of the commercial fishery and increased uncertainty related to harvest and price expectations. It could also lead to strategic behavior as recreational fishermen try to buy commercial quota to sell fish they caught in excess of the bag limit.

Limiting conversions to the time of permit renewal during the first month of the fishing year would help to stabilize the commercial and recreational markets for shares/quota during the fishing year and reduce the administrative costs of the system. This may lead to some misallocation since harvest rights cannot flow to the highest valued use during the season. But this will be only temporary and would not likely offset the benefits of greater stability in the ITQ share/quota markets. To minimize the costs of enforcing quotas and sale restrictions under a harvest/possession permit, it may be desirable to restrict a share owner from holding both harvest/sale and harvest/possession permits concurrently.

## 4. CONCLUSIONS

While theoretically an ITQ system will lead to more efficient harvesting and allocation of fishery stocks than traditional management systems, limitations associated with individual fisheries may hinder their success. In the south Atlantic mackerel fishery the conflict between commercial and recreational fishermen may automatically present problems for the successful implementation of an ITQ system. That is, if in fact the ITQ system includes both classes of recreational and commercial fishermen, trading between the groups must occur in order that shares are transferred to individuals with the highest value. Political interests may impede such transferability.

In addition, the success of an ITQ in the mackerel fishery (as in many other fisheries) may be limited if the administrative and enforcement costs of the system outweigh efficiency gains. The creation of ITQ shares requires an administrative system to record share ownership and transfers, issue annual harvest share quotas and permits, monitor compliance with share quotas, and enforce quota limits and other restrictions. Costs are also imposed on participants in the fishery since they must establish a personal recording system to assure compliance with their individual quotas, bargain with other fishermen over the sale or purchase of ITQ shares, and pay any administrative/legal expenses resulting from disputes under the system. Aside from enforcement costs required to monitor harvesting under traditional management system, most of these costs are unique to an ITQ system.

There are few rules that can be used to predict whether administrative and enforcement costs will exceed efficiency gains from an ITQ system. However, one general principle is that administrative and enforcement costs will be higher in fisheries that are dispersed over a wide geographic area with a larger number of participants and many landing sites. Unfortunately this is the situation in the mackerel fishery where harvesting occurs over the full south Atlantic region and in the Gulf of Mexico by a relatively large number of commercial and recreational fishermen. Given the migratory nature of mackerel, it is unlikely that ITQ shares would ever become concentrated in the hands of a few fishermen who would harvest the TAC from within a small geographic area.

The physical characteristics of the mackerel fishery (Sutter et al, 1990) suggest that the possible success of an ITQ system will depend heavily on the administrative and enforcement costs required to implement the system. Therefore, it will be important to design a system that reduces these costs as much as possible while achieving the objectives of ITQ management. This can be accomplished in the mackerel fishery by careful attention to the administrative and enforcement costs implied by different ITQ systems structure and operating requirements as cited in this paper.

Another constraint in developing an ITQ system for the south Atlantic mackerel fishery is the fact that mackerel are not regulated solely by the South Atlantic Fishery Management Council. The Coastal Migratory Pelagic Fishery Management Plan is administered jointly by both the South Atlantic, Gulf of Mexico and the Mid-Atlantic Councils. This coordination is necessary to manage the two separate migratory groups of king and Spanish mackerel. In addition, mackerel harvesting is not confined to the Federal Exclusive Economic Zone. Although there are no reliable statistics to document the percentage of catch from non-federal waters, it is an accepted fact that mackerel are frequently caught in state waters. As discussed previously, this has not been a major problem since most states in the south Atlantic and Gulf of Mexico regions have in the past coordinated their management efforts with the Coastal Migratory Pelagic Fishery Management Plan. However, Florida has argued for and adopted different catch regulations to address problems unique to mackerel fishing in that state. Since fishermen in Florida currently account for a major portion of the total mackerel harvest, it is clear that this unique problem, as well as those mentioned above, cannot be ignored if the objectives of a successful ITQ program are to be achieved.

## REFERENCES

**Milon J.W., K.F. Wellman and J. Gauvin** (1992). "Considerations of the Potential Use of Individual Transferable Quotas in the South Atlantic Mackerel Fishery". National Marine Fisheries Service *National ITQ Study Report*, Vol. 4.

**Muse B.** (1991). *Survey of Individual Quota Programs :* Alaska Commercial Fisheries Entry Commission.

**Sutter F.C., R.O. Williams and M.F. Godcharles** (1990). "Movement Patterns and Stock Affinities of King Mackerel in the Southeastern United States." *Fishery Bulletin* **89 :** 315-324.

# From Open Access to Communal Property : the Case of the Fishing Community in Muxía.

**Antonio García Allut**

University of La Coruña, Dept of Anthropology, Campus da Zapateira s/n, 15071 A Coruña, Spain

ABSTRACT

*The analytical model predicts the eventual over-exploitation of all common resources, attributing the causes of this degradation to the uncontrolled and maximalist conduct of the producer. Nevertheless, angles of this type are contradicted by the surprising number of cases where the producers have been able to restrict access to the resources and to establish rules among themselves concerning their use without the need for state intervention.*

*In this paper, we will present an example of how the fishing community of Muxía, Galicia (Spain) has modified the rights of the fishing community from certain common resources with open access to convert them into communal property rights, where both access and the resources themselves are controlled by the group of fishermen belonging to this community through the (informal) setting-up of a co-operative system of exploitation known as "A Compañía" (The Company).*

## 1. INTRODUCTION

This type of analysis draws attention to the fluctuations brought about in fish stocks once the exploitation begins. For those in defence of this model, the differences in the fish quantities beforehand (in their original state) and after the exploitation (diminishing to critical levels) represent the starting point in the developing of an approach, as far as the economic behaviour of the producer in relation to the open-access method of exploitation, is concerned.

According to this, the producer will operate on the fishing resources in an indiscriminate way, his only object being to obtain the maximum profit in the minimum time (Gordon, 1954 ; Scott, 1955), being unaware of the fact that fishing territories can only withstand, due to the finite nature of the resoures, a finite amount of exploitation (Hardin, 1968). From this point of view, uncontrolled, maximalist production behaviour, will not lead to anything else but ruin. In conclusion when the resources are granted for common use and exploited under a survival of the fittest régime, the Tragedy of the

Commons situation is brought about (degradation of nature). Only through state intervention or privatization of the resources can this free competition be curbed and over-exploitation avoided (Gordon, 1954 ; Hardin, G., 1978,1989). However this type of analytical approach, while giving more importance to the biological factors (equilibrium in ecosystems) and economics (stocks) than to the social factors themselves, that is to say, the people and the relationship between the social groups (Breton, 1987), interprets the fisherman as a individualistic predator. They do not take into consideration that the producer is subject to certain norms which are no more than ways of negotiating the common resources, they are territorial control processes linked as much as to access as to exploitation.

Therefore the fishermen are able to develop their own exclusive control and self-regulation (McCay, 1987), creating in fact territorial behaviour (economically defensible) where the costs of using and defending an area are inferior to the benefits. They are able to modify, once and for all free access to the resources, converting the common property use, "That which belongs to everyone and at the same time no-one" into exclusive use for a few.

According to McCay & Acheson (1987 :9) the impoverishment of the resources and the communities which depend on them, is closely related to the demands of capitalism, watering down the causes which motivate the tragedy by putting more emphasis on the milieu than on the free behaviour of the producer. On the other hand, the Theory of the Commons finds support in the individualism of the fisherman and the absence of the institutional control which regulates fisheries, deducting importance from the socioeconomic milieu and the regulatory mechanisms which interact in the granting of common property use. The error which Hardin made and which conditioned his complete analisis was identifing the open-access rights with those of common property use, forgetting the existence of certain non-governmental forms of controlling access and appropriation of resources, through the establishment of norms orientated towards regulating the negotiating rights.

Our interest lies in showing how this procces was "constructed", outlining the particular factors which intervened in the process and favoured the birth of an exploitation system in the régime of communal property use. The creation of "A Compañía" as the cornerstone upon which the exploitation is organized, is the gelling and cohesive element which will facilitate success.

## 2. THE ECOLOGICAL AND SOCIOECONOMIC ENVIRONMENT OF THE MUNICIPALITY AND COMMUNITY OF MUXÍA

This costal municipality situated in the far northwest of Galicia (Norwest of the Iberian Peninsula), pertains to the province of La Coruña. The municipality has 6,411 inhabitants distributed throughout a 120 square km., area, who live in small population groups ("aldeas"), spread out in the interior of the territory.

In Muxía, a village with a urban structure, there are 1,676 inhabitants of which 314 are dedicated to fishing.

The village is situated in the lowest area of a rocky headland which juts into the ocean ("Itsmo da Barca"), orientated to the north towards the Camariñas Ria.

In 1980 a harbour was built to give shelter to all the boats of the village. It also possesses a fish market administered by the town council, and since 1988 an ice factory, which is the property of the Association of Fishermen "Cofradía de Pescadores Virxen da Barca".

An economic envoirnment, generally showing a deficit, is going to reduce the prospect and opportunities of alternative employment in other sectors, leaving its inhabitants with the fishing industry as the main fallback to strengthen their economies. The service and commercial sector industry ( 11 shops, municipal administration, 4 banks, 24 bars, etc.), is the second important economic ambit, as its source of invigoration are the results of the fishing activities, that is to say, it is particularly sensitive to all the fluctuations which affect the latter. The success or failure of the catches affect the social relations and the economics of the community. If the fishermen do not catch anything, the fishermen's wives are obliged to dip into their savings in order to lend a hand, or to obtain food and sundry items on credit, until such time as the catch is more successful.

## 3. THE STRUCTURE OF THE FLEET

At present the fleet is made up of 73 vessels, varying in size and the type of work carried out. They can be classified into three large groups : The "gamelas" group, 40 vessels with a "eslora" of not more than 6 metres, powered by outboard motors. Each "gamela" is crewed by one or two men and its principal activity is the catching of crustaceans and molluscs ; in winter in the interior of the "ría" and in summer off the coast. In the "motoras" group there are 12 vessels. They have between 5 and 12 T.R.B., powered by motors of up to 200 H.P., a crew of up to 6 and their fishing techniques and types of catch are much more varied. They use different methods such as, trammel net, fish trap, seine-net,..., aimed at catching various species (octopus, hake, conger, spider craf,...). Their principal fishing grounds are between the coast and seven miles out. Finally we have the "palangreros" group, with a total of 21 vessels. They are the largest boats of all with between 15 and 100 T.R.B., and crews of up to 11. For practically the whole year, they fish in the area known as "El Cantil" (between 14 and 30 nautical miles from the coast) using the long-line ("palangre") technique. Our interest will be centered on this third group.

The boats equiped with long-lines are more specialized but less versatile vessels. During times of poor catches, some fishermen complement the long-line with the "rasco" (a varieted of gill net) and at certains times of the year (January to March) gill-nets are used. However the boats equiped with long-lines, have since 1968, concentrated their fishing activities in the fishing ground known as "El Cantil de Muxía". A fishing ground situated between 15-30 miles from the base port and with an extension of approximatly 16 square miles. It is a relatively homogenous area, whose limits come to be defined by their productivity, in which the resources are dense and predictable. This maritime area is lined along the continental platform, a very rugged area, consisting of major elevations and submarine valleys, which together with strong currents and outcrops of nutrients make it especially productive. Graphically it resembles a narrow strip of between 2 to 3 miles wide, which is prolonged uninterruptedly for 14 miles. It is here that the four principal fishing grounds which follow are distributed, "Quiniela", "Crimen", "Petón das Navidades", and "Papeles".

The wealth of these fishing grounds lured the attention of the fishing community of Muxía at a time (1964) when the coastal fisheries were showing evidence of a certain depletion. The absence of alternative fishing grounds at close proximity, combined with the difficulty involved in specializing in other types of more profitable fishing, forced the fishing community to concentrate on "El Cantil" as a way of improving their economic expectations.

However the entry into this territory brought with it a need to reform the structural conditions of the fleet, they had to be adapted to the characteristics which the new area presented. Due to this, the history of the long-line boats of Muxía is the result of a process of "conquest" in that in order to make their way to "El Cantil" and assure their permanence there, it was necessary to modify the former production system, and to compete with vessels from other communities. The problems that were posed in the entire process were brought about by a series of factors : the size of the fishing area, technology, the composition and the distribution of the species, the physical aspects of the environment, the alternative employment opportunity, legal loopholes,.... which all led to the creation of a territorial system practising an exploitation régime of common property use. It also led to the setting up of a co-operative negotiating model of the resources and benefits.

## 4. TECHNOLOGY AS A LIMITING FACTOR IN THE ACCESS TO THE CANTIL

From the outset of the twentieth century until the 1940's, the community lived in a situation of tight dependence on the rural environment. Fishing was the only source of gain, but insufficient to cover the basic necessities, which in turn had to be met by the agricultural products of the neighbouring villages. Due to geografical isolation, the limited value of the sea produce and the difficulty in commercializing it, the community was unable to reach a similar level of development that other Galician ports were benefiting from. During this period the community did not undergo significant changes. Onshore fishing was carried out (maximum 7 miles from the coast), using traditional fishing instruments and materials, and vessels unable to respond in the most effective way to envoirnmental changes.

The years that followed the Civil War, until the mid-sixties, are characterized by a period of transition, of a pre-capitalist method of production toward a process of modernization. Certain traditional methods of orientation, localization of fishing boats, and sea bed surveying were gradually done away with. Another part of this remodeling included the

abandoning of hand sounding, while at the same time new materials with added resistance, such as nylon were introduced in place of hemp and cotton. New styles of fishing were also introduced, while new apparatus for the surveying of the sea bed and the detection of shoals of fish meant a significant rise in production.

The appearence of more modern types of sounding in 1962, allowed a more meticulous exploration of the fishing grounds and also permitted an extension of the actual working area. This also contributed to important decision taking as far as entering into the rich fishing grounds outside of the usual limits was concerned. In our opinion, the introduction of modern methods of sounding in some of the production units was the determining factor in the decison to establish contact in the fishing grounds of " El Cantil "

There is evidence that in 1964 vessels form A Guarda (Pontevedra) and Finisterre( La Coruña) had already spent two and four years respectively, fishing in "El Cantil" grounds, with exceptional catch results. However the still deficient equipment of the productions units of Muxia represented for them a restrictive factor. They were not competitive enough to break through certain envoirnmental restrictions, such as bad weather, visibility, distance to the fishing grounds, etc.. As the new methods of sounding were able to orientate them in the surveying of the sea bed of "El Cantil" the overall effect of these restrictions was somewhat diminished. In fact in the summer of 1965, taking advantage of the good weather and visibility conditions, two vessels were able to break the 7-mile barrier, penetrating into this area, identified by its depth (300-400 fathoms) and the marked sinuosity of its underwater relief.

However access and regular permanence in "El Cantil" was still a long way off for the fishermen of Muxía. The unfavourable weather conditions (winds, fog, currents), the situation on a maritime traffic route, the presence of French boats fishing in the area, certain fluctuations in the resources, underdeveloped fishing techniques, etc, were the problems that the fishermen were faced with, some were problems of a physical nature and others were those induced by the effects of a socioeconomics setting in expansion, to which there was no immediate answer. Until 1968 the incursions into the new found area were only occasional and of a seasonal nature, alternating onshore winter fishing with summer fishing in "El Cantil".

The response to the overcoming of these limiting factors underwent a period of capitilization which made the acquisition of technology and improved vessel possible. The fishing ground wealth represented a guarantee which covered the risks of the heavy investments that were needed to orientate an onshore traditional type of fishing toward a more sophisticated type of fishing. In addition to this the decision making was tied up with expectations derived from future fishing. The capital which was invested was obtained principally from family savings, bank loans, and the easy-payment facilities which were offered by shops specialized in electronic aparatus and some boat builders.

It was not until the beginning of 1970 that the process of innovation became obvious, with the acquisition of more powerful boat engines and the incorporation of great depth. water sounding. From here on the growth of the fleet was set apart by newly built boats, a rapid increase in GRT and HP and by the adoption of more advanced technology (VHF, Gonio, winding engines).

The most significant innovation was the incorporation of the radar (1972) and the Decca system of navigation. These systems brought with it three major advances, it allowed safer navigation during bad visibility conditions. It allowed the situation of the boat to be known at all times, and last but not least it allowed the exact indication of the most productive fishing areas. This was probably the most advantageous and decisive tool which can be used as a response in order to justify, to a certain extent, a continual presence in the "El Cantil" fishing grounds since 1972.

The history of the technological development of the Muxía fleet is the response to a series of limitations which restricted the continual access to a fishing ground containing dense and relatively predictable resources. These were adaptable responses in that they met the needs of the fishermen advantageously at all times. The technology seems like a strategy which reveals the limitations and constrictions that affect the production processes. With innovation as a response, the units become more competitive not only in overcoming envoirnmental chance but also in order to be able to compete in better conditions than those of A Guarda and Fimisterre. It also represented an accelerated change with respect to the methods of production of the old system, coinciding with a period of industrial development in the state framework, where social and economic demands made traditional systems obsolete and unadaptable. The absence of new technology in this sense acts as a restricting function in the adaptation of the economic rationale. Its acquisition permits the possibility of greater control over the variations and fluctuations of the resources, entering into and fixing a stable method in an area which was previously prohibited and at the same time boasting the capacity of the production and becoming more competitive with respect to other producers.

## 5. "EL CANTIL" : THE RESOURCES, FISHING, AND THE VESSELS

"El Cantil" signifies for the fishermen of the village :

"a maior riquesa que podemos ter aquí en muitos anos,..., fui unha verdadeira mina de ouro " (The greatest source of wealth that we have had here in many years, a real goldmine").

From the early years until the beginning of the eighties a boat could fish in only one day more than 1.000 kilos of hake (in 1979 14,44 % of the hake unloaded in Galicia (17.325 metric tonnes.) was landed in Muxía : Varela de la Fuente, Manuel : 1985 :213.)). It also represented an area highly concentrated with a variety of resources. More than twenty species of commercial interest can be catalogued, although the fishing endeavour in the first years of its exploitation, concentrated mainly on the capture of hake (Merluccius merluccius), sea bream (Pagellus cenetrodontus), grouper (Serranus guaza), palometa (Brama raii) and red palometa (Beryx decadactylus). Hake and sea bream, species which give a high return, were always subject to the greatest control, in as far as one could predict with ease the seasonal variations in each.

All species are fished with long-lines, in two different ways : the deep sea method ; aimed at bethonic species, and with surface palangre, for the pelagic varieties. The differences between the two are in the amount of lead necessary to sink them to the desired depth.

The equipment involved requires substantial space to be thrown, as they can measure, in this case, up to to 6 km in length and contain 5000 hooks. They are easy to handle and can be stored in great numbers. Their construction and maintenance are simple and low in cost, given that only the line and hook are involved. This was an important factor when choosing this method in preference to that of the gill net (widely used in the 50s and 60s).

As this is an area with clearly defined "boundaries" (the sinuosity of the seabed being correlated with surface coordinates), it is simple for the fishermen to know where the fish are concentrated, "altos e caídas das montañas" (peaks and slopes of the mountains). Howeverm the physical characteristics of the area (size and shape) will determine the number of boats which can work there simultaneously.

Indeed, the fishermen themselves were aware of this fact, and taking into account the different methods involved, calculated that the fishing grounds could not deal with more than 18 or 20 units.

In 1960, the Cantil began to be worked by six boats from A Guarda. In 1962, 10 more arrived from Finisterre and from 1968 onwards, boats from Muxía gradually increased their presence, starting with 10 and reaching 27 by 1972. This high density of production units within a structurally limited area, which used, moreover, fishing equipment such as the palangres which require a lot of space, was the principal cause of the conflict which arose between the various parties involved.

To these variables were added others, of various kinds, which had an influence on the increase in tensions. The underwater currents (an ecological factor), gave rise to long-lines becoming tangled with others and thus affecting the relationship (social) between the fishermen, given that they had to decide who the fish in the tangled equipment belonged to (legal vacuum). This question was usually resolved by dividing the total catch into equal parts for all those involved ("ir a compañía"). However, deception and underhand tactics led to the frequent obstruction of this practice (nistrust as a psychological factor). The first one to raise his long-lines kept the whole catch ("roubaban" - they stole), which gave rise to conflict and menaces between the various producers. Nevertheless, this sort of incident tended to occur between producers of different communities. When the parties involved were from the same town, the former practice was normally respected (social cohesion factor).

## 6. ESTABLISHING THE PROBLEM ; EVENTUAL SOLUTION

The problems that the fishermen of Muxía had to overcome were not only related to the acquisition of the technology necessary to get to the fishing grounds. They also had to appropriate the Cantil to ensure their continued presence there and to consolidate a stable exploitation. The latter question is the central idea of this paper.

In such a competitive and conflictive situation, initially caused by the concentration of boats in a relatively small area, friction between the various producers was inevitable. It was a situation which caused a decrease in production to such

an extent that the survival of certain social groups was put at risk. New technology, despite providing better oportunities for the fishermen of Muxía, did not solve the main problem : to ensure the viability of potentially rich fishing grounds, when the latter was threatened by the presence of fishermen from other communities. All of the elementary rules which normally guide the fishing community were broken. Neither where the long-lines had been cast nor their order of casting was respected, generating a situation of anomie as far as production was concerned. With things in this state, Hardin appears to be correct when he states that fishermen behave like "anarchic villains". Not only do producers deplete the resources, they also hinder the activities of others. At this time, the Solomon-like formula of "ir a compañía" only worked between producers of the same town, thus reinforcing the links of identity between fishermen of the same community. This was the starting point for the fishermen of Muxía, who had the greatest number of boats, to begin to use force as a weapon of persuasion. Violence, as a real or ritualised phenomenon (simulations of boarding or chasing other vessels etc..) acted as a way to impose and maintain control over the area. Due to this type of action and the fact that the other communities were farther from the zone, fishermen from other towns (firstly those from A Garda in 1971 and boats from Finisterre a year later) began to abandon the Cantil.

Through a strategy of perimetric defence, where the boundaries of the territory were marked by the presence of boats from Muxía, boats from other communities were dissuaded from approaching the area. This social barrier towards fishermen of other communities had a function which was both dissuasory and distancing.

From this moment on, the systen of open access was converted into one of exploitation of common property (according to the distinction made by Berker and Farvar, 1989). This implied denying the same right to the fishermen of A Garda and Finisterre, as the group from Muxía, being all from the same community, retained exclusive access to the resources.

But the fundamental problem remained ; the high concentration of boats in a limited area. The Cantil fishing grounds can handle 18-20 production units ; in 1972, there were already 27. During this year and the following one, the level of internal competitiveness reached dangerous levels as far as social stability was concerned. The growth process reproduced the competitive scenarios of earlier times, except that now the economic and social differences between the various producers were emphasised. The most powerful boat reached the fishing grounds first and thus got to choose the best spot. The only team spirit involved now seemed to be the rivalry between the fastest boats. The result of all this was that the producers with the fastest boats got richer while the others got poorer, "porque si tí larjas en este mar e matas 10 caixas e eu unha... pois non podía ser. Entonses dábase, que o que tiña millores máquinas chejaba antes e tiña preferensia. E os outros a larjar por terra ou por fora. E entonses chejou a un serto extremo que xa non se dormía na cama" (Because if you fish here and bring in 10 boxes and I only bring in one... well, that's just not on. Anyway, what happened was that whoever had the best boats arrived first and had preference. And everyone else had to cast near land or further out to sea. And we ended up hardly ever going to bed.) The different boats found themselves in a constant race to see who could get to the fishing grounds first ; a vicious circle which only hurt the fishermen themselves. "... sobre as 7 da tarde cando chejábamos do mar, cambiámonos de calsetins e a bordo outra ves para salir ao mar e coller sitio... xa dormíamos no mar, e ao millor para non janar patacón por que viña aquel e ¡pelábache !" (At about 7 in the evening when we arrived home, we'd change our socks and go out to sea again to get and save a place... we were even sleeping at sea, because maybe then we'd wouldn't end up with nothing, 'cause the other guy'd come and take your catch off you). The incidents not only took place on a professional level but also between neighbours or relatives. In this way, tension at work (productive ones) were translated into social unease on land which had its effect on the community. Any conflict was emphasised by the problems which existed at sea. Therefore, not only social norms but also a sense of values was put at risk.

Faced with the need to restore not only social tradition but also that of production, the shipowners decided the create the basis for a system of equal production which would avoid conflict and make production profitable again without risking the livelihood of any of the parties involved.

In November 1973, A Compañía emerged as a way to "institutionalize" and manage efficiently the resources of and access to the Cantil. An informal set-up which, given the legal vacuum, enabled them to legitimize their exclusive rights of access to these communal-property resources where the exclusion of outsiders (the rest of the local communities) was achieved through use of a perimeter of cooperative defence. The acceptance of this right of communal-property on the part of the other fishing villages was clearly demonstrated in 1980 when certain boats from the nearby town of Camariñas wanted to fish in the waters of El Cantil. They based their claim on a rule which works in most Galician fishing communities (fundamentally for fishing grounds which are geographically stable) which states that the right to operate in a certain area depends upon the distance between it and the home port of the boats. The nearer your town was, the more rights you had.

The fact that the two towns were equidistant from the Cantil led to the community of Muxía (who had succeeded in appropriating the Cantil at a high cost) conceding in part the claim of the fishermen from Camariñas (traditional rivals). However, the concession was accompanied by the proviso that the others should use the long-line method exclusively and only after two o'clock in the afternoon.. "deixámoslos vir por non armar outro batifondo pero sempre baixo as nosas condisions, podían pescar pero despois de nos. Eles podían larjar po-la tarde ¡sempre e cando nos terminasemos ! e a sabendas que o millor lanse a larja é o de alborada" (We let them come to avoid any more quarrels, but on our terms. The could fish there, but only after us. They could cast their long-lines in the afternoon, providing that we'd finished ! and they knew that the best catch was to be made in the morning). This condition considerably limited the productive capacity of the boats from Camariñas. With winter coming on, the daylight hours were decreasing and long-lining was made increasingly difficult. This led to only a sporadic presence by the others and eventuall they give up coming altogether.

## 7. ORGANIZATIONAL BASIS OF A COMPAÑÍA : DESIGN

The name "A Compañía" has its origins in a traditional way of resolving ownership problems over resources brought in under certain conditions.

Both because of the way they distributed the production units in the fishing grounds and the method of organizing the extraction process and division of catch on an equal basis, this could be described as a cooperative system of production.

Within the Cantil, various sub-divisions of territory existed : Quiniela, Crimen, Navidades, and Papeles. The fishermen were aware of the approximate productivity levels of each of these due to their average daily catch. Consequently one of the shipowners (one of the most competent) organized once a week, on a drawing-lots basis, which area corresponded to which boat. In this way, they could fish in the most efficient manner and also lay their long-lines at the appropriate distances to avoid their getting tangled. Each crew knew in advance which area corresponded to their boat.

The second point controlled the amount of equipment permitted on each boat. All of then had to lay an equal number of long-lines, a number which increased progressively over the years.

The third point obliged all the crews to land their catch in their home port.

And finally, the income of the sale had to be distributed equally between all the shipowners so that he, in turn, could divide the profits according to the "a parte" system among the crew (half for the boat, half for the crew).

Nevertheless, there existed other inequalities which could act as destabilizing factors. The differences between the boats was reflected in their overheads (fuel costs, social security etc...) and if in some boats there was a larger crew, profits were made smaller both for the crew member and the owner. But these disadvantages were ostensibly overlooked, communal rights taking priority. Other costs were met "a Monte Mayor", that's to say from the total turnover of the whole fleet in that day.

The company came into being right from the start as the only way to peacefully exploit these limited resources that were subject to the law of diminishing returns. But it was not purely a method to make production more profitable ; it also served to alleviate tension within the community and between neighbouring towns. Moreover, it was a social solution arising from the whole community (family, neighbours etc...) and aimed at reestablishing the traditional social order. From this point of view, the appropriation of the fishing grounds by the producers of the same community demonstrates how social relationships can be the framework for those of production (productive relationships).

However, A Compañía's way of organizing production led to negative consequences which threatened its existence on at least two occasions (1974 and 1975) ; and for similar reasons on both occasions. The equal division of profits cuased some producers to become apathetic. In this sense irregularities arose in the work process. Some vessels used less long-lines than they were supposed to. Others did not put all the bait necessary on their hooks. Moreover, some producers used less efficient equipment and materials ; cheaper hooks and line. Some even skimped on the amount of lead they used to sink the long-lines. A group of supervisors (enjoying considerable social prestige) was formed to check on this sort of irregular activity. Economic defence, not so much of the area, but more of the way in which the production was organized, was therefore determined by the interaction and assumption of rules inherent in the extra-active activity itself.

Despite these irregularities, the criteria of A Compañía were consistently adhered to as long as the resources were abundant and predictable.

When the resources, because of their seasonal variability, decrease in quantity and become less predictable, above all the most profitable species (hake and sea bream), the exploitation method laid down by A Compañía is temporarily set aside.

The defendibiblity of the territory in these circumstances is not essential. Consequently the units involved change their territorial behaviour to a "non-territorial" one as a direct result of the seasonal alteration in the distribution of the resources. What happens is that the fishermen tend to disband and move into other fishing grounds (in El Cantil and further out to sea), increasing their working area and thus their possibilities of find a zone richer in resources. Each producer has a free choice of where he will cast his long-lines. Here, personal knowledge and experience appears as a function in the making of individual decisions. When a substantial find is made, A Compañía reorganizes its production process accordingly.

## 8. CONCLUSION

We have attempted to demonstrate that in a deficient economic environment where employment prospects are restricted, the appearance of a stable area, rich in resources, presents the members of a fishing community (during a time of low productivity of its traditional catches) with the conditions for its social reproduction.

We have seen also how the presence of "external" competitors, who endangered their stabilty, led them to protect their fishing grounds through the use of force, and how the appropriation does not become effective until a formula for the equal division of profits among the members of the community is discovered.

In this whole process, we have wished to underline how the rights to common-property resources, when the latter are abundant, predictable and in a stable area, are altered in favour of that competing group who have been able to create the conditions necessary for their appropriation.

## REFERENCES

**Breton Y.** (1987). The Common Property Theory and the social anthropology of fishing : the piftalls of problem formulation SSHRC Occasional Scholary Conference on Emerging Common Property Theory for Resource Management ; Brock University, St. Catherines.

**Dyson-Hudson R. and E.A. Smith** (1978). "Human Territoriality : A ecological rassesment". *American Anthropologist* **80** (1) : 21-41

**Furubotn E.H. and S. Pejovich** (1972). "Property rights and economy theory : A survey of recent literature". *Journal of Economic Literature* **10 :** 1137-1162.

**Godelier M.** (1968). "Territory and property in primitive society". *Social Science Information* **17** (3) : 399-426.

**Gordon H.S.** (1954). "The economic theory of common property resource : The fishery". *Journal of Political Economy* **62 :** 124-142.

**Hardin G.** (1968). "The tragedy of the commons". *Science* **162 :** 1243-1248.

**McCay B. and J.M. Acheson** (1987). *The question of the commons : The Culture and Ecology of Communal Resources.* Tucson, Arizona : Universety of Arizona Press.

**Pollnac B.R.** (1984). *"Investigating territorial Use Rights Among Fishermen".*Senri Ethnological Studie, **17 :** 1984

**Varela Lafuente M.M.** (1985). Procesos productivos en el sector pesquero de Galicia. Universidad de Santiago de Compostela.

# Impact of Product Mix on Optimal Fishing Quota

**Ingólfur Arnarson[a] and Páll Jensson[b]**

[a]Department of Agricultural and Resource Economics, Oregon State University, Corvallis, OR 97331, USA

[b]Faculty of Engineenring, University of Iceland, Hjardarhaga 4, 107 Reykjavik, Iceland

ABSTRACT

*In the management of many of the world's important fish resources, fisheries economic models are applied to help the authorities to find the most appropriate management method. Some of the management schemes are based on the allocation of an individual, annual fishing quota to every vessel participating in the fishery.*

*In these models of the optimal harvesting of a fishing fleet from a given fish stock, it has usually been assumed that the unit sales price of the fish caught is a given constant. Some studies have addressed the demand/supply characteristics, while other sources of price variability have not been dealt with.*

*In this paper, we focus on the impact of product mix decisions, made by the operators in the fisheries, on the sales prices and on the optimal, individual fishing quota allocated to each vessel. It is shown that an optimal fisheries management scheme should not be determined without considering the market prices and the production attributes of the fish products. Also, contrary to the fisheries economic models to now, it is not necessarily optimal to give as high quota as possible to each vessel, and thus to operate as few vessel as possible.*

## 1. INTRODUCTION

Since the middle of the seventies, most of coastal states of the world have extended their fisheries jurisdiction and nationalized their fishing grounds. Concern about the danger of over exploiting the fish resources has increased, so that now, few fisheries are expanding, and many are in fact in phase of declining.

Most of the fisheries nations have in the last years and decades been implementing, or at least discussing various methods (schemes) to regulate the fisheries. Although the objective may not always seem clear, in most cases it is a composition of stock conservation, economic resource utilization and social/regional political goals.

A convenient classification of these management schemes is given in Lawson 1984. One of the categories is the method of catch quotas, which can be divided into two main classes :

The "Olympic" System : A single overall quota, i.e. Total Allowable Catch (TAC) for the fishery, such that access is open to the fishery until TAC is reached.

The Individual Quota (IQ) System : The TAC is divided and allocated as annual catch quotas to the n vessels (or factories or groups).

In theory, if the fleet is homogenous, this means that IQ * n = TAC. The case of open access can be regarded as the special case of infinite TAC, and infinite IQs. Also, the IQs may be transferrable, in which case they are called ITQs.

The determination of TAC, i.e. how much to harvest from a fish stock annually, is often based on bio - economic models, which are the products of fisheries economics, a 20 - 30 years old discipline. These models have been used successfully to gain a deeper understanding of the dynamics of fisheries. For real life policy making and decision support, they have been criticized for being too simplistic (Helgason and Òlafsson 1988).

In these models, see for example Hannesson 1974, it has usually been assumed that the sales price of the fish, or rather of the fish products, is fixed. This implies that the revenue increases linearly with the allocated quota, up to the annual catch limit for the vessel, which in turn implies a "bang - bang" type of an economically optimal quota allocation : Either maximal annual quota, $IQ_{max}$, to a vessel, or zero. This is in accordance with the fact that no one seems to have questioned that, for a certain fishery with a given TAC, the number of vessels n should be as low as possible, if an economically optimal solution is to be reached.

In this paper, we will study the impact of product mix on these fundamental assumptions, and on the very important question of an optimal allocation of quotas. In section 2, we start with a harvesting model, which is as simple as possible to keep the presentation of our ideas clear. We define product mix in section 3 and add it to the model, which is then solved in section 4.Section 5 deals with the question of fleet size. In section 6, we present the results of simulation experiments to support our findings. In conclusion, the impact of our results is summarized.

## 2. A SIMPLE HARVESTING MODEL

We consider the annual, sustainable harvesting from a fish stock by a homogenous fleet, and introduce the following notation, in addition to the previously defined symbols :

n : Number of vessels

E : Total annual effort, for all vessels, for example time at sea catching

Y : Yield, or annual harvest, a function of E, Y(E)

P : Price of fish paid by the market

CE : Cost associated with each unit of effort (variable operating costs)

CV : Cost associated with each vessel (annual fixed operating costs)

e : Upper limit on annual effort per vessel, i.e. max time at sea per year for eachvessel given the annual catch $IQ_{max}$.

We assume the following, for clarity reasons :

- The fishermen are price takers, i.e. the quantity of fish products placed on the market by this fishery is too small to have any significant effect on the price
- A single species stock is considered
- The fleet is homogenous, i.e. all vessels are alike

- The cost of fishing is a linear function of E (variable operating costs per vessel) and n (annual fixed costs per vessel)

Then, the optimal effort is found by solving model (1) :

$$\text{Max } Z = P * Y(E) - CV * n - CE * E \quad (1.1)$$

$$e * n \geq E \quad (1.2)$$

$$IQ * n = Y(E) \quad (1.3)$$

$$E, n, IQ \geq 0 \quad (1.4)$$

Let us also define the average Catch Rate, CR (average yield per unit of effort) as

$$CR(E) = Y(E)/E$$

When solving this model, it becomes clear that n should always be as small as possible, and the individual quota IQ accordingly as large as possible, that is

$$n = E/e \text{ in } (1.2), \text{ and } IQ = IQ_{max}(E) = e * CR(E)$$

Keeping this triviality in mind, we get a well known solution to (1) :

$$P * Y'(E) = (CE + CV/e) \Rightarrow E1 \text{ and } Z1 \text{ (and } n1 \text{ and } IQ1)$$

see fig. 1, where the bioeconomic equilibrium at point *a* is also shown.

Let us assume as a hypothetical scenario that we have an open access fishery in state of equilibrium with $n_{eq} = E_{eq}/e$ vessels participating. A natural conclusion from model (1) would be to reduce the number of vessels to $n1 = E1/e$, with each vessel fishing $IQ1 = IQ_{max} = CR(E1)*e$ per year.

In fact, this scenario is by many experts believed to true for many fisheries of the world, and the conclusion drawn above is a commonly heard advice from fisheries economists and other experts. To take Iceland as an example, experts have stated that the fleet should be reduced by 30 - 40 %, see for example a collection of articles by number of experts, edited by Helgason and Jónsson 1990.

## 3. INTRODUCING THE PRODUCT MIX

Fish processing is a divergent production process, frequently resulting in a great number of alternative products from the same raw material. To take an example, a production manager may at any given time have the possibility to produce any of tens of different products from a load of cod.

These alternative products differ in prices and capacity requirements. Typically, there is a broad range between the most valuable product, which usually is the most labor intensive product, to the lowest priced but "fastest" product (Arnarson, Johnston 1990 and Johnston et al. 1990).

This is easier to understand by considering the processing stages in fish processing. To take the production of fillets as an example, the main stages are gutting, heading, filleting, skinning, trimming, packing and freezing. Many combinations of skipping some of these stages exist, leading to a variety of products. And by skipping processing stages like trimming, the production rate is greatly increased, usually at the cost of much lower price, depending on market segments preferences.

The product mix is well known and appreciated in fish processing, as the managers make use of it to absorb day to day randomness, at least to some degree. Fish is a highly perishable raw material, and at times of lively fishing, it is important to be able to speed up the processing by choosing "fast" products to save the raw material from spoiling.

Also, the product mix possibilities are used to adjust, in a more long term sense than day to day, the production process to a given capacity, and thus to balance the processing by variating the fishing operation. This applies in principle whether the processing is on shore or at sea. However, the impact of product mix can be seen more clearly in the case of processing at sea. Furthermore the factory trawler can be treadet as two companies or units where one operation is responsible for the production and the other for the fishing operation. That fact makes it easier apply the methods for mixed operation of shore based plants and factory trawlers later if it is feasible. Therefore, we will in the following restrict ourselves to discuss factory trawlers only.

In Jensson 1988, the product mix problem in fish processing is formulated as a linear programming problem, maximizing revenue with available raw material as one of the right hand sides (RHS). From the theory of linear programming, it is known that the revenue increases with a RHS in a concave, piece wise linear manner.

The operation of a factory trawler over a year can be regarded in a similar way (however more complicated, see Arnarson and Jensson 1991), with the allocated, individual quota as one of the RHS. In our case, it is therefore not unnatural to assume the general form in fig. 2 for the revenue R of a single vessel as a function of quota IQ.

Now, we have dropped the assumption of a single sales price P, and introduced a range of products and prices, such that

> $\mathbf{P_m}$ : Price for most valuable, and labor intensive, product. This would be the only product produced in case of a very small annual quota.
>
> $\mathbf{P_l}$ : Price for least valuable, but "fastest" product. This would be the only product produced in case of maximal possible quota $IQ_{max}$.

The revenue function R(IQ) increases first marginally by $P_m$ , but eventually the marginal increase becomes zero, when the vessel cannot catch the allocated quota anymore.

From fig 2, we can now deduct a general form for the average price AP and the marginal price MP at each quota level IQ, see figure 3.

Instead of our previous harvesting model (1), we now have model (2) :

$$\max Z = AP(IQ) * Y(E) - CV * n - CE * E \tag{2.1}$$

$$e * n \geq E \tag{2.2}$$

$$IQ * n = Y(E) \tag{2.3}$$

$$E, n, IQ \geq 0 \tag{2.4}$$

The only difference between (1) and (2) is that the price is no longer fixed, which is sufficient to cause the fact that n and IQ no longer have trivial solutions, as will be seen in the next section.

## 4. THE EXISTENCE OF AN OPTIMAL QUOTA

To solve model (2), we first eliminate n using (2.3), which gives

$$\max z = [\ AP(IQ) - CV/IQ\ ] * Y(E) - CE * EE,\ IQ \geq 0,\ IQ \Leftarrow IQ_{max}(E) = e*CR(E)$$

Let us either relax the upper limit on IQ or, which is more realistic, assume that IQmax is independent of E. Then we see that the model can be solved in two steps :

*Step 1 :* Determine $IQ = IQ_{opt}$ by maximizing the "net price"

$$\max NP(IQ) = [\ AP(IQ) - CV/IQ\ ]$$
$$0 \leq IQ \leq IQ_{max}$$

It is important to note that determining the optimal quota $IQ_{opt}$ is independent of determining the effort E and the harvest Y(E). Figure 4 shows how $IQ_{opt}$ is found.

The solution is derived from

$$IQ_{opt} = SQRT( CV/(-AP'(IQ_{opt} )) \Rightarrow IQ_{opt}$$

*Step 2 :* Determine the optimal effort E on basis of $IQ_{opt}$ and $NP(IQ_{opt})$

$$\max z = NP(IQ_{opt}) * Y(E) - CE * E$$
$$E \geq 0$$

resulting in the solution

$$NP(IQ_{opt}) * Y'(E) = CE \Rightarrow E_{opt}$$

To conclude this section, we notice that the question of how much quota should be allocated to each vessel can be separated from the determination of the rate of harvesting the fish stock, or in other words the determination of Total Allowable Catch TAC. Determining the size of the individual quota for each factory trawler is only dependent on the products (the market prices and the production attributes of the products) and the annual cost of operation the trawler CV.

## 5. THE FLEET SIZE

It can be shown that, under reasonable assumptions, when comparing the solutions to model (1) and model (2), the following is true :

$$n_{opt} > n1,\ IQ_{opt} < IQ1 = IQ_{max},\ E_{opt} > E1 \text{ and } Z_{opt} > Z1$$

So, taking the product mix into account, more vessels should be operated than concluded earlier from model (1), with less than maximal quota each, resulting in a higher rate of harvesting and returns.

Turning back to the scenario discussed at the end of section 2, it should now be clear that reducing the fleet to n1 is not an optimal solution. It may even not be any better than keeping the present number of vessels $N_{eq}$ unchanged, but imposing individual quotas of appropriate size.

Let us briefly study the impact of product mix on the fleet size, under the simplifying assumption that the effort E, and the total yield Y, is predetermined, i.e. a TAC = Y(E) is given.

By inserting IQ = TAC/n into model (2), we get model (3)

$$\max Z(n) = P(TAC/n) * TAC - CV * n \quad (3.1)$$

$$n \geq 0 \quad (3.2)$$

Figure. 5 shows the nature of the total revenue function for the fleet Z(n), and the cost function CV*n.

For a small fleet, not capable of fishing the TAC, the revenue first increases linearly by $P_1*IQ_{max}$, as all vessels have maximal quota and all the catches go to production of the "fastest" product, giving the sales price $P_1$. Increasing n to more than necessary to catch the TAC will give the vessels more time to produce more valuable products.

From fig. 5 we see how the error made by operating n1 vessels, compared to $n_{opt}$, depends on the difference between $P_m$ and $P_1$, as well as on the vessel cost CV.

## 6. RESULTS OF SIMULATIONS

The purpose with the models presented above was to demonstrate the impact of product mix on fisheries management in a simple and clear manner. They are of course much too simplistic to apply directly to any real life fishery.

To support the findings in this paper, a detailed simulation model of the operation of a factory trawler was built. The model and it's assumptions are presented in Arnarson and Jensson 1991. The model can be adjusted to practically any kind of factory trawlers and fisheries. In the following, we will see the results of model runs for the Icelandic factory trawlers fishing cod.

To summarize briefly the main assumptions for the simulation, the vessels are characterized by the following stereotype factory trawler :

| | |
|---|---|
| Fish Hold Capacity | 250 metric tons |
| Crew Size | 24 men (8 per shift in processing) |
| Max Trip Duration | 24 days (plus 3 for steaming and landing) |
| Fileting Capacity | 34 fish/minute |
| Freezing Capacity | 49 kg/minute |
| Catch Rate Distribution | LogNormal kg/hour |
| Mean Values (low - high) | 799 kg/h in dec. - 1385 kg/h in aug. |
| Trawling Time/Haul | 1 - 6 hours |

The products that can be produced by the trawler in these simulation experiments are :

| Product | Price (IKR/kg) | Labor req. (min/kg) | Raw mat. req. (kg fish/kg) |
|---|---|---|---|
| AM fillets (skinless, boneless) | 350 | 2.79 | 2.67 |
| RL fillets (skinless, with bones) | 213 | 2.56 | 2.26 |
| OSN fillets (with skin and bones) | 149 | 0.41 | 1.96 |
| HEI (H whole frozen fish) | 69 | 0.13 | 1 |

Also, mince blocks are produced as byproducts of the fillet products. Other assumptions can be found in Arnarson and Jensson 1991.

The model trawler was operated with different quota allocated. As would be expected, and as can be observed in reality, more of the "faster" products are produced as the quota increases, see figure 6.

The results shown in figure 6 witness that the decision behavior of the captain is realistic, which is of great importance for the interpretation of the simulated results.

Figure 7 shows how the revenue of the trawler increases with quota. This should be compared with the hypothesis in figure 2.

In the same way figure 8 shows the simulation results comparable with the postulated average and marginal price functions of quota in figure 3. And figure 9, where it is assumed that TAC is 300,000 metric tons of cod, and $IQ_{max}$ is 5,000 metric tons, is comparable to figure 5.

## 7. CONCLUSION

In this paper, we restricted our discussion to factory trawlers, where product mix decisions are made for the catch of each haul. In principle, our findings should apply as well to shore based processing buying the fish from fishing vessels. The main difference is that the product mix decisions are made for each trip, or each day. Also, the price differentiation between the products should then be reflected in the fish prices offered by the processing plants, which depends on factors as ownership, operations traditions and fish markets.

The product mix is one of the more important characteristics of fish processing management. Until now, it's impact has been overlooked in the literature of fisheries economics and management, although product mix is certainly not ignored by decision makers in the firms in their daily practice.

The main impact of product mix on quota allocation in fisheries management was shown to be the existence of an optimal individual catch quota, which is less than the maximally possible quota for each vessel. A consequence of this is that a fishing fleet should not necessarily consist of as few vessels as possible, as seems to have been believed, or at least implicitly assumed.

Although it is outside the scope of this paper, it should be mentioned here that other significant arguments point in the same direction regarding the fleet size of many fishing nations of theworld, opposing the commonly heard advice to reduce greatly the number of vessels. To list some :

(i) The sales value of existing fishing vessels on the world market is low (i.e. the cost coefficient CV, including the opportunity cost of a vessel, is low, which results in lower quotas and more vessels in the analysis in this paper).

(ii) Regional political problems, which are very common in fishing areas, usually become more difficult to solve when cutting down the fleet.

(iii) Year to year fluctuations in catches and markets, and the possibility of new fishing opportunities argue for a certain slack or even over capacity.

(iv) Fish finding often is more difficult when the vessels are fewer.

These arguments, and the product mix impact, have to be considered carefully before it is concluded that a "most economical" solution should be advocated and a fishing fleet should be reduced. However it may proven to be difficult in real fishery to realistically set optimal quota. As discussed above the optimal quota is depended on the product mix and therefore the market prices for the products. The factors influencing market prices are many and complex, such as currency rates (See Johnston et al 1990), and on the input factors complex ecosystems contribute to do the task lesser feasible. This is specially true in the fishery of North-, Atlantic and Pacific where the fishery is industrialised and competing on the world markets.

The simulation results in the last section support the hypothesis made in section 3 regarding the impact of product mix. For further evidence, an empirical study should be the next step. One of it's goal would be to analyse in depth the decision behaviour of the captains and the operators.

## REFERENCES

**Lawson R. M.** (1984). *" Economics of Fisheries Development "*, Praeger Publishers.

**Jensson P.** (1988). *" Daily Production Planning in Fish Processing Firms "*, European J. of Operations Research Vol. **35**, No. 3.

**Arnarson I. and P. Jensson** (1991). *" Simulation Model of Factory Trawler Operation"*, Working Paper, Agric.and Resource Economics, Oregon State University.

**Helgason Th. and O.D. Jonsson, editors** (1990). *" Hagsaeld i hufi "*, A collection of articles on fisheries management, University of Iceland (in Icelandic).

**Helgason Th. and S. Olafsson** (1988). *"An Icelandic Fisheries Model"*, European J. of Operation Research Vol. 33.

**Johnston et al.** (1990). *"The Role of Pacific Groundfish in International Groundfish Trade"*., Technical Report, Department of Agrcultural and Resource Economics, Oregon State University.

**Arnarson I. and Johnston R.S.** (1990). *"Modelling Groundfish Supply. A Linear Programming Approach with Application to Newfoundland"*. In William Schranck (ed). *" Econometric Modelling of the World Trade in Groundfish"*.

**Hannesson R.** (1974). *"Economics of Fisheries : Some Problems in Efficiency"*. Lund University.

FIGURE 1.
A SIMPLE SCHAEFFER MODEL BIOECONOMIC EQUILIBRIUM

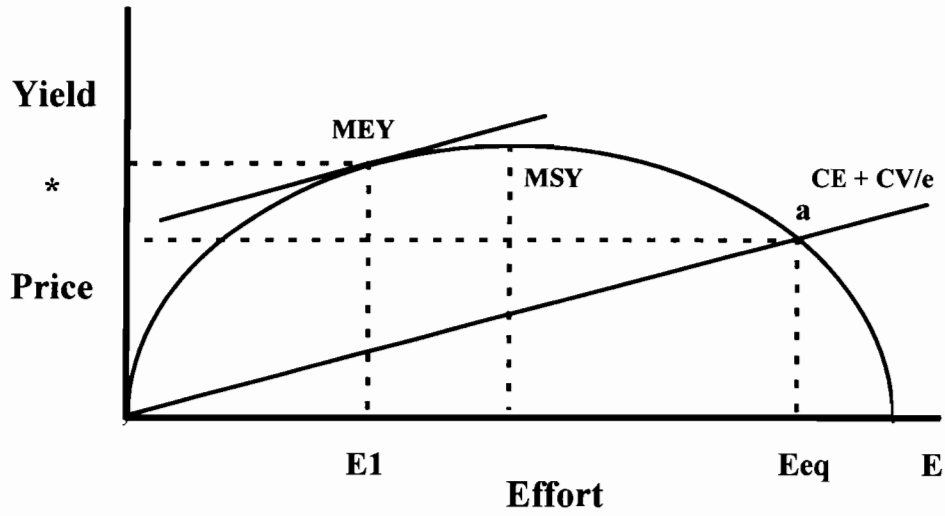



FIGURE 2.
TOTAL REVENUE, FACTORY TRAWLER

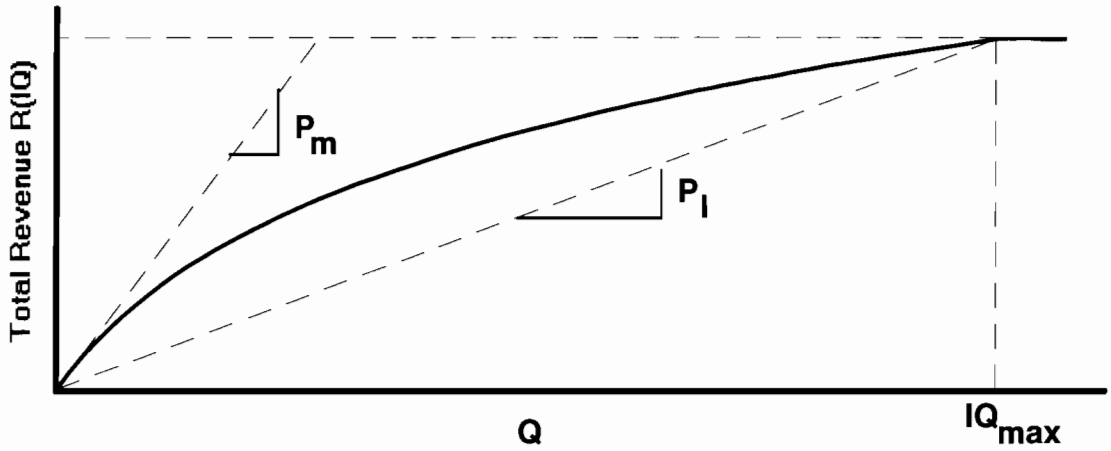


**FIGURE 3.**
**AVERAGE AND MARGINAL PRICE FACTORY TRAWLER**

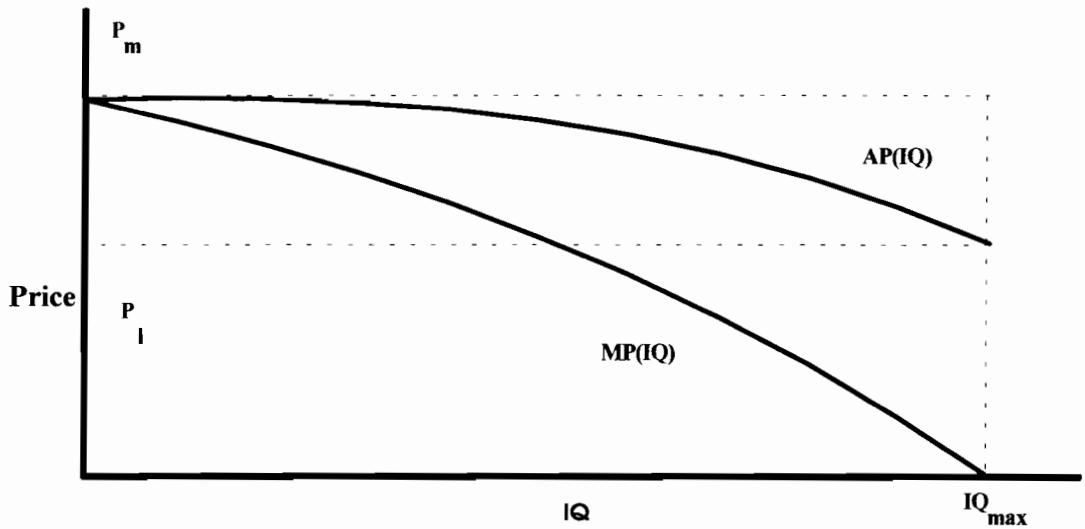



**FIGURE 4.**
**OPTIMA QUOTA FACTORY TRAWLER**

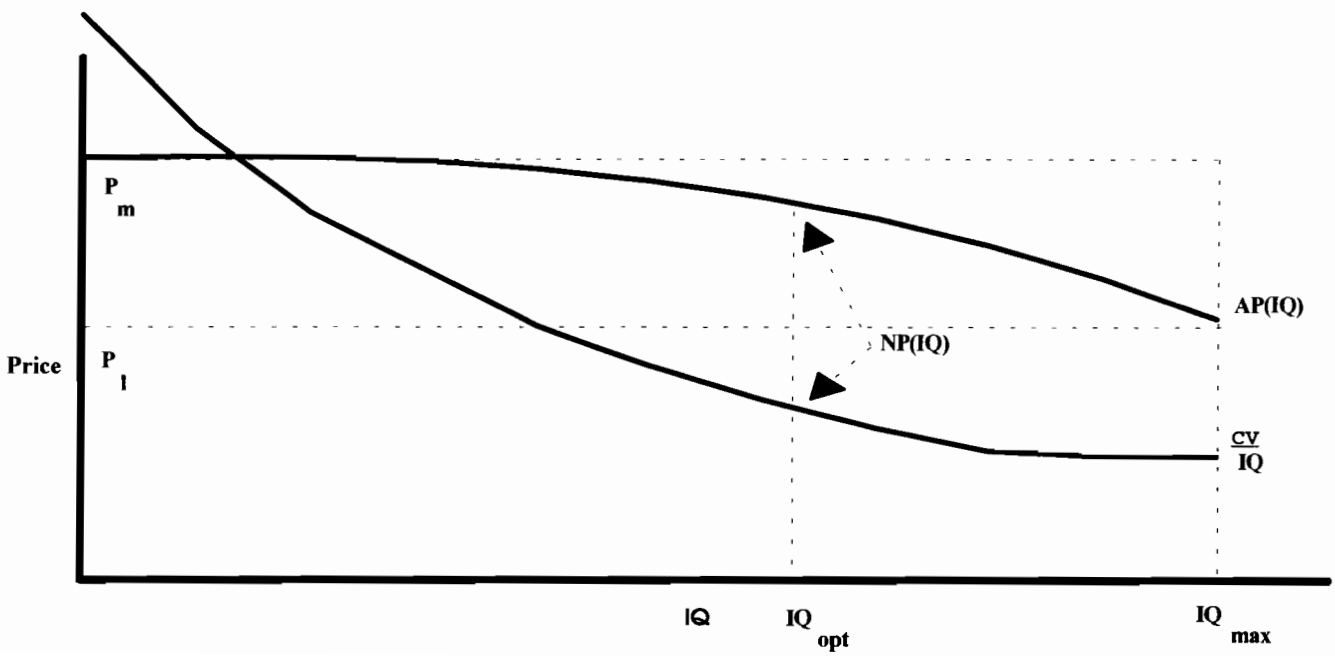


FIGURE 5.
TOTAL REVENUE FACTORY TRAWLER

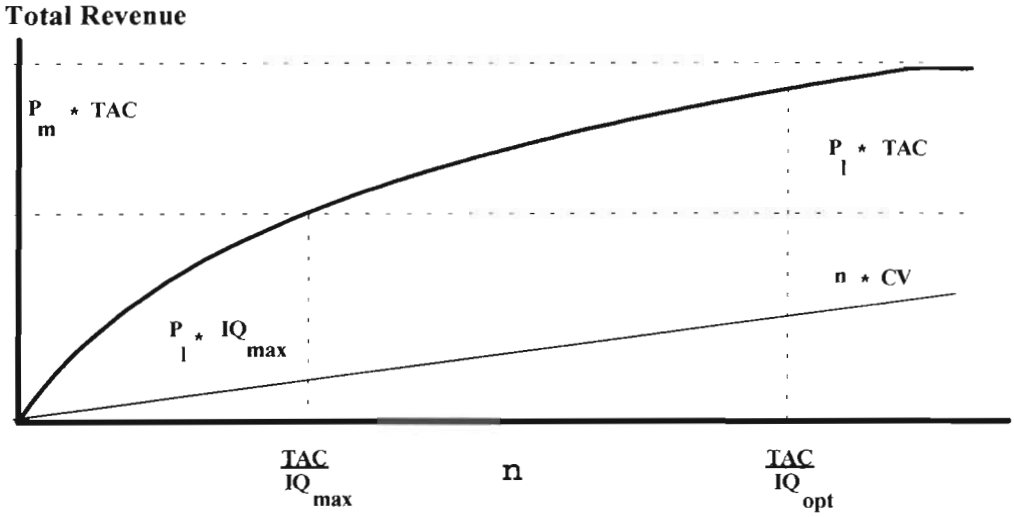



FIGURE 6.
DISTRIBUTION OF PRODUCT MIX AT DIFFERENT QUOTA LEVELS

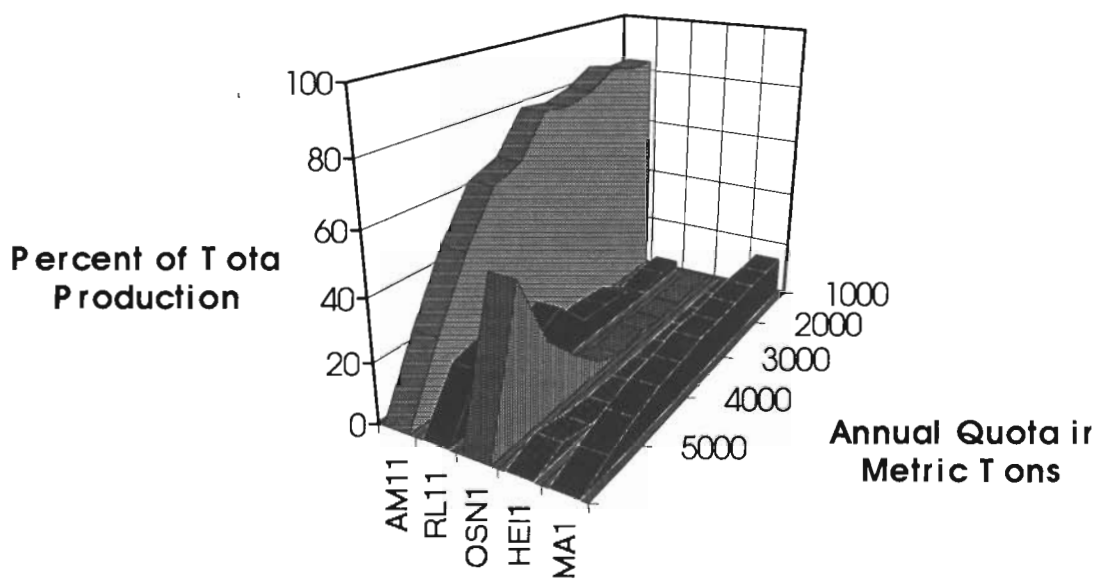


FIGURE 7.
TOTAL REVENUE FACTORY TRAWLER, SIMULATION

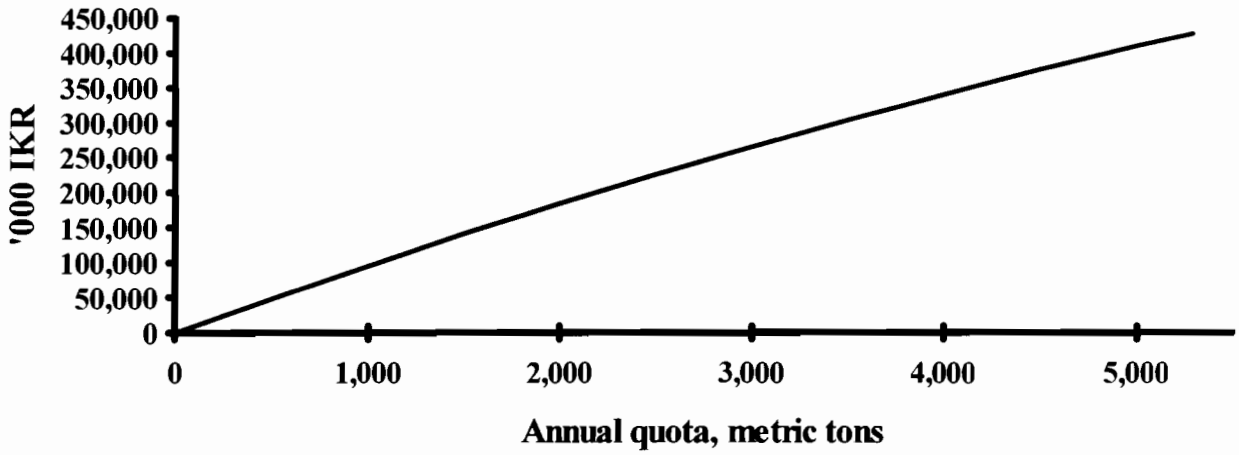



FIGURE 8.
FACTORY TRAWLER AVERAGE & MARGINAL REVENUE, SIMULATION

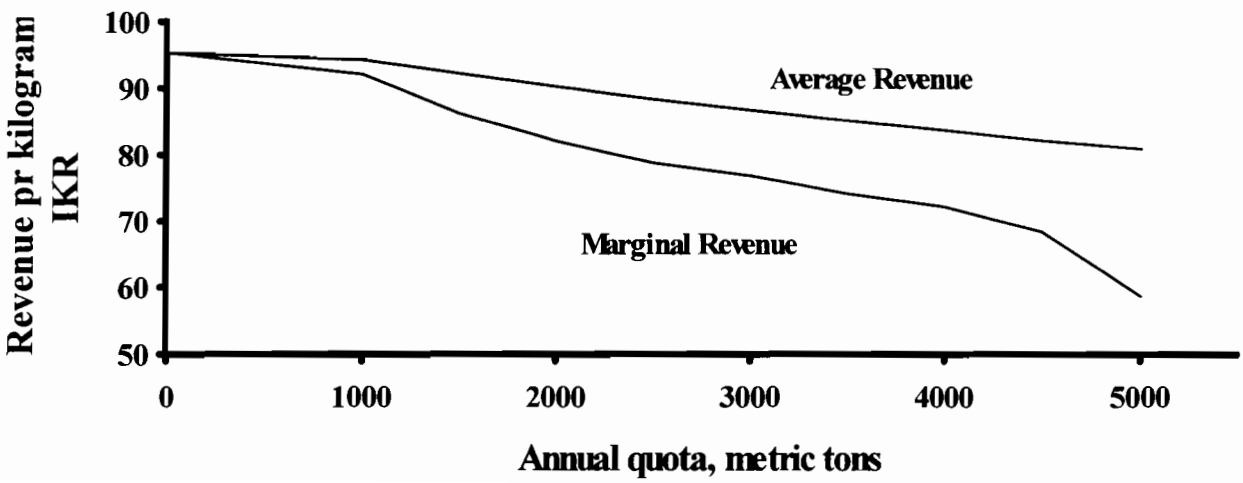
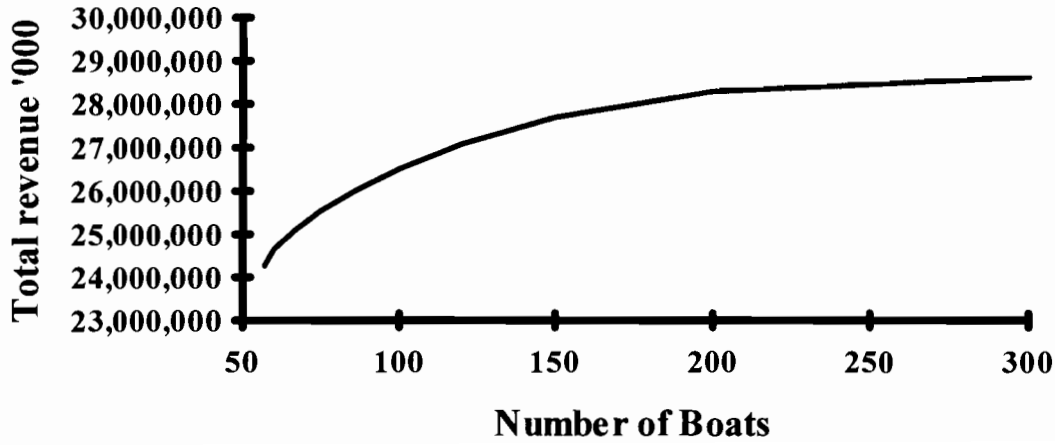


FIGURE 9.
TOTAL REVENUE FACTORY TRAWLER FLEET, SIMULATION



# Distribution and Processing by P. Guillotreau

Bien que dérivés de l'exploitation de ressources naturelles renouvelables, dont la spécificité requiert une réflexion économique originale, les secteurs de la transformation et de la distribution des produits de la mer s'apparentent davantage aux activités industrielles plus « classiques » par leur structure et leur mode de fonctionnement. A ce titre, leur analyse peut se concevoir à la lumière d'outils économiques développés notamment par le champ de *l'économie industrielle*. Ces outils s'inscrivent dans trois principaux courants théoriques. Le premier est issu de l'approche classique, avec le triptyque « Structures de marché-comportements-performances » initié par J. Bain en 1959, à la suite des travaux de Robinson et Chamberlain. Son application à l'industrie des pêches prise en tant que filière génère des problématiques relatives à la concurrence des marchés des produits de la mer, au changement technique et à ses effets, au comportement stratégique des acteurs et à la nature des relations clients-fournisseurs à tous les stades de la filière ou encore à la rentabilité des différents segments qui composent la filière. Le second courant théorique, issu de l'approche néo-classique, s'est développé autour de la théorie de la concurrence imparfaite et de la théorie des jeux. Son application aux industries connexes de la pêche permet d'aborder les questions relatives aux caractéristiques des produits (qualité, différenciation, compatibilité...), des entreprises (existence de réseaux, de coopération) et des marchés, afin de définir des modèles d'interactions entre entreprises du secteur. Enfin, le dernier courant théorique est issu de la théorie des organisations autour des travaux de Coase et Alchian et aborde les conditions d'organisation et de croissance des entreprises, la nature du capital et des comportements des partenaires de l'entreprise.

Outre cette dimension industrielle, la nette accélération des phénomènes concourant à la globalisation de la filière pêche lors de la décennie écoulée, milite en faveur d'une intégration plus systématique des théories de

Although deriving from the exploitation of renewable natural resources whose character requires a specific economic theory, sectors concerned with the processing and distribution of sea products are more closely connected to more "classic" industrial activities in their structure and their modes of operation. Therefore, they can be studied using the economic methods developed in the field of *industrial economics* in particular. These methods are related to three different theoretical approaches. The first one originates from the classical approach and the triptych "Structure-conduct-performance" introduced by J. Bain in 1959 following work by Robinson and Chamberlain. When applied to the fisheries industry as a chain of activities, it raises questions related to competition in sea product markets, technical change and its effects, the strategic behaviour of the actors involved and the nature of the relationships between buyers and suppliers at each stage of the chain and also to the profitability of the various activities along the chain. The second theoretical approach, originating from the neo-classical approach has developed from the theory of imperfect competition and games theory. Its application to fishery-related industries raises problems relative to the characteristics of the product (such as quality, differentiation, compatibility...), the business (existence of networks, of cooperation...) and the markets so as to define interaction models between the businesses in the sector. And finally, the last theoretical approach originates from the organisation theory of Coase and Alchian and deals with the conditions related to the organisation and the growth of businesses, the nature of capital and the behaviour of those involved in the business.

Besides the industrial dimension, the clear acceleration of events responsible for fishery globalisation in the last ten years speak in favour of a more systematic approach to the *theories of international economics*. Some of these events are the development of international trade in sea

*l'économie internationale.* Parmi ces phénomènes, on peut noter le développement du commerce international de produits de la mer, la multiplication des investissements internationaux dans les industries de la pêche et de la transformation ou encore les accords internationaux réglementant l'accès aux zones de pêche et aux marchés. Les questions soulevées se réfèrent alors aux opportunités et aux enjeux liés à l'internationalisation des échanges de produits de la mer, à l'analyse des investissements internationaux au sein de la filière pêche et des industries dérivées et aux effets des politiques commerciales sur leur développement.

Enfin, *l'exploitation d'une ressource naturelle renouvelable* confère à la filière un caractère singulier qui impose la prise en compte du caractère aléatoire de l'offre et des impératifs de gestion des stocks naturels, afin de pérenniser les activités économiques qui en dépendent. Ainsi d'un point de vue économique, de fortes contraintes d'approvisionnement en aval de la pêche jointes à des micro-marchés très interdépendants pèsent à la fois sur l'ajustement des capacités de production et leurs conditions d'utilisation, et par effet direct sur la satisfaction d'une demande finale croissante des consommateurs.

La conjugaison de ces trois champs d'analyse provoque l'émergence de nouvelles problématiques se rapportant à l'interprétation des faits économiques observés dans le secteur de la pêche et de ses industries connexes. A titre d'exemple, la question de la formation des prix à différents stades de la filière ou l'analyse de la concurrence entre produits carnés et produits de la mer sur les marchés de consommation relèvent de cette combinaison d'approches théoriques. De même, la réflexion menée sur le thème du commerce international de produits de la mer au regard des structures de marché imparfaites qui prévalent actuellement dans la plupart des pays peut s'enrichir de la fertilisation croisée des concepts développés en économie industrielle et économie internationale depuis plus d'une dizaine d'année.

La référence simultanée à ces trois domaines importants de la pensée économique ouvre de larges perspectives pour l'analyste soucieux de mieux comprendre les phénomènes économiques inhérents à l'exploitation, la transformation et la commercialisation des produits halieutiques. La session présentée ici illustre cette filiation commune des problématiques, même s'il est frappant de constater la diversité des thèmes et des approches retenus par les auteurs. De façon synthétique, trois thèmes émergent de l'ensemble des contributions. L'analyse de la contrainte d'approvisionnement du secteur de la transformation des produits de la mer est abordée par J.M. Young & J.F. Muir dans le cas du Royaume-Uni,

products, the multiplication of international investment in fishing and processing industries and also international agreements regulating access to fishing areas and markets. The questions raised relate to the opportunities and threats of the globalisation of trade in sea products, to the analysis of international investments within fishing and secondary industries and to the effect of trade policies on their development.

Finally, the *exploitation of a renewable natural resource* gives the chain a particular character wherein the random feature of supply and the need to manage natural stocks must be taken into account so as to ensure the sustainability of dependent economic activities. So, from an economic point of view, the important supply constraints downstream from the fishery together with strongly interdependent micro-markets weigh heavily on both the adjustment of productive capacities and their conditions of use and directly on the satisfaction of the growing final consumer demand.

From the combination of these three fields of analysis new problems emerge concerning the interpretation of economic facts observed in the fishing sector and its related industries. For instance, the problem of price formation at different stages along the chain or the analysis of the competition between meat and sea products on consumer markets is related to this combination of theoretical approaches. In the same way, all work on international trade in sea products in the context of imperfect market structures presently prevalent in most countries could benefit from mixing concepts which have been developed in industrial and international economics over the last ten years or so.

Reffering simultaneously to these three important fields in economic thought opens promising prospects for the analyst who wishes to improve his understanding of the economic phenomena inherent in exploitation, processing and marketing of fisheries products. This session illustrates the common ground underlying the problems even though the themes and the approaches of the different authors vary a great deal. In summary, three main themes emerge from the contributions. Analysis of the supply constraint to sea product processing sector is presented by J.A. Young & J.F. Muir in the case of the United Kingdom and M. Deme & M. Bakhayokho in the case of Senegal. The second theme, the problem of substitutability of sea products for other products on the final goods market is the subject of two papers by T. Naito & al. and by T. Vukina & J.L. Anderson. The final theme concerns the study of the causes and effects of imperfect market structures with contributions by L. Temri and S. Cruz.

In the first theme, J.A. Young and J.F. Muir develop their analysis of the processing sector with respect to the

M. Deme & M. Bakhayokho dans le cas du Sénégal. Le second thème, la question de la substituabilité des produits de la mer vis-à-vis d'autres produits sur les marchés de biens finals fait l'objet de deux contributions par T. Naito et al. et par T. Vukina & J.L. Anderson. Enfin, le dernier thème concerne les études des causes et des effets des structures de marchés imparfaits avec les apports de L. Temri et S. Cruz.

Dans le premier thème, J.A. Young et J.F. Muir développent leur analyse du secteur de la transformation au regard des différents événements institutionnels passés qui ont affecté le niveau des apports nationaux sur le marché britannique : accession du Royaume-Uni au Marché Commun en 1973, extension des Zones Economiques Exclusives en 1977, instauration de la Politique Commune des Pêches en 1983 ... Les auteurs confrontent la chute des débarquements territoriaux avec l'évolution des structures du secteur de la transformation et celle de la consommation de produits de la mer. Ils en tirent des conclusions sur le manque de perspectives de développement et la fragilité du secteur de la transformation au Royaume-Uni. M. Deme et M. Bakhayokho examinent quant à eux les potentialités d'approvisionnement de l'industrie sénégalaise grâce aux apports de la pêche artisanale. Ils en estiment les effets sur la stratégie des entreprises locales, notamment à l'exportation et soulignent les mesures institutionnelles qui encadrent l'ensemble de la filière. Les recommandations des auteurs vont dans le sens d'une nécessaire redistribution des subventions publiques sur l'ensemble de la filière afin de privilégier la commercialisation locale des produits.

Pour le second thème, les méthodes et les applications illustrées par les deux communications sont encore une fois très différentes. T. Naito, R.S. Johnston et A.L. Shriver traitent de la substituabilité des produits de la mer et des produits carnés (volailles et autres viandes) à travers deux modes de commercialisation distincts : la restauration et la grande distribution. Le modèle théorique vise à comparer les effets des prix relatifs et du différentiel de qualité de ces produits sur le comportement des consommateurs finals. Les auteurs souhaitent tester empiriquement leur modèle afin d'identifier les facteurs qui affectent la consommation des produits de la mer au regard de différents circuits de distribution. Dans un autre registre, T. Vukina et J.L. Anderson analysent la nature des liens existant entre les marchés de la farine de poisson et du soja, où est présent le même acheteur : l'industrie de l'alimentation animale. Le but de leur modèle, basé sur des séries temporelles, est d'établir des prévisions de prix sur ces marchés afin d'orienter la stratégie des entreprises de production de farine de poisson, compte tenu de la substituabilité de ces produits vis-à-vis des autres aliments protéiniques pour animaux.

different institutional events that have affected the level of national supply on the Bristish market: accession of the UK to the common market in 1973, extension of the EEZ in 1977, setting up of the Common Fisheries Policy in 1983... The authors compare the fall in territorial landings with the evolution of the structures in the processing sector and consumption of sea products. Conclusions are drawn about the lack of prospects for development and the weakness of the processing sector in the U.K. M. Deme and M. Bakhayokho examine the possibilities of supplying the Senegalese industry from artisanal fishery catches. They assess the effects on local business strategy in particular on the export side and underline the institutional framework within which the chain operates. The authors recommend a redistribution of government subsidies to the whole of the chain so as to develop local marketing of products.

In the second theme, the methods and the applications illustrated by the two papers are once again very different. T. Naito, R.S. Johnston and A.L. Shriver deal with the substitutability of sea and meat products (poultry and other meat) through two different modes of marketing: catering and wholesaling. The theoretical model aims at comparing the effects of relative prices and differential quality of these products on consumer behaviour. The authors wish to test their model empirically so as to identify factors affecting sea product consumption with regard to different distribution circuits. For their part, T. Vukina and J.L. Anderson examine the nature of the links between the markets concerned with fish and soya meal where the same buyer is present: the animal food supply industry. Their model, based on time series aim to establish price forecasts on these markets so as to guide the production strategy of fish meal businesses, taking into account that these products can be substituted by other proteinic animal foods. The results obtained tend to validate the use of such dynamic models where forecasting can help processors adjust their strategy according to expected prices.

The last group of papers is probably the most heterogeneous as the authors consider both the effects and the causes of imperfect competition on the sea product market. L. Temri deals with the relationship between innovation and technical change in sea product processing industries, a subject that has so far been little dealt with by fisheries economists. In particular, the authors considers the possibilities of improvement in the French processing industry – in terms of productivity gains or increased flexibility..., possibilities linked to the integration of new methods in the production process. Empirical results seem to show that these methods are underused compared to other economic sectors. In a conceptual then empirical fashion, S. Cruz studies the monopolistic

Les résultats obtenus tendraient à valider le recours à ces modèles dynamiques dont la capacité prédictive peut permettre aux transformateurs d'ajuster leurs stratégies en fonction des anticipations de prix relatifs.

Le dernier groupe de contributions est peut-être le plus hétérogène dans le mesure où les auteurs traitent à la fois des causes et des effets de la concurrence imparfaite sur le marché des produits de la mer. L. Temri aborde un aspect jusqu'ici peu exploré par les économistes des pêches c'est-à-dire les enjeux de l'innovation et du changement technique dans les industries de transformation des produits de la mer. L'auteur s'interroge notamment sur les potentialités d'amélioration de l'industrie française de transformation – en terme de gains de productivité ou de flexibilité accrue ... –, liées à l'intégration de procédés nouveaux dans le processus de production. Les résultats empiriques sembleraient témoigner d'une sous-utilisation de ces procédés comparativement à d'autres secteurs économiques. S. Cruz examine, sous un angle plus conceptuel d'abord et plus empirique ensuite, le pouvoir monopolistique de certaines entreprises portugaises, impliquées tant dans la production que dans le négoce ou la transformation et qui seraient à l'origine d'une croissance des prix à la consommation plus rapide que celle des prix à la production. Les deux contributions de cet auteur soulèvent notamment la question du rapport existant entre des structures de marché imparfaites et la nature du commerce international de produits de la mer à partir de l'exemple de l'industrie portugaise. Selon l'auteur, le pouvoir oligopsonique de quelques compagnies constituerait une entorse aux articles 85 et 86 du Traité de Rome relatifs au respect de la concurrence et pénaliserait les acteurs économiques de moindre poids. De ce constat, l'auteur tire quelques recommandations sur les choix de politiques économiques à adopter afin de réduire le différentiel de prix entre la production et la commercialisation de produits halieutiques.

L'analyse dynamique de la concurrence telle que l'a synthétisée M. Porter semble être un des vecteurs communs aux travaux présentés à l'occasion de cette session. Si les relations entre clients et fournisseurs ainsi que l'analyse de la substituabilité des produits ont été abordées et méritent une exploration plus systématique, quelques perspectives de recherche se dégagent dans le champ de l'économie des organisations, encore peu considéré dans le cas du secteur des pêches. Ainsi, le rôle croissant des pouvoirs publics – qui agissent à la fois comme acteurs et comme élément structurant du système – affecte le comportement de l'ensemble des acteurs et mérite à ce titre qu'on lui accorde une part plus importante des efforts de formalisation. Il apparaît également que, depuis environ une décennie, les secteurs de la

power of some Portuguese businesses dealing with production as well as trade and processing which are the cause of a faster increase in retail prices than in dockside prices. This author's two contributions raise more specially the issue concerned with the relationship between imperfect market structures and the nature of international trade in sea products taking the Portuguese industry as an example. According to the author, the oligopsonistic power of some companies is an infringement of articles 85 and 86 of the Treaty of Rome concerned with ensuring competition and penalizes lesser economic actors. From this statement, the author drawn some recommendations about the choices of economic policies to be adopted so as to reduce the difference in prices between production and marketing of fishery products.

The dynamic study of competition as synthesised by M. Porter appears to be one common element in all work presented during this session. If relationships between buyers and suppliers as well as the analysis of product substitutability have been examined and deserve a more systematic approach, research projects have emerged in the economics of organisation so far seldom applied in the case of the fishery sector. In the same way, the growing role of government – acting both as a player and a structural element in the system – affects the behaviour of all the actors and so deserves a more important role in the rorizing. It also appears that for about the last decade processing and distribution sectors have built increasingly closer ties with the companies responsible for funding, research and development, and marketing. The orizing about competitiveness in "non cost items› and taking into account intangible investments in the analysis of actors downstream from the fishery chain are hence justified. In the same way, the strong interdependencies between actors in the system on a world scale, induced in particular by the weight of supply constraints, highlight a field of study to be examined with questions about capital movements or technology transfer between countries.

The contributions in this session are therefore an encouraging step towards better economic understanding of the complex working of the fishery-related industries.

transformation et de la distribution tissent des liens de plus en plus étroits avec des sociétés de service assurant des fonctions de financement, recherche-développement ou marketing. La réflexion en terme de compétitivité dans le domaine du « hors-coût » comme la prise en compte de l'investissement immatériel dans l'analyse des acteurs en aval de la filière pêche trouvent ainsi leur justification. De même, les fortes interdépendances entre les acteurs du système à l'échelle mondiale induites notamment par le poids des contraintes d'approvisionnement éclairent un champ d'analyse à prospecter, avec des questions portant sur les mouvements de capitaux ou les transferts de technologie entre pays.

Les contributions de la présente session constituent donc un pas encourageant vers une meilleure compréhension économique du fonctionnement complexe des industries dérivées de la pêche.

# UK Fish Processing Industry Strategies: From the CFP Decade to the Single Market

**James A. Young[a] and James F. Muir[b]**

[a]Department of Marketing, University of Stirling, Stirling, FK9 4LA, Scotland

[b]Institute of Aquaculture, University of Stirling, Stirling, FK9 4LA, Scotland

ABSTRACT

*Within the EC there is growing concern at the increasing trade deficit in fish products. Apart from the trade balance issue, this deficiency is also significant because it implies some failure of the fish processing industry to adopt strategies generating additional benefits from fishing. As a major producer within the EC, the case of the UK is presented. The paper provides a contemporary analysis of the UK fish processing sector, primarily from a marketing perspective.*

*The paper begins with a retrospective analysis of the changes, and their significance, in the UK fish marketing environment. It is argued that many of the contemporary problems experienced within the processing sector are attributable to the failure of the EC Common Fisheries Policy (CFP). The supply side difficulties thereby engendered have resulted in decline and have precluded possible expansion of the sector at a time when the market for fish has become more buoyant.*

*Whilst past commentary on the CFP's failure has been focussed primarily upon the catching sector, comparatively little attention has been given to the onshore sector. This analysis thus incorporates some of the findings of a more recent investigation of the UK onshore sector which reveals the more widespread impact of the CFP's failure.*

*However, it is argued that decline is not attributable solely to the CFP; other policy measures too have been ineffective in surmounting processors' problems and, in some cases, have made the current situation worse. The paper latterly appraises the strategic implications for the UK industry in the future marketing environment of the single market.*

*The paper concludes that if the UK fish industry is to enjoy the opportunities of the single market there is a need for fundamental policy review. In particular it is argued that future fisheries policy should take more explicit account of the interdependence of the industry's sectors and particularly that of the onshore sector. Such an approach should go some way towards improving future EC fish trade deficits and increase the socio-economic benefits derived from the fish industry.*

## 1. INTRODUCTION

The aim of this paper is to present a contemporary analysis of the UK fish processing industry, primarily from a marketing perspective. The UK has been chosen as reflecting present events in the fish industry in many other EC member states. As elsewhere, the UK processing sector is currently beset by a number of critical factors which pose a significant threat to its future. Resolution of these issues will be essential if the industry is to profit from changes in the market for fish.

Somewhat ironically, these difficulties have come at the very time of increasing opportunities for the industry, due to a resurgence in demand for fish and the impending formation of the single market under the terms of the 1987 Single European Act (SEA). Put simply the industry continues to suffer from the effects of a level of fishing effort in excess of available resources. Although this has been widely accepted by the industry and related organisations for many years, the regulatory instruments imposed under the Common Fisheries Policy (CFP) are unanimously acknowledeged to have failed in their objectives of alleviating the situation (Cunningham & Young, 1983; Toerring, 1991).

We begin by presenting an assessment of the contemporary evolution of the industry, its supplies and the market for fish. After an overview of the processing sector's key characteristics, we next consider the impact of the various changes described. The analysis concludes with comments on the likely future responses of the processing sector, and the implications for the sector and for the fishing industry as a whole. Data is drawn from a series of face-to-face and postal interviews conducted with a representative sample of processing firms over the past year.

## 2. THE UK FISH INDUSTRY

The roots of the contemporary difficulties within the UK processing industry are complex but may be traced to events prior to the 1983 agreement of the CFP. In particular, the historical dependence of the UK industry upon distant water fisheries was severely curtailed by the Cod Wars with Iceland, and the 1977 international adoption of 200 mile EEZ's. Although the extension of EEZ's might have increased indigenous fishing opportunities, this did not materialise, because of the UK's earlier membership of the Common Market in 1973. In spite of accounting for around two-thirds of the EC sea area at the time, fishing opportunities were pooled along with the eight other member states. Under the subsequent 1983 agreement, a Total Allowable Catch (TAC) quota allocation system was formalised giving the UK 35.8 % of the seven major species. This agreement was intended to run for 20 years, subject to the mid-term review of 1992. Notwithstanding the outcome of the review, the combination of events has had a marked impact upon the UK industry.

## 3. TRENDS IN UK INDIGENOUS FISH SUPPLIES

The data on indigenous fish supplies shown in Figure 1 provide a starting point in identifying the significance of these changes. This shows a decline in the quantity of fish landed by British vessels; a fall of more than 40% in UK fish landings by volume between 1973 and 1990. In recent years supplies have also become more volatile; the 1991 figure, 0.59m tonnes, represents a decline of more than 25% over only four years.

The new regime of the fisheries sector is reflected not only in terms of reduced indigenous fish supplies, but also in the sub-national share of landings. As shown in Figure 2, Scotland's share of UK fish landings has risen dramatically to around 75%, whilst that of England and Wales, especially in the former distant water ports, has fallen in both absolute and relative terms.

The implications of these changes for the processing sector are considerable, given its development and its traditional reliance upon local supplies. As a raw material, fish is highly perishable and commonly yields less than 50 % finished product. These factors, *inter alia,* have favoured a raw-material-orientated (ie fishing port) location for the industry. Changes in quantity and location of fish available have been further compounded by the changing composition of

supplies, as shown in Figure 3. Cod and haddock, the most favourably received by the UK market, have experienced the greatest shortfall, and since 1987 the situation has worsened progressively, despite a slight increase in the 1992 North Sea haddock quota. Thus in 1990 TAC's for cod and haddock were reduced by 17% and 33% respectively.

To some extent the long-term decline in landings has been offset by an increase in quantity of pelagic species, notably mackerel and herring, although these too have witnessed periodic supply shortfalls. Pelagic species are in any event less preferred by UK consumers and they command a lower market price. Whilst in recent years, the domestic pelagic market has been usefully countered by large volume exports to the former Eastern bloc, the political and economic reforms therein have cast considerable doubt on future trade opportunities.

Some respite to indigenous supply deficiencies might be noted from aquaculture sources; from trout, shellfish, and in particular from the dramatic expansion in farmed salmon production. Over the last two decades this last sector has reached an output estimated to be worth more than £140 million. From 10,000t in 1980, 31,000t were produced in 1989, and 32,350t in 1990. This compares with salmon fishery landings of some 400-500t. There is evidence of substantial change in processing and distribution in servicing this sector, with both traditional and more recent industry participants (EAFE, 1990) However the growth of the sector is constrained by production cost, by site availability and by market development, and current assessments forecast modest growth or even contraction, in both the trout and salmon sector. While diversification into alternative higher value species is actively being pursued, technical difficulties continue to exert a substantial constraint. Even given favourable conditions, it would clearly take significant time before anything approaching the range and volume of the capture fisheries could conceivably be substituted. In the short run it is therefore likely that attempts to remedy the increasing deficiency in those indigenous supplies preferred by the UK market will continue to depend upon the international market.

## 4. TRENDS IN UK TRADE IN FISH

For the purposes of this paper, UK trade in fish is confined to volume data; the value of trade generally reflects similar trends, albeit more complex due to exchange rate fluctuations. Imports have increasingly been used to satisfy rising demand and by 1990 these accounted for over 50% of supplies for human consumption. The overall growth in the quantity of fish imported is shown in Table 1.

Given the variations in supply elsewhere, and relative currency movements, this general trend of increased imports contains significant counter-trends. For example, whereas imports of fish to the UK increased by 14% between 1988 and 1989, they fell back 4.5% by 1991. The most recent data for the first quarter of 1992 shows an increase of 7.1% over the corresponding period in 1991 (SFIA, 1992). Despite such temporal variations, in the absence of more stable indigenous supplies, the UK processing sector is more dependent than ever upon the international market and its attendant exchange rate movements.

Closer examination of the data also shows that imports have increasingly been in the form of processed product rather than raw material. This precludes to the UK fish industry the opportunity to add value and to enjoy associated benefits of income and employment multipliers. This is especially significant in view of the high dependence upon the fisheries sector in certain regions. Furthermore the benefits foregone have largely been to non-EC countries; Figure 4 shows these to have been the major source of the increased quantity of imports.

Although imports from other member states have remained relatively constant at levels around 100,000t - 150,000t, the EC has become increasingly important for UK exports. Over the 1980's, their volume has increased by 87%, with France being the principal recipient; aquaculture, particularly that of salmon, is a contributor to this trend. Indeed since 1986 the UK has moved to a position of a small trade surplus in fish with other EC members.

However, from 1983 this internal surplus has been more than offset by a widening trade deficit with non-EC countries. For example, in the late 1980's over 70% of cod and over 80% of haddock came from non-EC sources. Comparison of the overall UK trade balance with those of other EC states is complicated by the vagaries of compiled data. However, data does suggest that only Denmark, Ireland, and in most years the Netherlands, have positive trade balances in fish, whilst the UK's deficit is only regularly exceeded by that of Germany (Eurostat, 1991). Having thus determined something of the UK's international market, we now consider the domestic market.

## 5. TRENDS IN THE UK MARKET FOR FISH

Estimates of the UK market for fish in 1990 range between £1,600M (Leatherhead Food RA, 1991) and £2,260M (Marketing Strategies for Industry, 1992). The market is split fairly evenly between consumption in the home and that in various catering market segments. Table 2 below illustrates the trend in household consumption in terms of the total quantity consumed and the share of household food expenditure spent on fish.

The data show that since the mid-1970's, household consumption of fish has generally increased; by the end of the 1980's almost 16% more than in 1975. More significantly, fish consumption has shown a consistent improvement in terms of the share of household expenditure on all foods; in 1989 and 1990 fish accounted for 5.5%, compared to only 4.5% in 1980. Compared with 1960 and 1955, when fish accounted for only 4.4% and 3.7% respectively, it would appear to confirm that consumers now place a higher value on fish as a foodstuff.

This is also reflected in relative price movements. Since the mid-1980's, fish prices have increased at a rate in excess of other foods, yet volume consumption has remained surprisingly strong. This may be partly attributable to favourable exogenous influences on the fish consumer, and increased concern with health attributes in food may be particularly important. Fish is increasingly perceived as a healthy foodstuff which may confer benefits not offered by many competing substitutes. This perception is further reinforced by increasingly adverse attitudes to traditional alternatives, notably red meat. Evidence also suggests that many of the negative perceptions of fish, such as being difficult to prepare, bony, malodorous and lacking in variety and satiety are diminishing (Mogan, 1990). A further influence involves the increasing interest in variety, and a gradually widening acceptance of non-traditional species. In the UK, some part of these improvements may be attributed to the generic promotion of fish undertaken by the Seafish Industry Authority (SFIA) since the 1980's.

The form of fish consumed shows significant change. Since the 1970s, consumption of fresh fish has declined, although some redress in the trend is now evident. Frozen fish consumption has increased, reflecting a growth in preferences for convenience attributes in foods due to change in social and domestic circumstances. Canned fish and shellfish have also become more popular, and markets for aquaculture products, particularly various forms of trout and salmon have been substantially increased. Many of these changes reflect developments in the food retailing environment. The growth of MROs (multiple retail outlets) has ensured that the products stocked reach a larger number and wider range of potential consumers. MROs have traditionally been dominant in the frozen and canned fish sectors, typically accounting for over three-quarters of the retail fish market. More recently however they have made substantial gains within the fresh sector and the current market share of 32% (SFIA, 1992), can be expected to increase further still. This evolution reflects the trends of other competing foods established earlier in MROs.

Given this overview of both ends of the UK fish marketing chain we now consider the fish processing sector in further detail.

## 6. SOME KEY CHARACTERISTICS OF THE UK PROCESSING SECTOR

The Grampian (NE Scotland) and Humberside (E England) regions hold the principal concentrations of fish processing activity within the UK, although significant units are also found in other locations. This distribution reflects the regional concentration of the fishing fleet, although Humberside is now more important in fish processing than it is in respect of fishing capacity. This imbalance results partly from the dramatic decline of the distant water fishing opportunities formerly prosecuted by Humberside interests, but is also explained by the co-existent location of major firms with both fish and non-fish food interests. Grampian, the other major concentration of firms, accounts for around one-third of all UK processing jobs, and contemporary developments suggest that it may become a more dominant force in fish-specific food firms. Against this background however, there are very real concerns for the future structure of fish processing. In particular, many of the smaller-scale firms, and those which are no longer located near major supply sources, are at risk of closure. This may lead to marked change in the concentration of ownership and the distribution of activity.

In terms of the size of the processing sector, surveys in the 1980s identified around 1,000 UK companies, with up to twice this number of plants (Young, 1986; Banks, 1988). A more recent study estimated over 1,400 sites, in which a smaller number of firms operated (Dunn, Potten & Whitmarsh, 1991). The industrial structure of the processing sector is

characterised by a comparatively small number of large organisations and very many small firms. Estimates suggest that around 75% of the firms involved employ 10 or fewer people, whereas those employing more than 100 account for less than 4% of all firms.

Within the sector, operating costs have increased and are manifest in a general downturn in profitability. Results of a recent internal EC investigation found a decline in the return on capital invested from 17.9% in 1988 to an estimated 7% in 1990 (Scotland on Sunday, 1991). Similarly, growth in the value of output decreased from 9.6% in 1988 to an estimated 6% in 1990; whilst employment fell by 9.8% in 1989 and 8% in 1990 (Ibid). More recently, further closures have been announced, including a major branch plant of Findus in Grimsby, and the withdrawal of Geest from MacFish in Fraserburgh (Fishing News, 1991). Some indication of the local significance of such events is reflected in the estimate that the Findus closure alone will raise by 10% the total unemployed in the Grimsby travel-to-work area (Great Grimsby Borough Council, 1991).

Having considered some of the more salient features of the processing sector the next stage of the analysis requires some perspective on the impact of the forementioned changes within the fish marketing environment.

## 7. TRENDS IN THE UK FISH PROCESSING SECTOR

A notable consequence of increased volatility within indigenous supplies has been a rise in prices, tighter operating margins and greater reliance upon the international market. However the international market has also witnessed shortfalls in supplies, reinforcing the effects of domestic constraints. In the case of haddock, whose 1990 North Sea TAC was only 28% of that in 1988, the 1990 UK quayside price rose by 40% while the corresponding increase at the retail level was only 13% (Milne, 1991). Apart from the short run difficulty caused by such internal market price increases, these higher price levels will also drive up the future minimum prices of imported supplies upon which the EC industry is increasingly dependent.

This scenario results from the mechanism of the CFP Marketing Policy which determines annually a Guide Price for eligible species on the basis of their internal market prices over the preceding three years. The Guide Price in turn is used to set an Official Withdrawal Price (OWP) which acts as a floor price on the internal market, and a Reference Price (RP) which sets a theoretical minimum price for fish imports. Thus the 40% haddock price increase of 1990 will act to raise the RP for the period 1991 - 1993. Even if the TAC reductions which influenced the increase in internal prices, were effective in stock recovery and so permitted higher TACs to be set, thereby reducing pressure on internal prices, the price of imports would still reflect the higher levels established during the earlier period of shortage. Given the extent of processors' import dependence, this lag effect may then result in increased raw material costs in the internal market for the first year and, assuming an internal supply recovery thereafter, in increased price for external supplies for the following three years .

Moreover, any tendency for internal equilibrium prices to fall as a result of increased TACs will also be tempered by the existence of the OWPs. Therefore internal market floor prices too will exhibit the same lag effect; that is, high fish prices in any one year will tend to raise minimum prices for the subsequent three year period.

It may be argued that political considerations also come into play in determining the exact level of Guide Prices and thus their derivatives, RPs and OWPs. However significant deviations from the basis of determination, as laid down in the CFP, are likely to affect adversely both fish producers or buyers at various times; thus leaving comparatively little room for political compromise. This mechanism is important not only in terms of its cost (and revenue) implications. More fundamentally, it illustrates the complex interdependence of resource management policy and the market, and the risks of localised distortions and unintended disbenefits.

The impact of this lag effect will also be influenced by the speed of stock recovery. A near instantaneous recovery would produce the effect described above, whereas a more gradual recovery over several years would tend to reduce the differential between internal and reference prices, but not necessarily external equilibrium prices. In addition a more prolonged stock recovery would extend the related marketing costs of continuing supply shortfalls.

Shortfalls in supply are likely to remain an endenic feature for the foreseeable future. Although both the industry and Government now accepts the need for a reduction in fishing effort, 30% being recommended by the International

Commission for the Exploration of the Sea (ICES), the UK Government has failed to reach agreement with industry about how to achieve such reductions. Instead, it has relied upon a mixture of stricter technical conservation measures applied both unilaterally and by the EC.

The principal new measures applied, often against the advice of the industry (Allan, 1991), have included a restriction on days at sea and increased net mesh sizes. These have profound implications for the industry's ability to respond to existing and new market opportunities. Days at sea legislation has resulted in discontinuity of supply, contrary to the CFP objective of ensuring market stability. There is also reason to doubt its effectiveness in reducing effective fishing effort, as boats fish all the harder to compensate. Yet currently the UK Government seems intent on relying more on this measure in future. The increase in net mesh sizes, at least in the short run, will reduce the supply of certain marketable fish and begs numerous questions about the future of fish conservation, not least due to interaction in multi-species fisheries. This is especially significant in the context of the North Sea (Armstrong, 1991). More immediately, the measures will create yet further turbulence in the supply of demersal species upon which a number of processing firms, and related marketing channels have been established.

Although much of the political debate has focussed around the more immediate impact on the fishing fleet; clearly the processing sector is critically, and no less, dependent upon solutions to the EC's resource management problems. Resolution of these issues is a prerequisite for the future welfare of the processing sector. The EC would seem to accept the desirability of this, as is reflected in some aspects of policy implementation. For example, the EC has been active in providing financial assistance to firms to upgrade the marketing of fish products under the terms of Regulation 355/77 and its subsequent revision in Regulation 4042/89.

More controversially, the EC also has sought to make uniform, and to upgrade, standards of hygiene in the fish marketing chain, in an attempt to promote the longer term ability of the industry to compete within the market for foods. At the same time, uniformity of standards should preclude the free-trade caveat of Article 36 of the Treaty of Rome which permits trade barriers for reasons of hygiene. In the past this has been used more for reasons of national protectionism rather than concern with health and safety. The EC perceives that common hygiene legislation will generate economic benefits and ensure fair competition in intra and inter-Community trade (Daelman, 1989). Such moves are seen as a vital corollary to the single market.

However, these proposals have not met with universal approval. In the context of this paper the proposals are significant more for their broader implications, rather than the anomolies in the details which have been reviewed elsewhere (Maddock and Young, 1990). The imposition of the new legislation from 1993 will require many organisations to undertake investment at a time when they are perhaps least able to afford to do so.

Such measures may well be justifiable if there were grounds to suggest that fish was presently a danger to public safety; but evidence, at least for the UK, does not support this view. Thus in comparison to poultry, fish has been found to be a far less significant source of food-poisoning incidents reported in the UK (Hayes, 1989). The introduction of further quality standards generally imposes some further cost, borne by the industry and ultimately the consumer. So long as an appropriate standard of safety is being attained, it is arguable that firms should be free to determine the incremental quality attributes which they build into their products and for the level demanded by their target markets.

This "broad brush" approach is likely to have a profound impact upon the socio-economic welfare of EC and third country regions which are typically highly dependent upon fish. Evidence from within the UK industry during this present time of heightened uncertainty suggests that rather than make such investment, some firms will instead simply opt to leave the industry. In the absence of additional support, *ceteris paribus*, this trend may lead to a substantial decline in the number of plants and an attendant increase in concentration of ownership . There is every likelihood that there will be fewer firms around to enjoy any benefits to be had in the single market.

Having identified some of the more general trends surrounding the industry, it remains to consider the more likely responses of firms to the changes within their marketing environment. Given the multitude of decision making units present, comments necessarily run some risk of generalisation. Notwithstanding this caveat, the responses may be assessed in terms of their basis in supplies/ products and markets.

## 8. SUPPLIES, PRODUCT AND MARKET ORIENTATED RESPONSES

The fundamental nature of the changes in fish supplies has clearly had a profound impact on the procurement policies of most processing firms. Firms have become much more diverse in sourcing product and in some areas this has resulted

in a dramatic decline in the extent of dependence on local supplies. In the case of Humberside, many of the secondary processors report receiving less than 10% of their supplies from England and Wales. However, in the case of smaller firms with lower volume throughput such options are not viable and here reliance is placed upon the collective ability of port markets to attract supplies; an option with its own restrictions.

In some cases the more immediate problems of increased raw material costs have been alleviated to an extent by strategies of adding value and of product range extensions based on farmed, pelagic and other species. But such alternatives are not without their problems. There is evidence to suggest that firms are more diverse in the range of individual species processed, but given that most firms primarily process demersal species there are inherent constraints in terms of regularity and quality of supplies available, and their market acceptability. Moreover, many of the readily available alternate demersal species tend to command premium prices on the export market in the whole, fresh form, thus leaving little opportunity for species substitution.

Diversification into pelagic species tends to demand a fairly large scale investment, given the need to process large volumes of low unit value, often within a restricted time period. Moreover, the more capital intensive plant also tends to be more species specific. Whilst there have been some notable innovatory developments in this sector in recent years, significantly with vertical links in catching, it remains the case that pelagics have a somewhat restricted market appeal. It is therefore likely that pelagic species will tend to remain the preserve of a comparatively small number of firms. Within the shellfish sector, the market overall has warranted continued growth although much of this has rested upon imported supplies of a comparatively small range of species, and much of the recent increase in diversity in locally caught species has served the traditional fresh markets in mainland Europe.

The increasing availability of aquaculture supplies, particularly rainbow trout and salmon, but also mussels, oysters, and scallops, has offered opportunities for some processors, notably in smoking and portion pack development, and in specialised export products. While some of the traditional sector has participated successfully, a substantial part of this growth has come through new entrants to the sector specialising in aquaculture products, and developing their own distribution systems in conjunction with MROs, and with European wholesalers. This sector can be expected to continue its growth albeit at a reduced rate, as it now shows signs of restraint through increased international competition, through increasing site regulation, and through decreasing profitability of production enterprises.

The tighter operating margins experienced by processors have encouraged attempts to pass on price increases down the marketing chain. The ability to do this however has been constrained by the greater and growing power of the multiples and, consumer resistance to fish prices rising at a rate in excess of other competing foods. Throughout the 1980s processors dealt with this problem by adopting strategies of "adding value". Within some market sectors at least this was often interpreted as adding as much non-fish ingredient as could be incorporated. Whilst there undoubtedly remains scope to add value by way of incorporating further product attributes valued by consumers, it may increasingly be the case that the attributes so valued are less tangible, more sophisticated and difficult to incorporate.

In spite of the many internal and external problems involved in satisfying market demand, the overriding opportunity must be seen as the existence of a strong and growing market for fish. In addition to growth within the domestic market, the wider prospects of the single market loom. By any standards the aggregate market potential of 340 million consumers created by the SEA and subsequent expansion of the EC is considerable. However much uncertainty exists as to whether such goals are attainable. Irrespective of what new opportunities are created, and in spite of improved supply through the aquaculture sector, the whole industry's ability to exploit them is critically dependent on the stabilisation of resource management. This in itself may require no lesser political will than that necessary to agree the SEA. But certainly, from the fish industry's perspective, it is a vital condition.

## 9. CONCLUSION

In the absence of an improvement in supply there can be little reason to believe that the UK processing sector will become a much more competitive force within the EC market for food. The prospect is more likely that even greater dependence will be placed upon imports from third country firms eager to supply the growing demand for fish in the single market, and eager themselves to add value at the source of supply. An exception to this trend might be found in the aquaculture sector, where local conditions provide good prospects for quality supply. However this in turn will also

be vulnerable to competitive trends at the international level, and is in any event unlikely to match the capture sector in scale. From the perspective of the UK fish industry it is thus believed that the key to the potential benefits of the SEA lie more immediately within the sea than within the single market.

## REFERENCES

**Allan R.** (1991). Increasing Net Mesh Sizes. Are the Proposals Realistic and What Would the Effect Be?. Paper presented to: *An Industry in Crisis ? The European Community's Fishing and Fisheries Industry Conference*, Eurofish, London, 23-24 April.

**Armstrong D.** (1991). How the State of Fish Stocks is Assessed with Special Reference to North sea Cod and Haddock. Paper presented to: *An Industry in Crisis ? The European Community's Fishing and Fisheries Industry Conference,* Eurofish, London, 23-24 April.

**Banks R.** (1988). *Fish Processing in the UK: An Economic Analysis,* SFIA Edinburgh.

**Cunningham S. and J.A. Young** (1983). "The EEC Common Fisheries Policy: Retrospect and Prospect". National Westminster Bank Quarterly Review, May.

**Daelman W.** (1989). Introduction to the Community Proposals on Fish Hygiene. Paper presented to The *Proposed EC Fish Hygiene Measures Seminar*, MAFF, Torry Research Station, Aberdeen, 19-20 October.

**Dunn M.R, S. Potten and D.J. Whitmarsh** (1991). *The Sea Fish Industry in the UK: A Workforce Audit.* CEMARE, Portsmouth Polytechnic, November.

**EAFE** (1990). Country report No 11, United Kingdom, in *Evaluation of the effectiveness of the aquaculture support policies of the Commission with special reference to regulation EEC 4028/86;* Study prepared for EC DGXIV by University of Stirling/Portsmouth Polytechnic on behalf of the European Association of Fisheries Economists.

**Eurostat** (1990). *Fisheries Yearly Statistics*

**Financial Times** (1991). European Court Overrules UK Act of Parliament. 2 August p1.

**Fishing News** (1991). Findus to Close Grimsby Factory. 19 July p1.

**Great Grimsby Borough Council** (1991). The *Impact of the Closure of Findus on the Local Economy of Great Grimsby.* GGBC.

**Hayes P.** (1989). Hygiene and Fish Processing Paper presented to The *Proposed EC Fish Hygiene Measures Seminar*, MAFF, Torry Research Station, Aberdeen, 19-20 October.

**Leatherhead Food R.A.** (1991). *The UK Value-Added Fish and Fish Products Report,* LFRA August.

**Maddock S. and J.A. Young** (1990). EC Fish Hygiene Legislation: an Assessment of the Proposals. *British Food Journal* 92 (1).

**MAFF** (Various). *Sea Fisheries Statistical Tables,* HMSO.

**Marketing Strategies for Industry** (1992). MSI Databrief: Fish and Fish Products, UK MSI

**Milne, R.**(1991). Primary Processors Paper presented to: *An Industry in Crisis ? The European Community's Fishing and Fisheries Industry* Conference, Eurofish, London, 23-24 April.

**Mogan, A.J.** (1990). Personal Communication, Marketing Services Manager, SFIA December.

**National Food Survey** (Various). *Household Food Consumption and Expenditure,* MAFF HMSO.

**Scotland on Sunday** (1991). Hook Line and Sinking. 23 June p 17.

**SFIA** (1992). *Key Indicators,* SFIA Spring.

**Toerring P.** (1991). Can the Common Fisheries Policy Succeed in Reestablishling an Industry Currently in Crisis ? Paper presented to: *An Industry in Crisis ? The European Community's Fishing and Fisheries Industry Conference,* Eurofish, London, 23-24 April.

**Young J.A.** (1986). Onshore Adjustment to the Dynamic Change in the Catching Sector of the UK Fishing Industry Unpublished, PhD Thesis CNAA.

**TABLE 1.**
**UK IMPORTS OF FISH BY VOLUME.**

| YEAR | Thousand Tonnes |
|---|---|
| 1970 | 187.1 |
| 1973 | 210.5 |
| 1977 | 201.8 |
| 1980 | 340.9 |
| 1983 | 345.2 |
| 1986 | 413.7 |
| 1987 | 383.4 |
| 1988 | 403.0 |
| 1989 | 448.1 |
| 1990 | 439.7 |
| 1991 | 428.0 |

Source: HM Customs and Excise data

**TABLE 2**
**UK HOUSEHOLD FISH CONSUMPTION : QUANTITY AND PROPORTION OF EXPENDITURE.**

| YEAR | QUANTITY (ounces/capita/week) | % HOUSEHOLD FOOD EXPENDITURE |
|---|---|---|
| 1970 | 5.28 | 4.2 |
| 1975 | 4.49 | 4.2 |
| 1980 | 4.82 | 4.5 |
| 1985 | 4.90 | 4.9 |
| 1986 | 5.16 | 5.1 |
| 1987 | 5.09 | 5.2 |
| 1988 | 5.06 | 5.4 |
| 1989 | 5.20 | 5.5 |
| 1990 | 5.08 | 5.5 |

Source: MAFF NFS data

**FIGURE 1.**
**UK LANDINGS (BRITISH VESSELS).**

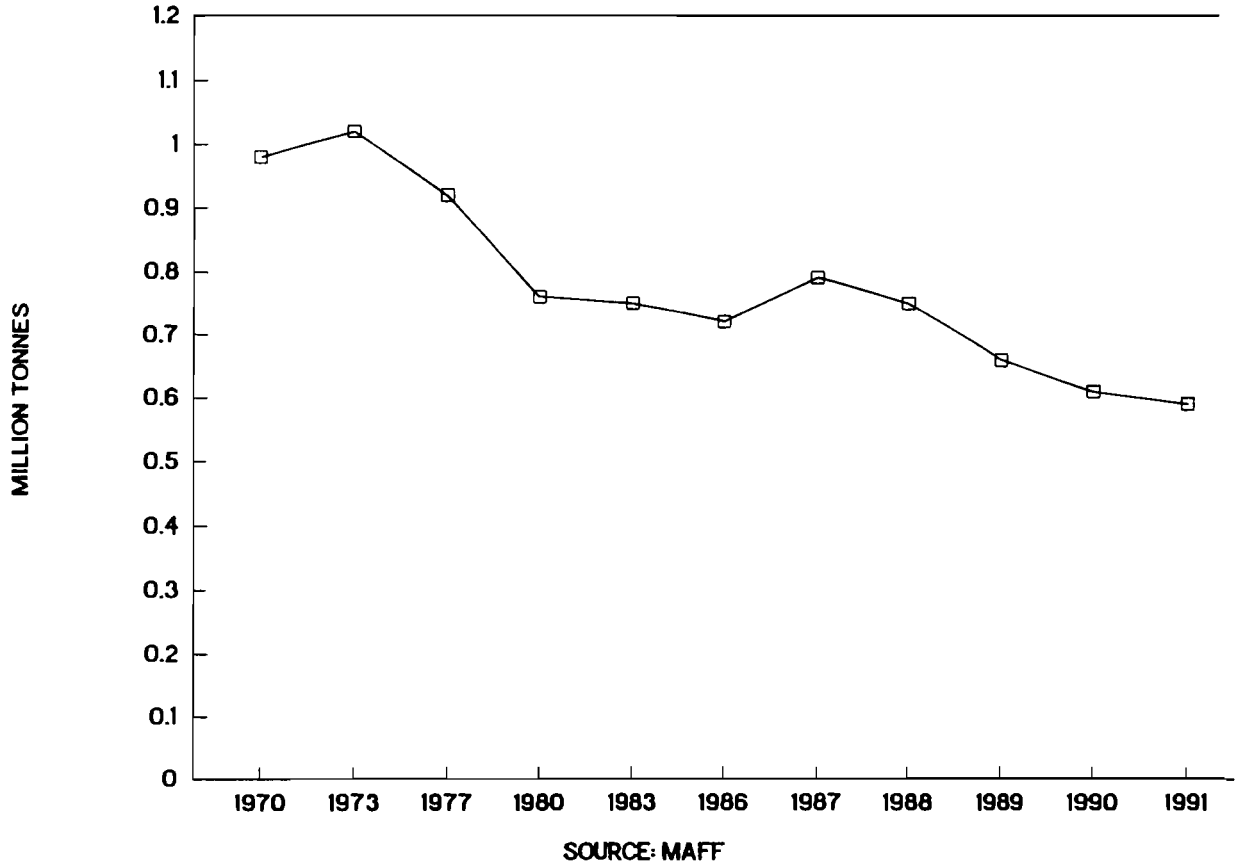
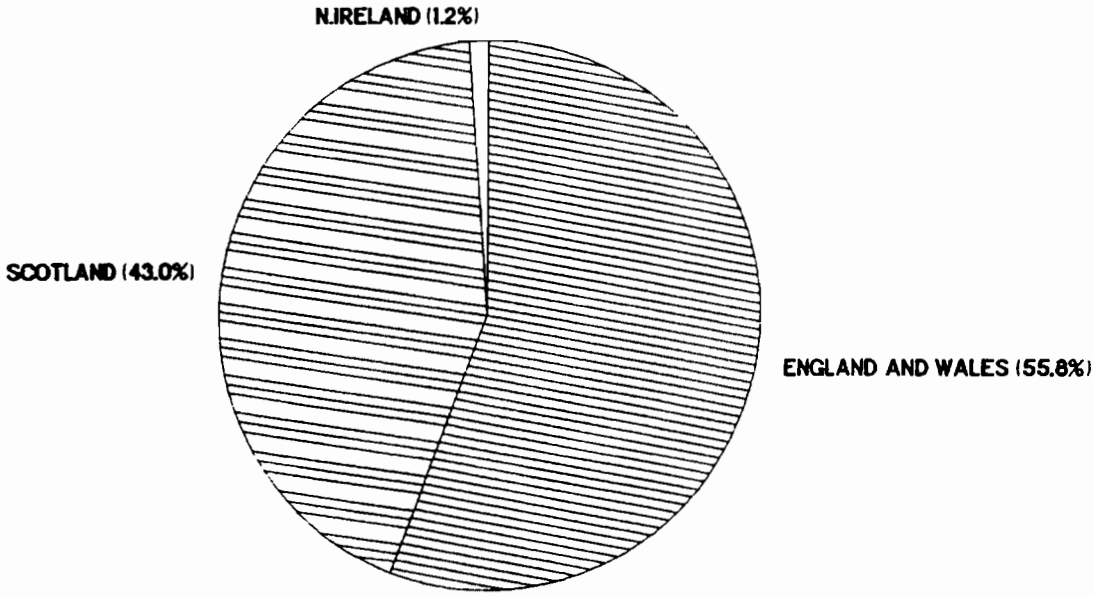


**FIGURE 2.**
**SUBNATIONAL SHARES : % QUANTITY LANDED.**




1970

1991

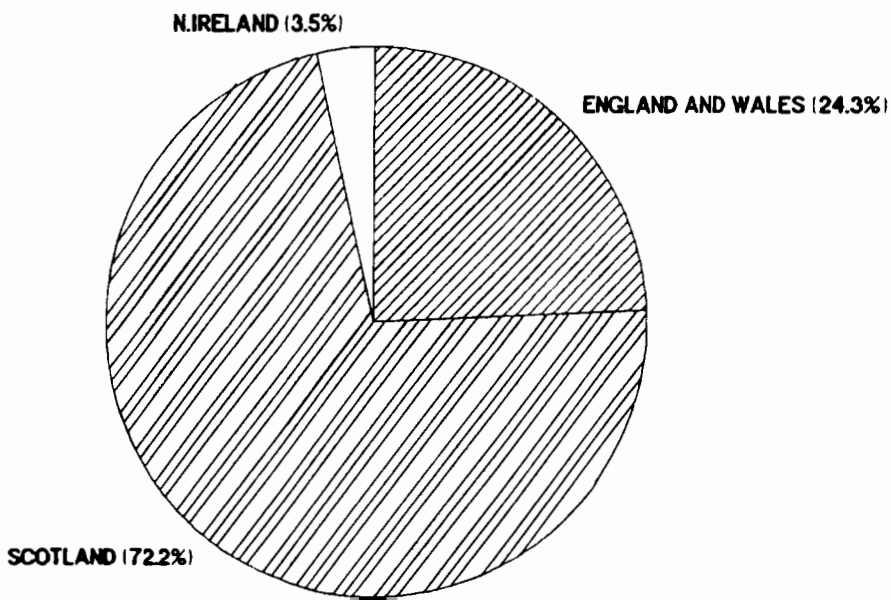


**FIGURE 3.**
**UK LANDINGS (BRITISH VESSELS).**

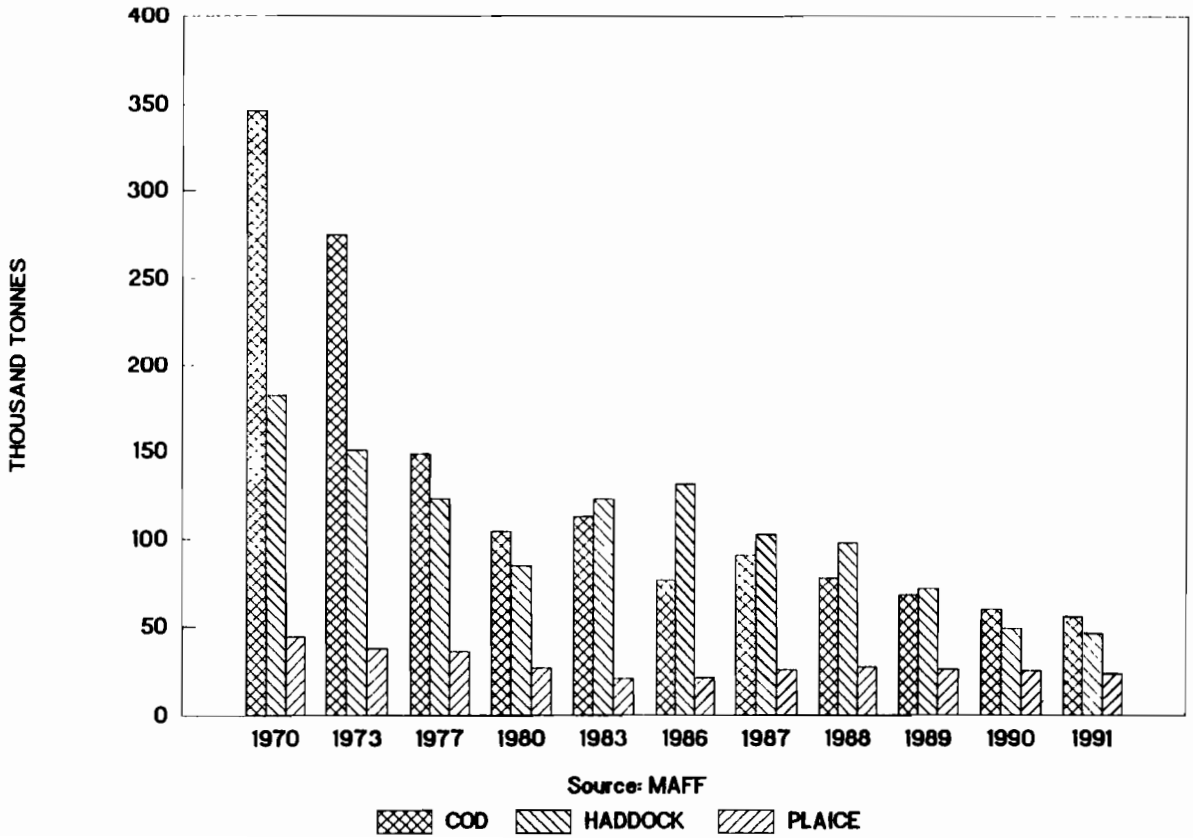


**FIGURE 4**
**UK BALANCE OF FISH TRADE (HUMAN CONSUMPTION : THOUSAND TONNES).**

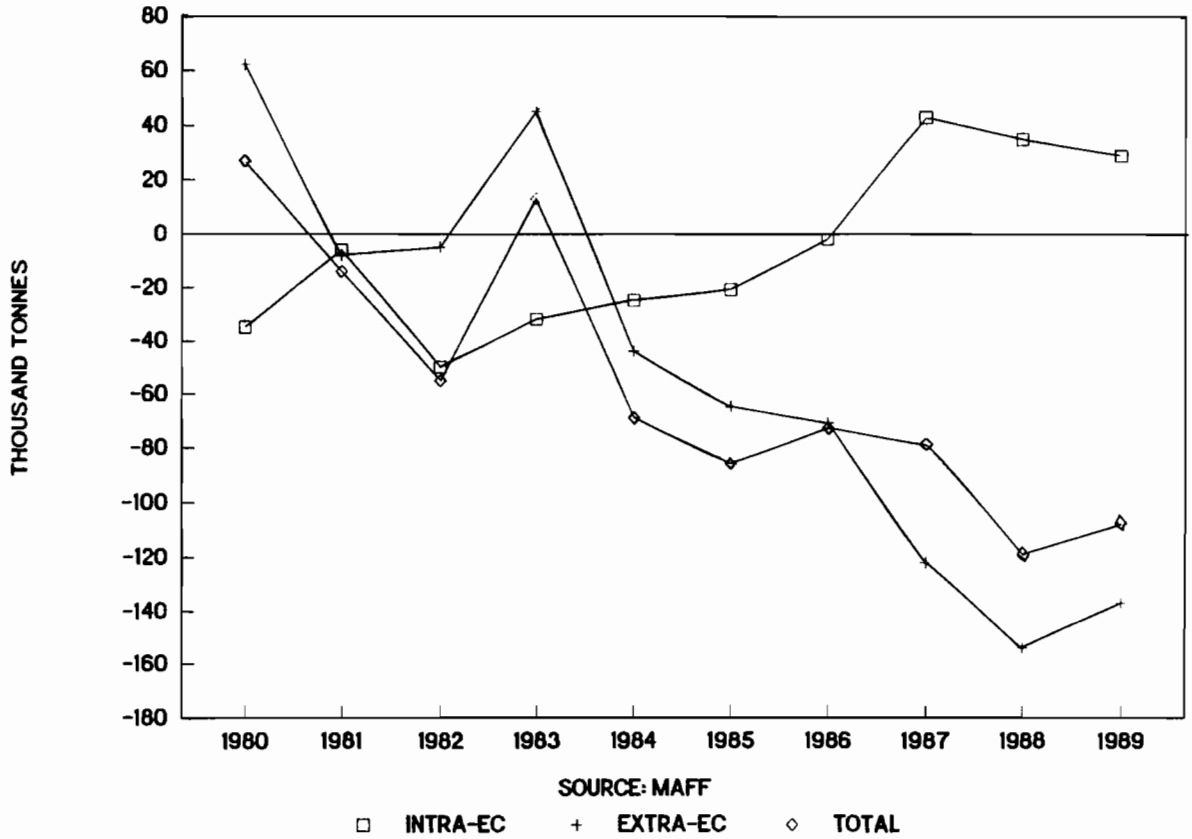
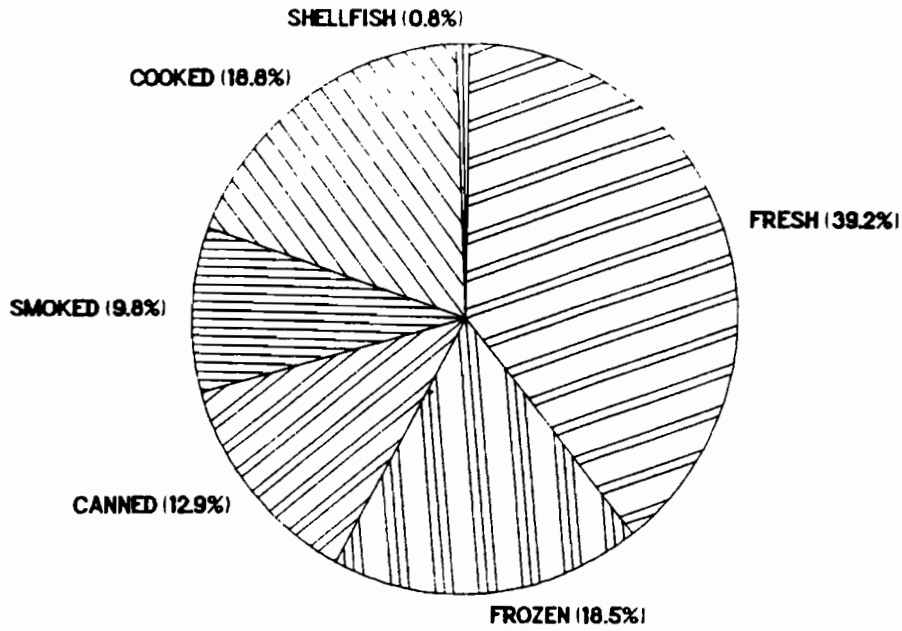
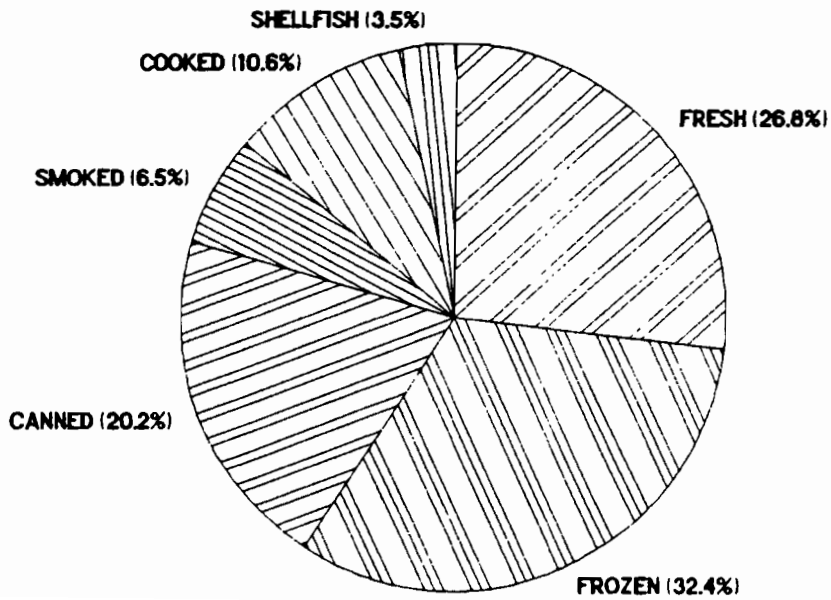


**FIGURE 5**
**HOUSEHOLD FISH CONSUMPTION (PRODUCT FORM BY % QUANTITY)**




1970

1990



# Stratégies des industries de transformation et approvisionnement en produits halieutiques : le cas du Sénégal

**Moustapha Dème[a] et Moussa Bakhayokho[b]**

[a] Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT-ISRA) BP 2241 Dakar, Sénégal

[b] Unité d'Information et de Valorisation de l'ISRA, BP 3210 Dakar, Sénégal

ABSTRACT

*It is often said that the small-scale fishing is meant to cover food needs of local populations whereas fishing caters for exports. However, the difficult situation in which many large scale fishing companies are as a result of too low revenue to cover high operating costs, insurance premiums and depreciation of their equipment has forced many industries to turn towards artisanal fishermen to supply their plants with raw materials. This paper analyses this new experiment and tries to measure its consequences on the level of the local consumption, exportations, fishing effort and the different types of fishing.*

RÉSUMÉ

*On a souvent tendance à avancer que la pêche artisanale est essentiellement destinée à couvrir les besoins alimentaires des populations du pays alors que la pêche industrielle approvisionne les exportations. Cependant, la situation déficitaire de beaucoup d'armements de pêche industrielle, consécutive à l'insuffisance des recettes pour couvrir les fortes charges financières, les assurances et l'amortissement de l'équipement, a obligé beaucoup d'industriels à se tourner vers la pêche artisanale pour approvisionner leurs usines. Le document se propose d'analyser cette nouvelle situation et tente d'en mesurer les conséquences sur le niveau de la consommation locale, des exportations, de l'effort et des différents types de pêche*

## 1. INTRODUCTION

Les autorités publiques ont souvent tendance à avancer que la pêche artisanale est essentiellement destinée à couvrir les besoins alimentaires des populations du pays alors que la pêche industrielle approvisionne les exportations (MRA, 1991).

Cependant la production insuffisante des armements de pêche industrielle a amené les usiniers à compléter leurs approvisionnements en se tournant vers la pêche artisanale afin d'assurer à leurs usines un volume de production suffisant pour couvrir leurs charges d'exploitation.

Il est très difficile d'estimer la part exacte de chaque sous-secteur dans les exportations de produits de la pêche. En effet, les statistiques officielles, fondées sur les déclarations des exportateurs et les statistiques douanières -lesquelles ne distinguent pas l'origine du produit - ne permettent pas de faire la distinction. Nous avons effectué des enquêtes auprès de 10 usines de transformation et congélation, représentant 70 % du marché et dont les activités sont orientées vers l'exportation. Il en est ressorti que 46 % du volume total de poisson vient de la pêche artisanale. Ce résultat, extrapolé à l'ensemble du secteur, situe à 40 % la contribution de celle-ci. Elle est donc en concurrence directe avec la pêche industrielle dans l'approvisionnement des usines.

Le document se propose d'analyser cette nouvelle situation et tente d'en mesurer les conséquences sur le niveau de la consommation locale, des exportations, de l'effort et des différents types de pêche. Il débouchera sur des recommandations susceptibles de donner à la pêche artisanale sa véritable place eu égard à l'un des objectifs des pouvoirs publics qui consiste en une rentrée massive de devises à travers les exportations de poisson.

La reconnaissance de certaines réalités dans l'approvisionnement des usines exportatrices de poisson doit en effet permettre une distribution plus équilibrée des capitaux disponibles entre les deux sous-secteurs.

En outre, la place de choix qu'occupe la pêche artisanale dans la politique d'auto-suffisance alimentaire lui fait bénéficier de subventions et de détaxes. Toutefois, l'orientation d'une partie de la production de ce sous-secteur vers les marchés extérieurs, couplée à une subvention à l'exportation, ne risquent-elles pas de générer des effets pervers ?.

Face à la dégradation des cours du phosphate et de l'arachide, les pouvoirs publics se sont intéressés à la pêche maritime pour restaurer le déficit de la balance commerciale du pays enregistré depuis de nombreuses années. Partant de l'idée acquise que les usines sont approvisionnées exclusivement par la pêche industrielle, un soutien financier considérable est apporté à ce sous-secteur.

## 2. MOYENS MIS EN OEUVRE

### *2.1 Subventions*

Au Sénégal les subventions accordées à la pêche industrielle sont de deux types : subvention à la production et subvention à l'exportation.

#### 2.1.1 Subvention à l'exportation

Pour stimuler et promouvoir les exportations sénégalaises et maintenir la compétitivité des industries locales sur les marchés étrangers, une subvention à l'exportation a été instituée le 25 août 1980 à titre expérimental pour quelques produits "non traditionnels" tels que les conserves de poisson, les denrées alimentaires et végétales, les engrais etc... L'exportation de ces produits donne droit au versement par le Trésor public de 10 % de leur valeur FOB. En février 1983, cette mesure d'incitation à l'exportation, relevée à 15 % avec une déduction des droits applicables aux matières premières importées, est élargie au poisson frais, transformé ou congelé. Suite à une refonte du système, la loi de 1986 étendait la subvention à l'ensemble des produits halieutiques transformés industriellement et exportés. Un taux de 25 % de la valeur ajoutée industrielle nationale est désormais appliqué. Cette subvention à l'exportation a connu une progression rapide et se chiffre à plusieurs milliards de FCFA de nos jours.

#### 2.1.2 Subvention à la production

Une autre mesure incitatrice dont bénéficie la pêche industrielle est la péréquation faite sur le carburant. Cette péréquation se décompose en :

(i) une subvention indirecte correspondant aux taxes non perçues sur le gazole au bénéfice des bateaux sénégalais et des bateaux basés battant pavillon étranger ;

(ii) une subvention directe supportée par la Caisse de Stabilisation au seul profit des unités de pêche industrielles sénégalaises.

La combinaison de ces deux mécanismes, selon les autorités publiques, devait atténuer les coûts d'exploitation dans le secteur industriel et maintenir le prix du poisson à un niveau ne remettant pas en cause la compétitivité des produits sénégalais sur les marchés extérieurs.

### *2.2 Le crédit maritime*

Les objectifs généraux du crédit maritime, institué en 1981 et dissous en 1989, étaient le renouvellement de la flotte sénégalaise vieillissante, la promotion des intérêts nationaux dans la pêche, l'extension des industries existantes et la création d'industries nouvelles plus performantes. Le sous-secteur de la pêche industrielle et de ses industries annexes en sont les bénéficiaires exclusifs. L'objectif visé était d'accroître la puissance de pêche des unités industrielles et, par là, les débarquements et les exportations.

Des fonds spéciaux (bonification d'intérêt, garantie, participation) étaient prévus pour rendre le crédit maritime plus souple et ses prestations moins onéreuses que celles des banques commerciales.

Parallèlement, jusqu'à une date récente (1987), seule la SONAGA [1] à travers les projets "maîtrisards" exerçait un financement marginal de la pêche artisanale. L'ouverture étroite des opérateurs économiques du sous-secteur artisanal sur les marchés financiers formels résultait de la combinaison de plusieurs facteurs : revenus saisonniers, difficultés des banques à immobiliser l'épargne dégagé, insuffisance d'actifs pouvant servir de garanties aux prêts et non affiliation à une compagnie d'assurances pour couvrir les risques de non-paiement.

### *2.3 Code des investissements*

Des mesures d'allégement fiscal dans le cadre du code des investissements (Loi 87-24 du 18 août 1987) permet aux professionnels de la pêche de bénéficier d'une exonération assez substantielle des droits d'entrée des navires et des équipements de pêche. En plus de l'assouplissement de la législation sociale pour tenir compte du caractère saisonnier de leurs activités, les armateurs étrangers bénéficient aussi d'une liberté de transfert des capitaux et revenus générés. Les conditions d'agrément au code des investissements ont été nettement assouplies. En effet, l'armateur doit simplement disposer d'une licence de pêche, investir au moins 5 millions FCFA, financer son investissement sur fonds propres à hauteur d'au moins 20 à 30 % suivant la nature de son entreprise et créer un minimum de 3 emplois permanents sénégalais.

### *2.4 Financement du secteur de la pêche*

A travers les quatre premiers plans de développement économique et social (1961-1977), la volonté des autorités publiques de développer quasi-exclusivement la pêche industrielle est manifeste. Pendant cette période, les actions retenues pour ce sous-secteur mobilisent en moyenne plus de 80 % des dépenses prévues pour l'ensemble du secteur de la pêche avec un taux de record de 90 % lors du troisième plan (Dème, 1991) (tabl. 1).

La tendance vers un partage équilibré des moyens financiers affectés à la pêche observée à partir du Cinquième Plan entre les deux sous-secteurs artisanal et industriel est trompeuse et pour deux raisons essentielles. Premièrement, la pêche artisanale étant condamnée dans l'optique des pouvoirs publics à évoluer vers des formes industrielles plus performantes (Chauveau, 1988), plus d'un milliard de FCFA a été prélevé des prévisions de réalisations dans le secteur artisanal pour financer cette opération de modernisation de la pêche par l'acquisition de sardiniers et de cordiers entre 1960 et 1980.

1. Société Nationale de Garantie, d'Assistance et de Crédit.

Deuxièmement, le classement du Projet de Surveillance de la Pêche Sénégalaise, concernant quasi-exclusivement la pêche industrielle, dans la rubrique pêche artisanale absorbe près de la moitié des fonds destinés à ce sous-secteur.

Globalement on peut retenir que le niveau de financement de la pêche artisanale, en comparaison avec la pêche industrielle, est resté faible malgré la priorité exclusive accordée à ce sous-secteur dans le discours officiel.

Malgré ce soutien financier important, la pêche industrielle est restée déficitaire et les usines sont en grande partie approvisionnées par les artisans. Quelles sont les stratégies adoptées par les industriels ?

## 3. STRATÉGIES D'APPROVISIONNEMENT DES USINES

### *3.1 Relations pêcheurs-usiniers*

Dans le souci d'assurer la régularité de leurs approvisionnements en produits halieutiques, certaines usines font appel à des pêcheurs artisans et vont jusqu'à leur procurer tout l'équipement nécessaire à leur activité. Ces derniers pêchent et réservent exclusivement le produit de leur pêche à l'usine, qui l'achète aux prix convenus à l'avance. Le remboursement s'effectue par prélèvement systématique lors de la livraison des produits. En général, 50 à 100 FCFA sont prélevés par kilogramme de poisson livré. Il s'établit ainsi un contrat de quasi-intégration entre le pêcheur et l'usine (Dème, 1983 ; Dème et Diadhiou, 1990).

### *3.2 Relations mareyeurs-usiniers*

La situation financière déficitaire de la plus part des usines exportatrices de poisson ne leur permet pas d'armer leurs propres unités industrielles. A côté des pêcheurs, certaines sociétés font appel à des mareyeurs. Elles mettent à leur disposition des moyens financiers et des moyens de transport pour collecter les produits pêchés par les artisans le long du littoral. Ces mareyeurs reçoivent en contrepartie une commission qui est fonction du tonnage collecté.

Pour d'autres usines, les mareyeurs sont des agents salariés qui en plus de leurs salaires perçoivent des primes en fonction du tonnage livré.

Avec les détournements fréquents des moyens financiers et matériels mis à leur disposition ainsi que des produits collectés, certaines usines se limitent à proposer aux mareyeurs des prix suffisamment rémunérateurs pour s'assurer leur exclusivité.

## 4. PÊCHE ARTISANALE ET EXPORTATIONS : EFFETS PERVERS

La place de choix qu'occupe la pêche artisanale dans la politique d'autosuffisance lui fait bénéficier d'un soutien financier de l'Etat à travers des subventions et des détaxes. Ainsi les moteurs hors bord, les filets de pêche et les pièces de rechange sont vendus aux pêcheurs exemptés de droits de douane et de taxes et le carburant intègre une dépéréquation de près de 64 % de son prix total. Cependant l'orientation d'une partie de la production du sous-secteur artisanal vers les marchés extérieurs par le biais des usines qui bénéficient d'une subvention à l'exportation nous amène à poser la question de savoir qui bénéficie finalement de ces mesures financières et quels sont les résultats obtenus au regard des objectifs assignés à la pêche artisanale.

### *4.1 Exportations et marché local*

Les pêcheurs artisans fournissent un peu plus de 39 % des produits servant à la confection des farines (Lleres, 1986). Jusqu'en 1982, la SOPESINE [2], elle seule, transformait près de 20 000 tonnes de sardinelles et d'ethmaloses, fournies

2. Société des Pêches du Sine.

exclusivement par la pêche artisanale, en farine et huile de poisson destiné au marché mondial de l'alimentation du bétail. Est-il judicieux pour un pays où sévit une sous-alimentation protéique de favoriser le développement de telles industries d'autant plus que les espèces transformées sont prisées par les populations locales et que leurs valeurs marchandes sont en adéquation avec les revenus existant à l'intérieur du pays. Pire, la subvention par kilogramme de poisson débarqué à la SOPESINE estimé à 22 FCFA représentait trois fois le prix payé aux pêcheurs par l'usine. Ce qui renforce l'idée que ce sont les industries locales et le consommateur étranger qui profitent le plus de la politique d'aide à la pêche artisanale (Freon et Weber, 1985 ; Dème, 1989). Selon les dernières statistiques disponibles, la contribution du poisson dans la fourniture de protéines animales avoisine les 15 % dans les zones rurales éloignées de la côte. En conséquence, il faut réserver exclusivement aux populations locales les espèces à faible valeur commerciale sur le marché international et limiter strictement la production de farine de poisson pour l'alimentation animale aux déchets des usines et aux seules espèces impropres à la consommation humaine.

L'un des objectifs de l'aide publique au sous-secteur de la pêche artisanale est de fournir du poisson de bonne qualité à un prix abordable aux consommateurs sénégalais. Cependant la présence permanente des usines sur les plages a favorisé une hausse rapide du prix du poisson au débarquement. Ainsi les prix des espèces nobles ont plus que triplé ces dix dernières années.

### *4.2 Transfert d'effort et types de pêche*

Les usiniers ont fortement influencé les orientations de la pêche artisanale. Sous leur impulsion, de nouveaux types de pêche sont apparus et ne se sont développés que pour l'exportation. On peut citer la pêche des céphalopodes à la turlutte et au casier introduite par les industriels japonais, celle de la langouste au filet fixe développée par les Grands Viviers, la pêche de poissons nobles à la palangrotte ainsi que celle de la crevette à Ziguinchor initiée par les industriels de cette localité.

Parallèlement, les pêcheries jusqu'ici orientées vers l'autoconsommation ont également rapidement évolué. Ainsi de nouvelles stratégies d'exploitation des ressources sont apparues (Bakhayokho et Kebe, 1989). C'est ainsi qu'en période de pêche des espèces nobles à haute valeur marchande comme les céphalopodes et la sole, tous les types de pêche artisanaux se tournent vers l'exploitation de ces espèces. On assiste ainsi à des reports importants d'effort des espèces devant approvisionner le marché local vers celles destinées à l'exportation. Par exemple, de juin à septembre sur le Petite Côte presque toutes les pêcheries artisanales recherchent les seiches et les poulpes. Il a même été constaté que des pêcheries de pélagiques à la senne tournante et au filet maillant encerclant se convertissent en pêcheries de démersaux à la turlutte pour capturer des poulpes. De même, d'octobre à mai, beaucoup de pirogues qui opéraient à la ligne utilisent le filet à soles.

Globalement le poisson destiné au marché local devient de moins en moins disponible au fur et à mesure que la pression de pêche est orientée vers les espèces exportables.

### *4.3 Autres effets pervers*

Pour la pêche industrielle, l'exploitation de la ressource est assujettie à l'obtention d'une licence de pêche et au paiement de compensations financières pour les armateurs étrangers. Une stratégie récente adoptée par ces derniers consiste à intégrer les deux types de pêche. Les pirogues artisanales remorquées jusqu'aux lieux de pêche par un bateau-mère sont chargées de capturer le poisson et de le vendre au bateau qui leur assure en plus un soutien logistique. Le recours des industriels aux unités artisanales leur permet d'améliorer leur approvisionnement tout en contournant les modalités d'accès à la ressource, ce qui constitue un manque à gagner énorme pour l'Etat.

Ces pratiques permettent aux bateaux industriels d'accéder aux ressources disponibles dans la frange côtière réservée exclusivement à la pêche artisanale.

Concernant les cargos non basés à Dakar, en général, les pêcheurs artisans se font avoir en fin de campagne car leurs employeurs "oublient" souvent de venir régler les comptes.

## 5. CONCLUSION GÉNÉRALE

Notre analyse remet en cause la théorie dualiste consistant à opposer au secteur dit "traditionnel" un secteur dit "moderne". Ces deux secteurs sont intimement liés, certaines usines fonctionnent totalement ou en grande partie grâce aux apports de la pêche artisanale et, réciproquement, certains types de pêche artisanale ne se sont développés que pour l'exportation.

L'impact de la pêche artisanale dans l'autosuffisance alimentaire du pays a poussé les pouvoirs publics à lui octroyer des subventions, des transferts et des détaxes ; seulement l'orientation de ce secteur vers les marchés extérieurs fait que ce sont plutôt les industriels de la place et le consommateur étranger qui en sont les bénéficiaires.

Source d'emplois et de devises, grand producteur de protéines animales pour une population en croissance rapide, maillon essentiel dans l'approvisionnement des usines et des marchés, la pêche artisanale doit désormais bénéficier d'une distribution plus équilibrée des capitaux disponibles pour le développement du secteur.

Face aux besoins importants des populations locales en protéines animales et la faible couverture en milieu rural, la production de farine de poisson doit être strictement limitée aux déchets des usines et aux espèces impropres à la consommation humaine. Cette mesure doit être accompagnée par une meilleure valorisation de la production artisanale sur le marché local. En effet l'essentiel de l'aide à la pêche artisanale a été concentrée sur la production, en marginalisant les aspects commerciaux. Un transfert d'une partie de ces subventions de la production vers la commercialisation permettrait une meilleure distribution du poisson à l'intérieur du pays.

## REFERENCES

**Bakhayokho M. and M. Kébé** (1989). Réactions des pêcheurs artisans face aux variations d'abondance et de disponibilité des ressources : approche méthodologique. *In DURAND J.R., et WEBER J. (eds.) : La recherche face à la pêche artisanale,* Symp. Int. ORSTOM/IFREMER, Montpellier 3-7 juillet 1989, Paris, ORSTOM, tome II : 943-955.

**Chauveau J.P.** (1988). Histoire de la pêche industrielle au Sénégal et politique d'industrialisation (Des origines aux premières années de l'indépendance). *Cah. Sci. Hum.* ORSTOM, **25** (1-2) : 237-258.

**Dème M.** (1983). Les exportations de poissons de la pêche artisanale sénégalaise. *Doc. Sci. Cent. Rech. Océanogr.Dakar-Thiaroye*, **85 :** 1-28.

**Dème M.** (1989). Les effets du soutien financier de l'Etat à la pêche artisanale : le cas du Sénégal. In *DURAND J.R., et WEBER J. (eds.) : La recherche face à la pêche artisanale,* Symp. Int. ORSTOM/IFREMER, Montpellier 3-7 juillet 1989, Paris, ORSTOM, tome II : 845-849.

**Dème M.** (1991). Les politiques d'investissement et d'intervention de l'Etat sénégalais dans le secteur de la pêche depuis l'indépendance : problématique et actions de recherche. *Doc. Sci. Cent. Rech. Océanogr. Dakar-Thiaroye*, **128,** 27 p.

**Dème M. and H.D. Diadhiou** (1990). Pêche des pirogues glacières à la ligne en Casamance : aspects biologiques et socio-économiques. *Doc. Sci. Cent. Rech. Océanogr. Dakar-Thiaroye*, **120,** 28 p.

**Freon P. and J. Weber** (1985). Djifére au Sénégal : la pêche artisanale en mutation dans un contexte industriel. *Rev.Trav. Inst. Pêches marit.* , **47** (3 et 4) : 261-304, 1983(1985).

**Lleres B.** (1986). La pêche piroguière maritime au Sénégal : son évolution, son introduction dans l'économie de marché. Thèse de doctorat d'Université, Université de Bordeaux III, 637 p.

**Ministère des Ressources Animales** (1991). Le point sur la politique sénégalaise en matière de pêche maritime, 66 p.

**TABLEAU 1.**
**PRÉVISIONS D'INVESTISSEMENT POUR LA PÊCHE INDUSTRIELLE (EN MILLIONS DE FCFA)**

| PLAN / SECTEUR | 1960-65<br>1 | 1965-69<br>2 | 1969-73<br>3 | 1973-77<br>4 | 1977-81<br>5 | 1981-85<br>6 |
|---|---|---|---|---|---|---|
| Total secteur Pêche | 2 909 | 3 881 | 5 888 | 16 345 | 16 798 | 14 377 |
| Pêche industrielle | 2 400 | 3 080 | 5 321 | 13 026 | 9 258 | 7 590 |
| % Pêche industrielle | 82 | 79 | 90 | 80 | 55 | 53 |

Source : Ministère du Plan et de la Coopération

# Stratégies technologiques dans les industries de transformation

**Leïla Temri**

Agropolis Stratégies, Centre International des Hautes Etudes Agronomiques Méditerranéennes,
Institut Agronomique Méditerranéen de Montpellier,
3191, route de Mende, B.P. 5056, 34033 Montpellier, France

ABSTRACT

*Since the whole industry is affected by technological changes and restructuring movements, production rationalization and automation seem to become the main requirements for competitiveness. The main purpose of this paper is to set out conditions and stakes for technological changes in the seafood processing industry in respect to specificities of the sector. What are the main advantages of automation in relation to the constraints threatening the firm's production systems ? What are the obstacles to automation in relation to the supply features (espacially quantitative and qualitative uncertainty) ? Perspectives of improvement for the seafood industry production systems will be compared to theoritical developements concerning technological changes, strategy and production rationalization, by the mean of an inquiry realised in France.*

RÉSUMÉ

*Dans le cadre du mouvement de changement technique et de restructuration qui affecte l'ensemble des industries, la rationalisation de la production voire son automatisation semblent devenir des impératifs majeurs de compétitivité. L'objectif de cette communication est de présenter les conditions et enjeux de ce changement technique dans les industries de transformation des produits de la mer, compte tenu des spécificités de ce secteur. Quels sont les avantages perçus de l'automatisation par rapport aux contraintes actuelles qui pèsent sur les systèmes de production ? Quels sont les obstacles à l'automatisation, en particulier en regard des caractéristiques de l'approvisionnement (incertitude quantitative et qualitative) ? Une enquête réalisée en France auprès d'entreprises permet de positionner la problématique de l'amélioration des systèmes de production dans le secteur concerné par rapport aux approches théoriques.*

## 1. INTRODUCTION

L'accélération des mutations technologiques constitue l'une des évolutions caractéristiques de l'environnement actuel des entreprises. Celles-ci doivent l'intégrer à tous les niveaux, et en premier lieu dans la définition de leurs stratégies. Ces mutations peuvent affecter toutes les composantes de l'entreprise, mais touchent particulièrement leurs systèmes de production, c'est-à-dire, en simplifiant, leurs systèmes de transformation des inputs, les matières premières, en outputs, les produits finis. Dans ces conditions et dans une situation de concurrence accrue, la rationalisation de la production devient un impératif majeur de compétitivité. Parmi les différentes alternatives d'amélioration des systèmes de production, l'automatisation est considérée par certains auteurs comme une évolution inéluctable, voire incontournable. Notre objectif est de présenter les enjeux et les conditions de ce changement technique, dans les industries de transformation des produits de la mer.

En effet, les industries agro-alimentaires dans leur ensemble présentent un certain nombre de caractéristiques qui les différencient des autres types d'industries. Le secteur de la transformation des produits de la mer est en outre particulièrement marqué par ses relations avec l'amont, c'est-à-dire la pêche, et les incertitudes qui en découlent. Nous étudierons donc les implications de ces spécificités dans le cadre de l'amélioration des systèmes de production des entreprises de notre secteur.

Dans une première partie, nous présenterons les approches théoriques sur lesquelles s'appuie notre travail. Dans une deuxième partie, nous analyserons les spécificités des industries agro-alimentaires en général, puis du secteur de la transformation des produits de la mer, en regard des perspectives d'amélioration de leur système de production. Puis nous présenterons les résultats d'une enquête menée auprès d'entreprises de transformation, afin d'identifier leurs besoins et intentions en matière de production. Ces résultats nous permettront de positionner le secteur de la transformation par rapport aux approches théoriques et de cerner la problématique de l'amélioration des systèmes de production dans le secteur considéré.

## 2. LE CHANGEMENT TECHNIQUE, SES IMPLICATIONS STRATEGIQUES, ET LE RENOUVEAU DE LA PRODUCTION

Toute entreprise vise à améliorer sa compétitivité, c'est-à-dire son *"aptitude à soutenir durablement la concurrence"* (Marchesnay *et al.*, 1984). A cet effet, elle définit une stratégie qui doit lui permettre de *"répondre avec le maximum d'efficacité aux impulsions de son environnement"*. Cet environnement est aujourd'hui marqué par un certain nombre de mutations, et en particulier par l'évolution technologique. Celle-ci rend nécessaire l'intégration du facteur "technologie" en tant que facteur compétitif dans la stratégie de l'entreprise. D'autre part, elle touche particulièrement la fonction "production", qui retrouve ainsi une place centrale dans les préoccupations des entreprises, et peut s'avérer une arme compétitive efficace.

L'automatisation des systèmes de production, considérée, dans notre cas, comme une innovation destinée à régénérer des "technologies déjà établies" dans un secteur ancien (Larue de Tournemine, 1991), constitue l'une des possibilités ouvertes aux entreprises par ces mutations technologiques. L'ensemble des techniques et procédures concernant l'automatisation des systèmes de production, élargie à leur gestion, constitue une démarche appelée "productique".

Dans un premier temps, nous tenterons de préciser, à partir des développements analytiques récents concernant le changement technique et l'innovation, les contraintes imposées aux entreprises par les mutations technologiques.

Dans un deuxième temps, nous expliciterons les implications de ces changements pour l'analyse stratégique.

En troisième lieu, nous présenterons les travaux consacrés au renouveau de la fonction "production" et à son intégration en tant que variable stratégique.

Enfin, nous ferons le point sur le débat concernant la productique dans les industries agro-alimentaires.

### *2.1 Contraintes induites par le processus de changement technique et l'innovation*

Longtemps ignorée par les économistes, et considérée comme une variable exogène, la technologie a été intégrée dans le champ de l'économie par Marx puis Schumpeter, qui a mis en évidence le rôle de l'entrepreneur innovateur (Parent, 1978).

D'inspiration néo-schumpeterienne, l'école évolutionniste, développée notamment par Nelson, Winter, Rosenberg, Freeman, Dosi, propose une conception du changement technique et de l'innovation comme étant un processus de développement d'un contenu technologique potentiel donné, exogène, suivant une voie dessinée graduellement par interaction entre des variables technologiques et économiques.

Amendola et Gaffard (1988) soulignent le caractère séquentiel et surtout la spécificité de ce processus : il sera orienté *" de manière à servir les intérêts particuliers, et à résoudre les problèmes spécifiques de ceux qui* [le] *conduisent..."*. Ce sont donc eux qui s'approprieront les résultats obtenus.

Larue de Tournemine (1991) note que cette analyse rend impérative pour les entreprises leur participation au processus afin de *"bénéficier de la dynamique cumulative du développement des technologies, c'est-à-dire des phénomènes d'apprentissages, de l'amélioration des savoirs scientifiques et des capacités managériales et organisationnelles "*.

Foray et Zuscovitch (1988) rappellent le caractère irréversible du processus d'innovation : lorsqu'un choix technologique est effectué, ceci se fait au détriment des autres technologies disponibles, et les applications de la technologie choisie auront elles-mêmes toutes les chances d'être développées ultérieurement. Selon Fanfani *et al.* (1990), cette irréversibilité signifierait que la consolidation d'un choix ou "paradigme" technologique tendrait à éliminer les précédents, et la base de la compétitivité deviendrait alors la capacité à maîtriser le nouveau paradigme. Ces auteurs remarquent toutefois que dans le domaine agro-alimentaire, coexistent simultanément plusieurs paradigmes d'apparition non synchrone.

Si l'on adopte cette approche du changement technique et de l'innovation, il semble donc important pour l'entreprise de participer au processus, afin de le façonner à son profit, de bénéficier des effets de l'accumulation par l'expérience et l'usage, et de s'intégrer dans les nouvelles normes techniques.

### *2.2 Les implications stratégiques de l'évolution technologique*

Il importe de prendre en compte l'évolution technologique dans l'analyse stratégique. En effet, elle a modifié les règles du jeu concurrentiel, et ceci à plusieurs niveaux.

- Tout d'abord, la technologie possède, selon Porter (1986) un caractère déterminant de la structure des secteurs. Son évolution induit donc des modifications de cette structure :

  • A l'intérieur d'un secteur, les activités peuvent être redéfinies, élargies, ou au contraire rétrécies. Leur développement peut être accéléré, ou, à l'inverse, freiné (Dussauge, Ramanantsoa, 1987).

  • Il en découle une modification du champ concurrentiel, et également de la structure de la concurrence : certains concurrents peuvent être éliminés, d'autres, éventuellement issus de secteurs antérieurement distincts, vont apparaître.

  • Enfin, l'évolution technologique peut induire une réorganisation industrielle, dans le secteur, mais aussi des relations avec d'autres opérateurs, notamment les fournisseurs d'équipements (Perez, 1987).

- En règle générale, l'évolution technologique rend nécessaire, mais aussi permet, une orientation des objectifs stratégiques, vers la recherche de flexibilité, de différenciation et de renouvellement des produits, adaptée aux évolutions de la demande (Larue de Tournemine, 1991). De plus, pour une activité donnée, les facteurs clés de succès, c'est-à-dire les facteurs dont la maîtrise est nécessaire pour assurer la compétitivité de l'entreprise dans un secteur, peuvent varier. Certaines entreprises seront mieux armées que d'autres pour répondre aux nouvelles exigences. La diffusion de l'innovation technologique est ainsi source de performances inégales pour les entreprises (Quelin, 1988).

- Enfin Porter (1986) développe le rôle de la technologie en tant que source d'avantage concurrentiel pour la firme dans le cadre des deux principales stratégies génériques qu'il a identifiées : stratégie de domination par les coûts, et stratégie de différenciation.

Dans tous les cas, il apparaît indispensable de prendre en compte la technologie aux deux niveaux de la stratégie : lors de l'analyse, du diagnostic stratégique, tant externe qu'interne, et dans la définition de la stratégie globale de l'entreprise.

### *2.3 Le renouveau de la fonction production*

Sous l'influence conjuguée de l'évolution technologique et des nouvelles exigences du marché, l'entreprise doit adapter sa fonction production. En même temps, celle-ci devient une arme compétitive, à condition de s'insérer de manière cohérente dans la stratégie globale de l'entreprise, et de ne plus être subordonnée aux fonctions marketing et finance.

- Le premier, Skinner (1969) a montré qu'il existait une relation entre stratégie et décisions de production, et a préconisé l'intégration des objectifs de production dans la stratégie globale de l'entreprise. De nombreux auteurs l'ont suivi dans cette voie. Lenoir (1986) remarque toutefois que les nouvelles technologies de production peuvent avoir elles-mêmes des implications stratégiques, en permettant de nouvelles orientations et stratégies. Ainsi, la relation entre stratégie et production est interactive et non univoque.

- La conjugaison de l'évolution technologique et des mutations des besoins du marché a plusieurs conséquences sur la fonction production. Tout d'abord, une modification des objectifs de la fonction, avec un fait nouveau : la recherche de flexibilité. La productivité reste cependant un objectif pertinent, favorisé également par l'évolution technologique, qui permet de lui donner un contenu plus global. Mieux encore, les développements récents des technologies de production dites "flexibles" permettent de dépasser le traditionnel dilemme productivité-flexibilité, et de concilier des objectifs autrefois conflictuels. En deuxième lieu, on constate une imbrication de plus en plus étroite entre politique de produit et politique de production, mais également de la production avec les autres fonctions de l'entreprise, créant des effets de synergie. Enfin, selon Ait el Hadj (1989), l'intégration des technologies de l'information dans les systèmes de production a entraîné des modifications allant au-delà du seul domaine technologique, mais touchant l'organisation et la gestion.

### *2.4 La productique*

Les développements consacrés à la productique synthétisent l'ensemble des approches théoriques énoncées ci-dessus, tout au moins ceux concernant l'interaction technologie-stratégie, et la fonction production.

Ainsi, Collombel et Joignaux (1987) constatent que l'évolution des systèmes de production est caractérisée par trois phénomènes : la recherche de flexibilité, pour répondre à la variabilité croissante de la demande ; l'irréversibilité des choix d'investissements, compte tenu du coût qu'ils représentent et des mutations organisationnelles qu'ils induisent. Cette irréversibilité confère un caractère stratégique à ces choix ; enfin, la complexification des systèmes de production, qui entraîne la recherche de procédures de simplification et d'intégration des processus. Ces évolution impliquent, au niveau des systèmes de gestion, la mise en place de nouveaux modes d'organisation et de régulation, ainsi que la mise au point de nouveaux critères d'évaluation des coûts et des résultats. Enfin, la démarche productique entraîne une redéfinition des relations externes, en particulier avec les clients et les fournisseurs, particulièrement ceux de biens d'équipement. Elle peut même induire des modifications dans l'organisation d'une filière.

Ces travaux confirment l'existence de relations dynamiques entre évolution technologique, stratégie et systèmes de production, et par là la nécessité d'une évolution des systèmes de production. Ils mettent en lumière le rôle de l'évolution de la demande dans cette dynamique. Mais, en réaffirmant le caractère irréversible et stratégique de l'investissement productique, l'importance des risques qu'il comporte, les modifications des relations externes de l'entreprise et même les reconfigurations sectorielles auxquelles il peut conduire, ils montrent la nécessité de s'interroger sur la pertinence d'une alternative à l'investissement productique : une rationalisation plus organisationnelle que technique de la production.

Qu'en est-il dans les industries agro-alimentaires, et plus précisément dans le secteur de la transformation des produits de la mer ?

## 3. LES PERSPECTIVES D'AMELIORATION DES SYSTEMES DE PRODUCTION DANS LES INDUSTRIES DE TRANSFORMATION DES PRODUITS DE LA MER

Comme l'ensemble des industries, les industries agro-alimentaires doivent s'adapter aux évolutions du système technique, et intégrer les mutations en cours. Nous préciserons leurs caractéristiques propres puis présenterons les travaux de recherche concernant les améliorations de leurs systèmes de production.

Le secteur de la transformation des produits de la mer se distingue en outre par ses relations particulières avec l'aval, la pêche. Une enquête nous a permis de préciser les implications de cette spécificité, en particulier par rapport au rôle éventuel de l'automatisation, et les besoins en amélioration des systèmes de production.

*3.1 Industries agro-alimentaires et évolution des systèmes de production*

Un certain nombre de recherches ont été consacrés à l'évolution des industries agro-alimentaires face aux mutations technologiques (notamment INRA-ESR/ENSAM, 1991). Ils précisent les principales caractéristiques du secteur et les problèmes spécifiques posés dans le cadre de l'amélioration des systèmes de production, et en particulier de l'automatisation. Les industries de la viande ont fait plus particulièrement l'objet d'études sur ce thème.

### 3.1.1 Des marchés spécifiques, marqués par l'évolution de la demande

Il s'agit en effet des traiter des produits vivants, périssables, présentant une hétérogénéité qualitative des variations de prix considérables, et souvent une incertitude quantitative (Joignaux, 1988). La demande est caractérisée par une exigence croissante de variété des produits et de qualité. D'un point de vue technologique, cette dimension s'étend progressivement d'une acception purement sanitaire à l'adaptation à des besoins dérivés de l'outil industriel et aux attentes du consommateur final (Fanfani *et al.*, 1990). Selon R. Perez (1989), les marchés sont diversifiés, allant du local au mondial, mais globalement ils sont marqués par le ralentissement à long terme de la demande, une certaine saturation, et les pressions croissantes de la grande distribution. Enfin, l'internationalisation de ces marchés entraîne une augmentation de la concurrence, et un renforcement du poids des normes internationales, et par là de la règlementation. Celle-ci soutient fortement les exigences de qualité sanitaire du consommateur, et agit sur les échanges, particulièrement par des interventions sur l'évolution des prix.

### 3.1.2 Concentration des structures de production

Les structures de production présentent une grande hétérogénéité de taille et de procédés de transformation. Mais on observe une tendance aux reconfigurations organisationnelles et financières, avec une concentration plus importante, et, selon Schwind (1987), une diminution du nombre d'unités de production.

### 3.1.3 La difficile modernisation des outils de production

Plusieurs secteurs, en commençant par les industries de process (huile, lait par exemple), ont déjà amorcé la modernisation significative de leur outil de production. Le Bars et Molle (1986) énoncent les caractéristiques de l'évolution des processus de production dans les industries agro-alimentaires, dans une perspective d'automatisation : recherche de flexibilité à cadence rapide -remplissage, conditionnement-, discontinuités exigeant des manipulations coûteuses -tri, conditionnement-, et enfin abondance de la quantité d'information à recueillir et à traiter pour assurer le contrôle des processus. Pour ces auteurs, les problèmes essentiels actuels de l'automatisation sont l'inexistence de capteurs d'information adéquats, et les difficultés de traitement de l'information disponible, émise à un débit considérable. Mais ces spécificités ouvrent des perspectives intéressantes à l'application des nouvelles techniques de traitement de l'information et à la robotique.

### 3.1.4 Un exemple : la productique dans les industries de la viande

Des travaux ont été consacrés plus particulièrement à la productique dans les industries de la viande (notamment Perez, Renault, 1989), qui présentent de nombreuses analogies avec celles des produits de la mer. Il apparaît tout d'abord que la nature des besoins en automatisation diffère selon le stade dans la filière de production. En particulier, le besoin de flexibilité est plus fort en aval qu'en amont. Par ailleurs, l'automatisation des industries de la viande se heurte à trois types de problèmes. D'une part, il existe des "verrous technologiques" à l'automatisation, dus à l'origine vivante de la matière première et à la discontinuité des processus. Les orientations qui seront induites par la résolution de ces problèmes n'apparaissent pas encore nettement. En second lieu, interviennent des facteurs économiques et financiers. L'investissement productique est à haut risque, comme pour toutes les innovations ; d'autres investissements, notamment sanitaires, sont prioritaires, du fait de la règlementation publique ; enfin, le marché étant globalement en stagnation, voire en régression, la rentabilité du secteur est faible, et laisse peu de ressources d'autofinancement. Ainsi, la recherche de flexibilité de l'outil de production peut entraîner des rigidités de nature financière et relationnelle telles que la dépendance vis-à-vis des fournisseurs en équipements. En troisième lieu, l'automatisation du secteur est freinée

par des facteurs humains. Beaucoup d'entreprises sont des PME familiales, où les connaissances scientifiques et technologiques sont souvent faibles, et les mentalités peu imprégnées de logique industrielle. Tous ces facteurs expliquent que le secteur des industries de la viande présente un certain retard dans l'évolution de son outil de production par rapport à d'autres industries agro-alimentaires.

*3.2 Amélioration des systèmes de production dans le secteur de la transformation des produits de la mer*

### 3.2.1 Caractéristiques du secteur

Les caractéristiques des industries agro-alimentaires s'appliquent globalement au secteur de la transformation des produits de la mer, notamment en ce qui concerne l'évolution de la demande -variété et qualité-, et les rôles respectifs de la règlementation publique et de l'environnement international. Les relations avec l'amont, la pêche, sont en revanche marquées par une incertitude plus importante, qualitative comme quantitative, due à la non maîtrise du renouvellement de la ressource. Le secteur se trouve en outre au centre de deux types de contraintes : en amont, des disponibilités en stagnation, voire en régression, et en aval une demande soutenue, en évolution permanente. Il en résulte une augmentation considérable des prix au niveau mondial, et un développement important des échanges. Parmi les produits alimentaires et forestiers, c'est le secteur dont les échanges mondiaux ont connu la plus forte augmentation ces dernières années (FAO, 1989). En France les produits de la mer participent structurellement et durablement au déficit du commerce extérieur, tant pour les produits frais que pour les produits transformés. Les perspectives d'augmentation des apports de poissons frais semblent fortement compromises par les mesures communautaires visant à limiter les captures. En revanche, des possibilités de meilleure maîtrise de la valorisation existent, soutenues par les tendances de la consommation, qui se déplace des produits frais vers les produits élaborés.

Le secteur est segmenté en plusieurs sous-ensembles correspondant généralement à des technologies différentes : frais, conserves, produits séchés, salés, fumés, surgelés. Cette segmentation traditionnelle est de plus en plus obsolète. En effet, d'une part l'évolution technologique, conduit à l'apparition fréquente de nouvelles technologies, telles que la fabrication du surimi par exemple. D'autre part, on observe dans la presse spécialisée une segmentation de type plus "marketing", basée sur l'utilisation du produit : plat principal, entrée, etc... quelle que soit la technologie employée. En troisième lieu, une même technologie permet la fabrication de produits ayant des degrés d'élaboration divers. Cette évolution a pour conséquence la difficulté d'identification des marchés, et de positionnement des entreprises. Quelle que soit la segmentation retenue, les marchés n'évoluent pas de la façon identique. Certains segments déclinent, d'autres émergent. Cette évolution inégale est certes à relier aux transformations de la demande, mais également, sans doute dans une moindre mesure, au dynamisme propre des opérateurs dans les segments considérés.

Les préoccupations majeures en matière de technologie, telles qu'elles ressortent du dépouillement de la presse spécialisée, d'entretiens avec les professionnels, administratifs et chercheurs du secteur, se situent surtout autour de la recherche de nouveaux procédés de conservation -sous-vide, ionisation, etc...-, l'élaboration de nouveaux produits, et la valorisation de nouvelles espèces marines. L'intérêt pour l'amélioration des systèmes de production, en particulier pour l'automatisation, semble plutôt le fait de grandes entreprises privées, ce qui limite considérablement la diffusion des informations.

Concernant les processus de production, on notera qu'ils sont très fragmentés, séquentiels, avec des opérations très spécialisées. D'ailleurs, les fabricants proposent essentiellement des machines spécialisées, et ce sont d'autres intervenants, issus généralement de secteurs agro-alimentaires différents, qui mettent au point des lignes complètes, intégrées, adaptées aux besoins propres de chaque entreprise cliente, en reliant et combinant des machines d'un ou plusieurs constructeurs. Certaines rares entreprises mettent elles-mêmes au point leurs équipements.

### 3.2.2 Perspectives d'amélioration des systèmes de production : les résultats de l'enquête

Afin de mieux évaluer les perspectives d'amélioration des systèmes de production dans les entreprises de transformation des produits de la mer, nous avons réalisé une enquête auprès d'un échantillon de 24 entreprises, réparties dans toute la France, et opérant dans plusieurs secteurs de la transformation, en dehors du mareyage que nous avons considéré comme une activité purement commerciale. L'objectif de cette enquête était double : d'une part identifier les besoins en matière

d'amélioration des systèmes de production, d'autre part évaluer l'impact des incertitudes liées aux approvisionnements sur la fabrication et la gestion de la production. Nous nous situons au niveau de la définition globale des objectifs de production, en liaison avec la stratégie de l'entreprise. Nous présentons ici une première approche des résultats, un traitement plus approfondi devant être effectué par la suite. Il convient enfin de préciser que cette enquête revêt un caractère exploratoire, qualitatif, et ne prétend donc pas à une représentativité statistique. Elle constitue néanmoins un point de départ indispensable, car à notre connaissance, aucune publication sur ce thème, dans le secteur de la transformation des produits de la mer, n'est disponible.

• Etat actuel du système de production et perspectives

Pour apprécier l'état d'automatisation du système de production, nous avons proposé une échelle de 5 niveaux, fortement inspirée du travail de Kalika (1988), en demandant d'estimer le pourcentage de l'activité correspondant à chacun d'entre eux.

- A travers l'échantillon, le secteur apparaît peu automatisé : seules 8 entreprises sur 24 estiment leur niveau d'automatisation supérieur à 10 %. Seules 2 entreprises font état de la possession d'au moins une machine entièrement automatisée, et aucune d'un système complet intégré. Par contre, 5 entreprises déclarent effectuer le travail entièrement à la main. A titre indicatif, nous obtenons un taux moyen d'automatisation -moyenne des taux d'automatisation- de 14 %, un taux moyen de travail manuel de 65,5 %, et un taux moyen de mécanisation de 20,5 %. Précisons que nous ne nous sommes préoccupés que de la fabrication, et n'avons délibérément pas cherché à évaluer l'informatisation périphérique, comme celle de la comptabilité ou de la gestion.

- Parmi les entreprises ayant un taux d'automatisation inférieur à 30 %, les principaux freins évoqués sont les suivants : en premier lieu, l'inexistence de machines adéquates. En second lieu, le coût trop élevé des équipements disponibles. Puis est mentionnée l'insuffisance du volume de production, qui ne justifie pas l'investissement, ensuite, l'inadéquation du matériel existant. Au total, les raisons plutôt techniques - inexistence ou inadéquation du matériel, qualité des produits- sont évoquées avec pratiquement la même fréquence que les raisons d'ordre managérial -coût, rentabilité, insuffisance du volume de production- (respectivement 14 mentions contre 13).

- Les entreprises mécanisées ou automatisées (14 sur 24) expliquent leurs choix avant tout par la recherche d'augmentation de la productivité : diminution des coûts de main d'oeuvre, augmentation de la productivité globale et du volume de production. Le souci de qualité des produits vient ensuite, puis l'amélioration des délais de fabrication et l'adaptation aux variations de volume de la demande, qui expriment le besoin de flexibilité.

- Sur l'ensemble de l'échantillon, plus de la moitié des entreprises souhaitent évoluer vers une automatisation plus grande de leurs équipements, de manière progressive. Un tiers envisage une simple réorganisation de leur système de production, sans investissement lourd (tableau 1). Ces intentions sont à relier d'une part aux préoccupations générales des entreprises quant à leur avenir, d'autre part aux besoins exprimés en matière d'amélioration des systèmes de production.

- Pour leur avenir, les entreprises craignent avant tout la concurrence, nationale ou internationale. En deuxième lieu, elles redoutent les conditions imposées par leur clientèle, en particulier quand celle-ci appartient à la grande distribution. Contrairement à notre attente, les inquiétudes quant aux approvisionnements n'arrivent qu'en troisième position, précédant l'incertitude quant à l'évolution de la demande. L'existence de débouchés ne semble préoccuper que modérément les entreprises (3 citations).

- En ce qui concerne l'amélioration des systèmes de production, les besoins en amélioration de la productivité sont largement supérieurs à ceux d'augmentation de la flexibilité ou de la qualité (tableau 2). Ce sont avant tout les coûts de main d'oeuvre et la productivité de la main d'oeuvre qui préoccupent les responsables de production. La progression de la productivité des machines n'est pas le souhait le plus fréquent, mais est le plus fréquemment cité comme besoin prioritaire. Les besoins en flexibilité sont exprimés surtout en termes de raccourcissement des délais de fabrication, et de polyvalence des équipements. Signalons enfin que plusieurs entreprises ont cité spontanément la mise aux normes européennes comme préoccupation importante, voire majeure.

Il semble donc globalement que pour faire face à l'intensification de la concurrence, les entreprises souhaitent moderniser leurs équipements dans le sens d'une automatisation plus grande, qui leur permettrait d'augmenter leur productivité, en limitant les coûts de main d'oeuvre. La polyvalence des équipements est en réalité souhaitée par un grand nombre d'entreprises, mais considérée comme une utopie à l'heure actuelle. Enfin, les entreprises, peu préoccupées par

l'incertitude quant à l'évolution de la demande, ne s'intéressent que modérément aux perspectives de flexibilité par rapport à cette demande. L'impératif de qualité leur paraît plus important, bien que certaines s'inquiètent de la difficulté de valorisation de la qualité par le marché.

• L'incertitude liée aux approvisionnements et ses conséquences sur la production

- Bien que la maîtrise des approvisionnements ne soit pas la préoccupation majeure des responsables de production, contrairement à nos attentes, ils y accordent quand même quelque importance, car elle entraîne certaines contraintes. L'inconvénient le plus vivement ressenti est l'instabilité des prix des matières premières. Vient ensuite le problème de la saisonnalité des apports, alors que la disponibilité des produits en saison n'apparaît qu'en dernière position. Les variations qualitatives, sanitaire d'abord, puis morphologiques, arrivent respectivement en troisième et quatrième position.

- Les principaux problèmes générés par ces incertitudes sont en premier lieu l'importance ou le coût des stocks de matière première, puis la difficulté de maîtriser les coûts de production. Les autres items proposés : difficulté d'honorer, qualitativement ou quantitativement, les commandes, respect des délais de production, et importance des stocks finis sont considérés comme un handicap moindre par les responsables de production.

Ces résultats confirment que l'impact de l'incertitude amont est ressenti par rapport aux coûts de production et non par rapport à la demande. Le concept de compétitivité par la flexibilité ne touche pas encore le secteur. Ce phénomène peut être expliqué par l'optimisme relatif, dans le secteur, quant à la tenue de la demande, généralement stable ou en croissance selon les segments. En revanche, l'amélioration de la productivité à travers les coûts de production est considérée comme la clé de la compétitivité face à l'accroissement de la concurrence.

## 4. CONCLUSION

En comparant les approches théoriques récentes en matière d'amélioration des systèmes de production aux réalités du secteur de la transformation des produits de la mer en France, on observe un décalage important :

- d'ordre technologique tout d'abord. L'automatisation ne touche que peu le secteur, et ne semble pas la préoccupation majeure, ni des entreprises, ni des institutions qui les entourent, ni même des constructeurs d'équipements. Ceux-ci se heurtent à des verrous technologiques forts, liés tout particulièrement à la nature des matières premières utilisées. L'atout essentiel -et souhaité- que constituerait la polyvalence des machines, par rapport aux opérations, mais surtout à la nature des entrants, n'est pas encore surmonté.

- d'ordre humain ensuite. La prise en compte de la flexibilité par rapport à la demande, et de l'atout que pourrait jouer l'outil de production dans cette optique, ne semble pas intégrée par les entreprises. On reste dans l'étape antérieure d'amélioration de la compétitivité par la maîtrise des coûts de production en augmentant la productivité, et en limitant les coûts de main d'oeuvre. C'est dans cette optique que l'automatisation apparaît comme un avantage, tandis que les obstacles majeurs sont perçus comme étant d'ordre technique ou financier. Il est à noter que paradoxalement, le risque lié au coût de l'investissement automatisé a souvent été relié à l'incertitude quant à l'évolution des débouchés, même si cela n'apparaît pas clairement dans les résultats.

Finalement, la demande de flexibilité semble orientée plus par rapport à l'amont qu'à l'aval, mais les caractéristiques de la pêche imposent des contraintes technologiques qui en limitent les possibilités. L'incertitude aval, quant à elle, est ressentie comme un risque qui restreint l'investissement automatisé, en contradiction avec les développements théoriques récents. On se trouve ainsi dans une logique particulière, qui exige des réponses adaptées. Les théories de l'évolution technologique et de ses conséquences sur la stratégie et la fonction production négligent en effet les contraintes liées à l'amont.

## REFERENCES

**Aït El Hadj S.** (1989). *L'entreprise face à la mutation technologique,* Paris, Les Editions d'Organisation, 258 p.

**Amendola M. and J.L. Gaffard** (1988). *La dynamique économique de l'innovation,* Paris, Economica, 161 p.

**Collombel B. and G. Joignaux** (1987). La productique et ses applications dans les IAA, Compte-rendu du séminaire de Montpellier, 15 mai 1987, 18 p.

**Dussauge P. and B. Ramanantsoa** (1987). *Technologie et stratégie d'entreprise,* Auckland [...], Mc Graw Hill, 248 p.

**Fanfani R., R.H. Green, M. Rodriguez Zuniga, J. Wilkinson** (1990). "Changement technique et restructuration de l'industrie agro-alimentaire en Europe : une réflexion théorique-méthodologique", Madrid : IEGA/CSIC, document AGRICEE-2000 "Changement technique et restructuration de l'agro-alimentaire en Europe", 41 p.

**F.A.O.** (1989). *La situation mondiale de l'alimentation et de l'agriculture,* Rome : FAO, 171 P.

**Foray D. and E. Zuscovitch** (1988). "L'innovation entre la production et le système technique", pp. 602-615 in *Traité d'Economie Industrielle,* R. ARENA et alii éds, Paris, Economica.

**INRA-ESR/ENSAM** (1991). Les changements techniques dans les industries liées l'agriculture ; séminaire final de l'appel d'offres PIRTEM, TET, INRA-ESR, Paris, CNRS, 287 p.

**Joignaux G.** (1988). "Productique et IAA : une approche socio-économique", *Economie Rurale*, n° 192-193, juillet-oct. 1989, pp. 60-65.

**Kalika M.** (1988). *Structures d'entreprises : réalités, déterminants,* performances, Paris, Economica, 428 p.

**Larue de Tournemine R.** (1991). *Stratégies technologiques et processus d'innovation,* Paris : Les Editions d'Organisation, 1991, 269 p. (Campus Entreprise Université).

**Le Bars Y. and J.F. Molle J.F.** (1986). "Electronique, automatisation et robotique dans l'agro-alimentaire", *Annales des Mines* n° 78, juillet-août 1986, pp. 76-78.

**Lenoir J.** (1986). "Les nouvelles technologies : mirage ou nécessité ?", *Annales des Mines, Gérer et comprendre* n° 3, juin 1986, pp. 47-51.

**Marchesnay M., R. Perez, R. Reix** (1984). "Compétitivité, systèmes de gestion et politique industrielle", pp. 19-40 in *Entreprise, Gestion et Compétitivité,* R. PERCEROU éd., Paris, Economica.

**Parent J.** (1978). "Evolution des techniques et analyse économique, pp. 1027-1061 in Histoire des techniques, B. GILLE éd., Paris, Gallimard.

**Perez R.** (1987). "La productique dans les industries agro-alimentaires, Montpellier : CIHEAM-IAM-M, Journée productique du 15 Mai 1987, 7 p.

**Perez R.** (1989). "Contraintes stratégiques et logiques d'action des groupes alimentaires", *Economies et Sociétés*, n° 7, série AG n° 20, pp. 9-26.

**Perez R. and C. Renault** (1989). "La productique dans la filière viande", *Economie Rurale* n° 192-193, juillet-oct. 1989, pp. 67-74.

**Porter M.** (1986). *L'avantage concurrentiel : comment devancer ses concurrents et maintenir son avance,* Paris : Interéditions, 647 p.

**Quelin B.** (1988). "La diffusion des innovations : une analyse inter-industrielle", pp. 668-681 in *Traité d'Economie Industrielle,* R. ARENA et alii éds, Paris : Economica.

**Schwind P.D.** (1987). "Why automate food processes ?", pp. 3-6 in *Changing Food Technology : innovation and communication,* M. KROGER, R. SHAPIRO eds, Lancaster : Technomic publishing Company.

**Skinner W.** (1969). "Ne perdez pas de vue votre outil de production", *Harvard-l'Expansion* n°1, été 1976, "Manufacturing - Missing Link in Corporate Strategy", *Harvard Business Review*, 1969.

TABLEAU 1.
INTENTIONS VIS-À-VIS DE L'AMÉLIORATION DES SYSTÈMES DE PRODUCTION.

| | Nbre de réponses obtenues* | % ** |
|---|---|---|
| 1- Changement complet et radical des équipements + automatisation | 0 | 0 |
| 2- Changement progressif des équipements + automatisation | 14 | 54 |
| 3- Changement d'équipements, radical ou progressif, sans automatisation | 0 | 0 |
| 4- Amélioration de l'organisation, sans automatisation | 8 | 30 |
| 5- Pas de changement | 2 | 8 |
| 6- Autres | 1 | 4 |
| 7- N.S.P. | 1 | 4 |
| TOTAL | 26 | 100 |

* Réponses multiples dans 2 cas : (2) et (4), (2) et (6)
** sur nombre total de réponses, y compris multiples

TABLEAU 2.
BESOINS EN AMÉLIORATION DES SYTÈMES DE PRODUCTION.

| Nature besoin | Niveau de réponse (*) | 1 | 2 | 3 | X | TOTAL |
|---|---|---|---|---|---|---|
| PRODUCTIVITE | Augment. volume de production | 3 | 2 | 4 | 6 | 15 |
| | Augment. productivité main d'oeuvre | 3 | 4 | 1 | 9 | 17 |
| | Augment. productivité machines | 5 | 0 | 1 | 4 | 10 |
| | Diminut. coûts main d'oeuvre | 6 | 5 | 1 | 7 | 19 |
| Total mentions | | | | | | 61 |
| FLEXIBILITE | Amélior. délais de fabrication | 0 | 0 | 3 | 6 | 9 |
| | Adapt. var. volume demande | 0 | 0 | 0 | 5 | 5 |
| | Augment. variétés produits | 1 | 2 | 0 | 0 | 3 |
| | Amél. renouvell. gamme produits | 0 | 0 | 0 | 1 | 1 |
| | Augment. polyvalence équipements | 0 | 1 | 0 | 7 | 8 |
| Total mentions | | | | | | 26 |
| QUALITE | Amél. qualité produits | 2 | 2 | 1 | 7 | 12 |
| | Amél. fiabilité équipements | 1 | 0 | 1 | 7 | 9 |
| Total mentions | | | | | | 21 |

(*) : Il était demandé de noter dans l'ordre les trois premiers besoins prioritaires, et de cocher (X) les besoins secondaires ou dérivés

# Consumption of Seafood, Poultry and Meat in Restaurants vs. Supermarkets

**Toyokazu Naito, Richard S. Johnston and Ann L. Shriver ***

Department of Agricultural and Resource Economics, Oregon State University, Ballard Extension Hall 213, Corvallis, Oregon 97331-3601, USA

ABSTRACT

*There is considerable evidence to support the hypothesis that seafood, poultry and meat are close substitutes in consumer demand. Thus the relationships among prices are important in determining consumption patterns among these protein sources. In addition, there are at least two kinds of outlets in which seafood, poultry and meat are sold to consumers : retail stores, including supermarkets, and away-from-home outlets, including restaurants. Because restaurants and retail stores add different sets of services to their products (dining facilities vs. packaging, for example), one would expect the price relationships among the three protein categories to be different, as between the two outlets. In turn, this should lead to consumption patterns that are different in restaurants than in retail stores. Some, however, argue that this is not the case because the different prices in the two outlets can be assigned directly to the services provided by the respective outlets and thus should not be included in the prices of the protein items themselves. Under this argument, there should be no differences in the consumption patterns as between the two outlets. This paper presents a theoretical model of the issue, reviews the competing hypotheses, and discusses preliminary results of an empirical test.*

## 1. INTRODUCTION

The "shipping the good apples out" issue is a very interesting real economic phenomenon with several varied applications. The example cited in Borcherding and Silberberg (1978) gave the phenomenon its name : an irate consumer complained that in the state of Washington, where apples are grown, local markets carry only small, poor quality fruit. The consumer demanded to know why better quality apples were unavailable, and where they had gone. The answer was provided by a leading economist in the Seattle Times of October 28, 1975 :

* Acknowledgements : This paper reports on research supported, in part, by the OSU Sea Grant Program and by the Cooperative States Research Service, U.S. Department of Agriculture, under Agreement No. 92-34276-7140.

> "Suppose, for example, a "good" apple costs 10 cents and a "poor" apple 5 cents locally. Then, since the decision to eat one good apple costs the same as eating two poor apples, two good apples cost four poor apples. Suppose now that it costs 5 cents per apple (any apple) to ship apples East. Then, in the East, good apples will cost 15 cents each and poor ones 10 cents each. But now eating two good apples will cost three - not four poor apples. Though both prices are higher, good apples have become relatively cheaper, and a higher percentage of good apples will be consumed in the East than here."

This answer is supplied in the context of Alchian and Allen's proposition (1964) that if a given transport cost is added equally to the prices of two similar goods, then, because they will reduce the relative price of the more expensive (i.e., higher quality) good, the effect will be a relative increase in the consumption of the higher-quality good.

This proposition can be applied to other "fixed charge" phenomena. The application of interest to us is the impact of differing price ratios on consumer choices between seafood and comparable options. When a consumer purchases fish and other protein sources such as chicken or beef at a retail outlet, she faces a certain price comparison between these items. If we add an equal "fixed charge" to each of these items - such as the cost of restaurant preparation and presentation as a "center of the plate" menu item - this price comparison (ratio) will change. Do consumers perceive the difference between these price ratios, and act as theory would predict, consuming relatively more of the lower priced item at retail outlets and relatively more of the higher-cost protein at restaurants ?

The proposition is not without controversy. Its formulation has been debated in the literature, and we now have two different, alternative formulations. These two formulations differ in their assumptions about how consumers perceive prices. One formulation supports the hypothesis that consumers view the fixed per-unit charge as a change in the price ratio, as just discussed. The other formulation hypothesizes that consumers view the charge not as affecting the price ratio at all, but, rather, as a fixed lump-sum charge for a separate third good or service, or an "admission fee". In the restaurant, this would be the portion of the patron's bill which pays for everything other than the food cost of her meal, including decor, ambience, the services of waiters and maitre d's, heating, lighting, etc. Under this latter formulation, relative prices of the food items themselves would be the same for restaurants as for retail stores.

While the Alchian and Allen proposition has been applied to explain several economic phenomena, no statistical test has yet been devised for distinguishing between these two formulations. The purpose of our research is to empirically test the hypothesis of Alchian and Allen's proposition, and also to test the two alternative hypotheses concerning its formulation. To do so, we will examine whether the ratio of fish to meat consumption is different in restaurants than in retail food stores, in view of the different price ratios in the two markets.

While the present paper reports on some preliminary empirical results, its principal purpose is to review the central features of the model in some detail. Through this effort, we hope to convince the reader that any analysis of seafood consumption patterns that seeks to explain the relative growth of seafood sales in away-from-home outlets should be sensitive to the need to consider not only such factors as the rising opportunity cost of time (Prochaska and Schrimper) but also the central variable of economic choice : relative prices. For these purposes, we devote the bulk of the paper to the conceptual issues. Then drawing on the work of Opaluch (1982) we develop an econometric model that should permit us to explore competing hypotheses about choice behavior. To date, only preliminary testing of the competing hypotheses has been conducted. In this paper, we first summarize the theoretical basis of these models in part II. The model itself is presented in the next section (part III), with results of preliminary tests and conclusions presented in part IV.

## 2. THEORETICAL MODEL

### *2.1 The Original Alchian and Allen Proposition*

The original Alchian and Allen proposition was presented in a two-good world, involving a higher-quality good, $x_1$, with higher price $p_1$, and a lower-quality good, $x_2$, with lower price $p_2$. Their proposition can be graphically illustrated on a two-dimensional graph as in Figure 1.

Here the higher-quality good $x_1$ with price $p_1$ is depicted on the vertical axis and the lower-quality good $x_2$ with lower price $p_2$ is depicted on the horizontal axis. The individual consumer has income Y ; hence she faces a budget line AB,

where $p_1 > p_2$ is assumed so that the slope of AB is less than one in absolute value. In this situation, the utility-maximizing consumer purchases the bundle $(x_1^*, x_2^*)$ at point E, which is the point of tangency with the consumer's indifference curve $I_1$. The slope of line OG, $x_1^*/x_2^*$, gives the consumption ratio of $x_1$ to $x_2$. If a transportation or other "fixed" charge, $t$, is added equally to prices $p_1$ and $p_2$, the consumer having the same income and utility function will operate on the new budget line CD (which is steeper than AB). She will then choose a new bundle $(x_1^{**}, x_2^{**})$ at point F, tangent to indifference curve $I_2$. Hence, the slope of line OH, presenting the new consumption ratio between $x_1$ and $x_2$, is steeper than before ($x_1^{**}/x_2^{**} > x_1^*/x_2^*$). Therefore consumption of the higher-quality good $x_1$ (relative to the lower-quality good $x_2$) will increase as the "fixed" cost $t$ is added equally to both prices $p_1$ and $p_2$ ($p_1 > p_2$).

However, Alchian and Allen's proposition requires one important assumption : that no income effect exists (*i.e.* income changes are compensated). This assumption was suggested by Gould and Segal (1969). They showed that, if the lower-quality good is an inferior good and an income effect is permitted, then the proposition may no longer hold, indicating that the "no income effect" assumption is important in the application of Alchian and Allen's proposition. Moreover, in the real world, we have to consider more than the two goods of the Alchian and Allen formulation.

### *2.2 The Borcherding and Silberberg Formulation*

The theoretical model of the Alchian and Allen proposition is reformulated by Gould and Segal (1969) [1] and Borcherding and Silberberg (1978). Both models are algebraically demonstrated by use of the composite commodity theorem [2] and Hicks' law. They are very similar ; however the latter model is made more tractable by use of Hicks' third law [3].

Suppose we have a three-good world, where goods $x_1$, $x_2$, and $x_3$ have prices $p_1$, $p_2$, and $p_3$, respectively, and where $x_3$ is a composite commodity representing all other goods. Let $x_1$ and $x_2$ be, respectively, the higher-quality and lower-quality goods, so that $p_1 > p_2$. Assume $x_1$ and $x_2$ are transported from another location, with a unit transport cost $t$, and $x_3$ is produced locally, producing a set of prices $p_1 + t$, $p_2 + t$, and $p_3$.

In this situation, we can set up the dual (expenditure minimization) problem. From the solution to this problem, the income compensated demand functions are derived (Binger and Hoffman, 1988, pp. 183-193). Thus, we minimize the objective function given by :

$$M = (p_1 + t)\, x_1 + (p_2 + t)x_2 + p_3x_3, \tag{1}$$

subject to the constraint :

$$U(x_1, x_2, x_3) = U^0.$$

Solving this problem the generalized forms of these compensated demand functions for each of the three commodities will be :

$$\begin{aligned} x_1 &= x_1^U(p_1, p_2, p_3, t, U^0) \\ x_2 &= x_2^U(p_1, p_2, p_3, t, U^0) \\ x_3 &= x_3^U(p_1, p_2, p_3, t, U^0). \end{aligned} \tag{2}$$

These are demand functions which hold utility constant and allow income to vary. We consider only compensated demand here because income effects are always indeterminate.

1. Their formulation uses Samuelson's development of the theory of consumer behavior, as presented in *Foundations of Economic Analysis*, Cambridge, Mass. : Harvard Univ. Press (1948) : p. 90-124.
2. The composite commodity theorem states that if the prices for a group of $k$ (<n) commodities always change in the same proportion in n-commodity space, the aggregate demand for the $k$ commodities behaves as if they were a single commodity (Henderson and Quandt 1980, p. 48). This was first introduced by John R. Hicks, in *Value and Capital* , 2d. ed. London : Oxford Univ. Press (1939) : p. 312-313.
3. Hicks' third law is derived from the homogeneity of degree zero of the compensated demand curves, $x_i = x_i^U(p_1, ..., p_n, U^0)$, with respect to prices. From Euler's theorem, we have $p_1 \cdot \partial x_i^U/\partial p_1 + ... + p_n \cdot \partial x_i^U/\partial p_n \equiv 0$. Letting $s_{ij} = \partial x_i^U/\partial p_j$, the pure substitution effect on $x_i$ of a change in $p_j$, we have $p_1 s_{i1} + p_2 s_{i2} + ... + p_n s_{in} \equiv 0$. However, for compensated changes $s_{ij} = s_{ji}$ . Hence, $p_1 s_{1i} + p_2 s_{2i} + ... + p_n s_{ni} \equiv 0$. These results are known as Hicks' third law. The law can be stated succinctly as $\Sigma^n_{i=1} p_i s_{ij} = \Sigma^n_{j=1} p_j s_{ij} = 0$. Hicks' first two laws are, respectively, $s_{ij} = s_{ji}$, $s_{ii} < 0$. (Silberberg 1990 P342-343) .

According to Borcherding and Silberberg (1978), Alchian and Allen's proposition can be stated as :

$$\partial(x_1^U/x_2^U)/\partial t > 0. \tag{2}$$

That is, as the transport cost rises, consumption of the higher-quality good increases relative to that of the lower-quality good, holding utility and the prices of all other goods constant.

Further, expanding the quotient in equation (3) gives :

$$\partial(x_1^U/x_2^U)/\partial t = (x_2 \cdot \partial x_1/\partial t - x_1 \cdot \partial x_2/\partial t)(1 / x_2^2). \tag{3}$$

An increase in $t$ is equivalent to increasing $p_1$ and $p_2$ by the same amount, hence $\partial x_i/\partial t = \partial x_i/\partial p_1 + \partial x_i/\partial p_2$, i = 1,2 [4]. Letting $s_{ij} = \partial x_i/\partial p_j$, the Hicksian pure substitution terms, equation (4) becomes :

$$\partial(x_1^U/x_2^U)/\partial t = (x_1/x_2)(s_{11}/x_1 + s_{12}/x_1 - s_{21}/x_2 - s_{22}/x_2). \tag{4}$$

Let us convert these terms to elasticities. Letting $\epsilon_{ij} = (p_j/x_i)(\partial x_i/\partial p_j)$, equation (5) becomes :

$$\partial(x_1^U/x_2^U)/\partial t = (x_1/x_2)(\epsilon_{11}/p_1 + \epsilon_{12}/p_2 - \epsilon_{21}/p_1 - \epsilon_{22}/p_2). \tag{5}$$

From Hicks's third law, $\Sigma_{j=1}^{n} p_j s_{ij} = 0$ and hence dividing by $x_i$ yields

$$\begin{aligned} \epsilon_{11} + \epsilon_{12} + \epsilon_{13} = 0 \text{ and} \\ \epsilon_{21} + \epsilon_{22} + \epsilon_{23} = 0. \end{aligned} \tag{6}$$

Substituting these expressions for $\epsilon_{12}$ and $\epsilon_{22}$ in equation (6), we have :

$$\partial(x_1^U/x_2^U)/\partial t = (x_1/x_2)[(\epsilon_{11} - \epsilon_{21})(1/p_1 - 1/p_2) + (\epsilon_{23} - \epsilon_{13})(1/p_2)]. \tag{7}$$

Equation (8) shows the implication of Alchian and Allen's proposition. Since $x_1$ is the higher-quality good, $p_1 > p_2$, and thus $1/p_1 - 1/p_2 < 0$. Also, $\epsilon_{11} < 0$ since own price elasticity is negative and $\epsilon_{21} > 0$ since two qualities of the same good are presumably substitutes [5]. Hence, the first term in the square brackets on the right hand side of equation (8), the direct substitution effect, must be positive. The last term, however, the interaction effect of $x_1$ and $x_2$ with $x_3$, $(\epsilon_{23} - \epsilon_{13})$, is mathematically indeterminate.

Alchian and Allen's proposition is that $\partial(x_1^U / x_2^U) / \partial t > 0$. Hence, this equation holds when either (1) only the first term is the entire expression in equation (8) (that is, a two-good world is assumed, as demonstrated by Gould and Segal (1969)), or (2), the higher and lower-quality goods interact in the same manner with the composite good $x_3$, that is, that $\epsilon_{13} = \epsilon_{23}$ or $\epsilon_{23} > \epsilon_{13}$.

The "shipping the good apples out" problem was conceived of in a situation where a higher-quality good, $x_1$ , and a lower-quality version of the same good, $x_2$ , are fairly close substitutes. It is not necessary that the goods be "higher" and "lower" quality versions of the same good, however, as long as they can be viewed as fairly close substitutes, where we can expect relatively high absolute values of $\epsilon_{11}$ and $\epsilon_{21}$, making the first term, $\epsilon_{11} - \epsilon_{21}$, in equation (8) relatively large. Moreover, the closer substitutes $x_1$ and $x_2$ are, the smaller their interaction with the composite commodity $x_3$ becomes, making the absolute values of $\epsilon_{13}$ and $\epsilon_{23}$ small. This means that the second term, $\epsilon_{23} - \epsilon_{13}$, in equation (8) will tend to be small.

Therefore, equation (8) can be approximated by the first term in the square brackets as an empirical matter :

$$\partial(x_1^U/x_2^U)/\partial t \approx (x_1/x_2) \cdot (\epsilon_{11} - \epsilon_{21})(1/p_1 - 1/p_2). \tag{8}$$

Thus when $x_1$ and $x_2$ are close substitutes, as an empirical matter, Alchian and Allen's proposition will hold ; that is, consumption of the higher-quality good should rise relative to that of the lower-quality good, if the same fixed cost is added to the price of both goods.

4. In this case, $\partial x_1/\partial t = \partial x_1/\partial p_1 + \partial x_1/\partial p_2 = s_{11} + s_{12}$ ; $\partial x_2/\partial t = \partial x_2/\partial p_1 + \partial x_2/\partial p_2 = s_{21} + s_{22}$.
5. In general, $\epsilon_{ij} > 0$ if $i$ and $j$ are substitutes, $\epsilon_{ij} < 0$ if complements, and $\epsilon_{ij} = 0$ if unrelated.

*2.3 The Umbeck Formulation*

Another formulation of Alchian and Allen's proposition is derived by Umbeck (1980). He points out that the Borcherding and Silberberg formulation is not useful in applying the proposition beyond the case of transport cost, because their $t$ variable is assumed to be a non-economic good. He argues that only transport costs and taxes qualify as such "goods". Furthermore, he suggests that, rather than viewing such a fixed charge as an addition to price, it should be thought of as an "entrance fee".

Consider an individual with a linear and compensated demand curve for apple juice as illustrated in Figure 2. Assume that the marginal cost of producing a unit of apple juice is constant at OC and that all transaction costs are zero. Also, suppose that consumer demands are homogeneous across consumers. The shaded area, ABC, thus represents consumer surplus.

In a two-part tariff scheme involving an admission fee, customers are asked to pay a lump-sum fee for the right to buy any quantity of the good, which has a uniform price. Amusement parks, for example, charge an entrance fee before any service is offered, although there is no connection to the cost involved in letting a customer enter the park. In this case the profit-maximizing owner of the park charges an entrance fee equal to the customer's consumer surplus (Phlips, 1983, pp. 160-163 and Pindyck and Rubinfeld, 1989, pp. 389-393).

Umbeck suggests viewing the "shipping the good apples out" proposition as an example of such two-part pricing. The good demanded is apple juice and the entrance fee is what is charged for access to the juice (the skin). From Figure 2, the seller can charge up to ABC, the consumer surplus, for the right to purchase apple juice and then charge one price, OC (the marginal price), per unit.

In the case of one time period, the situation is as depicted in Figure 2. However, when we consider more than one time period, the situation changes. Assume that the quantity which this individual purchases in each time period is inversely related to the quantities which she expects to purchase in the following time periods. In order to minimize the per unit cost, the wealth-maximizing consumer will reduce the number of times she buys apple juice and buy more juice each time.

With this background, consider the Alchian and Allen proposition as follows. Suppose we have a higher-quality apple, $x_1$, and a lower-quality apple, $x_2$, with prices $p_1$ and $p_2$ respectively. Also assume that the price $p_1$ is double $p_2$ and that the higher-quality apple has two times as much juice as the lower-quality apple.

Now the apples are shipped out to another location at a cost of $t$ per apple, producing a set of prices $p_1 + t$ and $p_2 + t$. Payment of the fixed cost $t$ is always required in order to purchase an apple, a payment for the right to buy. Thus it can be regarded as an "entrance fee" because it fits the requirements of a fixed charge. It is an essential condition for obtaining access to both apples and it has no value of its own. Because the marginal price of juice has not changed and we have assumed compensated demand curves, those consumers who continue to buy apples will buy the same amount of juice. However, they will buy fewer apples in order to minimize this entrance fee, and therefore they will switch to the higher-quality apple with more juice. According to Umbeck (1980), this formulation avoids the problem raised by Gould and Segall that substitution effects with some third good might destroy the "shipping the good apples out" effect.

Umbeck concludes, then, that the consumer increases the relative consumption of "high quality" to "low quality" apples not because their relative prices change but, rather, because this economizes on the payment of the entrance fee. However, he argues that this reasoning does not apply to the restaurant meal example because there is no comparable entrance fee in that case. The services provided by the restaurant are unlike transportation services in the restaurant or in the household : "...a nice, air-conditioned restaurant with a friendly waitress serving the food, a cook preparing the food, and a dishwasher to clean up afterward all have a value of their own." (Umbeck, p. 202). If restaurants have a comparative advantage (over the household) in providing some of these services, the consumer will purchase more of them in the restaurant than at home. However, since there is no effect on the relative prices of the food items, there is no reason to believe that the ratio of "high quality" to "low quality" food items consumed will be different at the restaurant than in the home [6].

Thus, there are two views of the issue. If that portion of the price of a restaurant meal in excess of what the consumer would pay to eat the same meal at home can be thought of as analogous to a transportation cost, affecting relative prices,

6. That is, unless the substitutional relationships in consumption between services and the "high quality" food is different than that between services and the "low quality" food.

then the "shipping the good apples out" proposition will lead to the prediction that the ratio of "high quality" (higher priced) food items to "low quality" items consumed in restaurants will exceed the ratio pertaining to home comsumption [7]. The alternative hypothesis is that the services provided by a restaurant are not analogous to transportation services and, thus, the "high quality" to "low quality" ratio will be the same in the restaurant and the home.

With these two alternative views of the Alchian and Allen proposition, it is appropriate to discuss ways to distinguish between them empirically. In so doing the literature on consumer response to block pricing is helpful in developing the empirical specification so that it provides a critical test of competing hypotheses.

## 3. ECONOMETRIC SPECIFICATION

In the neoclassical theory of consumer behavior, the determinants of quantity demanded are the price of the good, prices of related goods, income, and tastes. Hence, the demand relationship can be represented simply by the following single equation model :

$$Q = f(p_1, p_2, Y). \tag{9}$$

In the Alchian and Allen proposition, the demand function will be further affected by other variables such as the transport cost $t$. In this case the demand function would be represented by :

$$(x_1/x_2) = f(p_1, p_2, Y, t), \tag{10}$$

where :

$Q$ = the ratio of the consumption of the higher-quality good, $x_1$, to that of the lower-quality good, $x_2$ ;

$p_1$ = the price of the higher-quality good ;

$p_2$ = the price of the lower-quality good ;

$Y$ = consumer's income ; and

$t$ = the unit transport cost.

We now have two alternative formulations of Alchian and Allen's proposition. Under the formulation by Borcherding and Silberberg, the "fixed" cost (added equally) causes the price ratio of the two goods to change ; consequently, consumption of the higher-quality good increases relative to that of the lower-quality good. In this formulation, the demand equation (the ratio of the consumption of the higher-quality good to that of the lower-quality good) is :

$$(x_1/x_2) = f[(p_1+t)/(p_2+t)] \tag{11}$$

where :

$x_1/x_2$ = the ratio of the consumption of the higher-quality good, $x_1$, to that of the lower-quality good, $x_2$ ; and

$(p_1+t)/(p_2+t)$ = the price ratio of $p_1$ to $p_2$ with transport cost $t$ added equally

On the other hand, under Umbeck's formulation, the consumption ratio of the two goods is only affected, if at all, through block pricing, not by the change in price ratio but by the cost of services. Hence, the demand function (the consumption ratio of the higher to the lower-quality good) would be defined as :

7. Using Umbeck's reinterpretation of the Alchian and Allen proposition, one could argue that the charge for restaurant services is like an entrance fee in the same sense that charging a single price for a package that contains a razor and razor blades can be viewed as a case of multi-part pricing. The consumer pays the entrance fee associated with the razor plus a price per blade. Without blades, the razor is of little value to the consumer, although it could be priced independently of the blades. The higher the fixed charge the more likely is the consumer to purchase "high quality" (i.e. longer-lasting) blades in order to minimize payment of the entrance fee. Viewed this way, the higher the price charged for restaurant services the less frequently the consumer will dine in restaurants but the more likely that, when she does, she will select higher quality food items.

$$(x_1/x_2) = f(p_1/p_2 , t) \quad (12)$$

where :

$x_1/x_2$ = the ratio of the consumption of the higher-quality good, $x_1$, to lower-quality good, $x_2$ ;

$p_1/p_2$ = the price ratio of $p_1$ to $p_2$ ; and

$t$ = the unit cost of restaurant services.

In the Borcherding and Silberberg formulation, consumers respond to the new price ratio with the fixed cost added equally, $p_1 + t/p_2 + t$ . In the Umbeck model, however, the consumer's behavior does not depend on the new price ratio, but on the amount the payment of the service charge subtracts from her income and the substitutional relationships between the restaurant services and each of the two goods. The substitutional relationship is not observable, but the service charge is.

To test the competing hypotheses we draw on a similar debate in the literature on water demand where the issue is whether consumers choose on the basis of average or marginal prices, when faced with a multi-part pricing arrangement (Gibbs, 1978 ; Foster and Beattie, 1981 ; Opaluch, 1982 ; and Polzin, 1984). To test these competing hypotheses Opaluch suggests a single equation econometric model :

$$Q = B_0 + B_1P_x + B_2MP + B_3(D/Q) + B_4(Y - D), \quad (13)$$

where :

Q = total purchases of the good ;

$P_x$ = a price index for other relevant goods ;

MP = the block price of Q, *i.e.* marginal price ;

Y = consumer's income ; and

D = the expenditure difference between the actual utility bill and what the bill would have been if all Q units had been priced at the marginal price [8].

Applying Opaluch's model to our formulation of Alchian and Allen's proposition, we have :

$$(x_1/x_2) = \beta_0 + \beta_1 t + \beta_2(p_1/p_2) + \beta_3(p_1+t/p_2+t) \quad (14)$$

where :

$x_1$ = higher-quality good ;

$x_2$ = lower-quality good ;

$p_1$ = the price of $x_1$ ;

$p_2$ = the price of $x_2$ ; and ;

t = the transport cost (or entrance fee).

Following Opaluch's hypothesis testing procedures, if consumers respond to the change in price ratio between $p_1$ and $p_2$ when the fixed cost is added equally, then $\beta_2 = 0$, and the demand model can be written as Borcherding and Silberberg's formulation :

$$(x_1/x_2) = \beta_0 + \beta_3 (p_1+t/p_2+t). \quad (15)$$

8. D is Nordin's lump-sum income effect term. Average price can be shown as : AP = MP + D/Q ; therefore, if $B_2 = B_3$, this equation becomes : $Q = B_0 + B_1 p_x + B_2AP + B_4(Y - D)$.

Alternatively, if consumers react to an entrance fee, as in block pricing, then $\beta_3 = 0$, and equation (15) reduces to Umbeck's formulation :

$$(x_1/x_2) = \beta_0 + \beta_1 t + \beta_2(p_1/p_2) \tag{16}$$

Thus, to compare the validity of these alternative behavioral models, the following tests can be employed.

Test 1 :

$H_0 : \beta_1 = 0;$
$H_A : \beta_1 \neq 0$

Test 2 :

$H_0 : \beta_2 = 0 ;$
$H_A : \beta_2 \neq 0.$

Test 3 :

$H_0 : \beta_3 = 0 ;$
$H_A : \beta_3 \neq 0.$

The possible outcomes from these two tests and their implications for Alchian and Allen's proposition are summarized in Table 1. Outcome 1 suggests that consumers react to the price ratio between $p_1$ and $p_2$ with $t$ added equally ; i.e. Borcherding and Silberberg's formulation is correct. Outcome 2 proposes that consumers respond not to the price ratio but to the entrance fee, so that Umbeck's formulation is correct. Outcome 3 would indicate that the consumers do not react to price at all. Outcome 4 is indeterminant. As Opaluch (1982) states, this indeterminancy may simply be a reflection of weak data. It may also arise if some consumers react to the price ratio between $p_1$ and $p_2$ with $t$ added equally while others react to an entrance fee. Alternatively it might support a more general model of consumer behavior.

## 4. PRELIMINARY RESULTS AND CONCLUSIONS

The econometric model specified above was run using data from a Japanese restaurant for the period April-December 1991. Price ratios between salmon and beef, salmon and pork, beef and chicken, and beef and pork were tested. Several alternative models, including and excluding some of the explanatory variables, were tested.

Unfortunately, it is too early in the progress of our empirical work to draw any conclusions about the validity of either of the alternative formulations discussed above. Results to date show high correlation between the independent variables, indicating a multicollinearity problem within the models as currently specified. In addition, due to the low number of observations as compared with the number of variables, degrees of freedom are very low. Calculated "t" statistics on most of the explanatory variables were very low, indicating significance only at very low levels of confidence.

As these results are very preliminary, this should be regarded only as an interim report on the empirical testing of the alternative hypotheses, which is still in progress at this writing. Plans to improve the results so that conclusions can be drawn include experimenting with other functional forms such as the log linear ; eliminating some of the variables which appear to be highly correlated ; indexing variables through a weighting system to reduce multicollinearity ; and using a generalized rather than ordinary least squares analysis. If these methods fail to correct the problems of the model, we will need to seek a data set with more observations ; a longer series which covers a time period where more change in the price ratios is observed should provide more conclusive results.

Our goal in this paper has been to provide the theoretical background for a discussion of how consumers respond to differences in prices, and to devise an econometric test of several alternative hypotheses about these responses. We hope soon to be able to provide more definitive test results which will help to determine whether consumers respond to a change in the ratio of prices they face for two options, or whether in fact this difference in ratio is not perceived as such and does not affect consumer behavior. If no evidence is found to support the application of Alchian and Allen's theory (as formulated by Borcherding and Silberberg), future research may focus on how Umbeck's concept of the entrance fee

as a separate economic good, with a value of its own, can be tested with regard to consumer choices of seafood vs. competing goods in restaurants and retail outlets. The results of these tests will increase our understanding of consumer responses and perceptions. In particular we should have a better sense of what affects seafood consumption both in, and away from, the home.

## REFERENCES

**Alchian A.A. and W.R. Allen** (1964). *University Economics.* Belmont, Calif. : Wadsworth Publishing Co., 74-75.

**Binger R.B. and E. Hoffman** (1988). *Microeconomics with Calculus.* Scott, Foresman and Co., 183-93.

**Borcherding E.T. and E. Silberberg** (1978). "Shipping the Good Apples Out : The Alchian and Allen Theorem Reconsidered." *Journal of Political Economy,* vol.86, no.1, 131-38.

**Foster S.H. Jr and B.R. Beattie** (1981a). "Urban Residential Demand for Water in the United States : Reply." *Land Economics,* vol. 57, no.2, 257-65.

**Foster S.H. Jr and B.R. Beattie** (1981b). "On the Specification of Price in Studies of Consumer Demand under Block Price Scheduling." *Land Economics,* vol.57, no.4, 624-29.

**Gibbs K.C.** (1978). "Price Variable in Residential Water Demand Models." *Water Resources Research,* vol.14, no.1, 15-18.

**Gould J.P. and J. Segall** (January/February 1969). "The Substitution Effects of Transportation Costs." *Journal of Political Economy,* vol.77, no.1 , 130-37.

**Henderson J.M. and R.E. Quandt** (1980). *Microeconomic Theory : A Mathematical Approach.* 3rd. ed. McGraw-Hill Publishing Co. 48-51.

**Opaluch J.J.** (1982) . "Urban Residential Demand for Water in the United States : Further Discussion." *Land Economics,* vol.58, no.2 , 225-27.

**Phlips L.** (1983). *The Economics of Price Discrimination.* New York : Cambridge Univ. Press : 160-63.

**Pindyck R.S. and D.L. Rubinfeld** (1989). *Microeconomics.* Macmillan Publishing Co. New York , 389-93.

**Prochaska F.J. and R.A. Schrimper** (1973). "Opportunity Cost of Time and Other Socioeconomic Effects on Away-From-Home Food Consumption." *American Journal of Agricultural Economics,* **55** (4) : 595-603.

**Samuelson P.A.** (1948). *Foundations of Economic Analysis.* Cambridge, Mass. : Harvard Univ. Press : 90-124.

**Silberberg E.** (1990). *The Structure of Economics : A Mathematical Analysis.* 2nd. ed. New York : McGraw-Hill Publishing Co : 342-43, 381-89.

**Umbeck J.** (1980). "Shipping the Good Apples Out : Some Ambiguities in the Interpretation of "Fixed Charge"." *Journal of Political Economy* , vol. **88**, no.1 : 199-209.

**TABLE 1.**
**POSSIBLE RESULTS FROM THREE TESTS**

| Outcome | Test 1 | Test 2 | Test 3 | Implications |
|---|---|---|---|---|
| 1 | $\beta_1 = 0$ | $\beta_2 = 0$ | $\beta_3 \neq 0$ | Borcherding and Silberberg's formulation |
| 2 | $\beta_2 \neq 0$ | $\beta_2 = 0$ | $\beta_3 = 0$ | Umbeck's formulation |
| 3 | - | $\beta_2 = 0$ | $\beta_3 = 0$ | No price response |
| 4 | - | $\beta_2 \neq 0$ | $\beta_3 \neq 0$ | Indeterminant |

**FIGURE 1.**
**ORIGINAL ALCHIAN AND ALLEN PROPOSITION**

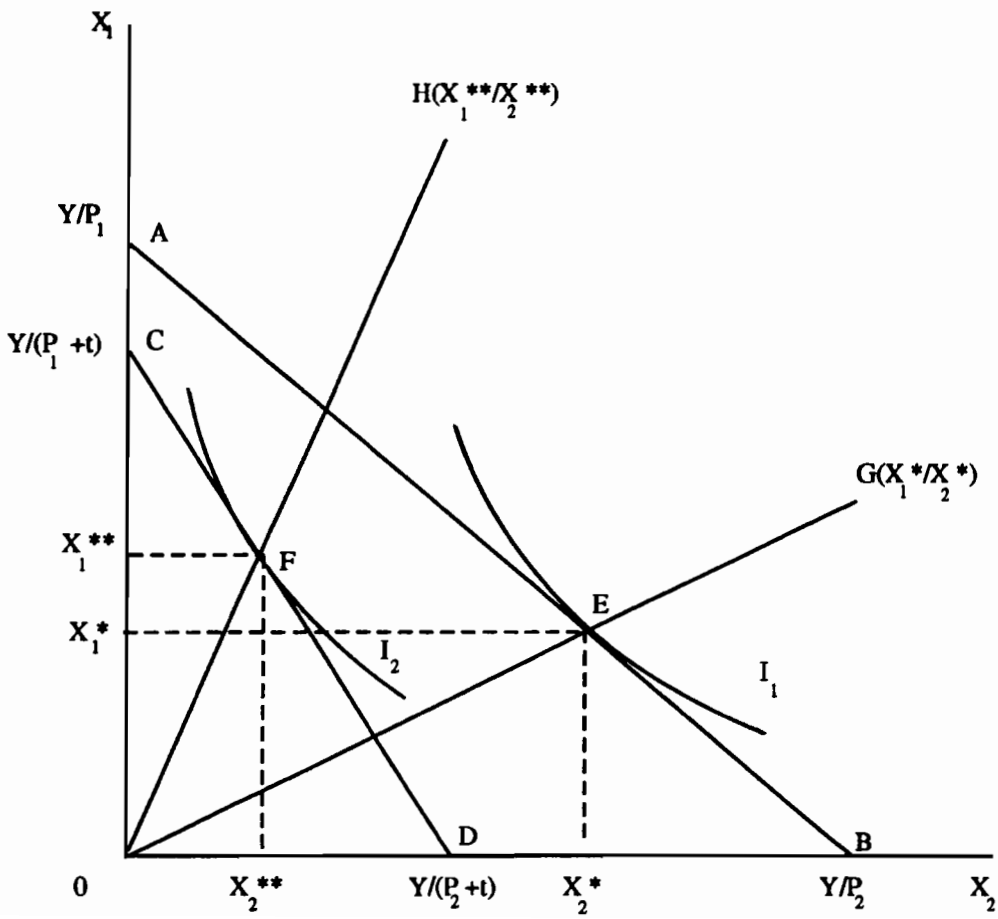
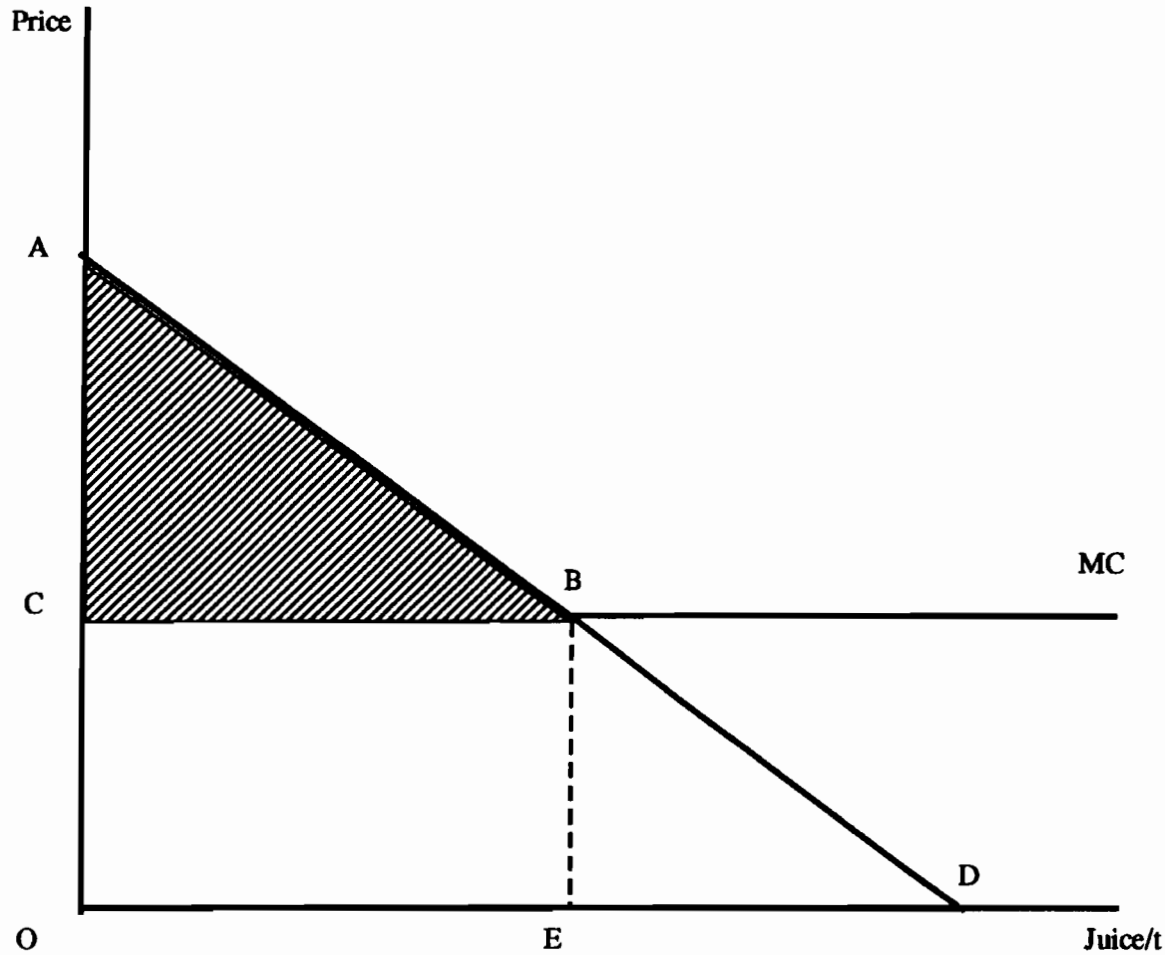


**FIGURE 2.**
**CONSUMER'S SURPLUS**



# Cross-Hedging Fishmeal with Soybean Meal Futures

**Tomislav Vukina and James L. Anderson**

Department of Resource Economics, University of Rhode Island, Lippitt Hall, Kingston, RI 02881, USA

ABSTRACT

*The paper explores the link between the fishmeal and the soybean meal markets and generates price forecasts using the state-space approach to modeling vector-valued time series. The study illustrates how fishmeal producers, could significantly increase their profits by utilizing the information from the forecasting models to construct a selective hedging strategy where the futures positions are established in soybean meal contracts.*

## 1. INTRODUCTION

This study establishes the link between the fishmeal market and the soybean meal market. It shows that an appropriate hedging strategy can be developed even for the commodity for which a viable futures market does not exist, provided that futures market exist for a close substitute commodity. The soybean meal has a full futures market system, whereas the fishmeal market, although closely tied to the soybean meal market, is entirely based on spot pricing. The relationship between the two markets presents an opportunity for fishmeal producers to cross-hedge their cash fishmeal positions with the use of soybean meal futures contracts.

The central hypothesis of this paper is that potential positive returns are available to traders who are able to outperform other traders in predicting price movements. The objective of the study is to explore the linkage between the fishmeal and the soybean meal markets, generate price forecasts, and combine the information from forecasting models with a selective hedging strategy that would increase revenues of the fishmeal producers.

While examining the forecasting ability of futures markets, most of the previous studies compared cash prices with lagged futures prices (e.g. Kofi 1973). Rather than using futures market prices to forecast future cash prices, the method employed in this study exploits dynamic relationship between contemporaneous time series of cash and futures prices and then forecast them simultaneously. The approach is based on a multivariate time series state-space modeling technique that has been proposed by Aoki (1987 ;1990). In order to test the quality and reliability of the forecasts, a

hedging signals generating model is constructed. Based on the forecasts, the model signals the hedger when to initiate the futures market position to counterbalance his predetermined cash position. The results are compared to those obtained by routine hedging and cash marketing strategy.

## 2. FORECASTS-BASED CROSS-HEDGING STRATEGY

The production of fishmeal in the United States amounted to 321,898 tons in the year 1988, 280,554 tons in 1989, and 264,871 tons in 1990 (U.S. Dept. of Commerce). Valued at the midmonth current Atlanta cash prices, the industry's gross revenue was $168 million in 1988, $116 million in 1989, and $92 million in 1990. The fishmeal producers are limited in formulating marketing strategies because there is no fishmeal futures market that can be used as an inventory management and pricing tool. In order to overcome this drawback, fishmeal producers can cross-hedge their cash positions using futures of a close substitute commodity (soybean meal). Cross-hedging should work if the behavior of fishmeal spot price is sufficiently similar to the behavior of the soybean meal futures price to produce a contemporaneous correlation coefficient significantly different from zero.

Fishmeal is a high-value, high-protein animal feed ingredient that is manufactured from the whole fish and fish offal. The demand for fishmeal is derived from its use in mixed feeds, primarily for poultry, livestock and farmed fish. The production of fishmeal is, given an ample and regular supply of fish at an acceptable price, a continuous process. The core of the production process is the separation of raw material into fat-free dry matter, oil and water. The duration of the process is typically 1-4 weeks, depending on the treatment of the freshly prepared meal (*curing* or anti-oxidant stabilization). Correct treatment will produce a product which can be stored indefinitely under dry conditions without deterioration (FAO, 1986).

The price of fishmeal is largely determined by the price of competing protein feeds, especially soybean meal. Because fishmeal contains certain growth promoting factors appreciated by the farmers, its price generally commands a premium. The primary industrial fish used by the United States fishmeal producers is menhaden, which usually accounts for more than 75 percent of the total annual production, and yields meal with a protein content of about 60 %.

Soybean meal is the dominant protein supplement used in livestock and poultry feeds, but it also can be found in baby foods, bakery goods, and various specialty food items, as well as in many industrial nonfood products. Soybean meal faces competition from various animal and vegetable products. In the animal category, fishmeal and tankage (the dried by-product of meat packing) compete with soybean meal. Vegetable oilseed meals include those produced from rapeseed, cottonseed, flaxseed and sunflower seeds. When the price of one of these products is more favorable than the price of soybean meal, there is a tendency toward substitution. In some uses, soybean meal has no substitute because of its high protein content and its suitability for feeding to all types and ages of livestock and poultry.

The model developed in this paper is different from the traditional approach to hedging because it is not based on any of the optimality criteria. In other words, an economic agent is neither maximizing nor minimizing any of the objective functions by choosing the decision variables at his disposal. Rather than being descriptive (positive), the model of this chapter is normative, i.e. it tells the hedger what to do, by generating *HEDGE* or *NO HEDGE* signals.

It has been shown that routine hedging strategy (forward pricing of the entire cash position) reduces risk (Peck 1975). However, this strategy frequently results in foregone potential positive returns from the correctly predicted movements in prices. A more sophisticated strategy, which incorporates the information from forecasts, can conceptually both increase expected utility and reduce risk relatively to strictly cash marketing or routine hedging.

The approach uses contemporaneous cash and futures prices, estimates the parameters of the multivariate time series state-space model, and then generates out-of-sample forecasts. Thus, rather than using futures market prices to forecast future cash price, as most of the previous studies have done, the proposed method exploits dynamic relationship between contemporaneous time series of cash and futures prices, and forecast them simultaneously.

Based on Brandt (1985), a simple rule for selective hedging is utilized. The producer (seller) will hedge and stay hedged as long as the current futures market price is greater than forecasted cash price, or will lift the hedge and remain unhedged as long as the cash price is forecasted to be higher than the current futures market price. However, any analysis which compares futures prices with cash prices must also adjust for the basis, particularly if the hedger has no intention of

delivery. Basis, as the difference between the futures price and cash price, has traditionally been more stable over time than cash or futures prices and is hence easier to forecast. Therefore as an operational rule for selective hedging, the producer (seller) will hedge and stay hedged whenever :

$$F_t - B^*_{t+1|t} > P^*_{t+1|t}. \tag{1}$$

Using the definition of the basis, expression *(1)* becomes :

$$F_t - (F^*_{t+1|t} - P^*_{t+1|t}) - P^*_{t+1|t} > 0 \tag{2}$$

$$F_t > F^*_{t+1|t}$$

where $F_t$ is the period $t$ quotation of the selected futures contract price, $F^*_{t+1|t}$ is the next period forecast of the same futures contract price, $P^*_{t+1|t}$ the next period forecast of cash price and $B^*_{t+1|t}$ is the next period basis forecast ; all forecasts based on information available at time $t$. The intent is to evaluate, *ex-post*, whether sellers (producers), by exercising the above selective hedging strategy, could have received a higher price for their commodity compared to sellers who used routine hedging procedure or cash marketing strategy only.

## 3. PERFORMANCE OF THE FORECASTING MODELS

The state-space models used in this paper consist of the state and the observation equations :

$$\begin{aligned} x_{t+1|t} &= Ax_{t|t-1} + Be_t \\ y_t &= Cx_{t|t-1} + e_t \end{aligned} \tag{3}$$

where $\{y_t\}$ to be modeled is a $m$ -series, zero-mean, weakly stationary vector-valued Gaussian stochastic process with auto-covariance sequence $\{\Gamma_j\}$. Matrices A, B, and C are parameters of the system, $x_t$ is a vector of $n$ unobservable states that are minimal sufficient statistics for the history of the process $\{y_t\}$, and innovations $\{e_t\}$ are white noise. The subscripts on x refer to the conditional expectation of x in the period of the first subscript given the information set at the time of the second subscript.

The estimates of the system matrices, together with the estimate of the initial state $x_1$ enable a straightforward generation of the in-sample and out-of-sample forecasts. In this paper, a departure from the standard Aoki's procedure for estimating the parameters of the covariance state-space model is made, and an alternative procedure based on Kung (1978 : 705-714) and Vaccaro (1986 : 105-112) is used. Additionally, the frequently suggested backcasting method for estimating the vector of initial states is abandoned, and the least squares solution for the vector of initial states is found. The details of the entire estimation and forecasting procedure can be found in Vukina (1991). The formula for the calculation of the out-of-sample forecasts is given by :

$$\hat{y}_{t+k+1} = CA^k x_{t+1} + \mu \tag{4}$$

Since centered data are used, the mean of the series $\mu$ which was initially subtracted from each observation, has to be added back to equation *(4)* to obtain the forecast of the same order of magnitude as the actual data. If $k=0$, expression *(4)* reduces to one-step-ahead forecast ; $k=1$ generates $\hat{y}_{t+2}$, etc. In case of a bivariate model, where for example, contemporaneous cash and futures prices are modeled together, vector $\hat{y}_{t+1}$ consists of the next period out-of-sample forecasts of the cash price (P*), and futures price (F *).

The data set used in this study covers the five year period between June 5, 1986 and May 23, 1991, for a total of 260 weekly observations on fishmeal cash and soybean meal futures prices (see Figure 1). The fishmeal prices are midweek observations of Atlanta menhaden fishmeal spot prices as available from *Feedstuffs*. Prices are quoted in dollars per short ton. Since the majority of the U.S. production is taking place in the South, the Atlanta price is the most frequently cited

in business periodicals as the U.S. domestic price. The average price in this period was $404.25 with the standard deviation of $67, the minimum price of $290, recorded in June/July 1986, and the maximum price of $620, recorded in June of 1988.

The soybean meal data were obtained from various issues of *The Wall Street Journal*. The futures data are Thursday closing prices for the Chicago Board of Trade soybean meal December contract. Trading unit is 100 short tons, and prices are quoted in dollars and cents per ton, with a minimum fluctuations of $0.10 per ton ($10.00 per contract), basis f.o.b. railcars, bulk, Decatur, Illinois. There is only one deliverable grade of meal with a minimum of 44 % protein content. The December contract was chosen because it is the most actively traded soybean meal contract for which the continuous series of prices exists throughout the year. The first trading day in December was used as the switching point between the expiring and the incoming December contract. The average price of the CBOT December contract for the entire period was $187.75, with the standard deviation of $33. In the same period, the average Decatur soybean meal cash price was $191.73.

The average fishmeal to soybean meal cash price ratio was 2.12, and was fairly stable throughout the period with the minimum value of 1.72, and the maximum value of 2.54. The contemporaneous correlation coefficient between the Atlanta fishmeal spot price and CBOT December soybean meal futures is 0.8827 which is significantly different from zero at the 1 % significance level. The magnitude of the coefficient is relatively high, having in mind that for the same five year period, the correlation coefficient between Decatur soybean meal cash price and CBOT December futures price was only slightly higher (0.8931). The result justifies the use of the soybean meal futures for cross-hedging fishmeal cash positions.

Although analytically equal, expressions *(1)* and *(2)* can lead to three distinct forecasting models. In order to use hedging rule *(1)*, forecasts of basis and cash price in period $(t+1)$ are needed. Bivariate time series may consist of cash and futures prices to give the basis forecasts indirectly as the difference between futures price forecast and cash price forecast. Alternatively, historical data for a particular location basis can be calculated by subtracting cash from futures prices, and then modeled together with cash prices. Using this approach, basis forecasts would be generated directly along with the cash price forecasts. Finally, the third alternative based on expression *(2)* would involve scalar time series model of futures market prices only.

All three models are initially estimated with the first 104 observations, and one-step-ahead, out-of-sample forecasts are generated. In the following step, an additional actual observation (the 105th) is added to the existing pool of data points to update the system matrices, thus generating the new one-step-ahead forecast. The same procedure is repeated 156 times. All models in each of the 156 rounds are estimated with the most distant auto-covariance lag of $k=2$. The number of states for the bivariate *cash and futures prices* model equals 2, while the second bivariate model *(cash and basis)* and the scalar *(futures prices)* model are estimated with one state $(\tilde{n}=1)$. The situation when an estimated covariance model does not define a positive sequence occurs occasionally, and is successfully dealt with using the procedure developed in Vaccaro and Vukina (1991). The forecasts generated by all three models are plotted in Figures 2-4.

In order to discuss alternative models it is necessary to have a criterion by which the performance of the predictors is measured. The usual criterion is the mean square error (MSE) or root mean square error (RMSE). However, in order to compare the models which attempt to model different processes (time series), we also use the mean absolute percentage error (MAPE) which is the measure of the average percentage deviation of the forecast from its corresponding actual value, and is therefore dimensionless. The model which generates forecasts with smallest statistics is according to the above specified criteria the most favorable one. The comparative forecasting statistics are presented in Table 1.

According to both MSE and MAPE criteria, the best forecasting result of the fishmeal cash price is obtained with two-channel cash and futures model. The average percentage deviation of the forecast from its corresponding actual value is 2.16 %. The forecasts of the soybean meal futures price generated by the scalar model, with MAPE statistics equals 2.43 %, slightly outperform the forecasts generated by the bivariate model. The basis forecasts yield more modest result, with the mean absolute percentage error of 6.3 %.

However, from the perspective of this study, a more valuable criterion for forecasts evaluation is their usefulness for different hedging strategies. This is the issue addressed next.

## 4. SIMULATION RESULTS

Although the data on fishmeal cash prices and soybean meal futures prices are available from June 5, 1986, the actual trading simulation starts on June 2, 1988 (the first 104 observations were used for initial estimation), and ends on May 23, 1991. The entire trading period is divided into six 6-months long sub-periods (see Table 2 and Table 3). At the end of each sub-period all outstanding cash and futures positions have to be liquidated. In the first week of each sub-period a hypothetical fishmeal producers (dealer) starts with 100 tons of fishmeal valued at the prevailing spot market price $P_0$, and sells his inventory at the price that prevails on the last trading day of the same period $P_T$. The price $P_0$ can be treated as the accounting unit cost of production, i.e. the price that would have been obtained had the product been ready for sale in the first week of the sub-period under consideration. In order to keep the problem tractable, the possibility of selling the inventory at any point in time between the two specified dates is ruled out. Since storage and handling costs were ignored, the difference in cash price between the two dates multiplied by the quantity (100 tons) is considered as profit from cash marketing.

During the period when he is long in cash market, the producer (dealer) faces three options :

i) to remain unhedged throughout the period ;

ii) to hedge the entire fishmeal inventory using soybean meal futures, and remain hedged throughout the period (routine strategy) ;

or iii) hedge selectively using the operational rule specified in expressions *(1)* or *(2)*.

For the sake of simplicity, it is further assumed that opportunity costs of capital (interest payments) are negligible and that hedging costs consist only of fixed costs per contract (brokerage fees). Because of the intraperiod price variation, margin calls present a distinct possibility and could potentially cause a cash flow problem for the hedger. However, since the likelihood of margin calls cannot *a priori* be considered any greater than the likelihood of margin surpluses, which would yield a favorable return to the hedger, the above assumption is probably not too restrictive.

If the dealer decides to remain unhedged (i), he assumes the entire risk of price variation, and his end-of-period total profit consists of profits from cash marketing only.

Routine hedging strategy (ii) involves selling short the entire inventory. The hedge is placed (one December soybean meal contract is sold) the first week of each sub-period, and lifted (one December contract is bought back) the last week of the same period. Under the routine scenario, the profit per one round of hedging is equal to the difference between the futures market quotation on the day when the hedge is placed and the day when it is lifted, multiplied by the quantity hedged (1 contract=100 tons), and corrected for the fixed cost of hedging per one contract, and per one roundturn.

Selective hedging strategy (iii) also involves selling short the entire inventory. However, the hedge will be placed only when the action is signaled by the forecasts, i.e. when the condition specified in *(1) or (2)* is fulfilled. More specifically, every week the parameters of the model are estimated, the prices for the next week (cash, futures, basis) are forecasted and the decision whether to hedge or not is made. The following week, the previous week prices are added to the pool of the existing data, the parameters of the model are re-estimated and the new one-step-ahead forecasts are made together with the new decision.

The performance evaluation of the forecasting approach to hedging for the period from June 2, 1988 to May 23, 1991, is summarized in Table 2. Measured by the combined percentage of correct *HEDGE* and *NO HEDGE* signals, both multivariate models outperform the scalar model. Additionally, the bivariate *cash and futures price* model clearly outperforms the bivariate *cash and basis* model with respect to both correct *HEDGE* and *NO HEDGE* signals.

The measured trading profits clearly show the superiority of the forecasts based selective hedging strategy over the routine hedging or cash marketing schemes. Trading is simulated with a fixed cost of $50.00 per contract per roundturn. Notice that once the hedge is in place, it is costless to continuously remain hedged in the same number of contracts afterwards. Only after a disruption of the continuous sequence of *HEDGE* signals has occurred (hedge was lifted), the establishment of the new position in the futures market would require additional expenditure. In other words, if the position in the futures market is already established, the cost of retaining the same position continuously through time is zero. Costs of hedging in our simplified model are associated only with changing the position in the futures market or entering it for the first time.

As seen from the Table 3, when profits are considered, both multivariate models are outperformed by the scalar model. The average profits in the entire period under consideration (all 6 subperiods) generated by the scalar model are 118.18 % larger than those obtained by the routine hedging strategy. Bivariate *cash and futures* model generates on average 63 % larger profits than the routine strategy, which was enough to outperform the *cash and basis* model with the profits of 28 % above the routine strategy.

The number of roundturns per period is fairly small. In fact, in the scalar model, the futures market was entered only one or two times. In case of one roundturn per period, the number of weeks a hypothetical trader was hedged corresponds to the number of *HEDGE* signals from Table 2. For example, it turns out that during the period from December 7, 1989 to May 31, 1990, the trader which used forecasts generated by the scalar model, entered the futures market once, and remained hedged for 4 consecutive weeks, making the profit of $1,010. In case of the multiple entry-exit, the average duration of the short hedge can be calculated as the ratio between the number of *HEDGE* signals and the number of roundturns.

## 5. CONCLUSIONS

Numerous simplifying assumptions are made in this paper. A simple decision rule is used ; no attempts are made to determine the optimal hedging ratio in the static framework, let alone in the intertemporal framework ; and opportunity costs of capital and cash flow problems are ignored. Also, no attempt is made to incorporate hedging strategy into the broader framework of optimal inventory management.

The objectives of the research can be summarized as follows :

i) to explore the linkage between the fishmeal and the soybean meal markets, and to forecast prices using an approach to modeling multivariate time series based on linear systems theory ;

ii) to utilize the information from the forecasting models to construct a selective hedging strategy ; and

iii) to test the performance of the forecasts by ex-post evaluation of the various hedging schemes.

The research results show the usefulness of state-of-the-art time series forecasting techniques in marketing fishmeal. Even without an established fishmeal futures market, the producers could still hedge in close substitute commodity with the viable futures market, and could significantly improve their marketing performance by combining the information from the forecasting models with an appropriate hedging strategy. With the use of personal computers, fishmeal producers can use the developed methodology as an effective marketing tool to improve profitability and sustainability of their operations.

A possible extension of this research lies in the possibility of adapting the forecasting methodology to model population dynamics of fish stocks which can help better management and utilization of limited marine resources.

## REFERENCES

**Aoki M.** (1987). *State Space Modeling of Time Series.* Berlin : Springer Verlag.

**Aoki M.** (1990). *State Space Modeling of Time Series.* 2d ed., Berlin : Springer Verlag.

**Brandt J.A.** (1985). "Forecasting and Hedging : An Illustration of Risk Reduction in the Hog Industry." *American Journal of Agricultural Economics* **67 :** 24-31.

**FAO** (1986). *The Production of Fish Meal and Oil* . Rome : FAO, Fisheries Department, Fisheries Industries Division. Fisheries Technical Paper 142, Rev.1.

**Kofi T.A.** (1973). "A Framework for Comparing the Efficiency of Futures Markets." *American Journal of Agricultural Economics* **55 :** 584-594.

**Kung S.Y.** (1978). "A New Identification and Model Reduction Algorithm via Singular Value Decomposition." In *Proceedings of the 12th Asilomar Conference, Pacific Grove, California.*

**Peck A.E.** (1975). "Hedging and Income Stability : Concepts, Implications and an Example." *American Journal of Agricultural Economics* **57 :** 410-419.

**U.S. Department of Commerce, NOAA, NMFS.** Current Fisheries Statistics ; Fish Meal and Oil, various issues.

**Vaccaro R.J.** (1986). "Finite-Data Algorithms for Approximate Stochastic Realization." In *Modelling and Application of Stochastic Processes*, ed. U.B. Desai. Boston : Kluwer Academic Publishers.

**Vaccaro R. and T. Vukina** (1991). "A Solution to the Positivity Problem in the State-Space Approach to Modeling Vector-Valued Time Series." Dept. of Resource Econ. Working Paper. Kingston : University of Rhode Island.

**Vukina T.** "(1991). *Hedging With Forecasting : A State-Space Approach To Time Series Modeling."* Doctoral Dissertation. Kingston : University of Rhode Island.

TABLE 1.
COMPARISON OF FORECASTING STATISTICS.

| OUT-OF-SAMPLE, ONE-STEP-AHEAD FORECASTING WITH UPDATING SYSTEM MATRICES | # OF FORC. | ZERO AUTO COV. | FORECASTING STATISTICS MSE | MAPE |
|---|---|---|---|---|
| BIVARIATE (CASH & FUTURES) MODEL: | | | | |
| k=2, n=2, obs=104-259 | 156 | | | |
| fishmeal cash | | 4554.0 | 216.1638 | 2.1608% |
| soybean meal futures | | 945.3 | 87.1687 | 2.5440% |
| BIVARIATE (CASH & BASIS) MODEL: | | | | |
| k=2, n=1, obs=104-259 | 156 | | | |
| fishmeal cash | | 4554.0 | 572.4982 | 2.3470% |
| basis | | 1726.4 | 351.3751 | 6.2967% |
| SCALAR (FUTURES) MODEL: | | | | |
| k=2, n=1, obs=104-259 | 156 | | | |
| soybean meal futures | | 945.3 | 73.6979 | 2.4336% |

TABLE 2.
FORECASTS GENERATED HEDGING SIGNALS.

| PERIOD | No. of Decision Points | No. of HEDGE Signals | No. of Correct Signals | % of Correct Signals | No. of NO HEDGE Signals | No. of Correct Signals | % of Correct Signals |
|---|---|---|---|---|---|---|---|
| ***BIVARIATE MODEL: (cash+futures)*** | | | | | | | |
| Jun.2,1988–Nov.24,1988 | 25 | 24 | 12 | 50.00% | 1 | 0 | 0.00% |
| Dec.1,1988–May.25,1989 | 25 | 22 | 11 | 50.00% | 3 | 2 | 66.67% |
| Jun.1,1989–Nov.30,1989 | 26 | 12 | 8 | 66.67% | 14 | 7 | 50.00% |
| Dec.7,1989–May.31,1990 | 25 | 18 | 9 | 50.00% | 7 | 4 | 57.14% |
| Jun.7,1990–Nov.29,1990 | 25 | 18 | 11 | 61.11% | 7 | 5 | 71.43% |
| Dec.6,1990–May.23,1991 | 24 | 16 | 12 | 75.00% | 8 | 8 | 100.00% |
| TOTAL | 150 | 110 | 63 | 57.27% | 40 | 26 | 65.00% |
| ***BIVARIATE MODEL: (cash+basis)*** | | | | | | | |
| Jun.2,1988–Nov.24,1988 | 25 | 23 | 12 | 52.17% | 2 | 1 | 50.00% |
| Dec.1,1988–May.25,1989 | 25 | 19 | 12 | 63.16% | 6 | 6 | 100.00% |
| Jun.1,1989–Nov.30,1989 | 26 | 18 | 12 | 66.67% | 8 | 5 | 62.50% |
| Dec.7,1989–May.31,1990 | 25 | 18 | 8 | 44.44% | 7 | 3 | 42.86% |
| Jun.7,1990–Nov.29,1990 | 25 | 21 | 10 | 47.62% | 4 | 1 | 25.00% |
| Dec.6,1990–May.23,1991 | 24 | 21 | 12 | 57.14% | 3 | 3 | 100.00% |
| TOTAL | 150 | 120 | 66 | 55.00% | 30 | 19 | 63.33% |
| ***SCALAR MODEL: (futures)*** | | | | | | | |
| Jun.2,1988–Nov.24,1988 | 25 | 24 | 13 | 54.17% | 1 | 1 | 100.00% |
| Dec.1,1988–May.25,1989 | 25 | 24 | 12 | 50.00% | 1 | 1 | 100.00% |
| Jun.1,1989–Nov.30,1989 | 26 | 7 | 5 | 71.43% | 19 | 9 | 47.37% |
| Dec.7,1989–May.31,1990 | 25 | 4 | 3 | 75.00% | 21 | 12 | 57.14% |
| Jun.7,1990–Nov.29,1990 | 25 | 1 | 1 | 100.00% | 24 | 12 | 50.00% |
| Dec.6,1990–May.23,1991 | 24 | 1 | 1 | 100.00% | 23 | 12 | 52.17% |
| TOTAL | 150 | 61 | 35 | 57.38% | 89 | 47 | 52.81% |

**TABLE 3.**
**PROFITS FROM HEDGING 100 TONS OF FISHMEAL USING SOYBEAN MEAL FUTURES.**

| PERIOD | CASH MARKETING | *Cost = $50.00 per Contract per Roundturn* | | | | | |
|---|---|---|---|---|---|---|---|
| | | ROUTINE HEDGING | SELECTIVE HEDGING | | | | |
| | | | Bivariate Model (Cash+Futures) | | Bivariate Model (Cash+Basis) | | Scalar Model (Futures) | |
| | Profits | Profits | Profits | No. of Turns | Profits | No. of Turns | Profits | No. of Turns |
| Jun.2,1988–Nov.24,1988 | $3,000 | $80 | $0 | 2 | –$1,070 | 2 | $3,410 | 2 |
| Dec.1,1988–May.25,1989 | –$10,500 | $900 | $610 | 1 | $3,350 | 2 | $1,280 | 2 |
| Jun.1,1989–Nov.30,1989 | $0 | $640 | $1,640 | 9 | $1,480 | 4 | $700 | 2 |
| Dec.7,1989–May.31,1990 | –$4,500 | –$240 | –$510 | 6 | –$910 | 2 | $1,010 | 1 |
| Jun.7,1990–Nov.29,1990 | $3,500 | $1,040 | $2,020 | 5 | $280 | 1 | $310 | 1 |
| Dec.6,1990–May.23,1991 | –$4,000 | $770 | $1,450 | 5 | $940 | 3 | $250 | 1 |
| TOTAL | –$12,500 | $3,190 | $5,210 | 28 | $4,070 | 14 | $6,960 | 9 |
| *Percent of Routine Hedge* | | 100.00% | 163.32% | | 127.59% | | 218.18% | |

**FIG. 1.**
**FISHMEAL ATLANTA CASH PRICES AND CBOT SOYBEAN MEAL DECEMBER FUTURES PRICES.**

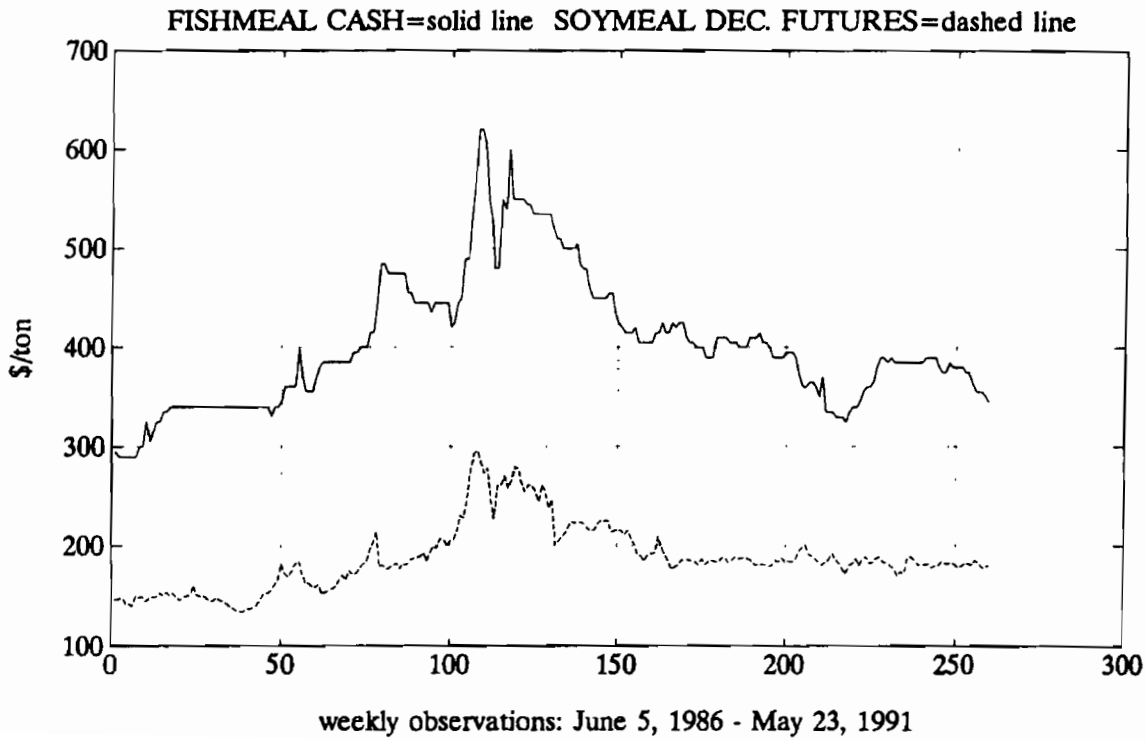
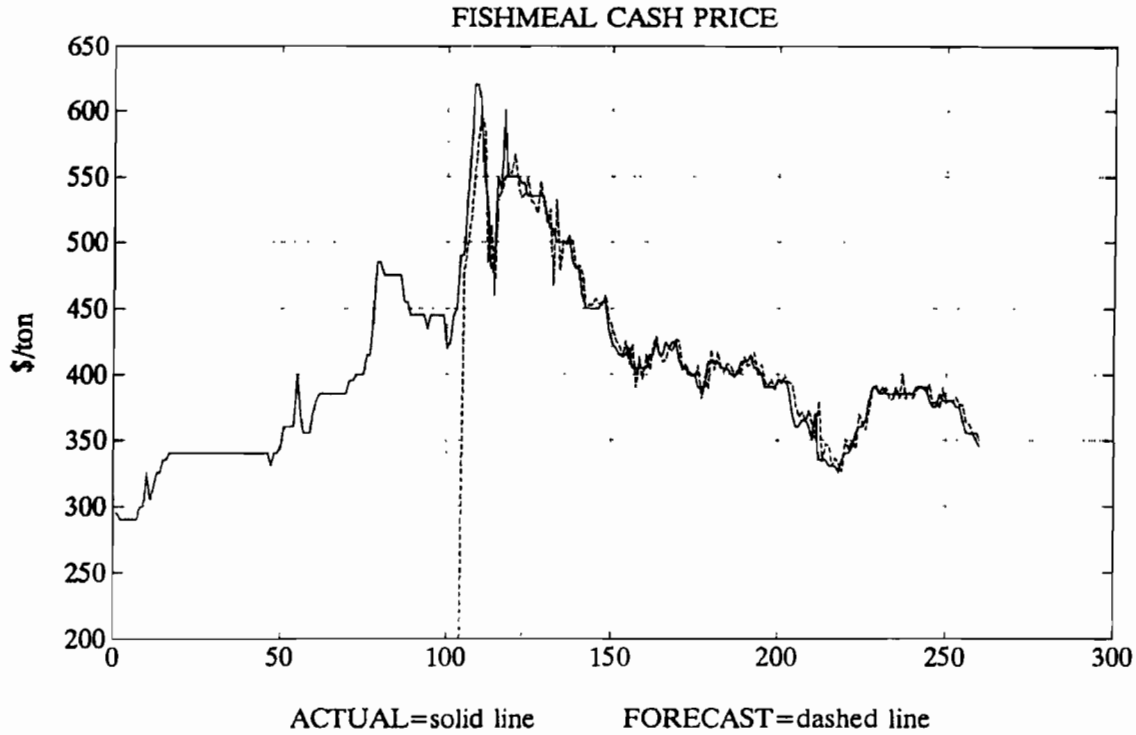


**FIG. 2.**
**ONE-STEP-AHEAD FORECASTS FROM A BIVARIATE (CASH & FUTURES PRICE) MODEL IN THE JUNE 2, 1988 - MAY 23, 1991 PERIOD.**



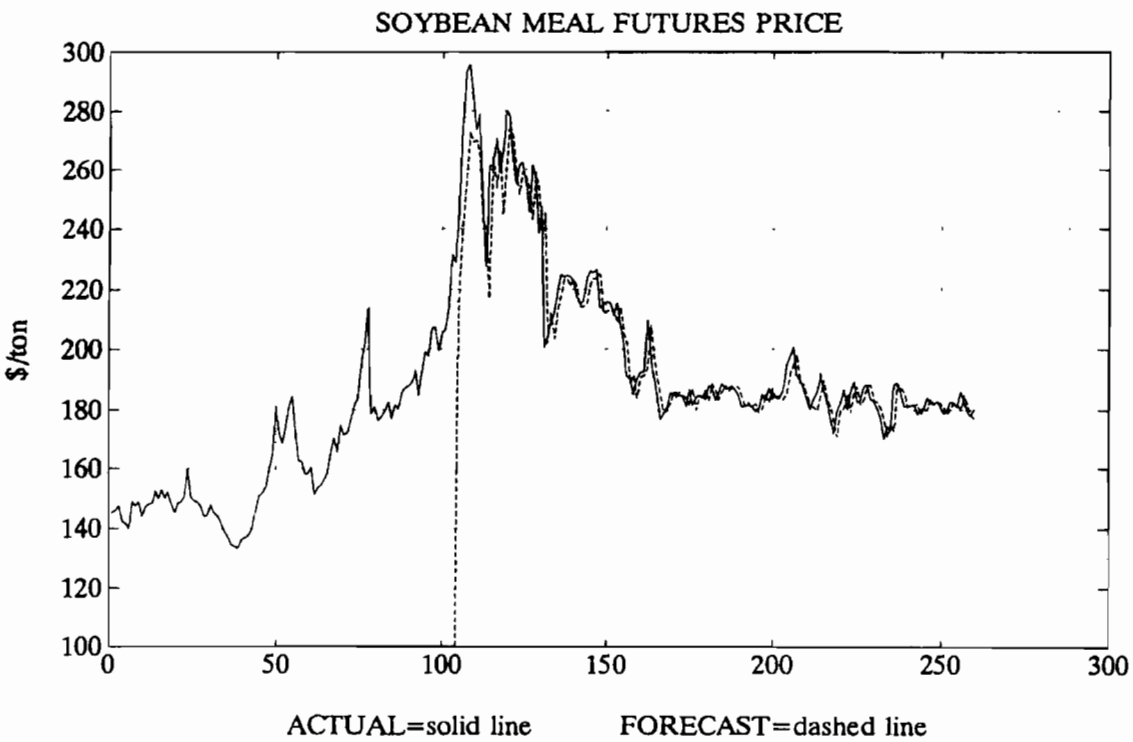
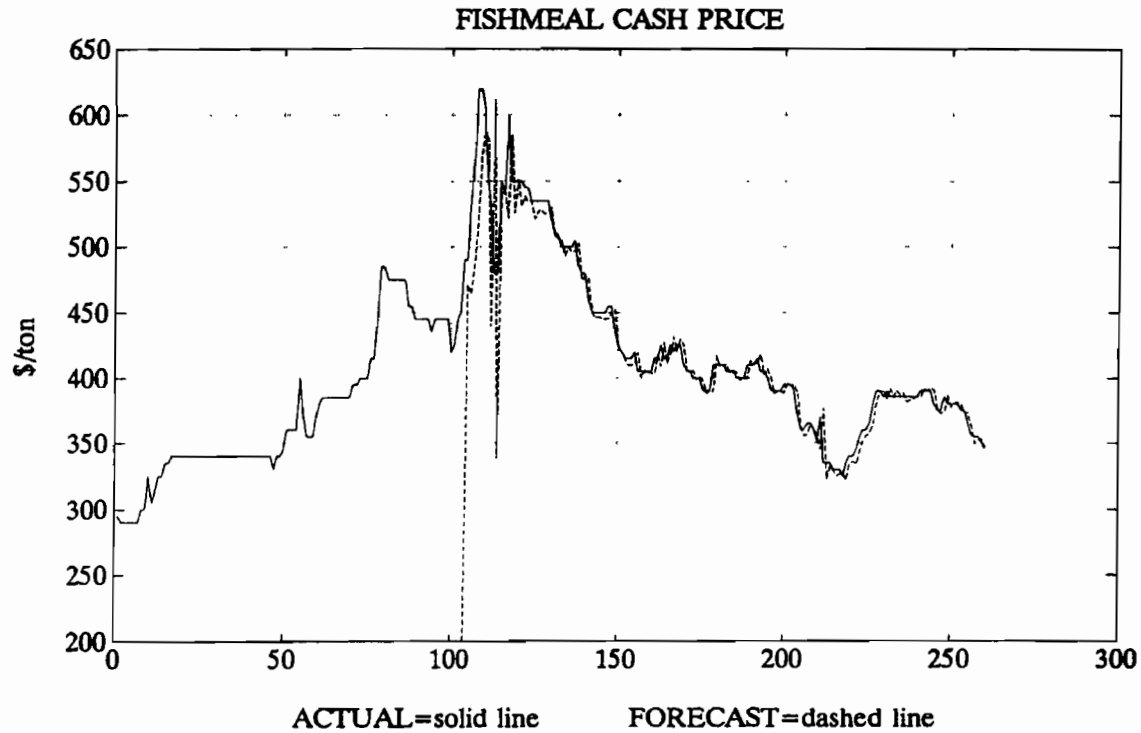



FIG. 3.
ONE-STEP-AHEAD FORECASTS FROM A BIVARIATE (CASH & BASIS) MODEL IN THE JUNE 2, 1988 - MAY 23, 1991 PERIOD.



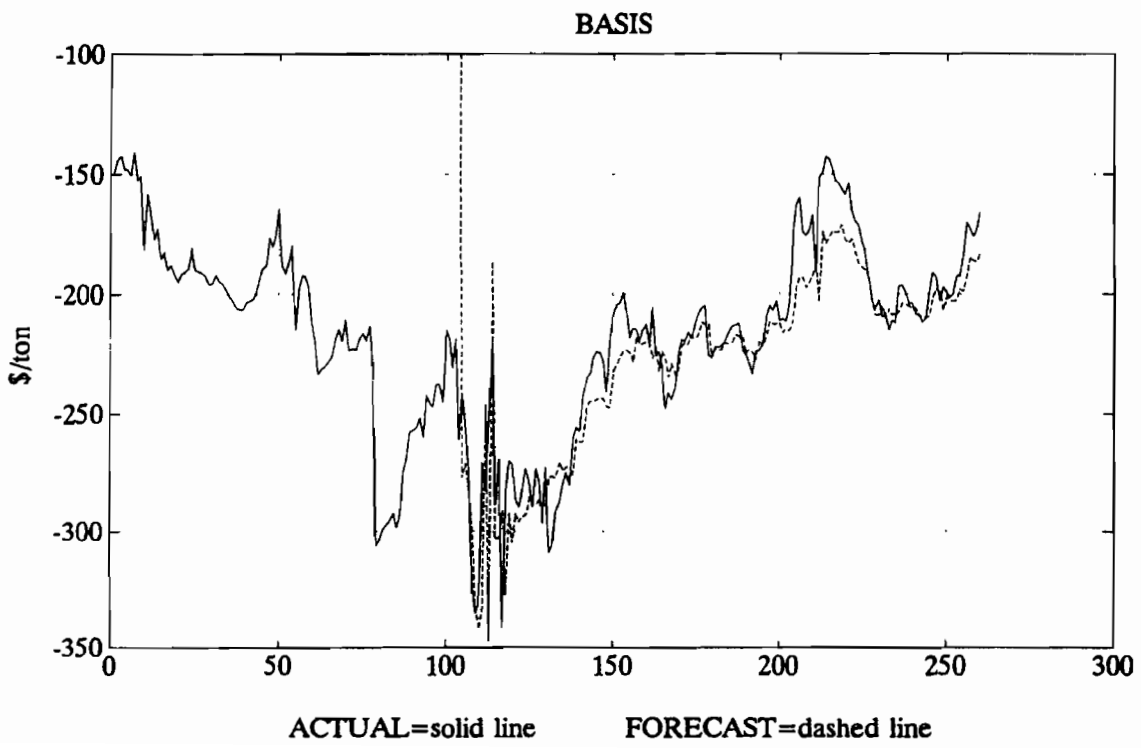
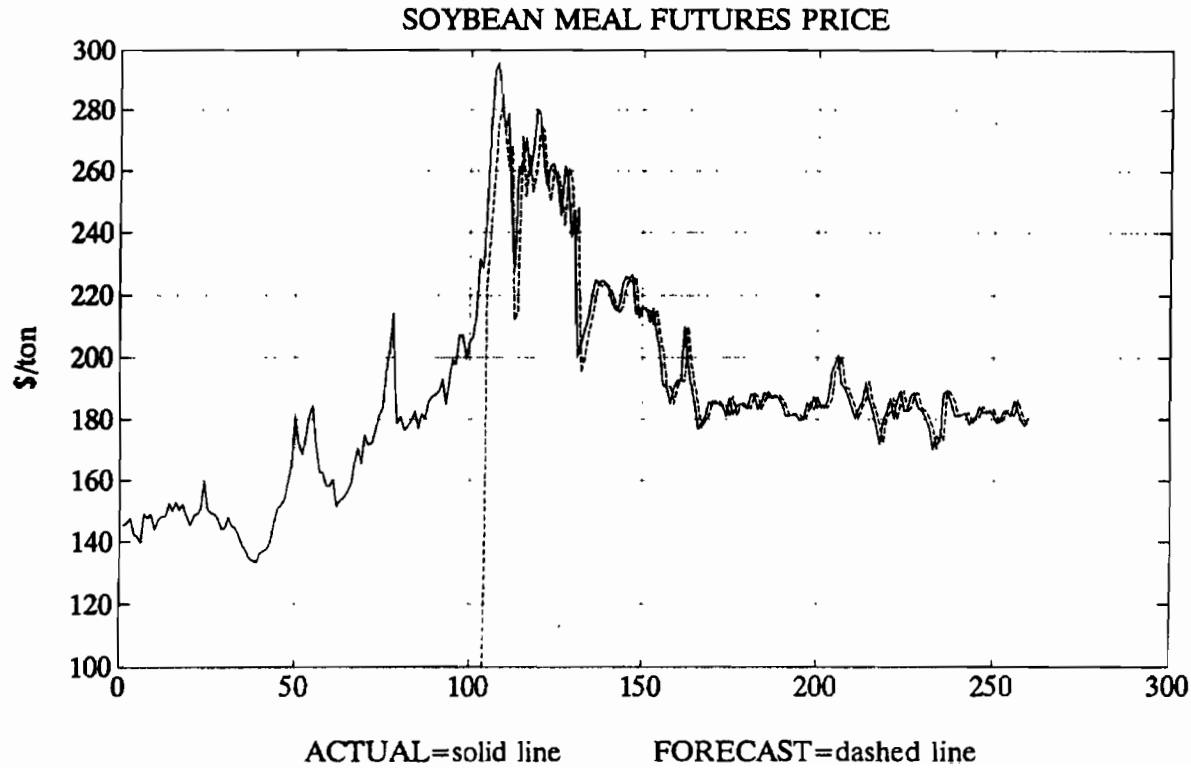



**FIG. 4.**
**ONE-STEP-AHEAD FORECASTS FROM A SCALAR (FUTURES PRICE) MODEL IN THE JUNE 2, 1988 - MAY 23, 1991 PERIOD.**



# Market Analysis Institutional Behaviour and Marketing of Fish in Portugal

**Salviano Cruz**

Estudos Económica Sociais. Rua Duque De Palmela, 27, 4°E 1200 Lisboa, Portugal

ABSTRACT

*Production of fish (landings) has been declining sharply since 1963, which has caused large imports and exports of fresh and frozen fish. Landings from continental waters have been strongly declining, which has provoked a rise in a new search for foreign fishing grounds and new sources of fishing supplies.*

*Prices of fish have increased sharply both in the producer price and to the consumers, due to monopolistic practices and abuse of economic power.*

## 1. DECLINE OF FISH CATCHES AND LANDINGS IN PORTUGAL.

The main tendency has seen a strong decline of fish catches and landings in Portugal over these years, both in total and also for the main species. Catches of fish have declined from 424.982t in 1965, to 343.942t in 1979, to a peak minimum of 273.681t in 1985. From this year on landings have picked up, continuing to rise to 403.303t in 1986, declining again to 385.600t in 1987, with a continuous decline in the years 1988 to 350.300 and 331.000t in 1989, see tables 1 and 3. Table I, indicates landings for 22 out of 25 main species landed in 1965, 1979, 1985 and 1989, indicating rise in prices.

We can see the main decline of various species including cod, which from landings of 71.280 t in 1965 to 41.450t in 1979, with a rise to 16.721t in 1979 increasing to 19.342t in 1989. From this table we can verify the importance which the cod fish industry represents in the species landed in Portugal. In 1965 this species was second only to sardine which landings were 137.931t. In 1979 landings of sardine was 101.150t occupying first place in the structure of the wholesale market in Portugal.

In 1989 sardine landings were 91.263t while cod landings were 19.342t, declining from second to third place after horse makerel (carapau) whose landings declined from 27.678t in 1965 to 26.735t in 1989.

Some species like dentex and sea bream are declining or disappearing. However new species like secabard (peixe espada) have appeared in relatively large quantities as "white" or "black". In 1965 landings of these species were 5.623t, rising to 7.747t in 1979. In 1989 landings were 5.461t for white and 3.552t for black. White occurs in the central and southern fishing zones of Portugal, while black "peixe espada" is mainly caught around the Sesimbra area located 50 kilometres south of Lisbon and also in the Madeira fishing grounds with 2.724.2t in 1988 and 2.476.5t in 1989.

Cod landings, have been declining strongly since 1965 and particularly, after the fixing of the 200 mile limit by Canada, Norway and Iceland and other countries. This makes Portugal a large importing country in place of a surplus fishing country before the 1960's, see table 3 Catches of the Portuguese Fishing Fleet 1986-1989.

In 1965 Portugal had a production of landings of 71.280t of cod, this declined to 41.450t in 1979, reducing to 16.721t in 1985, but increasing in 1989 to 19.932t.

Currently, Canadian fishing organizations are opposing the foreign fleets of Portugal and Spain alleging that these two fleets have destroyed the stocks of cod in the Canadian fishing grounds.

This accusation has no foundation, as the canadian fleet has also contributed to this situation of stock depletion by over fishing. Moreover, Canada needs to reorganize its own cod fishing industry along the coast where monopoly oligopolies and oligopsonies prevail. It seems that Canada wants to hold the control of cod by dominating fishing trade of the world, through quotas which again is a violation of Article 852 and 862 of EEC.

## 2. QUANTITIES AND PRICES 1987 - 1989
## LANDINGS OF FISH IN CONTINENTAL PORTUGAL AND AVERAGE PRICES

Table II indicates landings for the main species during the years 1987/1989, with variations. Total landings in 1987 was 224.573t with an average price varying from Esc.159$47 in 1987 to Esc. 199.40 $ in 1989 for 217.177.4t.

European Anchovy, landings were 1.621.6t at prices Esc.273.20 $ in 1987 declining to .774.0t at prices Esc.216$0, in 1989 rising to 822.9t at Esc.334.60$ in 1989.

Horse mackerel, landings declined from 31.112t to 26.775t in 1989 prices incresead from Esc. 149.90 $ in 1982 to Esc. 180.30 $ in 1989.

Congre landings in 1987 were 1852t for Esc.314 ;40 $ increasing to 21204t in 1988 at Esc. 351.90 $ declining to 2078t at prices Esc. 356.30 $ in 1989.

Secabard, there are two types of this species : white and black.

Landings in 1987 were 3.328.7t at Esc.188.5, rising in 1987 varying from Esc. 122.60 $, to Esc. 159.20 $ in 1988 for 384.4t rising, to 3.552.7t at prices Esc. 185.50 $ in 1989. Secabard white, landings were 4.249.8t at Esc. 304.70 $ in 1987 rising to 4673t ; price rose to Esc. 332.90 $ in 1988, declining to 4531.7t at Esc. 376.30 $ in 1989. The main landings centre for these species is Sesimbra 3.521.2t for black secabard and 3.976.6t in 1989 see Table V.

Faneca landings were 4.298t at price Esc. 198.10 $ declining to 2.883 tons in 1989 at price Esc. 302.30 $. Sole landings were 1.550t at price of Esc.1.159.00 $ in 1987 declining to 988.3t in 1988 at prices Esc.1.195.80 $ rising to 1.200.01 at price Esc.1.155.50 $ in 1989.

Hake, landings were 8.595.5t at price Esc. 587.00 $, in 1987, in 1988 landings were 6.470.1t at price of Esc. 688.90 $ and 5.416.5t at Esc. 702.60 $ in 1989.

Rays, landings were 2.760.02t at Esc. 116.70 $ in 1987, declining to 2.201.49t at price of Esc. 147.20 $ declining to 1.874.7t price Esc. 218.20 $ in 1989.

Seabream, landings were 358.9t at price of Esc.1.146.90 $ rising to 463.7t at price Esc.1.314.80 $ in 1988, rising to 629t at a price of Esc.1.459.50 $, in 1989.

Sardines, finally, we come tot eh sardine ; the species with the largest landings 90.199.6t at a price of Esc. 31.70 $ in 1987, rising to 94.836.1t at Esc. 38.30 $ in 1988, and declining again to 91.236t at price Esc. 42.00 $.

Monkeyfish, landings were 2.088.1t in 1987 at price of Esc. 470.10 $/kg, declining to 1.911.7t, at price of esc. 593.80 $ and still declining to 1.837.9t at price of Esc. 611.10 $.

Tuna and similar landings in 1987 in the continent were 587.8 tons selling at Esc. 238.2/kg, rising to 638.9t at price of Esc. 239.90 $, in 1988 declining to 238.2t at Esc.238.50 $ in 1989.

Kolb landings in 1987 were 390.1t at price Esc. 653.30 $, declining to 284.1t at Esc.882.31. in 1989 18.257t at price Esc. 354.00 $.

Average price for tuna landed in Azores for 1989 were Esc. 110.00 $ per kg, 8.800t. In Madeira landings of tuna in 1988 were 1.728.9 at Esc. 212.90 $, landings in 1989 were 3.744.0t at an average price of Esc. 140.70 $ /kg. Major species in Madeira besides tuna was Peixe Espada Preto, secabard black, 2.724.2t at price Esc. 217.10 $ in 1988, and 2.476.5 in 1989 price of Esc. 225.60 $.

Sources : Recursos das Pescas Estatiscas vol. 3A-B Aug. 1991, vol 2A-B 1980 Oct 1989, Gabinete Estudos e Planeamento das Pescas.

In table 3 we can compare catches and landings for the period 1986/89 by species and main fishing grounds supplying Portugal. Statistics of table 3 for continental Portugal, Azores, Madeira and Spain refers to landings by species. We compare the quantities landed for the fishing grounds.

*CECAF.*

In this traditional Portuguese fishing ground covering Marrocos and Mauritania catches varied from 20.300t in 1986 to 17.600t. Morrocos and Mauritania catches varied from 20.300t in 1986 to 14.600t in 1988, and 18.72 in 1989, see TABLE III.

*Northern Atlantic.*

Northern Atlantic catches of fish declined from 103.200t in 1986 to 42.700t in 1988. and 32.239.3t in 1989 NATO fishing ground catches declined from 98.100t in 1986 to 49.760t in 1989. Major decline in catches was cod with 43.100t in 1986 to 13.600t in 1988, and 24.128.0t in 1989. Redfish catch also declined from full 32.500t to 19.100t in 1988 and 18.820t in 1989, catches of other species aslo declined from 22.400t to 8.200t, in 1988.

Norway/Svolbank production catches declined from 5.100t in 1986 to 2.869t in 1988, and 1.272.6t in 1989. The catch of cod was 3.500t in 1986 to 0.49t in 1988, and to 339.7t in 1989, see TABLE III.

*Southern Atlantic.*

ICSEAF - Catches increased from 36.300t in 1986 to 44.000t in 1988. This was reduced to 35.800t in 1989. In 1989 catches in ICSEAF fishing grounds for the Portuguese fleet were, 17.800t for hake, 8.274t of other species, totaling 26.154t. However, Namibia appeared for the first time with a catch of 24.585t, South Africa had catches of 1.569t, Falklands 9.676t, totaling 35.830t.

Total catches for all fishing grounds, declined from 404.300t in 1988 to 331.007t in 1989 catches of fish have declined in all fishing grounds, but particularly in National Waters, see TABLE III.

Landings of Processed and Production of Fresh, Frozen, Smoked, Canned, Fish Meal and Fish Oil Industries.

Table 4 indicates the production of landings of fish since 1966-1989, and also processed fish.

Frozen fish industry grew from 361t in 1965 to 63.000t in 1986, declining to 50.299.10t in 1989. National production of canned fish increased from 42.789t in 1987 to 50.745t in 1989. For production of canned frozen and salted fish in the period of 1987 - 1989 we have a total of 114.500.9t in 1987 increasing to 112.665t in 1989.In addition to manufactured fishing industry, the Portuguese Fleet is also processing fish on board in the coastal fleet. Production of 51.2 tons from

the coast of Portugal and 37.801t from the North Atlantic ; 7.214t from Halvinas, which is a new fishing ground for the fleet, that has to look for new sources of fish, supplies, due to the closing of the Canadian fishing grounds, by the establishment of 200 mile limit.

This is a very vertically integrated industry, as the majority of the large industrial processors are also the fleet seiners and have their own companies for frozen and fresh fish production, export and import and drying units for cod.

This also shows the specialization by auction markets for certain species, e.g. Matozinhos - "sardines, Sesimbra -"black secabard fish" ; Olhao - "hake". It has not been possible to include the statistics for 1990 & 1991 as they are not reportedly available from the Gabinete Estudos e Planeamento das Pescas or their supplying source, which are prohibited from supplying those statistics.

The statistics available for 1989 refers to landings in tonnage and average values for Matozinhos, Peniche, Lisbon (DOCAPESCA), Sesimbra, Olhao.

Matozinhos with 34.485.8t for sardines the leading species at an average value of Esc. 42.60 $ compares to Peniche with 18.150.8t, at an average value of Esc. 47.30 $. Matozinhos is also the leading trade centre for horse mackerel 7.073.4t at an average value Esc. 210.40 $ ; Peniche with 5.169.0t at an average value of Esc.188.30 $ ; 251.40 $ /kg and landings of 1.537.8t in Sesimbra. Sesimbra is also the leading centre for black secabard, with Madeira.

As for hake, Olhao had a leading position of 1.354.3t at an average value of Esc.826.90 $, which was also the highest price paid in these 5 leading fishing markets.

*Price Spreads and Differentials Between Fishermen and Consumers.*

Price spreads between producers or fishermen are very high for many species as can be seen from TABLE VI, for the period 1987 to 1989. The main price spreads are for horse mackerel, national and imported, seabream, secabard, and also imported hake. This table indicates spreads or differences of prices between the producer or importers on one side, and consumers on the other, from 1987 to 1989. Horse mackerel has a price in the producer of Esc 140.60 $ and a price to the consumer of Esc 326.40 $. In 1989 price in the producers increased to Esc 164.80 $ and to the consumer Esc 362.90 $.

These high price spreads are due to intensive concentration in this industry, particularly in fresh, frozen, refrigerated and canned sectors. As will be shown in another study on the International Monopolistic Aspects of World Trade of Fishing Industries in Portugal, which will also be presented at this VI IIFET Conference. However, TABLE VI will indicate, price differentiations by types and categories of cod fish for 1989 and 1990.

*Price Differentiations by Qualities, Categories, Geographic Locations and Types of Craft (Fishing gear).*

There is also differentiating price by geography locations of landings, regions, by qualities, and categories vary for trawler, polivalente and cerco, as shown in statistics below. Prices vary for horse mackerel, TABLE VIII.

Price differentiation is also for hake, for trawler polivalente and cerco. There are differentials in prices by categories qualities of fish (cod) and price differentiation by typing of craft and regions for horse mackerel and hake, as follows.

*Price Differentiations of cod by Quality and Category.*

Prices of codfish varies by types and categories of fish which different as follows[1] :

| | 1989 | 1990 |
|---|---|---|
| 1. Special | 1.105,00 $ | 1.320,00 $ |
| 2. Matured | 1.000,00 $ | 1.230,00 $ |
| 3. Grown | 870,00 $ | 1.020,00 $ |
| 4. Corrent | 720,00 $ | 795,00 $ |
| 5. Small | 577,00 $ | 625,00 $ |
| 6. Big assorted | 520,00 $ | 560,00 $ |

In addition to this difference there is differentiation by type of craft and regions, as follows for 1989, as related to hake and horse mackerel in table 7.

Price differentiation also varied by fishing grounds or countries of origin. Price of hake from South Africa is higher than from Chile of Argentina. Price of cod from Iceland and Norway is more expensive than Canada or Spain.

## 3. CONCLUSIONS

1. Production of fish catches and landings have been declining strongly since 1963 to the present time, particularly landings from continental Portugal and Madeira Islands, and Azores.

2. This has led to strong imports of fresh and frozen fish and also processed fish on board, which has been an important innovation.

3. Price of fish by species has increased strongly in the producers or fishermen, but much less, than the increase in price to the consumers. In many cases this difference or spread, of fish prices, has been 300 % to 650 %. Due not only to the shortage of fish but also to the large price spreads between producer and consumer, fixed by monopolistic groups in the form of oligopolies and oligopsonies, which have replaced the former totalitarian government monopolies and corporative guilds.

Because the Portuguese government has refused to take action and also to undertake the necessary scientific studies. On the other hand, the Directorate general of Competition of EEC also refused to study this problem and take action according to their letter of 20/4071991 ref 0037321.

4. the Portuguese government has refused also to supply updates statistics on landings, prices, processing, imports and exports and aslo the heavy concentration of quantities and prices of species purchased in the main wholesale auction markets in Portugal. they allege that they have to protect individual firms. In so doing they are not really protecting the numerous small firms operating in the market under free competition under EEC regulations. In fact, they are really shielding the large and the influential, which are operating as trusts or oligopsonies and monopsonies in the market of fresh, frozen, canned and codfish. In exchange for this protection, these firms are reportedly major contributors to the main Portuguese political parties.

5. There are no statistics available since 1989 from Gabinete, a Estudos e Planeamento das pescas. In denying these statistics and blocking scientific research in the economics of fisheries, the Portuguese government, is impeding the realistic knowledge of fisheries in Portugal today.

6. These depth studies are also justified to verify to what extent those firms are responsible for the rise of prices to consumer, contributing also to the rise of inflation.

7. Moreover, the Directorate General of Prices and Competition of Portugal has not studied high prices spreads of fish caused by abuse of economic power in form of oligopolies and monopsonies.

1. Data from CRCB.

8. Also.Direcçäo Geral de Inspecçäo.Economica, Inspection of Supervision for Economic Activity, has also refused to study of high price spreads of fish, alleging they cannot intervene or interfere because of the rules of the EEC guaranteeing free competition, according to their letter of July 15th, 1991 ref 004425. They both confuse free competition with freedom to monopolise and speculate.

9. The monopolist aspects of fish monopolies in Portugal will be treated in a separate paper, also presented in this VI IIFET Conference.

10. We may conclude that there has been a decline in landed fish in Portugal with an increase in price. The decline of supply can be due to the depletion of stocks, but it can also be bcause of the influence of monopolistic practices. It is a well known fact that the existence of monopolies in fishing leads to the depletion of stocks.

11. Although the Portuguese Government claims to have invested over 50 million contos(£12.5 million) for the renewal of the fleet, only large vessel owners also operating processing units for frozen fish and drying cod, and also wholesalers operating as oligopsonies under vertical integration, they have been the main bonifarctors. Consumers ans small fishermen interests have been jeopardize. Moreover, the Government did not undertake economic studies, for planning and justify such investments to benefit the consumer, and the small fishermen.

There has been a recent ministerial reform extinguishing Gabinete das Estudos e Planeamento das Pescas, IPCP Instituto Portugues de Conservas Ipescado, Inspecçäo Geral das Pescas, and Instituto Investigaçäo das Pescas, alleging too many people which absorb 2/3rds of the budget, the point is that none of these organizations undertook the necessary research required for the development of fisheries.

**TABLE I**
**CATCHES AND LANDINGS IN CONTINENTAL PORTUGAL 1965, 1979, 1985 AND 1989. MAJOR LANDINGS OF SPECIES IN TONS**

| SPECIES | 1965 | 1979 | 1985 | 1989 |
|---|---|---|---|---|
| 1. Cod | 71.280 | 41.450 | 16.721 | 19.342 |
| 2. Sardine | 137.931 | 101.150 | 111.887 | 91.263 |
| 3. Spanish Mackerel | 36.642 | 28.009 | 7.665 | 3.113 |
| 4. Horse Mackerel | 27.678 | 17.616 | 16.662 | 26.775 |
| 5. Mackerel | 29.463 | 21.646 | 11.523 | 6.449 |
| 6. Hake | 3.327 | 27.125 | 19.691 | 5.461 |
| 7. Whiting | 5.014 | 4.937 | 1.290 | - |
| 8. Small Hake | 10.920 | 3.240 | 5.074 | - |
| 9. Silver secabard | 5.623 | 7.747 | 5.074 | 4.531 |
| Black secabard | | | | 3.552 |
| 10. Dentex | 3.442 | 2.886 | .849 | - |
| 11. Faneca | - | 2.280 | 3.178 | 2.883 |
| 12. Tuna | 3.534 | 9.395 | 9.330 | 12.081 |
| 13. Seabream | 4.340 | 4.443 | .806 | 602 |
| 14. Monkeyfish | - | - | - | 1.837 |
| 15. Robalo Sea Bass | - | - | - | 629 |
| 16. Other Species | 73.875 | 90.987 | - | 18.808 |
| CRUSTACES | | | | |
| 17. Lobster | 364.000 | 140.000 | 864.000 | 863.000 |
| 18. Shrimp | 584.000 | 651.000 | - | 175.000 |
| MOLUSCOS | | | | |
| 19. Calamar | 2.461 | 6.230 | - | 1.292 |
| 20. Octopus | 1.187 | .763 | - | 10.412 |
| 21. Cuttlefish | 2.619 | 1.062 | - | 1.582 |
| 22. Other Species | 1.977 | - | - | 8.837 |
| TOTAL CATCHES | 424.982 | 342.917 | 273.681 | 331.007 |

**TABLE II**
**LANDINGS OF FISH IN CONTINENTAL PORTUGAL AND AVERAGE PRICES ESC. /KG.**

| SPECIES | 1987 | | 1988 | | 1989 | |
|---|---|---|---|---|---|---|
| | TONS | PRICE | TONS | PRICE | TONS | PRICE |
| Bedejo | 2.518.0 | 361.00 | 1.525.9 | 528.80 | 406.2 | 595.70 |
| European Anchovy | 1.621.6 | 273.20 | 744.0 | 216.00 | 822.9 | 334.60 |
| Horse Mackerel | 31.112.8 | 149.90 | 28.841.9 | 165.50 | 26.755.5 | 180.30 |
| Mackerel | 8.429.8 | 46.70 | 4.081.9 | 72.80 | 6.449.4 | 41.30 |
| Congres | 1.852.9 | 314.40 | 2.204.4 | 351.90 | 2.078.8 | 356.30 |
| Secabard Black | 3.328.0 | 122.60 | 3.384.8 | 159.00 | 3.552.7 | 188.50 |
| Swordfish | 518.0 | 534.00 | 313.3 | 673.60 | 168.9 | 642.70 |
| Feneca | 4.298.0 | 198.10 | 3.547.3 | 263.70 | 2.883.0 | 302.30 |
| Sole | 1.559.0 | 1.159.00 | 988.3 | 1.195.30 | 1.200.0 | 1.155.00 |
| Pargos | 827.7 | 712.00 | 743.8 | 922.60 | 642.6 | 1.026.80 |
| Secabare White | 4.249.8 | 304.70 | 4.673.0 | 332.90 | 4.531.7 | 376.30 |
| Hake | 8.595.5 | 567.00 | 6.470.1 | 683.90 | 5.461.5 | 702.60 |
| Rays | 2.762.0 | 116.70 | 2.201.4 | 187.20 | 1.874.7 | 218.20 |
| Robalo | 358.9 | 1.146.90 | 493.7 | 1.314.50 | 629.0 | 1.458.00 |
| Spanish Mackerel | 5.532.1 | 57.30 | 4.348.1 | 61.00 | 3.113.5 | 48.40 |
| Sardine | 90.199.6 | 31.70 | 94.636.1 | 38.30 | 91.236.0 | 42.00 |
| Flounders | 248.5 | 305.10 | 220.1 | 397.00 | 185.9 | 395.90 |
| Monkeyfish | 2.088.1 | 470.10 | 1.911.7 | 593.8 | 1.837.8 | 611.10 |
| Xaputa | 490.8 | 187.70 | 322.3 | 267.60 | 289.3 | 300.50 |
| Tuna | 567.8 | 237.2 | 638.8 | 239.90 | 238.2 | 228.30 |
| Kolb | 390.1 | 653.20 | 284.1 | 815.10 | 256.4 | 882.30 |
| Clams | 1.232.3 | 138.90 | 1.335.1 | 165.60 | 715.4 | 135.00 |
| Cuttlefish | 1.459.3 | 396.00 | 1.906.1 | 413.20 | 1.589.6 | 480.00 |
| Squids | 1.295.3 | 477.50 | 1.058.8 | 625.70 | 1.214.6 | 611.50 |
| Octopus | 8.964.4 | 257.70 | 8.151.0 | 363.10 | 10.410.0 | 410.90 |
| Flying Squids | 914.7 | 190.00 | 429.3 | 251.20 | 369.8 | 279.00 |
| Shrimps | 166.7 | 1.366.30 | 147.8 | 1.571.30 | 175.5 | 1.200.00 |
| "Gambas" Prawns | 37.1 | 2.860.50 | 63.8 | 2.353.80 | 445.8 | 1.154.00 |
| Lobster | 299.6 | 1.838.20 | 733.0 | 1.613.90 | 883.3 | 1.483.30 |
| "Lagostin" | 1.626.1 | 1.212.80 | 1.211.5 | 1.887.30 | 508.7 | 1.723.00 |
| TOTAL | 224.573.0 | 139.40 | 209.131.8 | 186.60 | 217.117.4 | 199.40 |

**TABLE III**
**LOCATION OF FISHING GROUNDS, CATCHES AND LANDINGS BY SPECIES.**
**CATCHES FROM 1986 - 1989 IN 1000 TONS**

| AREAS & PRINCIPLE SPECIES | 1986 QUANT. | 1987 QUANT. | 1988 QUANT. | 1989 QUANT. |
|---|---|---|---|---|
| NATIONAL WATERS | 244.5 | 236.7 | 242.7 | 221.3 |
| Continental Coast | 218.2 | 210.0 | 212.9 | 196.2 |
| Sardine | 103.0 | 90.2 | 94.2 | 91.2 |
| Horse Mackerel | 28.0 | 28.0 | 24.9 | 26.7 |
| Octopus | 4.0 | 9.0 | 17.0 | 10.4 |
| Verdinho | 8.0 | 9.1 | 6.1 | 3.5 |
| Dourada & similar | 3.0 | 3.9 | 5.7 | .1 |
| Hake | 8.0 | 6.9 | 5.5 | 5.4 |
| Spanish Mackerel | 6.0 | 5.5 | 4.1 | 3.1 |
| Mackerel | 9.0 | 8.4 | 3.8 | 6.4 |
| Feneca | 0.0 | 0.0 | 3.7 | 2.8 |
| Black Silverfish | 0.0 | 0.0 | 3.4 | 3.5 |
| Azores | 18.8 | 19.7 | 22.2 | 16.3 |
| Bonito & Serrajao | 5.0 | 8.2 | 13.7 | - |
| Tuna | 4.0 | 4.1 | 7.6 | 8.8 |
| Horse Mackerel black | 3.0 | 3.0 | 3.0 | 2.8 |
| Madeira | 7.5 | 6.6 | 7.6 | 8.8 |
| Black Silverfish | 2.0 | 2.3 | 2.7 | 6.3 |
| Black Horse mackerel | 2.0 | 1.6 | 1.7 | 1.5 |
| Tuna & similar | 2.0 | 0.7 | 1.7 | 3.7 |
| Mackerel | 1.0 | 1.6 | 0.6 | 0.6 |
| SPANISH WATERS | - | 2.4 | 3.3 | 2.2 |
| ATLANTIC CENTRAL | 20.3 | 15.3 | 17.8 | 18.7 |
| Marrocos / Mauritania | 20.3 | 13.0 | 14.6 | 15.9 |
| Horse Mackerel | 5.2 | 3.1 | 2.2 | - |
| Silverfish | 1.4 | 1.5 | 2.0 | - |
| Hake | 2.1 | 1.2 | 1.0 | - |
| Rabeta and similar | 0.5 | - | 0.9 | - |
| Sea Bream | 0.5 | - | 0.4 | - |
| ATLANTIC NORTH | 108.2 | 85.8 | 42.7 | 52.2 |
| Nafe | 88.1 | 82.1 | 40.3 | 49.7 |
| Cod | 43.1 | 20.5 | 13.0 | 24.1 |
| Red Fish | 32.5 | 49.5 | 18.1 | 18.8 |
| Others | 22.4 | 13.1 | 8.2 | 3.6 |
| Norway/Svolbard | 5.1 | 3.7 | 2.8 | 2.9 |
| Cod | 3.5 | 2.5 | 1.9 | 1.2 |
| Red Fish | 1.6 | 1.2 | 0.5 | .3 |
| ATLANTIC SOUTH | 36.3 | 45.4 | 44.0 | 35.8 |
| Hake | 31.0 | 28.8 | 26.4 | 18.0 |
| Others | 5.3 | 15.5 | 8.0 | 8.3 |
| TOTAL | 404.3 | 385.6 | 350.3 | 331.0 |

**TABLE IV**
**THE PRODUCTION OF FRESH, FROZEN, REFRIGERATED, SMOKED, CANNED AND OTHER TYPE OF FISH**

| YEAR | PRODUCTION | FRESH | FROZEN | DRY SMOKED SALT FISH | FISH MEAL | FISH OIL | CANNED FISH (1) |
|---|---|---|---|---|---|---|---|
| 1965 | 442 982 | 343 983 | 361 | 67 118 | | 3 808 | |
| 1966 | 374 472 | 299 485 | 318 | 67 128 | | 3 776 | |
| 1968 | 366 045 | 275 142 | 6 995 | 90 020 | | 6 048 | |
| 1969 | 333 695 | 270 194 | 13 614 | 57 499 | | 4 094 | |
| 1970 | 365 423 | 280 633 | 26 623 | 60 778 | | 4 596 | |
| 1971 | 348 205 | 259 288 | 31 678 | 51 645 | 521 | 3 327 | |
| 1972 | 342 717 | 262 444 | 30 650 | 44 445 | 498 | 2 455 | |
| 1973 | 370 032 | 298 898 | 30 642 | 42 266 | 550 | 2 072 | |
| 1974 | | 214 914 | 22 406 | 44 039 | | | |
| 1975 | | 222 024 | 16 255 | 33 693 | | | |
| 1986 | 349 100 | 272 100 | 63 000 | 13 000 | | | |
| 1987 | 329 300 | 265 700 | 59 099 | 2 812 | 7 117 | 2 082 | 42 789 |
| 1988 | 335 400 | 274 300 | 53 188 | 1 894 | 7 094 | 2 041 | 44 950 |
| 1989 | | | 50 299 | 1618 | 8 280 | 1 793 | 50 745 |

Source : Plano Medio Prazo 77/80 pp. and int Estudos de Pescas nao officiak 90.02.89.
(1) National Production Instituto Portugues de Conservas e Pescado Quadro 4-Conserva de Preixe tons 1988/89.

**TABLE V**
**LANDINGS IN CONTINENTAL PORTUGAL 1989 MAIN WHOLE SALE AUCTION MARKETS OF FISH**

| PORT | LISBON | | SESIMBA | | OLHAO | | MTOZINHO | | PENICHE | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Tons | Esc/Kg | Tons | Esc/Kg | Tons | Esc/Kg | Tons | Esc/Kg | Tons | Esc/Kg |
| | | | | | | | 49.209.0 | 75.60 | 32.836.6 | 144.60 |
| Horse Mackerel | 1 203.7 | 193.40 | 1.507.8 | 251.40 | 1.309.3 | 199.60 | 7.073 4 | 110 40. | 5 169 0 | 188.30 |
| Sardine | 2.6 | 54.80 | 2.361.3 | 48.80 | 8.729.9 | 40.90 | 34.485.8 | 40.60 | 18.150.8 | 47.30 |
| Hake | 374.7 | 668 20 | 395.1 | 745.90 | 1.354.3 | 826.90 | 445.5 | 755.80 | 178.7 | 758.00 |
| Fanecas | 51 3 | 274.10 | 18.5 | 393.40 | 74.7 | 338.40 | 520.0 | 354 60 | 418.5 | 341.10 |
| Mackerel | 242.7 | 34.10 | 654.0 | 26.50 | 3.413.2 | 36.50 | 249 8 | 37.90 | 321.7 | 54.60 |
| Congres | 450 2 | 354.60 | 97.5 | 369.60 | 139.7 | 368.40 | 205.8 | 382.00 | 400.8 | 338.20 |
| Monkeyfish | 38.1 | 554.40 | 89.6 | 861.00 | 31.1 | 720.70 | 227.0 | 689.00 | 353.3 | 656.1 |
| Rays | 151.0 | 163.50 | 85.6 | 253.70 | 76.0 | 233.70 | 111.1 | 239 40 | 503.3 | 208.40 |
| Octopus | 92.5 | 362.50 | 360.1 | 435.90 | 915.5 | 469.30 | 729.9 | 425.30 | 1.067.4 | 476 50 |
| Verdinho | 82.5 | 30.50 | 2 8 | 61.30 | - | - | 2.419.8 | 25.20 | 106.0 | 41.78 |
| Sole | 4.0 | 1.451.40 | | | | | 813.5 | 927.50 | 144.4 | 1.459.20 |
| Black Scabard | 9.0 | 149.50 | 3.521.2 | 188.50 | 0.0 | 320.00 | | | 20.5 | 203.90 |
| White Scabard | 211.1 | 316.80 | 3.975.6 | 383.60 | 187.8 | 322.70 | 0.8 | 365.70 | 12.0 | 363.40 |
| Seabream | 276.9 | 777.60 | 8.4 | 1.190.60 | 62.4 | 956.00 | 3.1 | 1.082.00 | 79.4 | 1 459.70 |
| Dentex | | | | | | | | | | |
| Xaputa | 52 4 | 325.10 | 74.7 | 324.10 | 99.1 | 269 30 | 0.1 | 134.30 | 0.6 | 261.00 |
| Cuttlefish | 4 9 | 585.60 | 139.1 | 483.50 | 280.3 | 469.70 | 65.9 | 362.00 | 37.1 | 421.50 |
| Squid | 38 8 | 635.4 | 36 0 | 904.30 | 35.6 | 1.021.70 | 55.5 | 627.70 | 34.3 | 700.80 |
| Flying Squid | 8 1 | 236.40 | 14.4 | 292.50 | 7.4 | 182.00 | 131.3 | 270.40 | 7.6 | 284.20 |
| Spanish Mackerel | 9 2 | 43.00 | 24.2 | 73.20 | 5.3 | 133.60 | 756.7 | 55.80 | 1.316.0 | 41.10 |
| Shrimp | - | - | 0.1 | 214.30 | 0.0 | 1.397.00 | 4.3 | 1.529.10 | 0.1 | 1.073.00 |
| Lobster | 177.4 | 1.445.10 | - | - | 0.0 | 3.959.60 | | | 661.1 | 1.433.50 |
| Seabass | 4.0 | 1.092.00 | 46.9 | 1.532.80 | 20.3 | 1.982,70 | 49.7 | 1.064.60 | 188.8 | 1.707.20 |
| Ruivo | 29.7 | 87.30 | 7.2 | 141.40 | 6.5 | 388.00 | 257.9 | 219.40 | 95.2 | 158.20 |
| Grooved Carpet | - | - | 20.9 | 320.90 | 14.1 | 954.20 | 1.614.6 | 119.30 | 8.3 | 273.50 |
| America Plaice | 0.9 | 435.30 | 0.4 | 832.30 | 0 1 | 818.50 | 53.1 | 366.60 | 2.9 | 236.80 |
| European Anchovy | - | - | 0.0 | 39.0 | 21.4 | 259.01 | 342.8 | 310.60 | 133.2 | 198 10 |
| Cherne | 38.2 | 827.70 | 61.3 | 1.551.50 | 32.1 | 1.920.80 | 2.7 | 1.557 60 | 84.0 | 1.685 70 |
| Tuna | 28.2 | 196.00 | 5.3 | 340.00 | 107.0 | 240.70 | 1 2 | 306.60 | 19.3 | 360 80 |
| | | | | | | | | | | |
| TOTAL | 9.497.2 | 383.20 | 17.090.0 | 262.20 | 17.617.9 | 244.90 | 51.913.9 | 83.30 | 34.821.3 | 183.00 |

**TABLE VI**
**PRICE COMPARISON OF AUCTION MARKETS TO CONSUMER BY SPECIES 1987 - 1989**

| SPECIES | 1987 | | 1988 | | 1989 | |
|---|---|---|---|---|---|---|
| | Auction | Consumer | Auction | Conumer | Auction | Consumer |
| **Fresh and Refrigered** | | | | | | |
| National | 140.60 | 326.40 | 153.00 | 295 60 | 164.80 | 362.20 |
| Import | 100.00 | 362.20 | 104.00 | 295 60 | 115 00 | 362 20 |
| Faneca | 196 40 | 397 70 | 261 20 | 422 40 | 322 00 | 502 40 |
| Seabream | 698 10 | 1 155 70 | 893 00 | 1 510 40 | 994 40 | 1 627 10 |
| Hake | 560 00 | 1 092 10 | 633 90 | 1 318 70 | 693 60 | 1 470 80 |
| Sardine | 32 10 | 122 30 | 38 40 | 120 70 | 43 00 | 144 50 |
| Goraz | 639 00 | 1 109 30 | 843 50 | 1 109 50 | 953 50 | 1 405 10 |
| White Secabard fish | 305 50 | 510 50 | 332 20 | 513 50 | 378 60 | 623 80 |
| **Frozen Fish** | | | | | | |
| Hake Imported | 176 90 | 452 50 | 156 60 | 548 00 | 328 00 | 582 00 |
| Crustaceans and Moluscos | | | | | | |
| Squid | 355 50 | 768 40 | 513 00 | 764 60 | 618 50 | 924 80 |
| Octopus | 256 00 | 461 00 | 362 00 | 578 20 | 452 20 | 683 90 |

Sources : SL. V / DOCAPESCA and IPCP 1988/89

**TABLE VII**
**DIFFERENCE OF PRICE BY TYPES OF CRAFT AND REGIONAL DISTRIBUTION**

| REGION | SPECIE | TRAWLER Price Esc./kg | POLIVALENTE Price Esc./kg | CERCO Price Esc./kg |
|---|---|---|---|---|
| 1988 | | | | |
| Northern | Horse Mackerel | 97.30 | 193.21 | 169.10 |
| Centre | " | 161.90 | 177.90 | 179.70 |
| Vale de Tejo | " | 206.60 | 276.60 | 202.70 |
| Alentejo | " | - | 200.80 | 95.50 |
| Algarve | " | 275.10 | 332.30 | 308.70 |
| 1988 | | | | |
| Northern | Hake | 86.20 | - | - |
| Centre | " | - | 177.90 | - |
| Vale de Tejo | " | 672.40 | 1.299.13 | - |
| Alente jo | " | 508.20 | - | - |
| Algarve | " | 628.10 | 429.75 | - |

Source: Data from GEPP for 1988-1989.

# Monopolistic Aspects of Word Trade of Fishing Industries in Portugal

**Salviano Cruz**

Estudos Económica Sociais. Rua Duque De Palmela, 27, 4°E 1200 Lisboa, Portugal

ABSTRACT

*Concepts of free competition, monopolies, oligopolies, monopsonies in international trade are described for the portuguese markets. From a large producer-exporting country of fish, Portugal has been declining in production of fish. As a result, Portugal has increased the imports of fish. Portugal's import/export markets are controlled by foreign companies, particularly for cod, hake, redfish, etc. Portuguese companies also operate as oligopolies/oligopsonies particularly in the auction markets and export trade with product differentiation in large scale export market and monopolistic control through restrictions and denial of statistical data.*

## 1. INTRODUCTION

Present studies of fishing industries, seem to ignore the important differences of structure and price differences, "price spreads" between producers (fishermen) and consumers in Portugal and in other countries.

It is even more strange that the influence of dominant firms, operating as oligopolies, oligopsonies, and monopsonies, price differentiation and other forms of monopolistic competition and imperfect competition, is ignored by economists.

## 2. CONCEPTS OF FREE COMPETITION, MONOPOLIES, OLIGOPOLIES, AND MONOPSONIES IN INTERNATIONAL TRADE.

Definitely, although there is free access to auction markets, there is not free competition in the fish trade industries in Portugal. Table 1 indicates prices to producers (fishermen) and consumer and its relationship to production landings[1], for 29 species, including the most important ones,

1. This table is based on the authors study on Institutional Factors of Marketing and Distribution in the Fishing Industries Under Monopolistic Competition in Portugal (1990) ; for the NATO Advanced Scientific Research Workshop in Econometric Modelling in World Trade in Groundfish, held at Memorial University of Newfoundland, Canada, Aug. 14-18th 1989.

| | | |
|---|---|---|
| sardine, | horse mackerel, | mackerel, |
| hake, | secabard white, | faneca, |
| octopus, | secabard black | congres, |
| spanish mackerel, | squid, | lobster, |
| common sea bream, etc. | | |

The table reveals prices in the producer and consumer for the years 1967, 1973, 1979, 1985 and 1989. In this year it also studied prices in Lisbon and Porto only, and not for the total country.

These statistics also indicate price spreads from producers to consumers for each of these species and the relationship between these prices and production, (landings).

The difference on "spreads" in price indicate a situation synthomatic of monopolistic competition. Also table 2 on evolution of prices of imported frozen hake in 1987 and December 1988 in Lisbon and Porto and in the country and also regular prices for hake from January to December in 1988. The maximum point for consumers in Lisbon was Esc.566.3 in December 1988. The maximum price for Porto was Esc.565.3 in November 1988.

Although, there are really many sellers and many buyers for fish in the auction markets, there is no indication of free competition, as buyers and sellers have very little to say on market conditions, as trade is controlled by small powerful groups of buyers and sellers, oligopolies or oligopsonies, which operate under monopolistic competition on imperfect competition, and not under free competition.

Figure 1 discuses free competition with lines SS' indicating supply and DD' the meeting at point C to show the equilibrium price for quantity OQ and price OP. PCD is the area of surplus of consumer, the area OPCSOQ, indicates surplus of producers. This only occurs when there are many suppliers of fish and many buyers.

Monopolistic competition on oligopoly, oligopsony, as it is happening in fresh fish,frozen fish, export, import markets, cod imports, and buying in bulk directly from vessels as it is the situation for the Northwestern Atlantic Fleet and C.R.C.B. (Companhia de Refrigerados e Comercio de Bacalhau). This company and vessel owners are operating under bilateral monopoly or oligopsony, both are bargaining outside the auction markets, by vertical and reciprocal proposals, purchasing fish in bulk for the whole boat supply.

### *2.1 Buying Fish Under Monopsony and Oligopsony and Free Competition*

Figures 3 and 4, will indicate the direct relationship of price spread between the fishermen, wholesalers and consumers illustrated by table I for price between the fishermen and the consumers.

Wholesaler in figure 3 will purchase only quantity OC, at price CH under monopsony, at price AP not quantity O, as indicatedfor free competition. He will pay only to fishermen price CH monopsony price for quantity OC while price to consumer will be CS under monopsony (monopoly of the buyer), and not price AP for quantity OA under free competition.

Figure 4 indicates the spread of prices of fish sold in auction market and prices paid by the consumers, as shown in table I for sales of species from fishermen to the consumer, and also for table 2 indicating the relationship of prices paid by the important frozen hake from Chile, Argentina and South Africa and price paid by consumers in the continent of Portugal and Lisbon and Porto, in December 1987 and in several months from january through December of 1988.

The final price paid by consumer is theoretically fixed at point, where curve NA'C'meet AI POINT P' under figure 4 aggregate supply or aggregate cost all the cost involved between the fishermen and the consumer, meet the curve AGR at point P' for price to the consumer AP' under monopsony, and not, at free competition price OP for quantity OQ' larger than quantity OA at price AP under monopsony.

This explains the large price that Portuguese consumers are paying at retail market for fish. For example, sardines selling at one of the leading Supermarkets, retail sardine price between Esc.600-750 /kg, which auction market wholesalers were purchasing between Esc.100$00 and Esc.200$00/kg.

There is a company, Tavamar, which has the monopoly of importation of chilean frozen hake. How much the fishermen will receive for this consumers price ?. Refering to figure D AP', the answer depends on several relationships, between the final demand for the consumer AGR aggregate revenue curve for fish and the average revenue curve on aggregate cost and DAR for aggregate cost for processed fish sold to consumer. This will depend on the degree of elasticity of demand for fish sold by fishermen in the auction market and the elasticity of demand processed fish sold to the ultimate consumer, which it is not known.

*2.2 Fresh Fish, Dominant Firms in the Fishing Trade.*

We have divided the dominant firms by sectors. Under the sector of fresh fish, there are the following dominant firms :

i) Frescal with 22 % of fish, is the leader of fresh sector market

ii) A group with Coimbra cia 6 %, Tavamar, Central Atlantico, Manuel Carvalho, Paceco, F. Martins, Eurotejo, Tavamar.

Figure 5 indicates the flow of fresh fish from the producers to the consumer with main firms interfering in the flow, from the importer, or the fishermen in the auction market to the consumer. There are about 25 firms for all sectors under oligopolies, oligopsonies, monopolies, bilateral monopoly as follows :

- Fresh Fish
- Frozen Fish
- Processed Fish
- Exported Frozen Fish and Imports
- Imports of salt fish and cod fish
- Fish canning industry
- Coastal & long range fleet
- Cod monopolies
- Bilateral monopoly buying in bulk from vessels and not, through auction markets.

In table 4 the evolution of prices from 1984 to 1989 is indicated by species. This shows the large increase of prices by species and also the categories of fish by prices variation.

*2.3 Dominant Firms for Frozen and Salt Fish Industry.*

Although there is a pseudo free competition in auction markets for fish there is restriction into entrance. Moreover, there is the drop in price by competitive bidding of small buyers, so that large dealers may enter the market and force prices even lower.

Therefore in the buyer side in Portugal auction market there are symptoms of real practice of monopolistic competition, oligopsony. From the fisherman producer side there is practice of oligopolistic control as there is also large concentration of landings by a group of 15 out of 120 vessels which landed 40.8 % of fish of this craft for the period from 1979 to 1986 as presented in figure 5. From the buyer side for fresh and frozen fish, there is a small group of buyers that control a large majority of fresh and frozen, processing, and salted fish. These dominant companies are :

1. Coimbra Company.
2. Beirafrio.
3. Eurotejo.
4. Frescal.
5. CRCB.
6. Paceco.
7. Tavamar.
8. Central Atlantics.
9. Manuel Carvalho in Aveiro and Matozinhos.
10. Tavares Marcarenhas.

11. F. Martins.
12. Machado o Cardoso Aveiro and Lisbon cod imports.
13. RAR.

These companies operate not only in Lisbon (Doca Pesca), but also throughout the country through branches.

Coimbra and company hold branches in Viana do Castelo, Aveiro, Figueira do Foz, Nazar, Lisbon, Doca Pesca, Sesimbra, Olho, and Portimo. Moreover, Coimbra & Co owns 60 % of Beira Frio which in itself claims to have over 40 % of frozen fish trade. Coimbra constitutes a holding company for the fresh, frozen, processing, and catch of fish, through leasing of 5 fishing boats operating in northwest atlantic fleet.

Coimbra and Beira Frio constitutes holding companies for fresh, frozen, processed, and exports. Imports internal market and monopolistic control of exports and buying.

Coimbra and other dependant companies, have 60 % of their businesses in frozen fish, 40 % in the fresh fish market. They control the import and export trade market of frozen fish, holding 15 % of trade. Some these companies operate in inter partnership basis. Eurotejo is practically owned by Manuel Carvalho & Co. Eurotejo also owns a significant share in Manuel Carvalho & Co. Coimbra imports and sales of cod corresponds to 4 % to 6 % of fresh fish, represents 3 % of frozen fish, 4 % exports and 15.2 % of exports of frozen fish. The price structure for Coimbra from producer or importer is outlined in figure 6 :

Four companies (CEE, Grupagel, Fropesca, CRCB) controls 80 % of the frozen fish industry : Coimbra and Beira Frio claim to hold 40 % of frozen fish market.

Coimbra also states that it is almost impossible to import a single container of frozen hake from Chile, due to the iinternational monopolies which practice the abuse of economic power. Tavamar has the monopoly of frozen hake from Chile as noted before.

### *2.4 Vertical Integration of Frozen Fish.*

In frozen fish industry there is a high integration with fishing fleet due to large companies with freezing equipment on board. Most of these fishing companies also extended their activities to processing and selling of final product. They have also purchased vessels to meet the expanding demand for other frozen products. Table V Landings of Processed Fish on Board Vessels of the National Fleet in 1989 ; see table 6 on Import and Export of Fresh, Frozen, Fillets and Canned Fish 1986-1989.

In cod salting industry vertical integration is even more intensive. After salt ships, there are inland salting and drying places. They also fill out their excess capacity with imported green cod, see table VI Imports of Cod. They all possess their own processing and drying installations. The two most important companies produce over 5000 tons, each corresponding to more than 25 % of the market

In the fish canning industry there is no integration for raw materials fish, but there integration for processing cans.

In table 5 we have the production of all processed fish in Portugal in period 1987-89, which indicates a total of 114,500.9t in 1987 and 112,665 tons in 1989. Canned Fish increased from 42,789 tons in 1987 to 50,745.0 tons in 1989. The main production was sardines increasing from 26,171.7 tons in 1987 to 29,522 tons in 1989. Tuna also increased from 10,349.2 tons in 1987 to 13,980. Mackerel increased from 3,647.4 tons to 9,136. in 1989.

Fish canning is highly concentrated, COFACO controls 51 % of production of sardines and also tuna which is localized mainly in the Azores. Other important leading companies are also Vasco de Gama with 20 %, Serrano 10 % Ramirez 10 %. The distribution is concentrated in one company, CORESA with 51 %.

Frozen Fish had a production of 59,099.0t in 1987 and 50,299t in 1989. The main production was hake 17,060.00 in 1987 and 6,008 in 1989, red fish declined from 23,960t in 1987 to 11,812t in 1985.

Friopesca is a holding company for 17 companies indicated in table VI ; firms operating in vertical integration for fish processing marketing and distribution of frozen fish for internal and export markets. These companies dominate the fishing trade of Portugal. Most of these companies are also interconnected. and are also importers and exporters of fish.

The most important vessel owner companies also control fish exports and importing fish industries ; through frozen fish industries, Empresa de Pesca de Aveiro exported 406.000 contos of frozen fish in 1988 and a total volume of business 44.157 thousand contos. Sociedade de Pesca Miradouro the leader of FrioPesca a holding companies for exporting frozen fish also had sales of in 1.960.9 contos and also other vertical integration companies are indicated in table VI :

*2.5 Absorption of State Monopolies by Private Companies.*

According to recent legislation, the Portuguese government appearing to obey rules for "free" operation competition of EEC extinguished Comisso Regulidade do Comercio do Bacalhau CRCB, which controlled the landings and distribution of commerce of cod in Portugal and also the frozen fish trade operating as a monopsony, controlling the buying, landing and supply of the cod and also the frozen fish trade. Although against the EEC legislation the Government of Portugal, left in operation those 17 dominating vertical intergration companies operating as oligopolies and oligopsonies.

## 3. CONCLUSIONS

(i) Although there are over 19 auction wholesale fish markets in Portugal, there is no free competition, because small dealers and small fishermen cannot influence the buying and selling as the markets despite the fact that both groups may bid for fish.

(ii) Large wholesalers or manufacturers operating in various sectors, fresh fish, frozen fish, processed fish, exporting and importing and also cod fish importing or importingand canning industries a few of which operate as dominant firms controlling the market as oligopolies, monopolies, oligopsonies, monopolies or monopsonies and influencing prices.

(iii) "Armadores", or owners of trawlers also operate as controlling groups in vertical integration. In coastal fleet 15 vessels out of 120 control 40.8 % of landings which represents almost 51 % of the fish presented in auction markets during the period 1979-1986.

(iv) Price spreads between fishermen and consumers have varied from 200 % to 650 % or more.

(v) Abuse of economic power and monopsonies are recognised but no corrective steps are taken by authorities which confuse free competition with freedom to monopolise.

(vi) Portuguese authorities protect monopolies, by encouraging big business and abuse of economic power, even when it means violation of articles 85' and 86', refusing also to intervene in recognising situations of economic power jeopodising the interests of the consumer

(vii) International authorities like CEE.do not recognize the necessity of studying the abuse of economic power and violations of articles 85' and 86' of the Treaty of Rome by fishing firms in Portugal, as revealed by the letter of the Directorate General of Competition of 20/10/1991 Ref. 0037321. This has also beenfollowed by Directorate General of Prices and Competition of Portugal, and Dirreco Geral de Inspeco Economica. Inspection of economic activities according to the letter of July 15th 1991 Ref. 004425. They confirm the legislation of CEE. for free competition with abuse of economic power.

(viii) Government refuse to support economic scientific research and participation of Portuguese scholars on international meeting and advanced seminars. They prefer to accept religious bias pressure groups like Opus Day instead of studies.

**TABLE 1.**
**PRODUCER - CONSUMER PRICE SPREADS 1967-1989 IN RELATION TO PRODUCTION LANDINGS.**

| SPECIES | 1967 | | | 1979 | | | 1985 | | | 1989 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Prod Price Esc./Kg | Prod Tons | Consum Price Esc./kg | Prod Price Esc./Kg | Prod Tons | Consum Price Esc./Kg | Prod Price Esc./Kg | Prod Tons | Consum Price Esc./Kg | Prod Price Esc./kg | Prod Tons | Consum Price Esc./kg LISBON[1] | Consum Price Esc./kg PORTO[2] |
| Kolb | 11.81 | - | 17.70 | 115.60 | 434 | 177.10 | 392.69 | 334 | 602.90 | 699.20 | 281 | 960.50 | 1.162.50 |
| Sardine | 3.41 | 114.814 | 6.56 | 16.43 | 91.321 | 42.80 | 26.86 | 111.563 | 79.50 | 42.00 | 91.263 | 233.00 | 109.50 |
| Secabard Black | 7.49 | 5.436 | 15.15 | 112.22 | 5.194 | 159.70 | 268.80 | 3.622 | 460.30 | 188.50 | 3.522 | 357.00 | - |
| Hake | 21.38 | 17.850 | 24.03 | 89.92 | 14.714 | 262.40 | 253.53 | 19.679 | 772.80 | 702.60 | 5.461 | 1.161.70 | 1.689.25 |
| Goraz | 12.64 | 1.103 | 19.01 | 171.11 | 952 | 223.00 | 436.07 | 1.180 | 622.20 | - | - | 1.266.01 | 1.542.85 |
| Marmute | 9.67 | 11.394 | 15.78 | 86.57 | 2.592 | 208.00 | 265.56 | 1.507 | 543.40 | - | - | - | - |
| Common Sea Bream | 6.71 | 2.783 | 13.16 | 89.47 | 4.906 | 223.30 | 182.99 | 5.707 | 656.00 | 1.026.30 | 642 | 1.498.00 | 1.498.00 |
| Spanish Mackerel | 1.20 | 39.785 | 6.56 | 39.39 | 14.477 | 70.40 | - | - | - | 48.40 | 3.113 | - | - |
| Dentex | 6.91 | 2.780 | 13.16 | 66.12 | 895 | 190.50 | 211.00 | 899 | 419.10 | - | - | - | - |
| Horse Mackerel | 3.94 | 23.567 | 10.81 | 63.43 | 12.912 | 122.70 | 173.01 | 24.815 | 316.20 | 180.30 | 26.775 | 343.00 | 267.14 |
| Mackerel | - | 4.169 | - | - | - | - | - | - | - | 41.30 | 6.449 | - | - |
| Fresh Cod | 8.11 | 97.312 | - | 74.31 | 22.710 | - | 277.14 | 16.721 | - | - | 19.443 | - | - |
| Faneca | - | - | 16.54 | - | - | - | 194.46 | 3.174 | 309.90 | 302.30 | 2.883 | 431.00 | 544.60 |
| Whiting | 10.61 | 3.106 | 18.08 | - | - | - | - | - | - | - | - | - | - |
| Frozen Hake | - | . | - | - | - | - | - | - | - | - | - | [3] 582.00 | - |
| Squid | 10.22 | 1.985 | - | - | - | - | - | - | - | 611.50 | 1.214 | 1.092.00 | 1.107.50 |
| Cuttlefish | - | 2.421 | 6.62 | - | - | - | - | - | - | 480.40 | 1.596 | 516.00 | 664.00 |
| Octopus | 6.28 | 7.435 | - | - | - | - | - | - | - | 410.90 | 10.412 | 538.00 | 635.35 |
| Tuna | - | - | 26.66 | - | - | - | - | - | - | - | - | - | - |
| Large Cod | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cured Cod | - | - | 18.67 | - | - | - | - | - | - | - | - | - | - |
| Small Cod | - | - | 15.76 | - | - | - | - | - | - | - | - | - | - |
| Savel | 11.46 | 637 | - | - | - | - | - | - | - | - | - | - | - |
| Shrimp | 58.23 | - | - | - | - | - | - | - | - | 1.200.00 | 175 | 3.113.00 | 4.840.00 |
| Grouper | - | 739 | - | - | - | - | - | - | - | - | - | - | - |
| Sole | 24.51 | - | 37.74 | - | - | - | - | - | - | 1.200.00 | 1.200 | 1.931.00 | 1.735.00 |
| Congres | - | - | - | - | - | - | - | - | - | 356.70 | 2.078 | - | - |
| Lobster | 103.92 | - | - | - | - | - | - | - | - | 1.483.50 | 863 | 3.554.50 | - |

Source: Cruz, Salviano: INSTITUTIONAL FACTORS AFFECTING FOR MARKETING AND DISTRIBUTION OF FISHING INDUSTRIES IN PORTUGAL UNDER NONCOMPETITIVE SYSTEM. For NATO Advanced Scientific Workshop on World Trade Of Groundfish, Memorial University of Newfoundland, St. John's CANADA, Aug 14-18th 1989, completed 1990 and series Estatica das Pesces. Recursos das Pescas, Vol 3A-B. Gabinete de Estudos e Planeamento das Pescas Lisboa, Agosto 1990, and INE.- Instituto Nacional de Estatisca: Servico de Abastecimento.

[1] Camara Municipal de Lisboa. [2] Camara Municipal de Porto. [3] IPCP, Portugal.

**TABLE 2.**
**PRICE OF FROZEN HAKE IMPORTED AND TO THE CONSUMER (I.N.E.) ESCUDOS/KG**

| CONSUMER | 1987 | 1988 | | | | | | | | DIF |
|---|---|---|---|---|---|---|---|---|---|---|
| | DEC | JAN | APR | MAY | JUN | AUG | SEP | OCT | NOV | DEC | % |
| CONTINENT | 452.5 | 499.5 | 510.9 | 517.6 | 525.0 | 535.7 | 540.5 | 543.5 | 541.2 | 548.0 | 21 |
| LISBON | 456.5 | 500.3 | 522.0 | 525.3 | 524.8 | 546.3 | 555.2 | 557.2 | 543.2 | 566.3 | 24 |
| PORTO | 438.3 | 504.9 | 529.3 | 537.2 | 562.3 | 555.9 | 559.2 | 562.3 | 565.6 | 551.3 | 26 |
| IMPORTED | 190.0 | 168.0 | 160.0 | 206.2 | 180.4 | 152.3 | 182.7 | 183.8 | 217.6 | 180.0 | -5 |

TABLE 3.
MAIN SPECIES OF FISH LANDED IN AUCTION MARKETS OF PORTUGAL BY REGIONS, TYPES OF GEAR, AND DIFFERENT PRICES 1989.

| REGION | TRAWLER | | | LOCAL | | | COAST | | |
|---|---|---|---|---|---|---|---|---|---|
| | SPECIES | TONS | Esc./kg | SPECIES | TONS | Esc./Kg | SPECIES | TONS | Esc/Kg |
| NORTE | Horse Mackerel | 5026.14 | 97.30 | Sardine | 3822.45 | 40.50 | Sardine | 36017.70 | 40.60 |
| | Verdinho | 2363.30 | 35.10 | Polvo | 1643.41 | 443.50 | Horse Mackerel | 913.20 | 169.10 |
| | Spanish Mackerel | 493.30 | 61.20 | Amejoas | 1626.64 | 117.20 | Biqueirao | 319.21 | 318.30 |
| | Octopus | 146.80 | 307.50 | Faneca | 956.90 | 381.00 | Cavala | 209.69 | 35.70 |
| | Hake | 86.20 | 660.20 | Horse Mackerel | 933.41 | 193.20 | Spanish Mackerel | 172.27 | 31.20 |
| CENTRO | | | | | | | | | |
| | Horse Mackerel | 2108.65 | 161.90 | Berbigao | 293.41 | 20.30 | Sardine | 12375.33 | 37.80 |
| | Octopus | 1211.78 | 322.00 | Horse Mackerel | 177.90 | 239.40 | Biqueirao | 269.12 | 460.30 |
| | Spanish Mackerel | 439.40 | 38.10 | Faneca | 99.88 | 317.30 | Horse Mackerel | 249.86 | 179.70 |
| | Faneca | 407.59 | 262.50 | Congro | 66.26 | 311.40 | Robaio | 99.02 | 556.70 |
| | Squid | 384.14 | 622.30 | Octopus | 53.04 | 454.70 | Spanish Mackerel | 37.98 | 30.00 |
| LX. VL. DO TEJO | | | | | | | | | |
| | Horse Mackerel | 3002.53 | 206.60 | P.Esp.Preto | 3494.98 | 188.60 | Sardine | 21706.44 | 47.20 |
| | Verdinho | 633.63 | 45.90 | Octopus | 2301.73 | 457.10 | Horse Mackerel | 6206.58 | 202.70 |
| | Black Horse Mackerel | 579.09 | 52.30 | Horse Mackerel | 1704.58 | 276.60 | Black Horse Mackerel | 1342.96 | 56.70 |
| | Hake | 573.58 | 672.40 | P.Espada | 1306.68 | 352.90 | Spanish Mackerel | 1245.86 | 38.30 |
| | Spanish Mackerel | 308.24 | 50.10 | Hake | 1299.13 | 760.20 | Cavala | 771.03 | 46.10 |
| ALENTEJO | | | | | | | | | |
| | Hake | 0.85 | 508.20 | Horse Mackerel | 852.21 | 200.80 | Sardine | 3652.72 | 34.30 |
| | Squid | 0.31 | 475.70 | Octopus | 687.04 | 430.90 | Horse Mackerel | 33.60 | 95.50 |
| | Faneca | 0.25 | 129.50 | Cavala | 386.17 | 64.30 | Cavala | 11.24 | 56.70 |
| | Octopus | 0.24 | 160.50 | Sardine | 244.04 | 32.20 | Congro | 3.11 | 30.00 |
| | Raia | 0.23 | 209.00 | Choco | 176.46 | 514.50 | Spanish Mackerel | 0.07 | 35.00 |
| ALGARVE | | | | | | | | | |
| | Horse Mackerel | 871.32 | 275.10 | Octopus | 3378.89 | 457.00 | Sardine | 11562.78 | 43.50 |
| | Black Horse Mackerel | 476.83 | 61.00 | Horse Mackerel | 608.00 | 332.30 | Cavala | 3446.33 | 36.10 |
| | Prawns | 357.03 | 1440.90 | Choco | 603.76 | 453.60 | Horse Mackerel | 835.36 | 300.70 |
| | Lagostin | 328.91 | 1995.00 | Hake | 424.75 | 858.10 | Black Horse Mackerel | 100.02 | 116.30 |
| | Hake | 290.23 | 628.10 | Besugo | 332.86 | 332.90 | Sargo Safia | 69.05 | 436.10 |

Source: Gabinete de Estudos e Planeamento das Pescas.

**TABLE 4.**
**AVERAGE PRICE OF LANDINGS BY SPECIES**

| SPECIES | 1984 Esc./Kg (1) | 1985 Esc/Kg (1) | 1986 Esc./Kg (1) | 1987 Esc./Kg (2) | 1988 Esc./Kg (2) | 1989 Esc./Kg (2) |
|---|---|---|---|---|---|---|
| Sole | 581.05 | 682.74 | 806.99 | 1.036.00 | 1.172.11 | 1.400.90 |
| Pregado | 613.43 | 718.40 | 839.20 | 1.021.88 | 1.315.88 | - |
| Cherne | 565.19 | 740.22 | 944.49 | 1.019.12 | 1.381.64 | - |
| Cernier | | | | | | |
| Goraz Doura | 340.85 | 384.97 | 517.30 | 684.15 | 843.10 | 953.51 |
| de da Commune | | | | | | |
| Grouper | 44.3.32 | 533.61 | 638.66 | 609.99 | 958.27 | - |
| Sea Bass | 655.12 | 820.57 | 821.99 | 1.071.20 | 1.311.7 | 1.439.80 |
| Common | | | | | | |
| Sea Bream | | | 569.17 | 698.11 | 894.60 | 994.41 |
| Lobster | 13.88.221 | 426.82 | 1.675.45 | 1.839.41 | 1.607.60 | 1.467.51 |
| Lagostin | 568.00 | 651.64 | 637.54 | 1.070.60 | 1.805.00 | 1.972.31 |
| Shrimp | 888.83 | 933.15 | 1.308.58 | 1.385.58 | 1.480.20 | 1.432.00 |
| Prawns | | | 1.855.00 | 2.828.28 | 2.368.70 | 1.437.50 |

Sources: (1) INE 1986 (2) S.L.V. Doca Pesca

**TABLE 5.**
**PROCESSED FISH IN PORTUGAL 1987-1989**

| | 1987 | 1988 | 1989 |
|---|---|---|---|
| TOTAL | 114.500.9 | 109.469.4 | 112.665.0 |
| I) CANNED | 42.789.0 | 44.950.0 | 50.745.0 |
| Sardine | 26.171.7 | 26.100.5 | 29.522.0 |
| Tuna | 10.349.2 | 11.212.0 | 13.980.0 |
| Mackerel | 3.647.4 | 3.762.9 | 5.136.0 |
| Anchovies | 1.189.5 | 1.090.1 | 1.127.0 |
| II) FROZEN | 59.099.0 | 53.188.3 | 50.299.0 |
| Hake | 17.060.0 | 15.202.1 | 6.008.0 |
| Cod | 3.768.0 | 11.582.5 | 17.142.0 |
| Redfish | 23.960.0 | 13.388.0 | 11.812.0 |
| Flounder | 2.179.0 | 1.405.3 | 1.275.0 |
| Secabard | 3.100.0 | 662.4 | 326.0 |
| Ray | 1.667.0 | 1.052.0 | 399.0 |
| Palmela | - | - | - |
| Cuttlefish | - | - | 3.662.0 |
| Squid | - | - | 6.923.0 |
| Other Species | 7.365.0 | 9.891.0 | 1.492.0 |
| III) SALTED FISH | 2.812.2 | 1.864.5 | 1.618.0 |
| Derived Products | 33.2 | 29.6 | - |
| IV) FISH MEAL & OIL | 9.800.7 | 9.436.5 | 10.073.0 |
| Fish Meal | 7.117.7 | 7.094.8 | 8.280.0 |
| Oils | 2.082.5 | 2.081.6 | 1.793.0 |
| Waste | - | 16.916.0 | 1.105.0 |

Sources: Instituto Português de Conservas de Pescas. Estaticas de Pescas não oficial 90-02-09 quadras 4 Conservas de Peixe 70 1988/89 No statistics available for 1990/1991 according to the letter of 1992/04/16 from I.P.C.P.

**TABLE 6.**
**IMPORTS OF COD BY PORTUGAL 1985-1990**

| | 1985 | 1986 | 1987 | Average Price Esc./Kg | 1988 | Average Price Esc./Kg | 1989 | Average Price Esc./Kg | 1990 | Averag Price Esc./K |
|---|---|---|---|---|---|---|---|---|---|---|
| GREEN | 16.721 | 11.920 | 67.302 | 320 | 72.609 | 520 | 61.936 | 452 | 62.089 | 557 |
| DRY COD | 10.939 | - | 11.600 | 677 | 14.526 | 679 | 13.099 | 735 | 22.307 | 820 |
| TOTAL | 27.650 | 68.695 | 78.926 | | 87.185 | | 78.016 | | 84.396 | |

Source: IPCP.

**TABLE 7.**
**VERTICAL INTEGRATION COMPANIES**

| | NAME | VOLUME | S. LIQUID | ASSETS | R. LIQUID | Nº EMPLOYEES | EXPORTS 1988 |
|---|---|---|---|---|---|---|---|
| 1. | EPA EMPRESA DE PESCA AVEIRO | 4.157 | 633 | 6.168 | -203 | - | 406 |
| 2. | PESCA MIRADOURO | 1.969 | 1.712 | 2.660 | - 5 | - | 187 |
| 3. | EMPRESE DE PESCA DE VIANA. | 3.212 | 1.386 | 3.554 | -169 | 350 | 138 |
| 4. | PESCA TAVARES MASCARENHAS | 1.854 | 1.773 | 4.068 | - 76 | - | 61 |
| 5. | SNB. SOCIEDADE NACIONAL DE BACALHAU | 1.601 | 1.977 | 230 | - | 471 | 597 |
| 6. | PASCOAL E FILHOS | 1.325 | 649 | 1.589 | 9 | - | 5 |
| 7. | TESTA E CUNHAS | 659 | 755 | 1.224 | 43 | - | 128 |
| 8. | IAP. INDUSTREIS A. PESCA. | 535 | 611 | 858 | 31 | - | 30 |
| 9. | PESCAS S. JACINTO | 462 | 636 | 829 | 49 | - | 129 |
| 10. | PESCA BEIRA LITONAL | 449 | 461 | 567 | 31 | - | - |
| 11. | AÇORES PESCA. | 231 | 350 | 538 | - 4 | - | - |
| 12. | LUSITANIA | 208 | 424 | 575 | 5 | - | - |
| 13. | PESCRUL | 204 | 60 | 335 | - 93 | - | - |
| 14. | EMPRESA A.P. de PESCA de ARRASTO | 174 | 27 | 797 | - 71 | - | - |
| 15. | Cia. PESCA do ALGARVE | 119 | 350 | 538 | 21 | - | - |
| 16. | ABEL FIG. LUIS | 14 | 30 | 30 | 32 | 40 | - |
| 17. | VIV. INDUSTRIAS PORTUGUESA | 6 | 72 | 77 | - 22 | - | - |

Source: Semanário - Suplemento Economico 21/02,1990.

**TABLE 8.**
**COD - EVOLUTION OF LANDINGS AND IMPORTS**

**TABLE VIII COD - EVOLUTION OF LANDINGS AND IMPORTS**

| YEAR | TONS | VALUE contos | AVERAGE PRICE Esc./Kg | IMPORTS TONS | CATCHES | SUPPLIER | DEGREE OF | VALUE OF IMPORTS in contos |
|---|---|---|---|---|---|---|---|---|
| 1965 | 71.280 | 475.307 | 6.70 | 20.697 | | | | |
| 1966 | 71.280 | 480.346 | 6.74 | 22.667 | | | | |
| 1967 | 97.312 | 798.374 | 8.11 | 41.476 | | | | |
| 1968 | 79.413 | 645.493 | 8.13 | 23.165 | | | | |
| 1969 | 62.699 | 488.822 | 7.70 | 39.792 | | | | |
| 1970 | 66.250 | 559.366 | 8.44 | 37.848 | 41.441 | 73.667 | 43% | |
| 1971 | 56.894 | 620.629 | 10.91 | 44.855 | 35.396 | 75.351 | 53% | |
| 1972 | 49.513 | 643.790 | 13.00 | 46.970 | 30.265 | 70.342 | 59% | |
| 1973 | 41.450 | 647.305 | 13.80 | 36.588 | 29.009 | 87.865 | 50% | |
| 1974 | 49.661 | 1.107.543 | 20.49 | 24.916 | 30.827 | 55.743 | 45% | |
| 1975 | 38.745 | 1.021.771 | 26.37 | 35.885 | 23.885 | 59.470 | 60% | |
| 1976 | 35.144 | 1.084.195 | 30.45 | 32.930 | 21.956 | 54.886 | 60% | |
| 1979 | 22.710 | - | - | 28.482 | | | | |
| 1980 | 19.480 | - | - | 32.393 | | | | |
| 1981 | 14.738 | - | - | 38.936 | | | | |
| 1982 | 9.315 | - | - | 55.168 | | | | |
| 1983 | 9.680 | - | - | 61.176 | | | | |
| 1984 | 13.691 | 3.317.812 | - | 54.026 | | | | |
| 1985 | 16.723 | 4.633.992 | - | 88.813 | | | | |
| 1986 | 20.051 | 4.642.553 | - | 67.811 | 66.093 | | | 27.519.617 |
| 1987 | 6.554 | 1.743.643 | - | 78.617 | | | | 43.091.838 |
| 1988 | 30.437 | 2.877.584 | - | 80.036 | 14.825(1) | | | 46.775.429 |
| 1989 | 19.009 | - | - | | | | | 39.773.120 |
| 1990 | - | | | | | | | 82.913.500 |

(1) Gremio do Bacalhäu -

**TABLE 9.**
**ICELAND EXPORTS TO PORTUGAL OF SALTED COD**

| | PORTUGAL | | SPAIN | | EUROPE | | OTHERS | |
|---|---|---|---|---|---|---|---|---|
| YEAR | Tons | % | Tons | % | Tons | % | Tons | % |
| 1970 | 13.955 | 46.6 | 4.250 | 14.3 | 8.790 | 29.4 | 2.895 | 9.6 |
| 1971 | 14.788 | 46.7 | 4.545 | 14.4 | 8.574 | 27.0 | 3.754 | 11.9 |
| 1975 | 24.135 | 55.2 | 8.450 | 19.3 | 9.029 | 20.7 | 2.088 | 4.8 |
| 1980 | 24.174 | 45.1 | 12.026 | 22.4 | 15.678 | 29.3 | 16.960 | 3.2 |
| 1981 | 38.459 | 65.1 | 10.239 | 17.3 | 9.634 | 16.3 | 7.240 | 1.2 |
| 1985 | 26.314 | 51.5 | 10.549 | 21.5 | 11.809 | 24.0 | 1.491 | 3.0 |
| 1987 | 37.691 | 61.6 | 9.912 | 15.9 | 13.881 | 21.5 | 9.350 | 1.4 |
| 1988 | 37.223 | 60.7 | 10.716 | 17.5 | 11.865 | 19.3 | 1.569 | 2.6 |
| 1989 | 22.001 | | | | | | | |
| Average 1980-1988 | 30.189 | 54.8 | 10.193 | 19.1 | 12.703 | 23.8 | 1.256 | 2.4 |

Source: Felix Tayggvi Felixson - Iceland Groundfish Industry Production and Institutional Factors and Trends, preliminary report to NATO Advanced Scientific Workshop, Memorial University of Newfoundland, August 14-18, 1989.

**FIGURE 1.**
**BOATS OPERATING UNDER FREE COMPETITION**

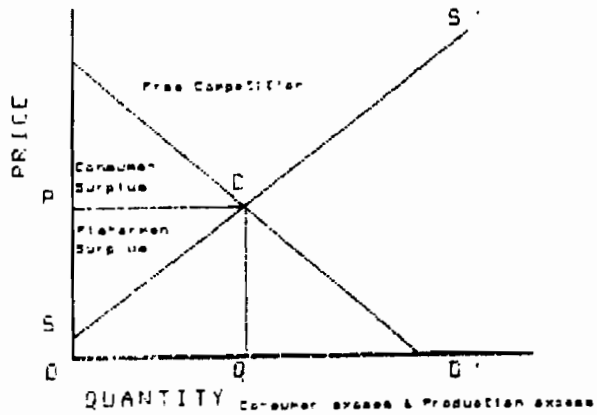



**FIGURE 2.**

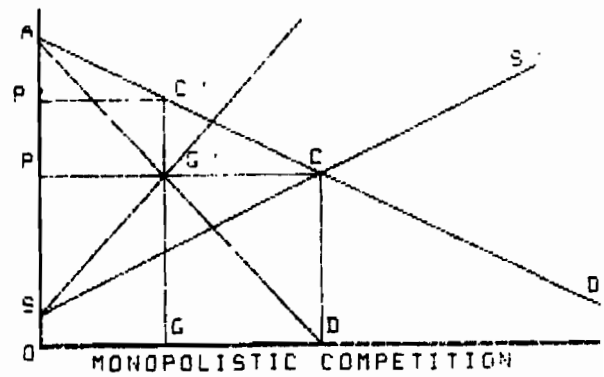



**FIGURE 3.**
**FISHERMEN/CONSUMER PRICE RELATIONSHIP**

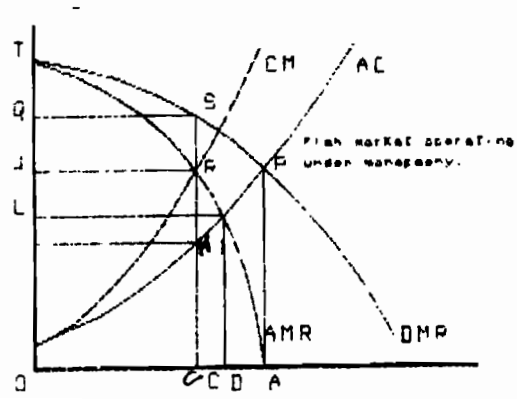



**FIGURE 4.**

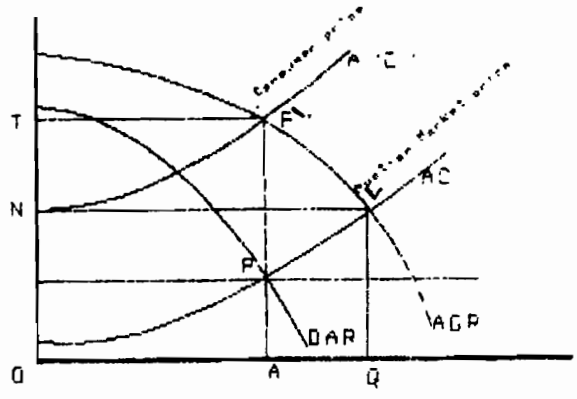
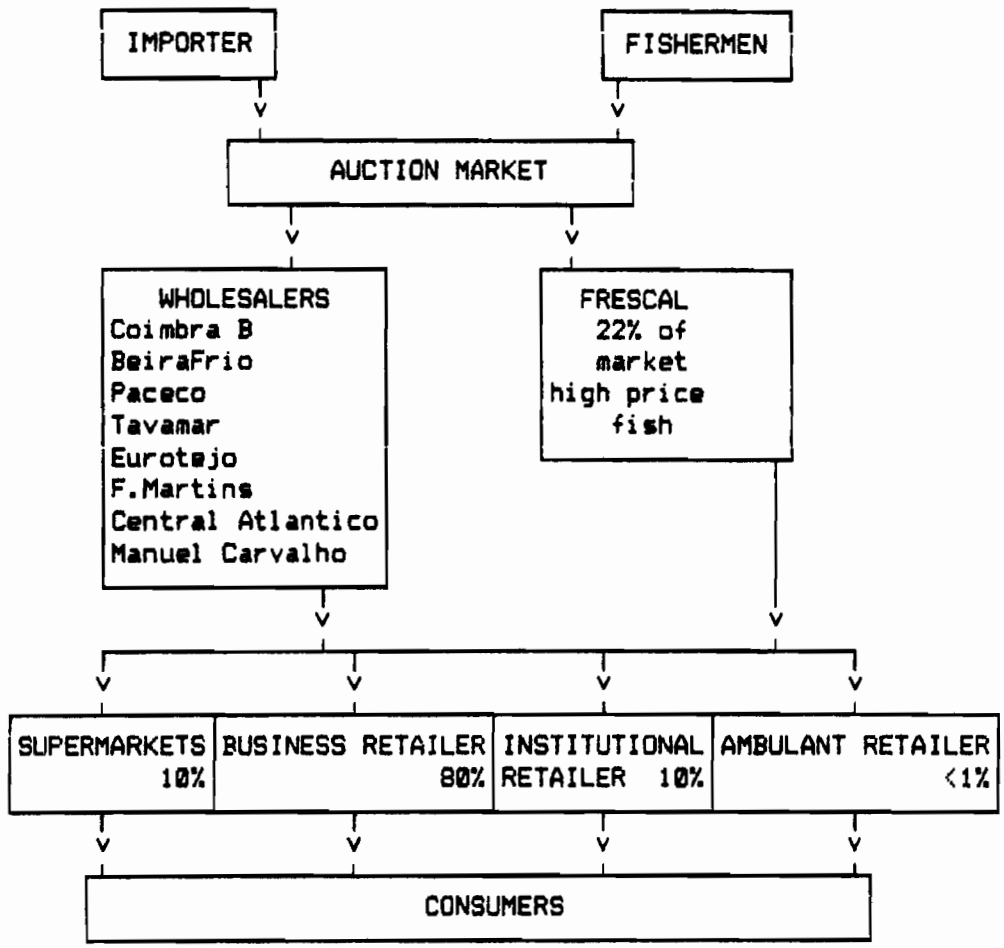
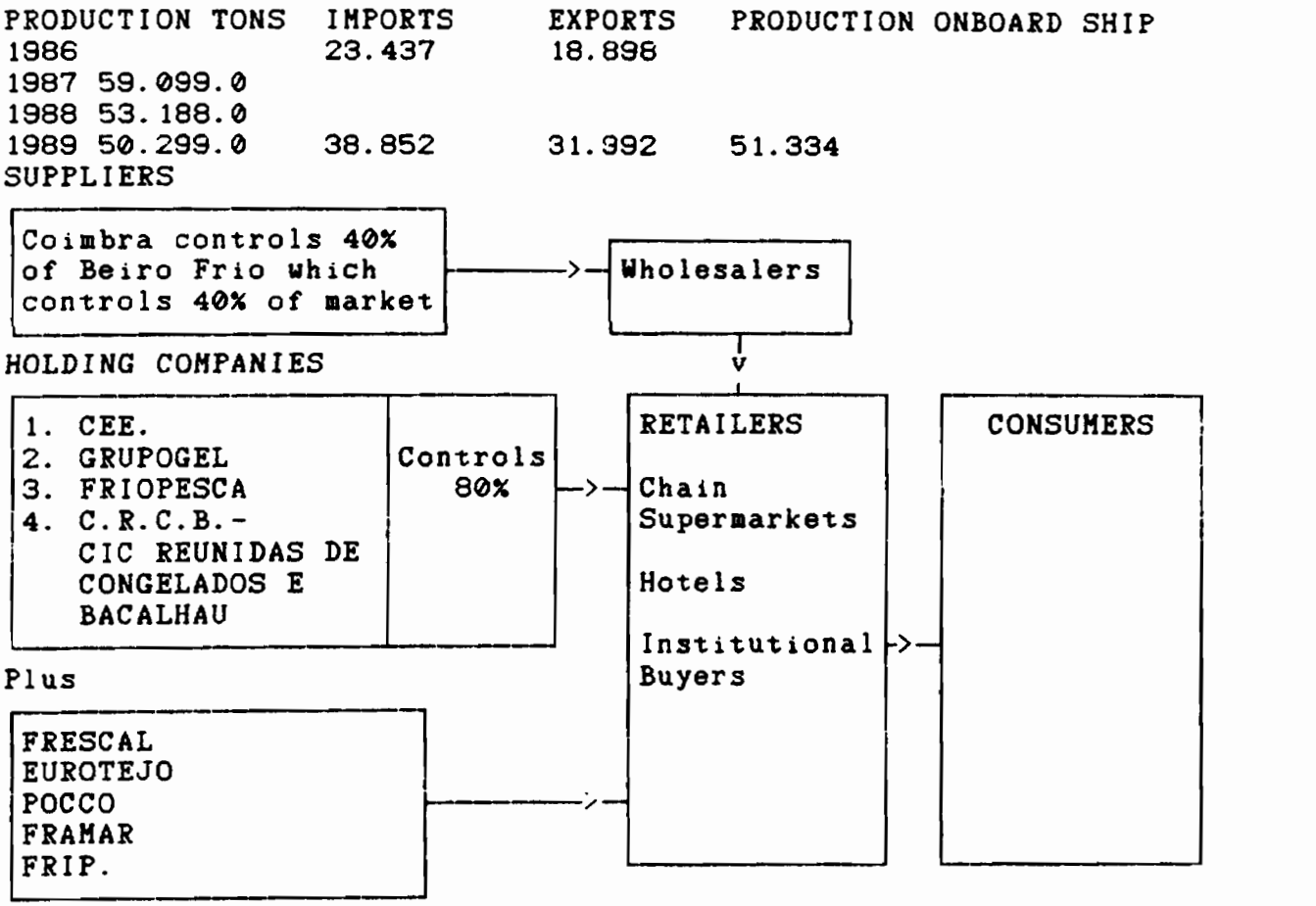


**FIGURE 5.**
**STRUCTURE OF MARKET AND DIAGRAM DOMINANT FIRMS AND REFRIGERATED FLOW OF DISTRIBUTION OF FRESH FISH FROM PRODUCER FISHERMEN TO CONSUMER**




1)Frescal purchases 80% of fish from the high price coastal fleet
2) Network in several auction market
3) Imports hake from South Africa depends on licenses
4) Fish frozen local fleet more expensive than trawler fleet
5) Foreign market -specializes in high price species exports
Italy, France, Spain, Switzerland.

**FIGURE 6.**
**FLOW OF FROZEN FISH FROM PRODUCERS TO CONSUMERS.**




Sources: Cruz S. Institutional Factors Affecting Marketing and Distribution Fishing Industries in Portugal Under Monopolistic Competition. 1990. for NATO Advanced Scientific Workshop in Econometric Modelling in World Trade in Groundfish; Memorial University, Canada, August 14th-18th 1989

**FIGURE 7.**
**EVOLUTION OF TRAWLER LANDINGS 1979-1986.**

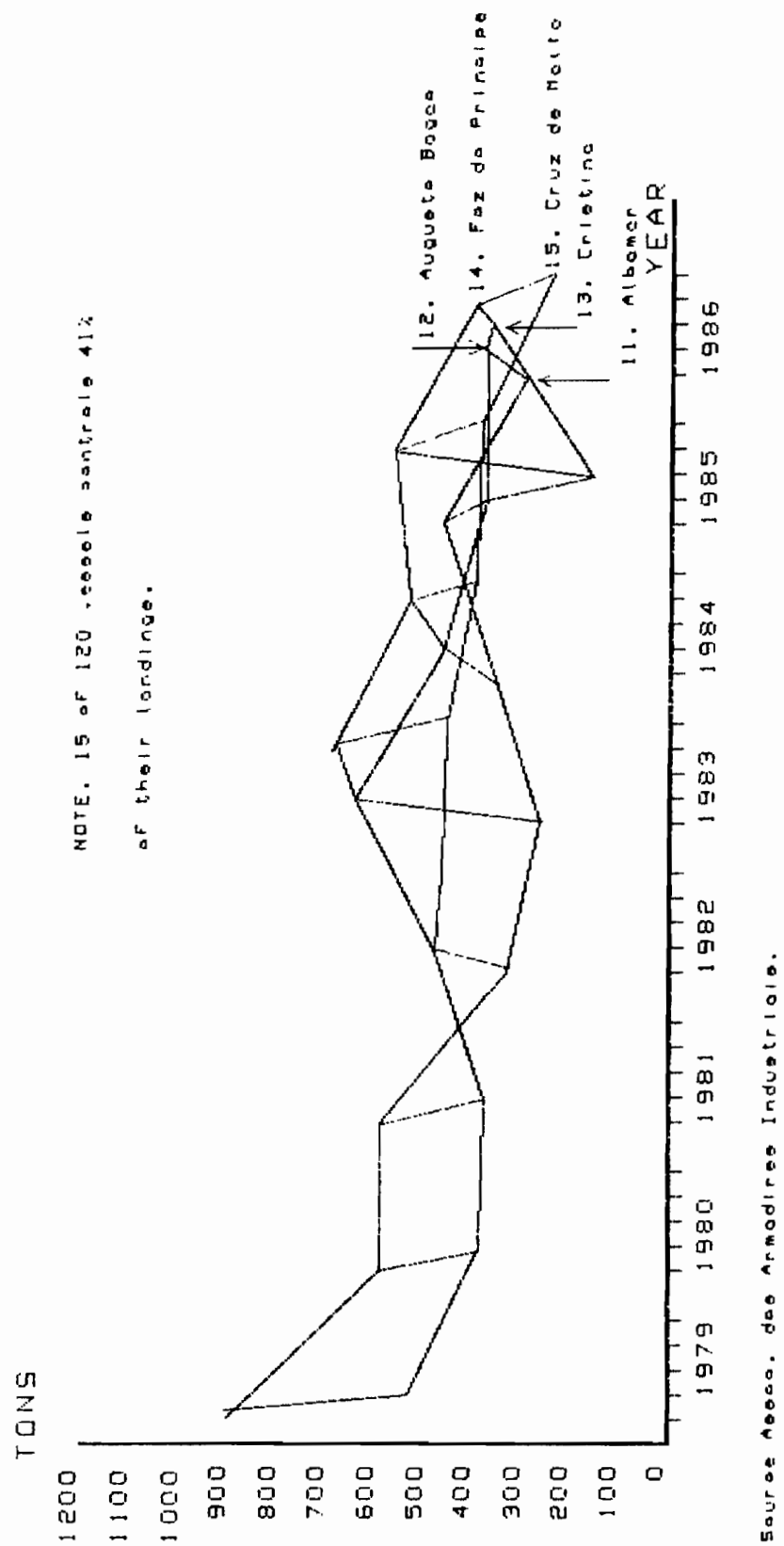


**FIGURE 8.**
**FLOW & MARKETING DISTRIBUTION IN THE COD INDUSTRY OF PORTUGAL.**

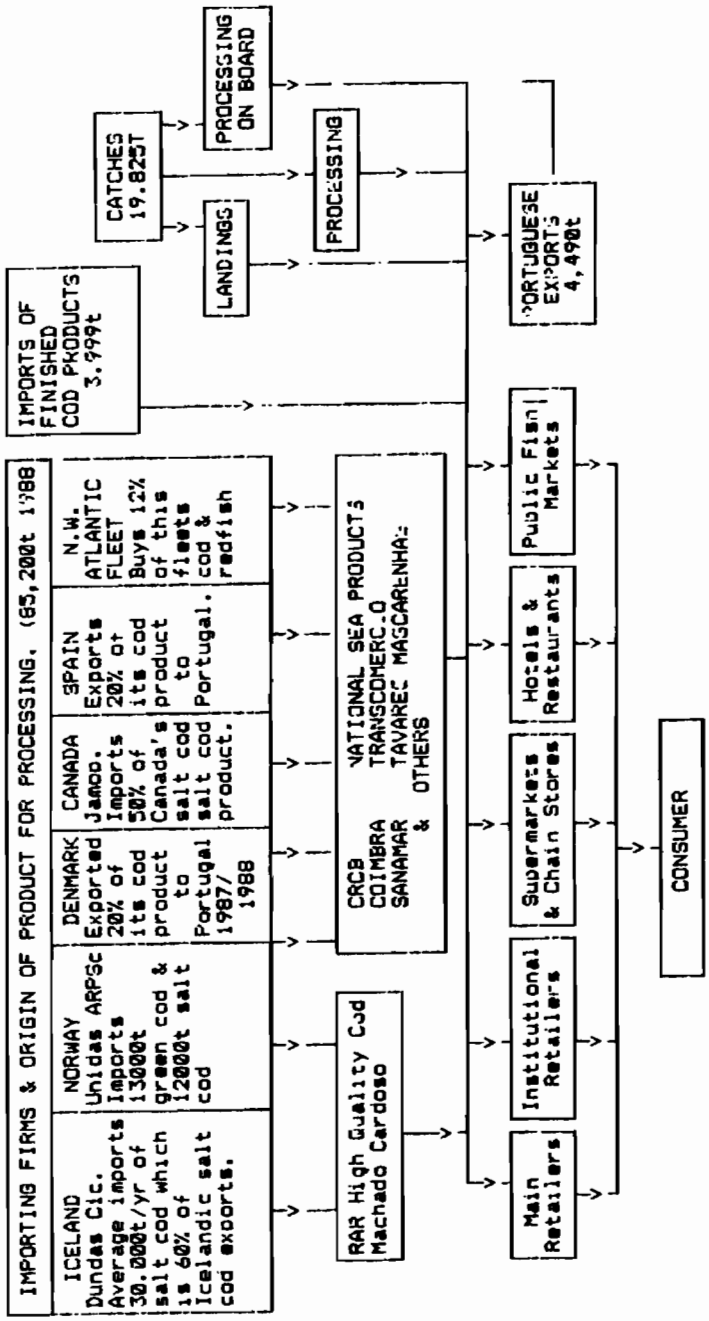


**FIGURE 9.**
**OUTLINE OF COIMBRA HOLDING COMPANY FOR FRESH, FROZEN, PROCESSED, AND IMPORT/EXPORT OF FISH AND IMPORTED SALT CO.**

| IBERPARQUE | PORTUGAL | FROZEN FISH | PROCESSED FISH | EXPORT IMPORT FISH | IMPORTER OF SALT COD 6% | OWNER OF FIVE VESSELS |
|---|---|---|---|---|---|---|
| Spain wholesaler of fish. | Fresh fish 6%<br>Fresh fish operate with<br>Frescal 22%<br>Coimbra 6%<br>Eurotejo 4%<br>Paceco 6%<br>F. Martins | Operates with C.R.C.B.<br>Coimbra 6%<br>BeiraFrio 40%<br>Central Atlantico<br>Manuel Carvalho | Operates with BeiraFrio 40%<br>Coimbra 15%<br>BeiraFrio 15% | Coimbra C.R.C.B.<br>BeiraFrio<br>Eurotejo | C.R.C.B.<br>Machado Cardoso<br>RAR<br>Transcomercio<br>Senamar | Operating northwest Atlantic under vertical integration<br><br>Has 2 firms |

# Markets and prices
# by
# Frederic LANTZ and Martine ANTONA

La formation des prix des produits de la pêche fait l'objet de nombreuses études qui mettent en évidence la disparité et la variabilité des prix comme résultante des conditions d'offre et de demande. Les pêcheries sont confrontées à des problèmes d'adéquation entre une offre instantanée sujette à de fortes fluctuations et des capacités d'absorption du marché souvent peu flexibles. Cette offre aléatoire, peu dépendante à court terme de l'évolution des prix, caractérise les marchés des produits de la mer. Elle est en revanche fortement dépendante de facteurs environnementaux et biologiques qui jouent sur la taille, la disponibilité et l'accessibilité du stock. La question du mode de formation des prix a donc été intégrée à l'analyse globale des pêcheries pour étudier les conséquences du fonctionnement et/ ou de l'évolution des marchés sur l'exploitation des ressources.

Cette session présente différentes approches de ces questions. Quelques communications abordent la modélisation du marché d'un produit particulier en s'attachant aux spécifications des fonctions d'offre et de demande (Ioannidis, Wright & Copes). D'autres sont consacrées à la modélisation de la formation des prix sur les marchés au débarquement. Les contributions portent en particulier sur l'influence des conditions spécifiques de chaque transaction - nature de la ressource, type de vente...- sur la détermination des prix (Kirman, Ty & Gates). Ces analyses amènent à s'interroger sur la signification du prix qui est fixé lors de l'échange et sur l'agrégation qui peut être envisagée, tant au niveau des paramètres de l'offre (facteurs qualitatifs liés au poisson, taille, type de pêche, origine...) qu'au niveau des prix. Enfin, plusieurs communications s'attachent à caractériser la nature et les conditions de l'offre et de la demande de produits de la mer, sans recours à la modélisation.

Les récents travaux dans le domaine de l'analyse des prix et des marchés montrent qu'il convient, en particu-

The formation of fish price has been the object of many research studies. They have revealed the disparity and variability of prices resulting from conditions of supply and demand. The fisheries are faced with adequation problems between an instantaneous, strongly fluctuating supply, and markets with a frequently inflexible capacity to absorb the products. This uncertain supply, relatively independent of prices in the short term, is typical of fishproducts. On the other hand, this supply is very dependent on environmental and biological factors influencing the size, availability and accessibility of the stock. The question of how prices are determined has therefore been integrated into the overall analysis of fisheries in order to study the influence of market fuctioning and /or evolution on resource exploitation.

This session will present different approaches to these questions. Two communications will deal with modelling markets of a particular product, concentrating on the specifications of its supply and demand functions (Ioannidis, Wright and Copes). Others are devoted to modeling the formation of prices on landing markets. They are particularly concerned with the impact of the specific conditions of each transaction - nature of the resource, type of sale - on price setting (Kirman, Ty and Gates). These analyses lead to questions about the significance of the price established during the transaction ; the formulation of aggregates concerning supply parameters (qualitative factors linked to type and size of fish, fishing technique, catch location...), as well as prices. And finally, several communications will not adopt a modeling approach. Their goal is to describe the nature and conditions of supply and demand of fishproducts, particularly in Iceland and Japan.

Recent work in the area of price and market analysis has shown that it is preferable to proceed on a disaggregate level, particularly in modeling. This approach takes into

lier dans le cadre d'une modélisation, de conserver une désagrégation fine pour prendre en compte la diversité des prix et leurs interaction. En effet, l'utilisation d'un prix unique associé à une espèce, ou encore le recours à un agent représentatif pour caractériser les comportements sur un marché sont le plus souvent inapproppriés. Plusieurs analyses allant dans ce sens sont présentées dans cette session (Kirman, Ioannidis). Il faut souligner que ces travaux ont pu être réalisés grâce à l'essor de moyens de calcul permettant de stocker et de traiter l'information.

Dans sa communication, A. Kirman présente ainsi une modélisation d' un marché au débarquement sur la base de données individuelles de transactions gré à gré. L'analyse empirique des données recueillies revèle l'absence de convergence vers un prix d'équilibre mais montre en revanche une distribution des prix qui apparaît stable dans le temps. Des comportements individuels d'achat et de vente sont spécifiés, d'où un second résultat intéressant : les propriétés standards de la fonction de demande qui n'apparaissent pas au niveau individuel, sont en revanche observables lorsque l'on traite les données agrégées. En conclusion, l'auteur souligne que la structure et l'organisation du marché déterminent la nature de l'équilibre réalisé, ouvrant ainsi des perspectives de recherche dans l'analyse de différentes structures de marché (marchés aux enchères, marchés contractuels...)

N. Ty et J. Gates s'interrogent sur l'influence de la nature de l'offre sur la formation des prix au débarquement du cabillaud, dans le cas d'un marché d'enchères. Ils effectuent une régression en terme de prix hédonistes, sur la base de données de transactions individuelles. Les facteurs qualitatifs testés sont d'une part, ceux relatifs au produit lui-même, d'autre part ceux relatifs au marché.

Un second groupe de communications apparaît plus centré sur la question de la spécification des fonctions d'offre et de demande. Ainsi, pour C. Ioannidis, considérer un prix moyen pour établir un système de prix de retrait peut être source d'une allocation sous-optimale. L'illustration en est fournie par les marchés français du cabillaud et de l'églefin qui se caractérisent semblablement par une demande sensible à la taille du produit. La prise en compte de la variabilité due à la nature de la demande permet alors de limiter le coût budgétaire de mesures de stabilisation du prix, du type prix de retrait. La communication de C. Wright et P. Copes aborde la question de la spécification de la fonction d'offre pour le marché du saumon aux USA. Les auteurs s'intéressent à la relation de long terme qui résulte de la compétition entre deux segments d'offre (offre de pêche et d'élevage) confrontés à une seule demande. Ils en déduisent les

account the diversity of prices and of their interactions. Use of a single price for a species, or characterizing market behavior with a representative agent, is usually inappropriate. Several analyses on these lines will be presented in this session (Kirman, Ioannidis). It should be noted that these works could not have been carried out without the rapid development of means of calculation enabling information to be stored and processed.

Thus, A. Kirman presents a landing market modeling on the basis of individual data about mutual agreement transactions. Empirical analysis of collected data does not show convergences toward an equilibrium price but rather a range of prices which appear to be stable over a period of time. Individual buying and selling behavior is specified, leading to a second interesting result : the standard characteristics of the demand function do not appear on an individual level but are observable when the aggregate data is treated. In conclusion, the author emphasizes that market structure and organisation play a determining role in the equilibrium established. This opens perspectives of research in the analysis of different market strutures (auctions, contractual markets...)

N. Ty and J. Gates focus on the influence of the type of supply on the formation of landing prices for cod in an auction context. They formulate an hedonic price function as a regression of the observed price of cod against its qualty attributes, on the basis of individual transaction data. The qualitative factors tested are the factors relative to the product itself, and those relative to the market.

A second group of communications are more centered on the question of the specification of supply and demand functions. For instance, for C. Ionnadis, using an average price to establish a withdrawal price system can result in a sub-optimal allocation. This is illustrated by the French cod and haddock markets which are characterized both by a demand influenced by product size. Taking into account variability due to the nature of the demand can therefore reduce the budget cost of price stabilization measures, such as withdrawal price scheme. The communication of C. Wright and P. Copes raises the question of the specification of the supply function for the salmon market in the USA. The authors are interested in the long-term relationship resulting from competition between two supply segments (fishing and farm supply) confronted with a sole demand. They deduce from this, the potential consequences on the activity of the two sectors. O. Klemenson and G. Bourgignon emphasize the role of imports and exports. O. Klemenson describes the impact of export incentive measures on price variability in Iceland and the consequences for the fisheries. G. Bourgignon makes an analytic description of the role of imports and exports in the supply and demand of Japanese seaproducts.

conséquences potentielles sur l'activité de chacun des deux secteurs. O. Klemenson et G. Bourguigon mettent l'accent sur le rôle des importations et des exportations. O. Klemenson décrit l'impact de mesures d'incitations à l'exportation sur la variabilité des prix en Islande et leurs conséquences sur les pêcheries. G. Bourguigon effectue une analyse descriptive du rôle des importations et des exportations sur l'offre et la demande de produits de la mer au Japon.

Trois communications fournissent une analyse détaillée des structures d'organisation de l'offre et du marché des produits de la mer au Japon. Ainsi, K. Miki et T. Yamamoto présentent le rôle du système de stockage pour la stabilisation des prix. N. Odaka et T. Yamamoto montrent l'importance du réseau de coopératives de pêche y compris dans la mise en marché. Le système très complet de statistiques des pêches fait l'objet de la communication de T. Yamamoto, qui souligne son intérêt pour le suivi économique et social des activités artisanales et industrielles.

Les perspectives qui s'ouvrent dans le domaine de l'étude des marchés et de la formation des prix sont multiples ; d'une part, les aspects séquentiels relatifs aux marchés - séquences de vente, nature périssable du poisson- et leurs implications sur la dynamique de l'exploitation des pêches peuvent être traités sous la forme de problèmes dynamiques dans le cadre des développements de la théorie des jeux. D'autre part, les méthodes d'analyse économétriques liées à la théorie de la cointégration permettent d'aborder au travers de tests statistiques les questions relatives aux relations d'équilibre et de dépendance entre les prix et les marchés, qu'il s'agissent de tendances communes d'évolution des prix de certains produits ou encore de relations entre prix d'un même bien sur différents marchés.

Three communications make a detailed analysis of organizational structures of the Japanese fishmarket. K. Miki and T. Yamamoto present the role of storage systems in price stabilization ; N. Okada and T. Yamamoto show the importance of the fishing cooperative network, all the way to the market stage. The very complete system of fishing statistics is the subject of the communication of T. Yamamoto, who underlines its usefulness for economic study and social supervision of artisanal and industrial activities.

Multiple perspectives are being opened in the area of market and price formation study :

on one hand, the sequential aspects relative to markets - sales sequences, the perishable nature of fish - and their implications for the dynamics of fish exploitation can be treated in the form of dynamic problems in the framework of game theory development ;

on the other hand, methods of econometric analysis linked to the cointegration theory make it possible to study, through statistical tests, questions concerning the relations of equilibrium and dependence between prices and markets, whether they be common tendencies in price evolution of certain products or relations between prices of the same product on different markets.

# Market Structure and Prices : the Marseille Fish Market

**Alan Kirman** *

European University Institute, Department of Economics, via dei Rocettini 9, Badia Fiesolana, 50016 San Domenico de Fiesole, Fi, Italy

ABSTRACT

*The purpose of this paper is to give a brief account of some recent work at the micro level on the formation of fish prices. What has become clear is that the behaviour of the individuals on the particular market that we have studied, the wholesale fish market in Marseille, is rather complicated and does not correspond to the classical description of actors in a competitive market even though there are many buyers and sellers. Indeed the purchases and sales at the individual level often bear little resemblance to standard demand and supply functions. In the aggregate, however, standard properties, in particular that of downward sloping demand, do reemerge. This leads to two conclusions which are important in studying such markets. Firstly, the "good behaviour" at the aggregate level should not be thought of as resulting from the underlying actions of well behaved individual participants, but rather as emerging from the procedure of aggregation itself. Secondly it would be a mistake to try to base predictions as to the consequences of a change in the economic environment on the reactions of a single "representative agent". Furthermore an examination of the market does reveal interesting patterns in behaviour which are of interest in themselves when trying to explain market outcomes.*

## 1. INTRODUCTION

The fish market has a long tradition in the economic literature. It was the subject of a debate between John Stuart Mill [1869] and Thornton [1869, 1870]. The subject of this discussion was the nature of the prices charged for the same type of fish during auctions. The two points of view were firstly that there were either multiple equilibria or no equilibrium

* I owe a special debt to Annick Vignes with whom I started this work and who spent many cold, very early mornings at the Marseille fish market She obtained the raw data from the market authorities and a first analysis may be found in Kirman and Vignes [1990]. I am also indebted to Mary McCarthy, Wolfgang Härdle, Jean-Pierre Malrieu, Nick Vriend, and Gilles Teyssière for their collaboration. Lastly I would like to thank Paul Klemperer who asked several pertinent questions, some of the answers to which are given here.

prices, and secondly, that these were out of equilibrium or disequilibrium prices. This debate was reopened by Negishi [1986] and was followed by a discussion by Ekeland and Thommesen [1989] and a reply by Negishi [1990]. The central issue of this debate was how one should interpret the notion of equilibrium on a market such as that for fish.

One of the reasons for the interest of economists in the fish market is that successive days are separated since the product is perishable. It was this that led Pareto and Marshall's followers [1] to use it as an example. Such a market can be considered, with some reservations, as one in which, in each period, stocks are fixed and prices are used as the strategic variable.

In the particular market analysed 574 buyers and 37 sellers come together each day and transact 129 types of fish. Prices are not posted and all transactions are pairwise. There is no auction mechanism unlike the Thornton examples, and unlike many of the major fish markets. Given the numbers of agents involved in the same place at the same time one might be led to expect that, at any moment, the same type of fish would be sold at essentially the same price. This, as we will see, is far from being the case. Furthermore, one could expect to see evidence of the standard assertion that as the day progresses, prices diminish. This is again not true. What is needed first is a general analytical framework which would permit the sort of price dispersion and evolution of prices over time that one actually observes. Such a framework clearly is not competitive in the standard sense. At no point in time is there an "equilibrium price" which clears the market. Nor, however, is there convergence to such a price after trading at "disequilibrium prices". Thus neither Walrasian nor Edgeworth type analysis is applicable to this sort of market. Rather, the market should be thought of as a game in which individuals have strategies consisting, for sellers, of prices to charge at each point in time, or for buyers, of demand functions at each round which will depend on the history of the market up to that point. Thus after a series of meetings between buyers and sellers and a number of transactions each individual decides on what to charge for the remaining stocks, or what to demand at any given price. The nature of the equilibrium will depend on the information possessed by the individuals. Buyers may or may not know sellers' characteristics and vice versa. Individuals may or may not know what transactions have taken place and what initial stocks were held on the market. All of these factors will enter into the information sets which condition the strategy. How complete information is will determine the characteristics of equilibrium prices. Equilibrium price distributions in this sense, will then be different from those described by Diamond [1987] and Butters [1977] for example. The fact that there is price dispersion may in part be due to lack of information and the cost of obtaining that information but may also be due to price discrimination by sellers who know the demand of the buyers they face. Buyers may choose to search over sellers or to purchase from some limited subset. As we will see, both types of behaviour are apparent in the market. However, close examination of the data shows that the separation between "loyal" and "searching" buyers is not as clear cut as it might seem.

All of these phenomena should be captured by the theoretical model. I shall give a very general framework which will allow the specification of strategies based on particular levels of information at each point in time. This model is sufficiently general to allow, as possible outcomes the phenomena actually observed. I shall then present an account of various analyses of the data which reveal certain features of market behaviour. The problem then remains, and it will be difficult to solve in full generality, of giving informational assumptions and optimising rules which will generate all these phenomena.

Our data are unusual in that they allow us to "follow" individual traders in the market. Hence, at each point we know who buys what from whom. We thus have a very clear picture of the evolution of the market over the day, although we do not have statistics on the initial stocks for each day : In fact, of course, we should treat the market as a dynamic game and recognise that the changes in stocks at the beginning of each day are, at least in part, endogenous and the result of the previous history of the market. However, if, as we shall see, the behaviour of the market is relatively stable over time then it is not unreasonable to think of the supply of fish as being largely dependent on factors exogenous to the market in question.

In a previous paper, Kirman and Vignes [1991], we examined the data for a single week. In Kirman and McCarthy [1990] we took a full month involving over 40,000 transactions and examined to what extent some of the price variability could be explained by "seasonality", i.e. the fact that the level of transactions varies considerably over the days of the week. We also tried to give explanations for some of the apparently asymmetric behaviour observed. In Kirman and Härdle

1. Hicks [1989] points out that Marshall himself, actually talked about the corn market whereas his successors used the fish market to eliminate the problems posed by the carrying over of inventories. More recently, Gorman [1959] in a well known unpublished paper and Barten and Bettendorf [1989] have analysed the demand system for the fish market.

[1993] we examined individual purchases over three months and found no simple classical monotone relation between prices and quantities. However, using non-parametric regression techniques we found such a relation at the aggregate level. Furthermore we found that, although there was no tendency towards a single equilibrium price for each type of fish the *distribution* of prices on the market was stable from month to month. Thus, however complicated the underlying game it is not illegitimate to think of it as being repeated over time.

This paper then presents a suggested analytical framework together with a number of salient empirical features of a fish market with a particular organization. The challenge for other economists is to specialise the framework by providing behavioural justification for strategies which yield equilibria with the characteristics revealed by the empirical data that we present. Some of the results described here provide indications as to some possible explanations but they are far from being complete. What is, however, already clear and has been emphasised by many authors[2] is that the structure and organisation of the market are of particular importance in determining the nature of the equilibrium realised. In particular the results in Härdle and Kirman [1993] showing that, at the aggregate level, the relation between prices and quantities purchased possesses the classical monotone declining property, is of interest. This reveals that simple aggregate properties may be the result of very complicated strategic behaviour at the individual level. It also shows that one should be wary of making any recommendations as to changes in market organisation based on the idea that the individual buyers in the market each have standard demand curves.

## 2. A SIMPLE MODEL

We consider the market for one perishable product with $m$ sellers and $n$ buyers[3]. The market evolves in a fixed number $T$ of rounds. Each seller $i$ has strategies which at each round $t$ specify a vector $x_{it} \in R_+^n$ of the prices which he will charge to each of the buyers. A strategy for each buyer $j$ specifies at each round $t$ a demand function $q_{jt}(p) : R_+ \to R_+$. In both cases the choice of the prices set and the demand functions will depend on two things : firstly, the strategies of the other players and, secondly, on who has met whom in the market. The model is then completed by specifying a matching process which, in keeping with the literature, will be supposed random. Thus a matching at time $t$ , a realisation of the random variable, will be a mapping $g$ from the integers $I = \{1, ..., n\}$ to the integers $I = \{1, ..., m\}$. A probability distribution must then be specified over the outcomes of the matching process for every time $t$. One might think, as an example, of each buyer as choosing a seller with uniform probability $\frac{1}{m}$, independently at each time $t$. A best strategy for a buyer i, then, will consist for each realisation of the matching process and for the associated price vectors of each seller i and demand functions of the other buyers $h \neq c$ of a demand function for each period $t$. Similarly for a seller it will consist of specifying the best price vectors for each matching and each period.

Thus to sum up, the model consists of :

1) A basic strategy set $B$ for buyers which is a subset of the product space of $Q$ where $Q$ is the set of functions $q : R_+ \to R_+$ satisfying

   i) every $q$ is continuous and monotone of economy

   ii) there exists a $\bar{p} > 0$ such that for every $q$ in $Q$ $q(p) = 0$ for all $p > \bar{p}$.

   Thus

   $B \subset \prod_T Q$ *i.e.,* $q \times q : \ldots Q$. Furthermore, we assume, $B$ is compact and convex.

2) A basic strategy set $S$ for sellers which is a compact convex subset of $R_+^{nT}$.

3) A matching process $M$ i.e.,

2. See, for example, Phlips [1988], Salop and Stiglitz [1982], Varian [1980].
3. In Kirman and Vignes [1991] we considered a continuum of buyers and sellers but this was to facilitate the technical problem later of establishing the continuity of strategies.

i) The mappings $f = (f_1, f_2, ..., f_t)$ where $f_t : I \to J$.

ii) A probability distribution over the finite set F of f.

4) A strategy $q$ for a buyer then associates with each $f$ an element of $Q$ i.e., $q : F \to B$ and $s$ for a seller associates with each element of $F$, an element of $S$ i.e., $s : F \to S$. The set of strategies for buyers is denoted $\tilde{Q}$ and for sellers $\tilde{S}$.

5) There is a continuous payoff function for each player $i$.

$$\prod_i (q_i \ldots q_n, \; s_{n+1} \ldots s_{n+m}) \quad i = 1, \ldots \ldots n + m..$$

6) The response function $\Gamma$ for each player is given for buyers by

$$\Gamma ; : \tilde{Q}^n \times \tilde{S}^m \to \tilde{Q} \text{ where } \Gamma_i = \underset{q}{Max} \prod_i (q_1 \ldots q_{i-1}, q, q_{i+1} \ldots q_n, s_{n+1}, s_{n+m})$$

and for sellers by

$$\Gamma ; : \tilde{Q}^n \times \tilde{S}^m \to \tilde{S} \text{ where } \Gamma_j = \underset{s}{Max} \prod_i (q_1 \ldots q_n, s_{n+1} \ldots s_{j-1}, s, s_{j+1}, \ldots s_{n+m})$$

We assume that for every $i$, $i = 1, ..., n$ and $j$, $j = n + 1, ..., n + m$, $\Gamma_i$ is continuous.

Denoting by $\tilde{Q}^n$ the $n$ product of $\tilde{Q}$ and by $\tilde{S}^m$ the $m$ product of $\tilde{S}$ then each $\Gamma$, $(\Gamma_1 \ldots \Gamma_{n+m})$ defines a mapping from $\tilde{Q}^n \times \tilde{Q}^m$ into itself. Given our assumptions a standard fixed point argument can be used to show the existence of an equilibrium.

The market can be envisaged as follows :

| | |
|---|---|
| Period 0 : | Initial stocks. |
| Period 1 : | Sellers specify prices. Buyers specify demands.<br>Matching takes place. Transactions take place. |
| Period 2 : | Given their information about what happened in period 1, sellers respecify prices, buyers respecify demands. Matching occurs. Exchanges follow. |
| Period T : | Last specifications by sellers and buyers, last matching and exchanges. |

All this does no more than give a formal framework which enables us to define the concept of an equilibrium. To characterise precisely the nature of an equilibrium requires that the $\Gamma_i$ be derived from maximising behaviour. For example, for a buyer would maximise his expected utility at each round $t$ given the known strategies of the other players and the matching up until $t$. The real difficulty here is *proving* the continuity of $\Gamma_i$ for the players. The difficulty of proving continuity is illustrated by Kormendi [1979] and Benabou [1988].

Without such a complete specification, however, our model would allow for extensive price dispersion (particularly since we have assumed that price discrimination is possible as each seller knows the buyers' characteristics), there will be no necessary tendency for prices to decline during the day as is commonly supposed and there is no a priori reason to assume that individual buyers will or will not search.

One important point to emphasise is that any strategy must be such that if the information set up to time $T$, is the same in two realisations, the next component of the strategy at time $t + 1$ should be the same. Thus it is important to specify what is known at each time. If, for instance, the individuals know initial stocks but only observe their own transaction strategies, they will be much more limited than if they observe everything that has occurred. Furthermore, it may well be the case that individuals choose to condition strategies on a limited part of the information they have available.

Although it is difficult to prove the continuity of strategies in a fully optimising context, it may well be the case that agents develop simple rules which are continuous. An interesting problem is the origin of such rules.

We now turn to a description of the data set and to an analysis of some of its features.

## 3. THE DATA

i) The market is open every day and there are 37 sellers and 574 buyers dealing in 129 types of fish. We have the following information for each transaction.

a) Name of seller
b) Name of buyer
c) Type of fish
d) Quantity sold (weight)
e) Unit price

Transactions are listed in chronological order for each seller.

### *3.1 Some Summary Statistics*

Of the 37 sellers one seller accounted for 15.5 % and 6 sellers shared 50 % of all transactions during the month. On the buyer side one buyer participated in 14 % of all transactions while all other buyers each recorded $\leq$ 1 % of the total volume of transactions. Ten of the 129 fish types were involved in just over half of all transactions. The average number of fish types traded by a seller in a day ranged from 1 to 32. Approximately 50 % of the sellers recorded average daily trading in 1 to 10 fish types over the three months analysed in Kirman and Härdle [1993].

As we observed in Kirman and Vignes [1991], the variation of prices over a week was extensive and this is reinforced by the results given in Härdle and Kirman [1993]. Two of the possible explanations for such dispersion are the effect of differing market volume, and the effect of price changes over the day (typically thought of as diminishing). We shall examine both of them.

### *3.2 Variations in Market Activity*

There are clear differences in the level of market activity. Some days are less active (Sunday is very inactive, for example) and the relative activity varies over the month.

A first and obvious question is to what extent is the level of prices correlated with the level of activity in the Market ? We tested this by looking at the correlation over the month of July between the daily average price charged and the corresponding number of transactions carried out for a selection of fish types, involving both a large and a small number of transactions. We were unable to find any significant differences across types of fish in these correlations.

A second observation is that buyers and sellers differ considerably in their level of activity. Distributions of numbers of transactions for buyers and sellers are illustrated in Figures 5 and 6. The number of transactions is influenced, for sellers, by the relative degree of specialisation and for buyers by two factors. Firstly, there is the nature of the buyers, activity (fish retailer, supermarket, restaurant) and, secondly, there is the extent to which buyers search. The latter merits some discussion.

### *3.3 Searchers and Loyalists*

In Kirman and Vignes [1991], and Kirman and McCarthy [1990] we noted that, even looking at one week's data, there seemed to be a very clear distinction between those buyers who visited [4] few sellers and those who "shopped around" extensively. We suggested then that this division could be considered by buyers as an "evolutionarily stable strategy".

4. Visited is not quite accurate since we have no record of visits which did not result in transactions.

This is, no individual would have an incentive to shift from being a "loyalist" to being a "searcher" or vice versa. Such a situation could be collectively rationalisable, in the sense that the externality produced by searchers for loyalists is internalised[5] . Thus different buyers would be using different strategies but none would have an incentive to change.

More recently we have taken into account the fact that buyers visit the market with different frequencies and examined how the distribution of number of sellers visited would look if buyers simply chose amongst sellers with the same uniform probability. Although this did not give a very good fit, if we take account of the fact that when all sellers are equally attractive a buyer could visit his previous supplier with probability one half and choose a new one at random with the same probability then the fit was greatly improved. Now, if we assume that there are some costs to switching suppliers then the probability of returning to the same seller would be correspondingly higher. The question is, can we find a value of this probability which would give us a good fit of the observed distribution ? The somewhat surprising result is that we can obtain a perfect fit by the appropriate choice of this probability. Thus if all buyers return to their usual seller with p= 0.905, the distribution of visits is precisely that observed in reality. Thus in this alternative explanation all buyers have identical behaviour once they appear on the market but the difference in the frequency with which they do so gives rise to the observed asymmetric distribution.

### *3.4 Different price behaviour for different sellers*

Participants in the market sometimes refer to the existence of sellers who systematically charge higher prices. In Kirman and McCarthy [1990] we tested this by ranking sellers by average price charged for a given fish for each day and then doing a rank-correlation test between days. When the correlation was significant, it was negative. Thus a high priced seller one day was more likely to be a low priced seller the next. However, this test does not completely rule out the existence of sellers with systematically different mean prices since the effect of those who vary their prices a great deal might be enough to dominate the effect of those who maintain very stable prices. If these sellers are such that 1 and 2 systematically charged the highest and lowest prices and change places from day to day, then we would obtain our result even if seller 3 charged the same price every day and that price were above the average of those charged by 1 and 2. An alternative explanation for the existence of high average price sellers would be precisely that they have lower variances. Thus risk averse buyers would frequent such sellers.

We tested this by looking at the correlation between the average transaction price for a particular type of fish and the corresponding variance in price (1) over sellers and (2) over buyers. In the case of sellers, of the 8 fish types[6] tested, 5 had significantly negative correlations while in the remainder of cases the correlation was insignificant. On the buyer side 6 fish types displayed significantly negative correlations.

### *3.5 Prices Over the Day*

It is commonly argued that as the day passes, prices will decline. In our model it is clear why this should not necessarily be the case. Consider the situation in which there are two sellers and two buyers in the market in period $T\text{-}1$ . If one of the sellers, say 2, has no more of a given fish market whilst the other has a stock then the following may occur. Buyer 1 visits seller 2 with a demand $q(p)$ . Now if buyer 2 who will visit seller 2 with probability 1/2, $T$ has a demand which is $nq(p)$ then clearly the price charged to buyer 1 in time $T\text{-}1$ may be lower than that charged to buyer 2 at time $T$.

We tested the proposition of declining prices for different types of fish for individual sellers by fitting a linear trend model to the prices recorded by an individual seller over one day for a particular fish type. This test was carried out for the 8 fish types mentioned above and 10 sellers for various days of the month. In no case was the trend in prices found to be significant.

One interesting observation is that a seller who is known here to leave the market early, say at Time $T\text{-}x$ may be discriminated against. At time $T\text{-}x$ the seller can charge the optimal price without fear that the buyer sell elsewhere.

5. It might seem that since there is price discrimination, searchers will not affect prices charged to loyalists. However, the fact that searching leads searchers to change their demand will influence indirectly the prices sellers wish to charge to non-searchers.
6. The set of fish types used for illustration here is a subset of those which were involved in a large number of transactions over the month, an important factor for carrying out some of the statistical tests referred to below. The fish types are : #40 Conger Eel, #44 Whiting, #116 A type of Eel, #118 Lemon Sole, #196 Red Mullet, #214 Sole, #224 Sardines, #250 Trout.

However, at time *T-x-1* the preceding seller does the same and so forth recurrently. By this reasoning, the buyer will have to pay the monopoly price from the outset. This would explain why fish costs more in the interior of France rather than the usual explanation of transport costs. There is a flaw in this reasoning since otherwise it would apply to all buyers since they all face a fixed horizon *T*. The flaw is that the "monopoly" price varies depending upon the history or the day of the seller and that is therefore different between sellers at any point in time. Thus the buyer has an interest in staying in the market. However, this may be a partial explanation for the higher prices paid by those who leave early.

### *3.6 Aggregate "Demand"*

In economics, aggregate behaviour is often tested to see if it meets restrictions that can be derived from individual maximising behaviour. Thus it is common practice to treat data arising from aggregate purchases of some commodity over time as if these were the expression of the competitive demand of some representative individual. This approach involves a number of implicit assumptions, in particular that the underlying micro-data observed can be thought of as corresponding to individual Walrasian demand, and furthermore that aggregation considerations do not invalidate the use of restrictions derived from individual behaviour.

In Härdle and Kirman (1993) we find empirically that, for the Marseille fish market, properties which we show to hold at the aggregate level and which might be thought of as "downward sloping demand curves" are not derived from similar properties at the individual level. Furthermore, using the model specified above, we show that there is no theoretical reason to expect any such simple relation between individual and aggregate behaviour. In this we are following directly in the line of work by Becker (1962) [7] who showed that downward sloping demand curves at the market level could be derived from random individual choice behaviour subject only to a budget constraint. Whereas he summarised his result as saying that "households may be irrational and yet markets quite rational", a better summary of our results would be that "sophisticated and complicated individual behaviour may lead to simple aggregate properties."

In particular, we examined this problem by looking at the properties of the purchases of particularly perishable goods, the different types of fish, for which we have the data already described, at the individual level, from the Marseille fish market. Although, as I have mentioned, fish markets have been widely used as an example in the economic literature, we argued, in that paper, that, for several reasons, it is inappropriate to think of purchases on such markets as corresponding to Walrasian demand. In the context of the theoretical model it is clear that the quantities "demanded" or "supplied" by the individuals in question cannot be expected to correspond to those that would be "demanded" or "supplied" by the standard individual in a competitive market. Instead we use a more appropriate theoretical notion, that of "strategic demand and supply".

With this, the appropriate equilibrium concept can be defined and corresponds to a non-degenerate price distribution (see Diamond [1987], Butters [1977]). For the use of the theoretical model to be justified and if we are to be able to use data from the whole period that we study, it should be the case that the observed price distributions remain fairly constant over time. If this is the case, then one can think of the market as repeating itself from day to day, or at least from week to week. We test for the intertemporal stability of the price distributions for some representative types of fish. In particular, it should be noted that we did this without imposing any a priori restrictions on the form of the distributions. Then, having established that these do indeed remain constant, we used non-parametric methods to fit two different aggregate price quantity relations and found that these relations, in contrast to those at the individual level, exhibit monotonicity once a certain class of observations is identified and removed. The important thing to notice is that non parametric methods are, in a certain sense, the least favourable to monotonicity since they will pick up any small non monotonic deviation and the resultant smoothed curve will preserve this. The counterpart is that this enables one to identify the observations that create the problem, in our case late transactions whose price varied substantially, depending, amongst other things on the total amount of fish available on the market on the particular day in question.

7. This idea has been developed recently by Gode and Sunder [1993].

## 4. CONCLUSION

The data from the fish market that we have studied are unusually rich and provide a number of interesting possibilities for further investigation. However, what is clear from our analysis is that the notion of an equilibrium price system is very complicated and rather far from standard competitive markets. Simply because a large number of buyers and sellers are gathered together dealing in the same product at the same time does not mean, for example, that the price of that product will be the same in simultaneous transactions. In the particular market that we have studied, no prices are posted and sellers know buyers' characteristics. Changing these two basic features would understandably modify many of the conclusions and it would be of interest to compare the outcomes of this market with those of markets organised on an auction basis for example.

## REFERENCES

**Benabou R.** (1988). Search, Price Setting and Inflation, *Review of Economic Studies*, July, **55** (3) : 353-376.

**Becker G.S.** (1962). Irrational behavior and economic theory, *Journal of Political Economy*, **70** : 1-13.

**Butters G.R.** (1977). Price Distributions of Sales and Advertising Prices, *Review of Economic Studies*, **44** : 465-491.

**Diamond P.** (1987). Consumer Differences and Prices in a Search Model, *Quarterly Journal of Economics*, May, 1987.

**Ekelund R.B. Jr. and S. Thommensen** (1989). Disequilibrium Theory and Thornton's Assault on the Laws of Supply and Demand, *History of Political Economy*. 21.

**Gode D.K. and S. Sunder** (1993). Allocative efficiency of markets with zero-intelligence traders : markets as a partial substitute for individual rationality, *Journal of Political Economy*, **101**, 1: 119-37.

**Gorman W. M.** (1959). The Demand for Fish : An Application of Factor Analysis, Research Paper No. 6, Series A (Faculty of Commerce and Social Science, University of Birmingham), abstracted in *Econometrica* **28** : 649-650.

**Härdle W. and A. Kirman** (1993). Non classical demand : a model-free examination of price quantity relations in the Marseille Fish Market, forthcoming, *Journal of Econometrics.*

**Hicks J.** (1989). *Market Theory of Money* , Oxford University Press, Oxford.

**Kirman A.P. and M. McCarthy** (1990). Equilibrium prices and market structure : the Marseille fish market, mimeo E.U.I., Florence.

**Kirman A.P. and A. Vignes** (1991). Price dispersion. Theoretical considerations and empirical evidence from the Marseille fish market, in *Issues in Contemporary Economics*, K.J. Arrow (ed.), Macmillan, London.

**Kormendi R.C.** (1979). Dispersed Transactions Prices in a Model of Decentralised Pure Exchange in Lippman, S. A. and J. McCall (eds.), *Studies in the Economics of Search*, North Holland.

**Mill J.S.** (1869). Thornton on Labour and Its Claims", In idem, 1967. *Essays on Economics and Society* (Toronto) : 631-668.

**Negishi T.** (1990). On Equilibrium and Disequilibrium--Reply to Professors Ekelund and Thommesen, *History of Political Economy*, forthcoming.

**Phlips L.** (1988). *The Economics of Imperfect Information*, Cambridge University Press, New York.

**Salop S.C. and J.E. Stiglitz** (1982). The Theory of Sales : A Simple Model of Equilibrium Price Dispersion with Identical Agents, *American Economic Review*, **72** : 112-130.

**Thornton W.H.** (1869). *On Labour*, London.

**Varian H.R.** (1980). A Model of Sales", *American Economic Review*, **76** : 651-659.

# Relative Price Variability in Fisheries some Policy Implications

**Chris Ioannidis** *

Cardiff Business School, University of Wales, Aberconway Building, Colum Drive, Cardiff CF1 3EU, U.K.

ABSTRACT

*The paper comments on the currently operating intervention scheme and suggests that it is important to distinguish the sources of price changes. It then investigates the size-specific price variability in fisheries and finds evidence of significant non-proportional price variation. It goes on to suggest a method to isolate the influences of demand on the size-specific price changes, and suggests a compensation system based exclusively on insuring producers from demand fluctuations only. An empirical example, is provided, using French data for Cod and Haddock. Significant differences in the fluctuations of demand for each size were found.*

## 1. INTRODUCTION

It is well known that a result of fluctuating prices at fish auctions at the quays, is the intervention of the authorities in the market to stabilise prices thus ensuring 'stable' incomes for the producers.

Within the European Community the system in place is the withdrawal price scheme which is operating since the mid 70's. An economic analysis of the system is developed in Young (1984) and the ramifications of the system's operations for both producers and consumers are discussed.

## 2. THE CURRENT POLICY REGIME

The point of departure for the operation of the scheme is the 'guide price' which is a notional price in (ECU/tonne) and it applies throughout the community. The 'guide price' reflects the prices that the Commission expects to be attained.

* The author would like to thank Paolo Maggioni and Nigel Driffield of the Cardiff Business School for their help and advise. Remaining errors are of course the author's responsibility.

These 'expectations' are based on passed experience and possibly some heuristic forecasts of future trends. Once the 'guide price' is established the 'withdrawal price' is then derived and it is guarantied as the minimum price that the product will be sold, it therefore acts as the 'floor price' at the auction. If the price of fish for human consumption were to fall below the 'withdrawal price' the fish whose price has thus fallen, is then removed from the market at this price. Once bought at the 'withdrawal price' it does not enter the food chain but it is processed for animal feed. It must be emphasized here that the 'withdrawal price' does not fully reflect the amount that producers receive. In fixing the 'withdrawal price' the Commission takes into account the 'guide price', a 'quality factor' and the 'regional coefficient'. What the fishermen actually receive is the 'compensation price' which is a proportion of the 'withdrawal price'. Young (1984) explains in detail how this proportion varies as a function of landed quantities. The use of the Green rate in setting the 'guide' and 'withdrawal' prices provides for considerable stability in terms of domestic currency insulating producers from spot rate variability. The sterling price received by British fishermen will be raised only if the Green pound is devalued. The graphical analysis depicts the impact on producers' incomes when the withdrawal price scheme is operational (graphs 1a, 1b).

As it is commonly assumed the supply of fresh fish at any given time is price inelastic, Q(s). For any given demand DD, if the equilibrium price P(e) is below the 'withdrawal' price P(w), the quantities allocated to human consumption will be Q(a) and Q(a)Q(s) represents the quantities to be withdrawn. By varying P(w) for any given volume of demand and supply conditions we can establish the 'withdrawal price' schedule WW in figure 1a. But unlike producers of other agricultural commodities fishermen do not receive the 'withdrawal price' for their produce but a variable proportion of it, the compensation price. The BE schedule, in figure 1B, represents such relationship between the compensation price and the level of withdrawals. Thus for any given intervention price P(w) the fishermen actually receive P(c), in figure 1a. Total revenue can now be calculated as the sum of those revenues raised by selling fish for human consumption (P(w)*Q(a)) and the revenues accrued from the withdrawn fish (P(c)*Q(s)Q(a)). Fishermen vial their lobbying organisation attempt to influence the policy instrument as it is vital to their interest. From their point of view, they will asking for a withdrawal price taking into account the following elements :

$$P(w) = F(-e(d), -dP(c)/dw, -Q(s)) \quad (1)$$

where e(d) is the elasticity of demand, the second term captures the rate at which the compensation price declines in response to withdrawals, and finally Q(s) stands for total landings. The sign below indicate the direction of the response on P(w) due to a change in any of the three elements. In the case of the UK and France the role of imports in increasing total available supply is crucial in maintaining lower than otherwise 'withdrawal prices'. In the UK where cod and haddock are by and large the main species demanded by consumers, the price elasticity of demand for domestic landings is being estimated at -3.03 and -1.55 respectively Ioannidis and Whitmarsh (1989). For other less popular species the substitution opportunities increase and the implied demand price elasticities are considerable higher.

## 3. SOURCES OF PRICE VARIABILITY

The scheme, as it is currently working does not discriminate what causes the equilibrium price to fall below the 'withdrawal' price. The price fall can be either due to higher than anticipated supply or lower than anticipated fall in demand. In a recent paper Van Kooten and Schmitz (1988) extent the analysis of commodity price stabilisation to the case of nonstorable commodity, under uncertainty. The problems of price stabilisation for storable agricultural commodities has been addressed by Oi (1961) and Massell (1969) among others.

The following discussion, which aims to highlight the importance of the source of the price shocks, relies on Van Kooten and Schmitz (1988).

Consider initially the case of price variability caused due to demand fluctuations. Assume that there are n probable states of demand, denoted by D(1),...,D(n). Risk neutral producers will attempt to supply(ex-ante)

$$S = S(f(i)\ P(i))\ i = 1,...,n \quad (2)$$

where f(i) is the probability associated with price P(i). The stabilisation rule can thus be set as :

$$P(E) = \Sigma_i \, (f(i)*P(i)) \tag{3}$$

thus if the producers were to operate a buffer fund, the fund's expected revenue will be given by :

$$\Sigma_i \, f(i) \, S(P(E) - P(i)) = 0 \tag{4}$$

So the fund is actuarial sound and the scheme sets producers' output such that producers' price will be P(E) and output will be given by (2) (see graph 2).

As the scheme is actuarial sound there is no transfer from consumers to producers. With risk averse producers the existence of such policy results in a Pareto improvement as it reduces price variability and thus improves the welfare of the fishermen.

Now consider the case where price variability is due to unpredictable fluctuations of the supply. The quantity offered to the market from one period to next varies with known probability j(i). Given the position of the demand curve the expected price will be given by

$$P(E) = \Sigma_i \, (j(i) \, P(i)) \tag{5}$$

and the realised supply will be

$$S = S(P(E),U) \tag{6}$$

where U is a random variable with known distribution. The equilibrium will be characterised by the distribution of prices and quantities such that the market clears ex-ante. If the aim of the policy is set prices at P(E), producers will act as in the previous case and under the competitive assumption and rick neutrality will plan production as in (2). However their expected revenues will be higher with the scheme than without it. The Graph 3 depicts the situation

Consider the case of two equiprobable states of supply S1 and S2, for any given downward sloping demand curve DD, the expected revenues for the fund and the producers can be calculated as follows.

Without the scheme the expected producers' revenue is given by :

$$E(RV1) = (1/2)*(P(1) \, Q(1) + P(2) \, Q(2)) \tag{7}$$

but by setting P = P(E) their revenue will now be

$$E(RV2) = (1/2)*(Q(1) \, P(E) + Q(2) \, P(E)) = (1/2)* \left(E(RV1) + .5 \, [(Q(1) - Q(2))*(P(1) - P(2))]\right) \tag{8}$$

under normal demand conditions

$$E(RV1) < E(RV2) \tag{9}$$

Thus there is a net transfer of resources from consumers to producers.

## 4. RELATIVE PRICE VARIABILITY

The above discussion helped to the fact that price stabilisation of a non storable commodity which does not discriminate between demand and supply shocks responsible for price variability has quite important budgetary implications for the authorities.

Most landing prices for fresh fish are determined in competitive auction markets. Prices change because of the discrepancies between the actual and expected values of the conditioning variables. Each species landed is further separated into standard sizes, depending of the weight of the individual fish. At the quay auctions the final quoted prices

are size specific and their weighted combination is referred to as the 'species price'. As the fish vary in size and weight according to their classification their yield will also vary. The differences in the yield will generate distinct demand conditions, depending on the nature of the final user. The demand for 'small' and 'unclassified' fish by processing enterprises will be stronger compared to those of restaurateurs and fishmongers. Demand conditions for each particular buyer may be changing according to seasonal factors, advertising campaigns and other changes in tastes. Yet, as it was previously discussed, policy measures tend to ignore these differences and the 'average price' for each species is used as a guide-line for intervention. The use of such average disguises the various pressures due to demand changes and 'confuses' them with possible size specific supply changes.

The 'average price' of a species j categorised into k sizes can be written as :

$$P(j, t) = \Sigma_{i=1,k}\, w(i, t)\, P(j, i, t) \quad i = 1,...,k \tag{10}$$

the weights w(i, t) are taken to be proportional to the contribution of landings of size i to total landings. P(j, i, t) is the size specific price for species j.

Two sources of disturbance are now present :

(i) variations the total catch and in the size distribution of landings

and

(ii) variations in the size specific prices due to changes in the size specific demand conditions.

In the standard Divisia price index formation changes in the 'average price' of species j can be written as :

$$DP(j, t) = \Sigma_{i=1,k}\, w(i, t)\, DP(i, j, t) \tag{11}$$

where

$$DP(i, j, t) = \log (P(i, j, t)) - \log (P(i, j, t - 1)) \tag{12}$$

A simple measure of relative price variability can be given by the weighted sum of squared deviations of the size specific price changes from the average 'species price.

$$VP(j, t) = \Sigma_{i=1,k}\, \{(DP(i, j, t) - DP(j, t)\}^{\wedge} 2 \tag{13}$$

Thus VP(j, t) measures the non-proportionality of price movements, for if all prices change by the same rate, the quantity VP(j, t) will be zero. The measure will be larger the more non-proportional the price changes become. In a previous study Ioannidis(1989) tested for the existence of relative price variability, using the regression

$$VP(j, t) = c0 + c1*DP(j, t) + u(j, t) \tag{13a}$$

has found significant non-proportional variations for cod and haddock in Scotland for the period 1983-1988, as the estimate of c1 was found positive and significantly different from zero.

This is taken as prima-facia evidence that there exists important differences in the demand conditions of each size.

If the authorities wish to compensate fishermen for the variations in price which are exclusively due to demand conditions then some appropriate measure is needed.

## 5. A 'NEW' SCHEME

The authorities observe a single signal, the change in price and on the basis of this intervene, however to compensate fishermen for temporary fluctuations in supply or its composition is not desirable. Fishermen should compensated for fluctuations in demand but not for those in supply. The task here is to develop an approximation in order to measure the contribution of price changes due to shifts in demand.

Consider the market situation at t + 1, where S(i, t + 1) fish are landed and the market clearing price is quoted at P(i, t + 1). Assuming linear demand curves (which are non-integrable) let me postulate a simple linear relation between prices and quantities

$$P(i, t + 1) = a(i, t + 1)*S(i, t + 1) \quad (14)$$

where a(i, t + 1) is some measure of the slope of the demand curve at t + 1, which remains unchanged along the curve for this time period, t + 1. The authorities have observed from the previous period, t, the market clearing prices and quantities traded, (here we may assume that at this period the 'equilibrium price' was the one 'desired' by the authorities). The question the authorities will ask is the following : ' If the fishermen had not altered their supply, therefore if S(i, t) = S(i, t + 1), given the now (t+1) prevailing demand conditions, what would the price be ? '.
The answer to this question can be calculated as follows

$$P^*(i, t) = a(i, t + 1)*S(i, t) \quad (15)$$

Now if P*(i, t) < P(i, t) then the fishermen will be compensated to the tune of [P(i, t) - P*(i, t)] S(i, t), this part of the price fall can be attributed to a fall in demand. The graph 4 depicts the situation.
In this scheme fishermen will be compensated even if the final price of the fish has risen, provide that demand has fallen, as in Graph 5.
As the fishermen will not be expected to pay a levy if P*(i, t) > P(i, t) a net contribution from consumers to producers will take place. In this scheme the authorities will not react immediately as prices are falling but they will retrospectively compensate producers for lost revenue due to falls in demand. Such a income stabilisation program will also act as a deterrent to overfishing. For if prices were to fall because in the current period (t+1) producers have overfished no compensation will be paid despite the fall in prices if demand has remained unchanged. Furthermore if fishermen break net size regulations and land more 'small' fish than anticipated they will drive down their prices but again no compensation will be paid.

## 6. SOME EMPIRICAL EVIDENCE

Using monthly data covering the period 1983m1 to 1988m12 for cod and haddock, by size, measures of relative price variability were constructed vpc,vph.
Running the same regression as in (13a), it was found that the price of cod did exhibit significant relative price variability and haddock prices also did show evidence of non proportional price changes.
To investigate whether such phenomena were due to differential changes in demand (by size) the following method was followed employing the methodology outlined in section 5. To estimate a(j, t + 1) a 12 period rolling regression was run using the linear function for each size of both species.

$$P(j, i, t) = c0(j, i, t) + c1(j, i, t)\ S(j, i, t) + U(j, i, t) \quad (16)$$

the series of the rolling coefficients are collected and the series of imputed prices due to demand only changes are computed. These are then compared to the actual quoted prices to isolated the exclusive influence of demand factors on price chamges. The graphs 6 and 7 show that within each of the species there are considerable differences in the movements of demand causing prices to vary over and above fluctuations due to changes in the quantities landed. There is no doubt that demand movements across size of the same species show a considerable amount of comovement between the computed P*(j, i, t), but to perceive them as identical will be mistake. An intervention scheme will have therefore to be fine enough to discriminate and award compensation only to those sizes whose prices have fallen due to adverse demand changes.

## 7. CONCLUSIONS

In this paper an attempt was made to quantify the differences between the demand and supply size-specific shocks. It was argued that compensation schemes based on 'average' prices are not based on sufficiently detailed information and

consequently are thus more expensive than they need be. As the regulatory framework of the Community imposes severe restrictions on the quantities to be fished and the nature of the capital equipment used they control both total supply and its size composition. To compensate producers for temporary fluctuations in supply which is already regulated seems to be rather misguided. Fishermen should be insulated from fluctuations in demand over which there is no control. It was asserted that Demand conditions may vary across sizes of the same species thus requiring separate monitoring. The empirical evidence presented here, using French data, supports the basic assertion that each size for the same species faces demand conditions are sufficiently different, justifying the use of a more information intensive scheme.

## REFERENCES

**Van Kooten G.C., A. Schmitz and W.H. Furtan** (1988). The Economics of storing a non storable commodity, *Canadian Journal of Economics :* 579-586.

**Young T.** (1984). Market Support Arrangements for Fish : The Withdrawal Price Scheme, *SFIA Occasional Paper* series No 1.

**Ioannidis C.** (1989). What can Aggregate Prices Tell us ? 2nd EAFE Conference, Lisbon.

**Ioannidis C. and D. Whitmarsh** (1989). The impact of fish imports on domestic fresh fish prices in the UK, SFIA report : 1-69.

**Oi W.Y.** (1961). The desirability of price instability under perfect competition, Econometrica : 58-64.

**Massell B.F.** (1969). Price Stabilisation and Welfare, *Quarterly Journal of Economics* : 284-298.

**FIG. 1(A-B)**
**THE WITHDRAWL PRICE SCHEME.**

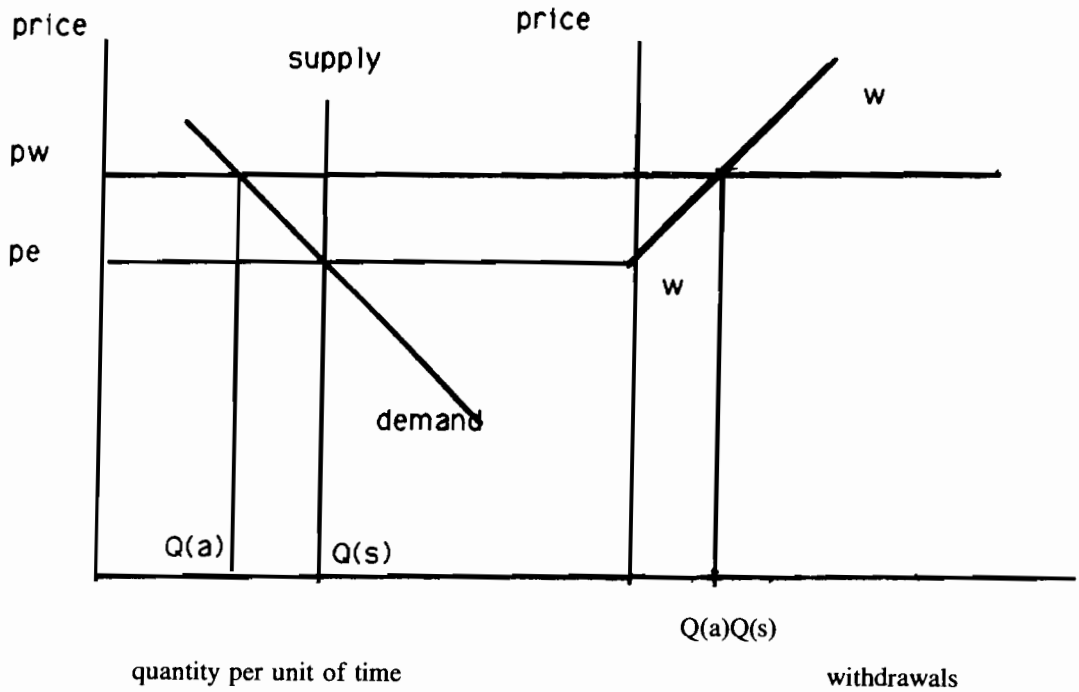



**FIG. 2.**
**DEMAND VARIABILITY.**

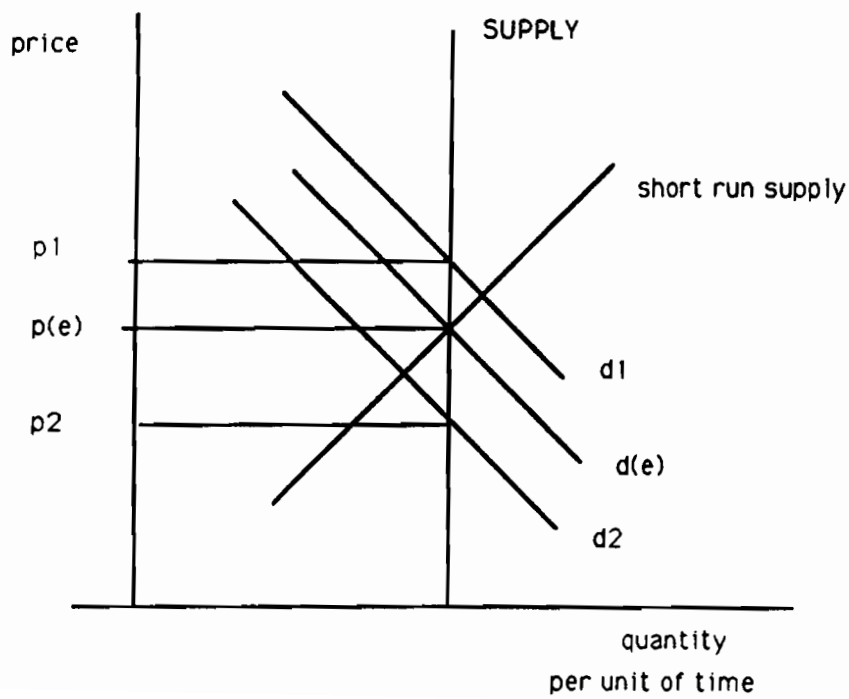


**FIG. 3.**
**SUPPLY UNCERTAINTY.**

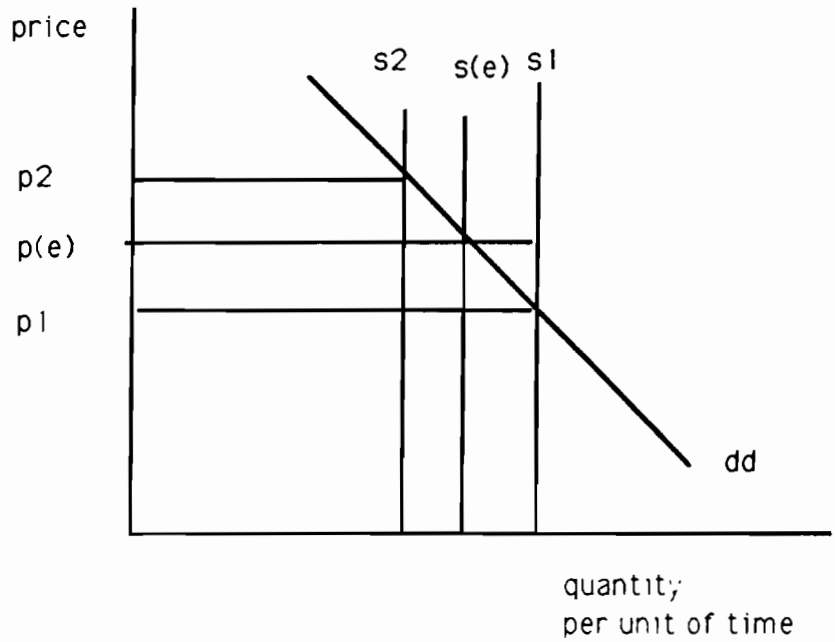



**FIG. 4.**
**CALCULATION OF P*.**

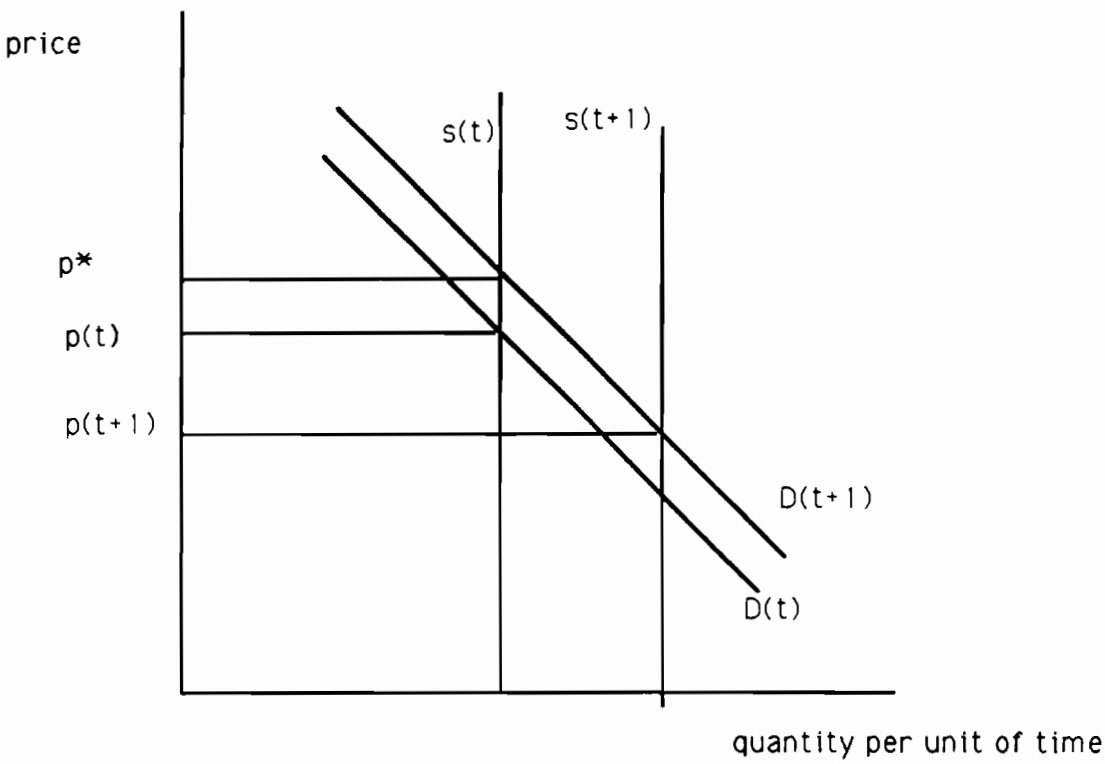


**FIG. 5.**
**CALCULATION OF P***

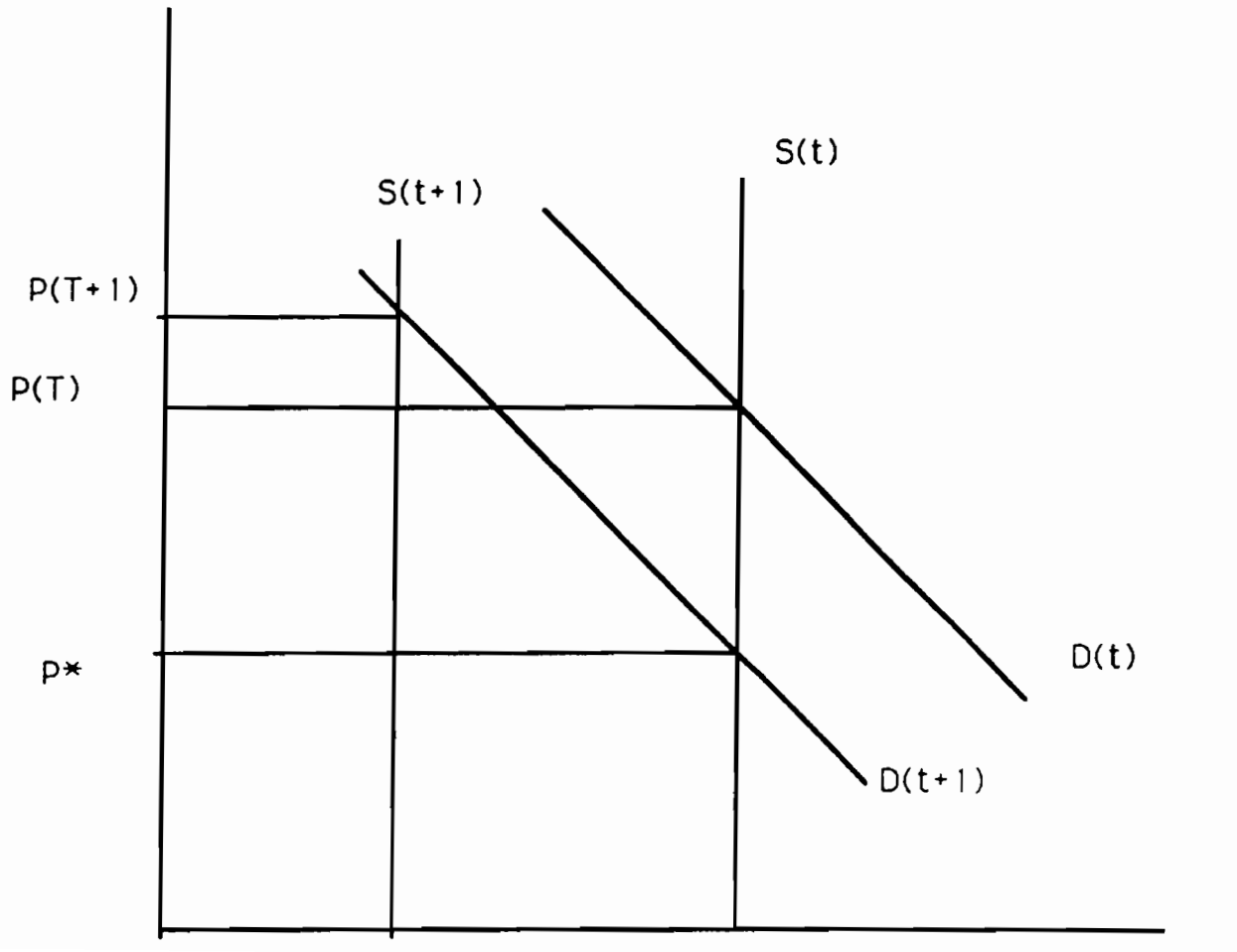


**FIG. 6.**
**DEMAND FLUCTATIONS FOR SIZES 3 AND 5 : COD IN FRANCE.**

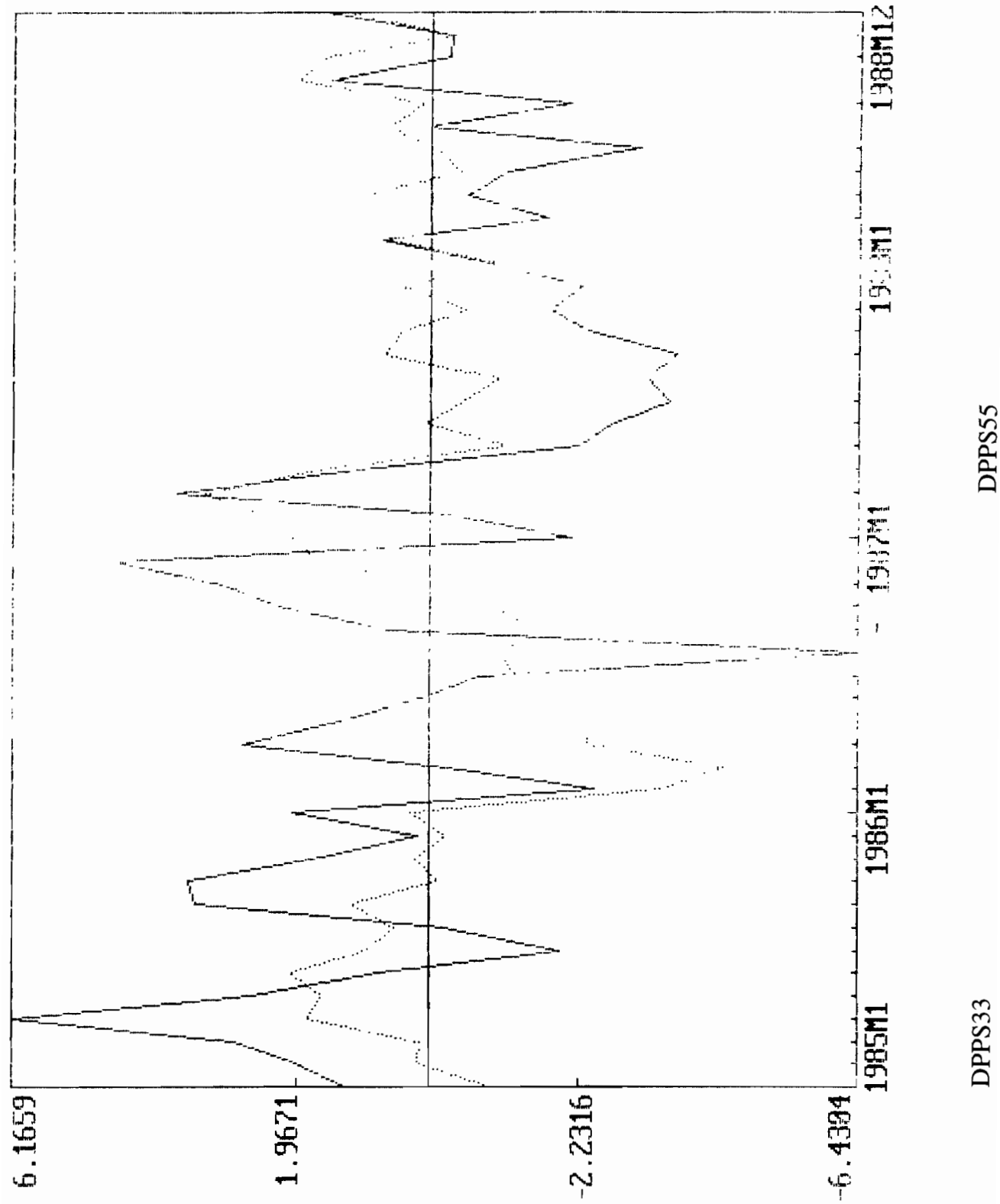
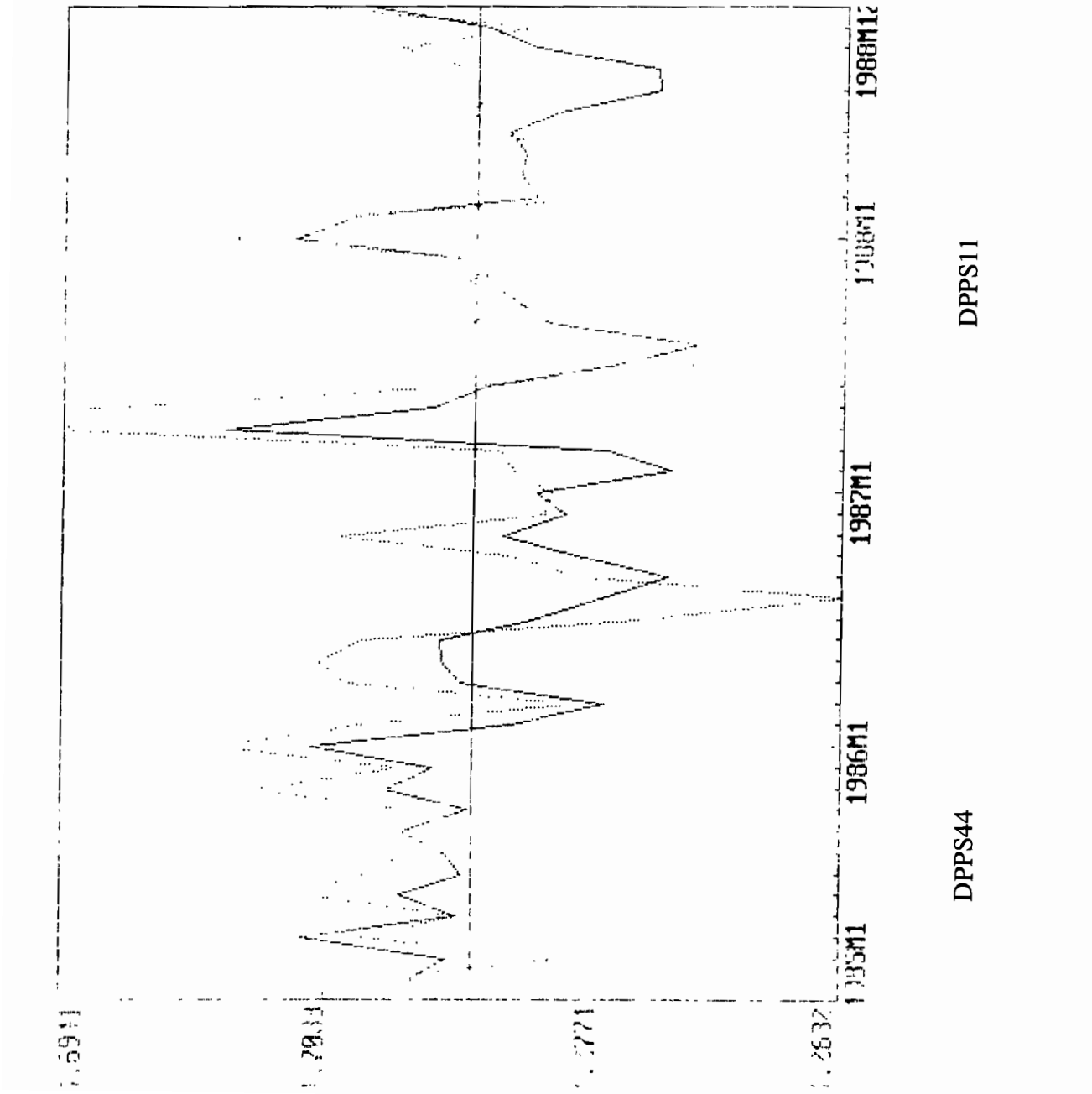


**FIG. 7.**
**DEMAND FLUCTUATIONS FOR SIZES 1 AND 4 : HADDOCK**



# The Market Interaction of Wild Salmon Fisheries and Salmon Aquaculture

**Christopher S. Wright[a] and Parzival Copes[b]**

[a]Faculty of Business Administration and Institute of Fisheries Analysis, Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada

[b]Institute of Fisheries Analysis, Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada

ABSTRACT

*The rapid expansion of farmed salmon production during the 1980s has raised concerns among many fishermen and analysts that aquaculture may supplant the commercial fisheries of wild salmon. However, dramatic as the increase in farmed output has been, it neither constitutes evidence that farmed salmon is currently replacing wild harvests, nor does it give reason to believe that such a replacement will soon ever occur.*

*This paper provides a framework for examining this and related concerns by modeling both industries and examining how they interact under a variety of wild fishery management regimes.*

*Under all scenarios considered likely, wild-salmon supply was either inelastic or increased as salmon prices fell. This counter-intuitive response arises from the common- property resource condition of wild fisheries where falling fish prices reduce activities that dissipate resource rent and/or reduce the market value of fishing rights.*

*The results indicate that lower salmon prices generated by competition with farmed salmon will tend to force rationalization on wild fisheries. While this rationalization may bankrupt individual fishermen and/or make various fishing methods non-viable, the wild salmon supply will tend to be inelastic or may even increase as prices fall. Most of the surplus generated by this rationalization is likely be in the form of consumer surplus and thus not to the fiscal benefit of either governments or fishermen.*

*If the basic premises and formulation of the models in this paper are valid, aquaculture (as an industry) is the source of salmon at the margin, as compared to the wild fishery. Thus, while farmed salmon may determine the price of salmon, it is unlikely to supplant wild salmon via price competition.*

## 1. INTRODUCTION

The rapid expansion of farmed salmon production during the 1980s raised the question : "Will aquaculture supplant commercial fisheries of wild salmon ?" Cunningham, et al. (1985, p. 311) observed that "Moiseev (1977) and others have

predicted that ultimately aquaculture will replace capture fisheries." Larkin (1990, p.68) noted that "...there is evidently a trend toward farming sea foods rather than chasing after them." Bjorndal (1990, pp.8-9) predicts that by 2000 AD farmed salmon may account for a 65 to 85 percent share of its market and asserts that "...in a few years farmed salmon will dominate the markets for Atlantic, coho and chinook salmon."

This paper gives a theoretical analysis of the long-run market interaction between a now well-developed salmon aquaculture industry and the large North American Pacific salmon fishery. The wild salmon fishery, historically, has been burdened by the many external diseconomies of a *common use resource.*[1]

This has resulted in a severely suboptimal industrial structure that dissipates enormous potential resource rents (Crutchfield and Pontecorvo, 1969). This, however, has left open opportunities for large improvements in productivity through rationalization, which allows the wild salmon fishery to accommodate to much lower prices generated by competition with the salmon farming sector.

### *1.1 The elements of the model*

This study uses a *hierarchical general system approach* where influences from outside the scale of the model are embodied by assumptions and modules portray logical and/or useful (but not necessarily physical) components within the system. Each module is represented by a single equation or a set of simultaneous equations in which lower scale details are represented by parameters or other assumptions. Interactions between modules are captured in the form of variables that are *output* of the *signaling module* and *input* to the *receiving model.*

This paper arranges the elements of a stylized salmon market into three modules--*salmon demand, wild fishery supply* and *aquaculture supply.* Detailed descriptions of the latter two modules are available from the authors, as appendices (equations with an A or B prefix are from those appendices).

## 2. THE DEMAND FOR SALMON

While, salmon demand is a complex amalgam of the demands of several user groups (DeVoretz, et al., 1991a, pp.1-2), this paper makes the simplifying assumption that salmon is a uniform product having an aggregate demand of the form :

$$P = ae^{-bQ} \tag{1}$$

Q = quantity demanded
P = observed market price
a, b = parameters
*e* = exponent

## 3. THE WILD FISHERY

In keeping with a simple general-model theme, the wild fishery is assumed to involve one stock, harvested by one gear type, in a common-use resource fishery. Both open access and limited entry conditions will be explored. As shown in Appendix A, the equilibrium harvest at a given effort level may be defined by :

$$\overline{H}^{\circ} = (\delta / \beta)\ln [\alpha (1 - qE)] / [1 / (qE) - 1] \tag{A5}$$

$\delta$ = landed portion of M

1. The authors suggest that *common use resource* is a more apt term than the conventionally used *common property resource*, as fish resources are often unowned rather than owned in common.

$\overline{H}^o$ = escapement allowed catch (EAC)
M = annual fishing caused mortality
q = catchability coefficient
E = total effort
α, ß = parameters

*3.1 Wild fishery : supply curve in an open-access fishery*

The competition in an open access fishery will tend to drive out vessels that are not cost-efficient. As a result, all vessels tend toward the following minimum cost configuration :

$$f^* = g^{-.25}/\tau \tag{2}$$

g = effective fishing season length (part of a year)
f* = optimal fishing power per vessel[2]
τ = parameter reflecting economies or diseconomies of scale

The vessels in a fishery can be defined by substituting the RHS of eqn (2) into eqn (A8) and rearranging the result to :

$$V^* = E\tau g^{-.75}/m \tag{3}$$

V* = vessels associated with f*
m = technology parameter

And the total cost of fishing can be defined by substituting the RHS of eqns (2) and (3) into eqn (A9) to produce :

$$C_F^* = (\Phi + g\Omega)\, E\tau g^{-.75} e^1/m \tag{4}$$

$C_F$* = cost of effort at f *
Φ = fixed cost of a fishing vessel
Ω = season related fixed cost of fishing power

When the escapement is binding ($S \leq S^0$), the fishery managers limit the fishing effort by regulating the effective length of the season and eqn (4) becomes :

$$C_F^* = (\Phi + g\Omega)\, E^0\tau g^{-.75} e^1/m \tag{4a}$$

In eqn (4a), the fishing effort is fixed at $E^0$ and the season length is a variable.

In an open access fishery all resource rent is dissipated by increased effort costs and/or decreased harvests. Thus, eqn (A6) can be set equal to eqn (4). That result, if the escapement is not a binding constraint, can be reorganized to define the supply price of salmon as a function of fishing effort :

$$\overline{P} = \beta(\Phi + g\Omega)\tau\, [1/q - E\,]\, e^1/(m\,\delta \ln [\alpha\,(1 - qE)]\, g^{.75} \tag{5}$$

The harvest associated with that price/effort combination is defined by eqn (A5) :

$$\overline{H} = (\delta / \beta) \ln [\alpha(1 - qE)] / [1 / (qE) - 1] \tag{A5}$$

If the escapement is a binding constraint, eqn (5) is still valid, but fishing effort becomes a parameter (eqn (A4b)).

2. If the AC of f (eqn (A9)/f) is differentiated with respect to f, that differential can be set equal to nil and reorganized :

$$d(C_f/f) / df = V(\Phi + g\Omega)\, e\, [\, g^{.25}\tau f\,]\, (\, g^{.25}\tau f - 1\,)\, f^{-2} = 0$$

$$f^* = g^{-.25}/\tau$$

$$\overline{E^{\circ}} = (1 - e^{\beta S^{\circ}} / \alpha) / g \qquad \text{(A4b)}$$

$E^0$ = target effort

$S^0$ = target number of spawners

and season length is an independent variable. The resulting supply curve of an open access fishery is shown in Figure 1. It is a *backward-bending supply curve* (Copes, 1970). However, the *Ricker surplus-yield curve* (eqn (A1)) that underlies the supply curve causes several differences between that supply curve and Copes' (1970) supply curve. Specifically :

- At low prices the average cost of supplying salmon falls. This occurs because, as fishing effort rises from nil, recruitment initially increases until the maximum recruitment is attained (point B in Figure 1).
- The supply curve is strictly convex (with respect to the origin) at any point above MSY, where the escapement is not binding. Where escapement is binding, the season is set to prevent the harvest from rising and cause the salmon supply curve to become infinitely inelastic with respect to price.
- These two features tend to make the supply curve very inelastic at high prices and very elastic at low prices.

In Figure 1, there are two open-access equilibriums. The one that occurs when escapement is not binding is labeled OAE and the one that occurs when escapement is binding is labeled *EAC shifted OAE* to show that is defined in part by the *escapement- allowed catch* [3].

### *3.2 Wild fishery : supply curve in a limited-entry fishery*

If there is a limit on the number of vessels licensed to fish in a fishery, the vessel owners will seek to maximize their share of any resource rents by stuffing inputs into their vessels. If a vessel's share of the total fishery revenue is proportional to its share of the effort in the fishery then (based on eqn (A8)) the income of a vessel can be defined by :

$$Y_i = gmf(PH^{\circ} / E^{\circ}) \qquad (6)$$

and a vessel's net income can be defined by dividing eqn (A9) by the number of vessels and deducting the RHS of that result from the RHS of eqn (6) :

$$\pi_i = gmf(PH^0 / E^0) - (\Phi + g\Omega)\, e\, [g^{.25}\tau f] \qquad (7)$$

$$d\pi_i / df = gm(PH^0 / E^0) - g^{.25}\tau\, (\Phi + g\Omega)\, e\, [g^{.25}\tau f] \qquad (8)$$

If the RHS of eqn (8) is set equal to nil it can be rearranged to :

$$f^{\$} = g^{-.25} \ln [g^{.75}(m/\tau)\, P(H^0/E^0)/(\Phi + g\Omega)]/\tau \qquad (9)$$

or to :

$$P = g^{-.75}(\tau/m)(E^0/H^0)(\Phi + g\Omega)\, e[g^{.25}\tau f] \qquad (9a)$$

When the RHS of eqns (A8) and (A4b) are set equal, the result can be reorganized to :

3. It is interesting to note that the total fishing power at the *escapement-allowed* open-access equilibrium (2,339 units--Table 2, Appendix C) was 3.6 times the fishing power at the natural open-access equilibrium (645.2 units--Table 1, Appendix C). The result is consistent with Wright's (1991, pp. 87-89) results.

$$f = (1 - e^{\beta S} / \alpha) / (qgmV) \quad (10)$$

If the RHS of eqn (10) is substituted into eqn (9a) the result defines the supply price as a function of escapement, fishing effort, harvest, vessel numbers and season length :

$$P = \tau (\Phi + q\Omega) g^{-.75} e [\tau g^{-.75} (1 - e^{\beta S^0} / \alpha) / (qmV)] (e^0 / H^0) / m \quad (11)$$

The fishing effort and the harvest can be eliminated from eqn (11) by substituting in the RHS of eqns (A4a) and (A7) :

$$P = \tau (\Phi + q\Omega) g^{-.75} e [\tau g^{-.75} (1 - e^{\beta S^0} / \alpha) / (qmV)] / [\alpha e^{-\beta^\circ} qm\delta S^0] \quad (12)$$

In the open-access salmon fishery in subsection 3.1, eqn (5) is the average social cost (ASC) and the marginal private cost (MPC) of supplying wild salmon. In the limited entry fishery, described in this subsection, eqn (5) is the perceived MPC.[4]The average cost of supplying salmon was defined by dividing the result of eqn (A9) by the EAC (escapement-allowed catch).

The limited-entry fishery salmon supply curve (Figure 2) appears to be an exact duplicate of the open-access supply curve (Figure 1). This occurs because where limited entry is binding (above point A) the supply curve is infinitely inelastic, as a result, any visual differences are lost in that infinity.

In a limited-entry fishery, not all resource rent is dissipated. Fishermen supply salmon according to their perceived MPC. In an open-access fishery (Figure 1) the MPC equals the AC. In a limited-entry fishery (Figure 2), imperfect substitution for the limited input (e.g. vessels) drives the MPC above the AC and fishermen will only add inputs as long as the MPC is below the landed price of salmon.

The Figure 2 supply curve can be divided into three portions, for prices :

i) above point A, escapement and limited entry are binding constraints in the fishery ;

ii) between points A and B, escapement is a binding constraint ;

iii) below point B, neither escapement nor limited entry is a binding constraint.

The shape of the limited-entry fishery salmon supply curve is identical to that of the open-access fishery. As a result, the conclusions with respect to price and elasticity of the supply curve are identical to those of the previous subsection.

## 4. THE CONCEPT OF A RESIDUAL INDUSTRY

If the wild-fishery and salmon-farm outputs are perfect substitutes and there is no producer surplus in either industry (Copes, 1972) then, the output from the industry with the (potentially) lowest cost of supply will always be sold and the other industry can be characterized as catering to the residual market.

If collusion and/or oligopoly is absent, the marginal output in the market aligns with the market price and, by definition, the residual supplier/industry supplies the marginal output in a market. Thus, the market price is determined by the actions of the residual industry and that market role reflects weakness rather than strength.

The question of which industry will, in the long run, be the residual supplier of salmon is empirical in nature. However, there are at least two reasons for treating aquaculture as the residual supplier : 1) salmon aquaculture is a relatively new source of salmon and has tended to act as a residual supplier ; 2) wild salmon, that can be had for the cost of harvesting in a gauntlet fishery, is likely (at some scale of output and/or some gear type) to be cheaper than output that must be fed and otherwise husbanded over an 18- to 60-month lifespan.

4. The MPC of supplying fish is extrapolated on the assumption that the relations that held in the fishery in the previous season will hold in the current season. Fishermen are assumed to not know the actual future marginal cost of supplying fish (i.e. that would involve, among other things, a simultaneous precognition of how other fishermen will act and how those actions and their own actions will affect the fishery).

## 5. SALMON FARMING : THE RESIDUAL DEMAND

If aquaculture is the residual supplier of salmon then the farmed salmon industry perceive the demand for their product as the gross demand (eqn (1)) less the wild fishery supply (Tables 3 and 4).

The residual supply curve (Figure 3) has four distinct zones :

i) To the left of point A, the residual demand is relatively elastic.

ii) Between points A and B, the elasticity of the residual demand declines because the wild harvest is increasing (i.e. effort is low enough that the target escapement is not a binding constraint on the wild harvest).

iii) Between points B and C, the elasticity of the residual demand increases because the salmon prices are below the wild fishery MSY price (i.e. the wild salmon supply is falling).

iv) To the right of point C, prices are below the minimum cost point on the wild-fishery supply curve (point B, Figure 1) --this causes the residual demand curve to shift to the gross demand curve (eqn (1)).

### *5.1 Salmon farming : the salmon supply curve*

In Appendix B, the long run farmed salmon supply curve, for the sake of simplicity, is assumed to be infinitely elastic (though input restrictions, such as site availability, may cause the supply curve to increase slightly with quantity).

$$P^* = MC^* = AC^* = \$3.0838/kg \qquad (B15)$$

## 6. HOW WILL SALMON AQUACULTURE AND THE WILD FISHERY INTERACT ?

The minimum supply cost of farmed salmon is likely the most important determinant of salmon prices in the long-run. As the farmed salmon additions to output drive down prices, much of the potential social surplus in fisheries may be realized in the form of consumer surplus. In the process, aquaculture tends to force the wild fisheries sharing a market to rationalize in order to remain competitive.

If the long-run minimum supply cost of farmed salmon should ever fall below the minimum supply cost of the rationalized wild salmon fishery, the market replacement of wild salmon by farmed salmon may become a reality. Given the great potential for cost reduction through rationalization in wild salmon fisheries (Crutchfield and Pontecorvo, 1969), this eventuality appears unlikely for the foreseeable future. It is conceivable though, that some higher cost smaller components of the North American salmon fishery would be abandoned owing to competition from farmed salmon.

Figure 3 shows how salmon farmers should perceive their market :

i) At high prices, where the backward bending portion of the wild salmon supply curve does not come into play, the residual demand curve appears to be normal (see the curve between the Y-axis and point A).

ii) As prices fall low enough to activate the backward bending portion of the wild fishery supply, the increase in wild salmon supply appears as a decline in the elasticity of the residual demand (see the curve between points A and B).

iii) As prices fall below the wild fishery MSY price, the fall in wild salmon supply appears as an increase in the elasticity of the residual demand (see the curve between points B and C).

iv) Only if prices fall below the wild fishery minimum cost (point B, Figure 1) will the residual demand shift to the gross demand--as at point C, Figure 3, the wild fishery is abandoned.

Several factors not directly considered in this analysis will tend to make the *residual demand elasticity effect*, observed between points A and B (Figure 3) more pronounced and may increase the range of prices over which it is observed.

(i) Salmon fisheries are often exploited by several types of fishing gears[5]. Each gear type has a different cost profile. Thus, the number of viable gear types in a salmon fishery will tend to fall as prices fall. This should have several effects :

- In salmon fisheries, higher cost gears may impose cost increases on intrinsically more efficient gears via external diseconomies (e.g. interception). Restrictions on higher- cost *intercepting* gears may allow a potentially a more efficient gear to realize its advantages.

- The higher-cost gears tend to harvest salmon in mixed stock fisheries, leading to suboptimal productivity of the combined stocks (Pearse, 1982, pp.47-57). The lower-cost gears tend to harvest in terminal fisheries that have fewer mixed -stock effects. Thus, if lower prices drive the higher cost gears from salmon fisheries, the wild salmon stock productivity could rise.

- Nonharvest fishing mortality is high for some gears. The salmon killed-to-landed ratio is 3 :2 for trolling and 5 :4 for gillnetting (Ricker, 1976, p.1485). Salmon traps can be designed to have a killed-to-landed ratio of close to 1 :1. Thus, if lower prices drive higher-cost gears from salmon fisheries, the wild salmon stock productivity could rise significantly.

(ii) As salmon prices fall, fishing pressures on the wild salmon stocks may decline, which should allow restrictions on the salmon fishing season to be relaxed, which, in turn, should decrease the farmed salmon market window (i.e. the period each year when fresh wild salmon is unavailable).

(iii) As salmon prices fall, communities dependent on the salmon fishery start to hurt financially. Governments often respond to such suffering by salmonid enhancement schemes and other forms of subsidization.

Given the above factors, it is likely that the region of decreased elasticity in the residual demand curve (i.e. between points A and B, Figure 3) will cover a large enough range of prices for the farmed salmon supply curve to intersect the residual demand curve at a point well above point B.

## 7. CONCLUSIONS

The burden of this paper has been to explore and explain the basic nature of the market interaction between the wild salmon fishery and salmon aquaculture, and thereby to speculate on the outcome of growing competition between the two sectors.

Their intrinsic economic structures are quite different, affording each sector a unique but different opportunity to access their joint market competitively. The lingering burden of common-use inefficiencies in the wild fishery has given it a reserve capacity to maintain market competitiveness by responding to salmon price reductions through rationalization. It may be speculated that the price-cost squeeze imposed on the wild salmon sector by expanding salmon aquaculture production will help to overcome inertia and remove political and social constraints against rationalization.

Salmon aquaculture owes its initial progress to technological success in producing at reasonable cost a commodity enjoying a high market value. It faces both advantages and disadvantages in its juxtaposition with the wild salmon fishery. On the one hand, competition from the wild salmon sector is held in check but the relatively fixed production capacity of that sector, which is constrained by the output limits of a natural system (as modified by limited enhancement possibilities). On the other hand, the staying capacity of the wild salmon sector is strong because of its reserve capacity to rationalize operations. This makes it difficult for aquaculture to capture market room from the wild salmon sector. As a result, the salmon farming industry will likely remain largely in the position of a residual market supplier. However, this still allows salmon aquaculture almost unlimited opportunities to expand through price reductions fueled by improved production efficiency.

5. *Competitive exclusion* (i.e. two species cannot both persist in the same niche) is a basic axiom of population ecology (Begon and Mortimer, 1986, pp. 76-80). Based on that axiom, two types of gear can only both persist in a fishery if they exploit different niches in the fishery or if regulation prevents one gear from excluding the other from the fishery.

## REFERENCES

**Begon M and M. Mortimer** (1986). *Population Ecology : A Unified Study of Animals and Plants.* 2nd edition. Sinauer Associates Inc., Publishers, Sunderland, Massachusetts.

**Bjorndal T.** (1990). *The Economics of Salmon Aquaculture.* Blackwell Scientific Publications. London.

**Copes P.** (1970). The Backward-Bending Supply Curve of the Fishing Industry. *Scottish Journal of Political Economy.* **XVII :** 69-77.

**Copes P.** (1972). Factor Rents, Sole Ownership and the Optimal Level of Fisheries Exploitation. *The Manchester School.* June : 145-163.

**Crutchfield J.A. and G. Pontecorvo** (1969). *The Pacific Salmon Fisheries, A Study of Irrational Conservation.* Johns Hopkins University Press, Baltimore.

**Cunninghan S., M. Dunn and D. Whitmarsh** (1985). *Fisheries Economics : An Introduction.* Mansell Publishing Limited. London.

**DeVoretz D., K. Salvanes and C. Wright** (1991a). Analysis of the Norwegian Salmon Aquaculture Long-Run Average Cost Function. *Proceedings of the 5th Conference of the IIFET.* (International Institute of Fisheries Economics and Trade). Held : 3-6 Dec/90 in Santiago, Chile.

**DeVoretz D., K. Salvanes and C. Wright** (1991b). A Disequilibrium Approach to Delineating the Long-Run Market Demand for Fresh Salmon. *Proceedings of the 5th Conference of the IIFET.* (International Institute of Fisheries Economics and Trade). Held : 3-6 Dec/90 in Santiago, Chile.

**Larkin P.** (1990). From Hunting Fish to Farming Fish : Trends in the Transition. *Aquaculture International (September 4-7, 1990) Congress Proceedings* . Vancouver, Canada. 68-70.

**Moiseev P.A.** (1977). Living Resources of the World Ocean : Prospects of Utilization and Augmentation. *Proceedings of the 5th Japan- Soviet International Symposium on Aquaculture.* Tokyo and Sapporo.

**Pearse P.** (1982). *Turning the Tide : A New Policy for Canada's Pacific Fisheries.* Final Report of the Commission on Pacific Fisheries Policy. Vancouver, B.C.

**Ricker W.** (1975). Computation and Interpretation of Biological Statistics of Fish Populations. *Bull. Fish. Res. Board Can.* Vol. **191.**

**Ricker W.** (1976). Review of Pacific Salmon Growth Rate and Mortality. *J. Fish. Res. Board Can.* Vol. **33 :** 1485-1524.

**Salvanes K.** (1987). The Structure of the Norwegian Fish Farming Industry : An Empirical Analysis of Economies of Scale. Discussion Paper 87-2, IFA, Simon Fraser University, B.C., Canada.

**Salvanes K.** (1988). Skalakonomi og den Usynlige Hand i Norsk Matfiskoppdrett. *Norsk Økonmisk Tidsskrift.* Vol. **102 :** 87-113.

**Salvanes K.** (1989). The Structure of the Norwegian Fish Farming Industry : An Empirical Analysis of Economies of Scale and Substitution Possibilities. Discussion Paper. Institute of Fisheries Economics, Norwegian School of Econ. & Bus. Admin., Bergen, Norway.

**Wright C.S.** (1991). *A Systems Approach to Fisheries Management* . Ph.D. Thesis, Simon Fraser University. B.C., Canada, Dec/91.

TABLE 1A.
FARMED SALMON AS A PERCENT OF THE WORLD PRODUCTION OF SALMON (1980 TO 1987).

| YEAR | WORLD SALMON PRODUCTION (000s mt) WILD | FARMED | TOTAL | FARMED % OF TOTAL |
|---|---|---|---|---|
| 1980 | 573.4 | 4.8 | 578.2 | .8% |
| 1981 | 649.0 | 11.6 | 660.6 | 1.8% |
| 1982 | 557.2 | 16.5 | 573.7 | 2.9% |
| 1983 | 678.7 | 24.6 | 703.3 | 3.5% |
| 1984 | 624.1 | 32.6 | 656.7 | 5.0% |
| 1985 | 793.5 | 47.1 | 840.6 | 5.6% |
| 1986 | 675.0 | 70.0 | 745.0 | 9.4% |
| 1987 | 650.2 | 87.5 | 737.7 | 11.9% |

TABLE 1B.
FARMED SALMON AS A PERCENT OF THE WORLD PRODUCTION OF ATLANTIC, COHO AND CHINOOK SALMON (1980 TO 1987).

| YEAR | ATLANTIC, COHO & CHINOOK (000s mt) WILD | FARMED | TOTAL | FARMED % OF TOTAL |
|---|---|---|---|---|
| 1980 | 65.9 | 4.8 | 70.7 | 6.8% |
| 1981 | 63.3 | 11.6 | 74.9 | 15.5% |
| 1982 | 76.0 | 16.5 | 92.5 | 17.8% |
| 1983 | 59.8 | 24.6 | 84.4 | 29.1% |
| 1984 | 71.8 | 32.6 | 104.4 | 31.2% |
| 1985 | 69.6 | 47.1 | 116.7 | 40.4% |
| 1986 | | 70.0 | | |
| 1987 | | 87.5 | | |

**TABLE 2.**
**OPEN ACCESS SALMON FISHERY (ESCAPEMENT UNMANAGED NO AQUACULTURE).**

| MARKET PRICE ($/kg) | SALMON DEMAND (000s mt) Eqn (1) | EFFORT (000s of units) | NUMBER OF VESSELS Eqn (3) | TOTAL HARVEST (000s mt) Eqn (A5) | FISHING POWER/ VESSEL Eqn (2) | FISHING COSTS ($/kg) Eqn (5) | SALMON PRICE ($/kg) Eqn (1) | ($ millions) FISHING REVENUES P*H | FISHING COSTS Eqn(A9) | RESOURCE RENTS |
|---|---|---|---|---|---|---|---|---|---|---|
| $20.00 | .0 | 1 | 17 | .89 | 118.92 | $3.836 | $19.969 | $ 17.8 | $ 3.4 | $ 14.4 |
| 19.00 | 29.5 | 25 | 420 | 22.69 | 118.92 | 3.777 | 19.225 | 436.3 | 85.7 | 350.6 |
| 18.00 | 60.5 | 50 | 841 | 46.13 | 118.92 | 3.716 | 18.456 | 851.5 | 171.4 | 680.0 |
| 17.00 | 93.3 | 75 | 1,261 | 70.35 | 118.92 | 3.655 | 17.694 | 1,244.8 | 257.2 | 987.7 |
| 16.00 | 128.2 | 100 | 1,682 | 95.39 | 118.92 | 3.595 | 16.940 | 1,615.8 | 342.9 | 1,272.9 |
| 15.00 | 165.2 | 125 | 2,102 | 121.27 | 118.92 | 3.534 | 16.193 | 1,963.7 | 428.6 | 1,535.2 |
| 14.00 | 204.9 | 150 | 2,523 | 148.03 | 118.92 | 3.474 | 15.456 | 2,288.0 | 514.3 | 1,773.7 |
| 13.00 | 247.4 | 175 | 2,943 | 175.71 | 118.92 | 3.415 | 14.729 | 2,588.0 | 600.0 | 1,988.0 |
| 12.00 | 293.4 | 200 | 3,364 | 204.32 | 118.92 | 3.356 | 14.013 | 2,863.2 | 685.7 | 2,177.5 |
| 11.00 | 343.4 | 225 | 3,784 | 233.89 | 118.92 | 3.298 | 13.310 | 3,113.1 | 771.5 | 2,341.7 |
| 10.00 | 398.1 | 250 | 4,204 | 264.43 | 118.92 | 3.242 | 12.621 | 3,337.3 | 857.2 | 2,480.2 |
| 9.75 | 412.7 | 275 | 4,625 | 295.91 | 118.92 | 3.186 | 11.948 | 3,535.5 | 942.9 | 2,592.6 |
| 9.50 | 427.6 | 300 | 5,045 | 328.31 | 118.92 | 3.133 | 11.293 | 3,707.5 | 1,028.6 | 2,678.8 |
| 9.25 | 442.9 | 325 | 5,466 | 361.54 | 118.92 | 3.082 | 10.658 | 3,853.2 | 1,114.3 | 2,738.9 |
| 9.00 | 458.6 | 350 | 5,886 | 395.47 | 118.92 | 3.034 | 10.046 | 3,973.1 | 1,200.0 | 2,773.0 |
| 8.75 | 474.8 | 371.41 | 6,246 | 424.92 | 118.92 | 2.997 | 9.544 | 4,055.6 | 1,273.4 | 2,782.1 |
| 8.50 | 491.5 | 375 | 6,307 | 429.88 | 118.92 | 2.991 | 9.462 | 4,067.6 | 1,285.8 | 2,781.9 |
| 8.25 | 508.6 | 400 | 6,727 | 464.40 | 118.92 | 2.953 | 8.910 | 4,138.0 | 1,371.5 | 2,766.5 |
| 8.00 | 526.3 | 425 | 7,148 | 498.48 | 118.92 | 2.923 | 8.397 | 4,185.7 | 1,457.2 | 2,728.6 |
| 7.75 | 544.5 | 450 | 7,568 | 531.23 | 118.92 | 2.904 | 7.932 | 4,213.5 | 1,542.9 | 2,670.6 |
| 7.50 | 563.4 | 466.36 | 7,843 | 551.31 | 118.92 | 2.900 | 7.659 | 4,222.6 | 1,599.0 | 2,623.6 |
| 7.25 | 582.8 | 475 | 7,989 | 561.27 | 118.92 | 2.902 | 7.527 | 4,225.0 | 1,628.6 | 2,596.3 |
| 7.00 | 603.0 | 500 | 8,409 | 586.41 | 118.92 | 2.923 | 7.205 | 4,225.2 | 1,714.3 | 2,510.8 |
| 6.75 | 623.9 | 525 | 8,829 | 603.09 | 118.92 | 2.985 | 6.999 | 4,221.0 | 1,800.1 | 2,420.9 |
| 6.50 | 645.6 | 540.99 | 9,098 | 606.7152 | 118.92 | 3.057 | 6.955 | 4,219.6 | 1,854.9 | 2,364.7 |
| 6.25 | 668.1 | 550 | 9,250 | 605.34 | 118.92 | 3.115 | 6.972 | 4,220.1 | 1,885.8 | 2,334.4 |
| 6.00 | 691.5 | 575 | 9,670 | 582.83 | 118.92 | 3.383 | 7.250 | 4,225.6 | 1,971.5 | 2,254.1 |
| 5.75 | 716.0 | 600 | 10,091 | 516.68 | 118.92 | 3.982 | 8.135 | 4,203.3 | 2,057.2 | 2,146.0 |
| 5.50 | 741.5 | 605 | 10,175 | 495.48 | 118.92 | 4.187 | 8.441 | 4,182.3 | 2,074.4 | 2,108.0 |
| 5.25 | 768.2 | 610 | 10,259 | 470.75 | 118.92 | 4.443 | 8.812 | 4,148.4 | 2,091.5 | 2,056.9 |
| 5.00 | 796.3 | 615 | 10,343 | 442.01 | 118.92 | 4.771 | 9.265 | 4,095.0 | 2,108.6 | 1,986.4 |
| 4.75 | 825.7 | 620 | 10,427 | 408.68 | 118.92 | 5.202 | 9.818 | 4,012.4 | 2,125.8 | 1,886.6 |
| 4.50 | 856.8 | 625 | 10,511 | 370.08 | 118.92 | 5.790 | 10.500 | 3,886.0 | 2,142.9 | 1,743.1 |
| 4.25 | 889.6 | 628 | 10,562 | 344.07 | 118.92 | 6.258 | 10.987 | 3,780.3 | 2,153.2 | 1,627.0 |
| 4.00 | 924.4 | 630 | 10,595 | 325.42 | 118.92 | 6.638 | 11.350 | 3,693.3 | 2,160.1 | 1,533.3 |
| 3.75 | 961.5 | 632 | 10,629 | 305.65 | 118.92 | 7.090 | 11.747 | 3,590.4 | 2,166.9 | 1,423.5 |
| 3.50 | 1,001.1 | 634 | 10,663 | 284.69 | 118.92 | 7.636 | 12.184 | 3,468.5 | 2,173.8 | 1,294.7 |
| 3.25 | 1,043.7 | 636 | 10,696 | 262.47 | 118.92 | 8.308 | 12.664 | 3,324.0 | 2,180.6 | 1,143.3 |
| 3.00 | 1,089.7 | 638 | 10,730 | 238.91 | 118.92 | 9.156 | 13.194 | 3,152.3 | 2,187.5 | 964.8 |
| 2.75 | 1,139.7 | 640 | 10,763 | 213.93 | 118.92 | 10.258 | 13.781 | 2,948.1 | 2,194.4 | 753.8 |
| 2.50 | 1,194.4 | 642 | 10,797 | 187.43 | 118.92 | 11.744 | 14.432 | 2,704.9 | 2,201.2 | 503.7 |
| 2.25 | 1,254.9 | 644 | 10,831 | 159.31 | 118.92 | 13.860 | 15.156 | 2,414.5 | 2,208.1 | 206.4 |
| 2.00 | 1,322.6 | 645 | 10,848 | 144.62 | 118.92 | 15.292 | 15.548 | 2,248.5 | 2,211.5 | 37.0 |
| 1.75 | 1,399.3 | 645.207 | 10,851 | 141.514 | 118.92 | 15.632 | 15.633 | 2,212.2 | 2,212.2 | .0 |
| 1.50 | 1,487.8 | 646 | 10,864 | 129.48 | 118.92 | 17.107 | 15.964 | 2,066.9 | 2,214.9 | (148.0) |
| 1.25 | 1,592.5 | 648 | 10,898 | 97.80 | 118.92 | 22.717 | 16.869 | 1,649.8 | 2,221.8 | (572.0) |
| 1.00 | 1,720.7 | 650 | 10,932 | 64.17 | 118.92 | 34.731 | 17.886 | 1,147.7 | 2,228.6 | (1,080.9) |

**TABLE 3.**
**OPEN ACCESS SALMON FISHERY (ESCAPEMENT MANAGED AND NO AQUACULTURE).**

| MARKET PRICE ($/kg) | SALMON DEMAND (000s mt) Eqn (1) | EFFORT (000s of units) | NUMBER OF VESSELS Eqn (3) | TOTAL HARVEST (000s m Eqn (A5 | FISHING PER VESSEL Eqn (2) | SEASON LENGTH (% of a year) | FISHING POWER (000s of units) | FISHING COSTS ($/kg) Eqn (5) | SALMON PRICE ($/kg) Eqn (1) | ($ millions) FISHING REVENUES (P*Q) | FISHING COSTS Eqn (A9) | RESOURCE RENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $20.00 | .0 | 1 | 16.8 | .9 | 118.921 | 50.0% | 2 | 3.836 | $19.969 | $ 17.8 | $ 3.4 | $ 14.4 |
| 19.00 | 29.5 | 25 | 420.4 | 22.7 | 118.921 | 50.0% | 50 | 3.777 | 19.225 | 436.3 | 85.7 | 350.6 |
| 18.00 | 60.5 | 50 | 840.9 | 46.1 | 118.921 | 50.0% | 100 | 3.716 | 18.456 | 851.5 | 171.4 | 680.0 |
| 17.00 | 93.3 | 75 | 1,261.3 | 70.4 | 118.921 | 50.0% | 150 | 3.655 | 17.694 | 1,244.8 | 257.2 | 987.7 |
| 16.00 | 128.2 | 100 | 1,681.8 | 95.4 | 118.921 | 50.0% | 200 | 3.595 | 16.940 | 1,615.8 | 342.9 | 1,272.9 |
| 15.00 | 165.2 | 125 | 2,102.2 | 121.3 | 118.921 | 50.0% | 250 | 3.534 | 16.193 | 1,963.7 | 428.6 | 1,535.2 |
| 14.00 | 204.9 | 150 | 2,522.7 | 148.0 | 118.921 | 50.0% | 300 | 3.474 | 15.456 | 2,288.0 | 514.3 | 1,773.7 |
| 13.00 | 247.4 | 175 | 2,943.1 | 175.7 | 118.921 | 50.0% | 350 | 3.415 | 14.729 | 2,588.0 | 600.0 | 1,988.0 |
| 12.00 | 293.4 | 200 | 3,363.6 | 204.3 | 118.921 | 50.0% | 400 | 3.356 | 14.013 | 2,863.2 | 685.7 | 2,177.5 |
| 11.00 | 343.4 | 250 | 4,204.5 | 264.4 | 118.921 | 50.0% | 500 | 3.242 | 12.621 | 3,337.3 | 857.2 | 2,480.2 |
| 10.00 | 398.1 | 300 | 5,045.4 | 328.3 | 118.921 | 50.0% | 600 | 3.133 | 11.293 | 3,707.5 | 1,028.6 | 2,678.8 |
| 9.75 | 412.7 | 350 | 5,886.3 | 395.5 | 118.921 | 50.0% | 700 | 3.034 | 10.046 | 3,973.1 | 1,200.0 | 2,773.0 |
| 9.50 | 427.6 | 371.41 | 6,246.3 | 424.9 | 118.921 | 50.0% | 743 | 2.997 | 9.544 | 4,055.6 | 1,273.4 | 2,782.1 |
| 9.25 | 442.9 | 400 | 6,727.2 | 464.4 | 118.921 | 50.0% | 800 | 2.953 | 8.910 | 4,138.0 | 1,371.5 | 2,766.5 |
| 9.00 | 458.6 | 425 | 7,147.6 | 498.5 | 118.921 | 50.0% | 850 | 2.923 | 8.397 | 4,185.7 | 1,457.2 | 2,728.6 |
| 8.75 | 474.8 | 450 | 7,568.1 | 531.2 | 118.921 | 50.0% | 900 | 2.904 | 7.932 | 4,213.5 | 1,542.9 | 2,670.6 |
| 8.50 | 491.5 | 466.36 | 7,843.2 | 551.3 | 118.921 | 50.0% | 933 | 2.900 | 7.659 | 4,222.6 | 1,599.0 | 2,623.6 |
| 8.25 | 508.6 | 475 | 7,988.5 | 561.3 | 118.921 | 50.0% | 950 | 2.902 | 7.527 | 4,225.0 | 1,628.6 | 2,596.3 |
| 8.00 | 526.3 | 500 | 8,409.0 | 586.4 | 118.921 | 50.0% | 1,000 | 2.923 | 7.205 | 4,225.2 | 1,714.3 | 2,510.8 |
| 7.75 | 544.5 | 525 | 8,829.4 | 603.1 | 118.921 | 50.0% | 1,050 | 2.985 | 6.999 | 4,221.0 | 1,800.1 | 2,420.9 |
| 7.50 | 563.4 | 540 | 9,081.7 | 606.7 | 118.921 | 50.0% | 1,080 | 3.052 | 6.955 | 4,219.6 | 1,851.5 | 2,368.1 |
| 7.25 | 582.8 | 540.99 | 9,098.3 | 606.7 | 118.921 | 50.0% | 1,082 | 3.057 | 6.955 | 4,219.6 | 1,854.9 | 2,364.7 |
| 7.00 | 603.0 | 542 | 9,115.3 | 606.7 | 118.921 | 50.0% | 1,084 | 3.063 | 6.955 | 4,219.6 | 1,858.4 | 2,361.3 |
| 6.75 | 623.9 | 550 | 9,249.9 | 605.3 | 118.921 | 50.0% | 1,100 | 3.115 | 6.972 | 4,220.1 | 1,885.8 | 2,334.4 |
| 6.50 | 645.6 | 575 | 9,670.3 | 582.8 | 118.921 | 50.0% | 1,150 | 3.383 | 7.250 | 4,225.6 | 1,971.5 | 2,254.1 |
| 6.25 | 668.1 | 600 | 10,090.8 | 516.7 | 118.921 | 50.0% | 1,200 | 3.982 | 8.135 | 4,203.3 | 2,057.2 | 2,146.0 |
| 6.00 | 691.5 | 610 | 10,258.9 | 470.8 | 118.921 | 50.0% | 1,220 | 4.443 | 8.812 | 4,148.4 | 2,091.5 | 2,056.9 |
| 5.75 | 716.0 | 620 | 10,427.1 | 408.7 | 118.921 | 50.0% | 1,240 | 5.202 | 9.818 | 4,012.4 | 2,125.8 | 1,886.6 |
| 5.50 | 741.5 | 621 | 10,443.9 | 401.4 | 118.921 | 50.0% | 1,242 | 5.304 | 9.943 | 3,991.2 | 2,129.2 | 1,862.0 |
| 5.25 | 768.2 | 621.18 | 10,447.0 | 400.1 | 118.921 | 50.0% | 1,242 | 5.324 | 9.966 | 3,987.2 | 2,129.8 | 1,857.4 |
| 5.00 | 796.3 | 621.19 | 10,447.1 | 400.0 | 118.921 | 50.0% | 1,242 | 5.325 | 9.968 | 3,987.0 | 2,129.9 | 1,857.1 |
| 4.75 | 825.7 | 621.19 | 10,462.8 | 400.0 | 118.980 | 49.9% | 1,245 | 5.328 | 9.968 | 3,987.0 | 2,131.1 | 1,855.9 |
| 4.50 | 856.8 | 621.19 | 11,306.2 | 400.0 | 122.095 | 45.0% | 1,380 | 5.494 | 9.968 | 3,987.0 | 2,197.4 | 1,789.6 |
| 4.25 | 889.6 | 621.19 | 12,350.3 | 400.0 | 125.743 | 40.0% | 1,553 | 5.707 | 9.968 | 3,987.0 | 2,282.9 | 1,704.1 |
| 4.00 | 924.4 | 621.19 | 13,651.3 | 400.0 | 130.012 | 35.0% | 1,775 | 5.984 | 9.968 | 3,987.0 | 2,393.5 | 1,593.5 |
| 3.75 | 961.5 | 621.19 | 14,431.5 | 400.0 | 132.443 | 32.5% | 1,911 | 6.154 | 9.968 | 3,987.0 | 2,461.6 | 1,525.4 |
| 3.50 | 1,001.1 | 621.19 | 15,324.4 | 400.0 | 135.120 | 30.0% | 2,071 | 6.353 | 9.968 | 3,987.0 | 2,541.0 | 1,446.0 |
| 3.25 | 1,043.7 | 621.19 | 16,357.8 | 400.0 | 138.091 | 27.5% | 2,259 | 6.586 | 9.968 | 3,987.0 | 2,634.6 | 1,352.5 |
| 3.00 | 1,089.7 | 621.19 | 17,569.9 | 400.0 | 141.421 | 25.0% | 2,485 | 6.865 | 9.968 | 3,987.0 | 2,746.2 | 1,240.8 |
| 2.75 | 1,139.7 | 621.19 | 19,014.6 | 400.0 | 145.196 | 22.5% | 2,761 | 7.204 | 9.968 | 3,987.0 | 2,881.6 | 1,105.5 |
| 2.50 | 1,194.4 | 621.19 | 20,770.7 | 400.0 | 149.535 | 20.0% | 3,106 | 7.622 | 9.968 | 3,987.0 | 3,048.9 | 938.1 |
| 2.25 | 1,254.9 | 621.19 | 22,958.6 | 400.0 | 154.611 | 17.5% | 3,550 | 8.152 | 9.968 | 3,987.0 | 3,260.8 | 726.2 |
| 2.00 | 1,322.6 | 621.19 | 25,772.5 | 400.0 | 160.686 | 15.0% | 4,141 | 8.845 | 9.968 | 3,987.0 | 3,537.9 | 449.1 |
| 1.75 | 1,399.3 | 621.19 | 30,255.3 | 400.0 | 169.509 | 12.1124% | 5,129 | 9.968 | 9.968 | 3,987.0 | 3,987.0 | .0 |
| 1.50 | 1,487.8 | 621.19 | 34,932.1 | 400.0 | 177.828 | 10.0% | 6,212 | 11.157 | 9.968 | 3,987.0 | 4,462.9 | (475.9) |
| 1.25 | 1,592.5 | 621.19 | 51,240.2 | 400.0 | 202.052 | 6.0% | 10,353 | 15.391 | 9.968 | 3,987.0 | 6,156.4 | (2,169.4) |
| 1.00 | 1,720.7 | 621.19 | 69,451.1 | 400.0 | 223.607 | 4.0% | 15,530 | 20.200 | 9.968 | 3,987.0 | 8,080.1 | (4,093.1) |

**TABLE 4.**
**LIMITED ENTRY SALMON FISHERY (NO AQUACULTURE).**

| EFFECTIVE SEASON LENGTH (g) (% year) | EFFORT (000s of units) | FISHING POWER (000s of Units) Vf | f Eqn(10) | Open Access f | NUMBER OF FISHING VESSELS | ESCAPMENT ALLOWED HARVEST (000s mt) | SUPPLY PRICE ($/kg) Eqn (9a) | FISHING COSTS ($/kg) Eqn (A9) | SALMON PRICE ($/kg) Eqn (1) | ($ millions) FISHING REVENUES | FISHING COSTS | RESOURCE RENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a) Escapement and Limited Entry are Binding Constraints | | | | | | | | | | | | |
| .18 | 621 | 3,451 | 287.59 | 153.53 | 12,000 | 400.00 | $19.241 | $10.272 | $9.968 | $3,987.0 | $4,108.6 | $ (121.6) |
| .20 | 621 | 3,106 | 258.83 | 149.53 | 12,000 | 400.00 | 15.831 | 9.146 | 9.968 | 3,987.0 | 3,658.4 | 328.6 |
| .22 | 621 | 2,824 | 235.30 | 146.01 | 12,000 | 400.00 | 13.419 | 8.327 | 9.968 | 3,987.0 | 3,330.8 | 656.2 |
| .24 | 621 | 2,588 | 215.69 | 142.87 | 12,000 | 400.00 | 11.641 | 7.711 | 9.968 | 3,987.0 | 3,084.4 | 902.6 |
| .26 | 621 | 2,389 | 199.10 | 140.04 | 12,000 | 400.00 | 10.287 | 7.236 | 9.968 | 3,987.0 | 2,894.3 | 1,092.7 |
| .265558 | 621 | 2,339 | 194.93 | 139.30 | 12,000 | 400.00 | 9.968 | 7.123 | 9.968 | 3,987.0 | 2,849.2 | 1,137.8 |
| .28 | 621 | 2,219 | 184.88 | 137.47 | 12,000 | 400.00 | 9.228 | 6.862 | 9.968 | 3,987.0 | 2,744.7 | 1,242.3 |
| .30 | 621 | 2,071 | 172.55 | 135.12 | 12,000 | 400.00 | 8.380 | 6.562 | 9.968 | 3,987.0 | 2,624.9 | 1,362.1 |
| .32 | 621 | 1,941 | 161.77 | 132.96 | 12,000 | 400.00 | 7.689 | 6.320 | 9.968 | 3,987.0 | 2,527.9 | 1,459.1 |
| .34 | 621 | 1,827 | 152.25 | 130.96 | 12,000 | 400.00 | 7.117 | 6.121 | 9.968 | 3,987.0 | 2,448.6 | 1,538.4 |
| .36 | 621 | 1,726 | 143.79 | 129.10 | 12,000 | 400.00 | 6.636 | 5.958 | 9.968 | 3,987.0 | 2,383.2 | 1,603.8 |
| .38 | 621 | 1,635 | 136.23 | 127.37 | 12,000 | 400.00 | 6.227 | 5.822 | 9.968 | 3,987.0 | 2,328.9 | 1,658.1 |
| .40 | 621 | 1,553 | 129.41 | 125.74 | 12,000 | 400.00 | 5.876 | 5.710 | 9.968 | 3,987.0 | 2,283.8 | 1,703.2 |
| .41 | 621 | 1,515 | 126.26 | 124.97 | 12,000 | 400.00 | 5.719 | 5.660 | 9.968 | 3,987.0 | 2,264.2 | 1,722.8 |
| .415646 | 621 | 1,495 | 124.54 | 124.54 | 12,000 | 400.00 | 5.635 | 5.635 | 9.968 | 3,987.0 | 2,253.8 | 1,733.2 |
| b) Escapement is a Binding Constraint | | | | | | | | | | | | |
| .42 | 621 | 1,479 | 124.22 | 124.22 | 11,907 | 400.00 | 5.615 | 5.615 | 9.968 | 3,987.0 | 2,246.2 | 1,740.8 |
| .44 | 621 | 1,412 | 122.78 | 122.78 | 11,498 | 400.00 | 5.532 | 5.532 | 9.968 | 3,987.0 | 2,212.9 | 1,774.1 |
| .46 | 621 | 1,350 | 121.43 | 121.43 | 11,121 | 400.00 | 5.457 | 5.457 | 9.968 | 3,987.0 | 2,182.7 | 1,804.3 |
| .48 | 621 | 1,294 | 120.14 | 120.14 | 10,772 | 400.00 | 5.388 | 5.388 | 9.968 | 3,987.0 | 2,155.1 | 1,831.9 |
| .49 | 621 | 1,268 | 119.52 | 119.52 | 10,607 | 400.00 | 5.355 | 5.355 | 9.968 | 3,987.0 | 2,142.2 | 1,844.8 |
| .499999 | 621 | 1,242 | 118.92 | 118.92 | 10,447 | 400.00 | 5.325 | 5.325 | 9.968 | 3,987.0 | 2,129.9 | 1,857.1 |
| c) Neither Escapement nor Limited Entry are Binding Constraints | | | | | | | | | | | | |
| .50 | 621 | 1,242 | 118.92 | 118.92 | 10,444 | 401.40 | 5.304 | 5.304 | 9.943 | 3,991.2 | 2,129.2 | 1,862.0 |
| .50 | 600 | 1,200 | 118.92 | 118.92 | 10,091 | 516.68 | 3.982 | 3.982 | 8.135 | 4,203.3 | 2,057.2 | 2,146.0 |
| .50 | 575 | 1,150 | 118.92 | 118.92 | 9,670 | 582.83 | 3.383 | 3.383 | 7.250 | 4,225.6 | 1,971.5 | 2,254.1 |
| .50 | 550 | 1,100 | 118.92 | 118.92 | 9,250 | 605.34 | 3.115 | 3.115 | 6.972 | 4,220.1 | 1,885.8 | 2,334.4 |
| .50 | 540.99 | 1,082 | 118.92 | 118.92 | 9,098 | 606.72 | 3.057 | 3.057 | 6.955 | 4,219.6 | 1,854.9 | 2,364.7 |
| .50 | 525 | 1,050 | 118.92 | 118.92 | 8,829 | 603.09 | 2.985 | 2.985 | 6.999 | 4,221.0 | 1,800.1 | 2,420.9 |
| .50 | 500 | 1,000 | 118.92 | 118.92 | 8,409 | 586.41 | 2.923 | 2.923 | 7.205 | 4,225.2 | 1,714.3 | 2,510.8 |
| .50 | 475 | 950 | 118.92 | 118.92 | 7,989 | 561.27 | 2.902 | 2.902 | 7.527 | 4,225.0 | 1,628.6 | 2,596.3 |
| .50 | 466.36 | 933 | 118.92 | 118.92 | 7,843 | 551.31 | 2.900 | 2.900 | 7.659 | 4,222.6 | 1,599.0 | 2,623.6 |
| .50 | 450 | 900 | 118.92 | 118.92 | 7,568 | 531.23 | 2.904 | 2.904 | 7.932 | 4,213.5 | 1,542.9 | 2,670.6 |
| .50 | 425 | 850 | 118.92 | 118.92 | 7,148 | 498.48 | 2.923 | 2.923 | 8.397 | 4,185.7 | 1,457.2 | 2,728.6 |
| .50 | 400 | 800 | 118.92 | 118.92 | 6,727 | 464.40 | 2.953 | 2.953 | 8.910 | 4,138.0 | 1,371.5 | 2,766.5 |
| .50 | 375 | 750 | 118.92 | 118.92 | 6,307 | 429.88 | 2.991 | 2.991 | 9.462 | 4,067.6 | 1,285.8 | 2,781.9 |
| .50 | 371.41 | 743 | 118.92 | 118.92 | 6,246 | 424.92 | 2.997 | 2.997 | 9.544 | 4,055.6 | 1,273.4 | 2,782.1 |
| .50 | 350 | 700 | 118.92 | 118.92 | 5,886 | 395.47 | 3.034 | 3.034 | 10.046 | 3,973.1 | 1,200.0 | 2,773.0 |
| .50 | 325 | 650 | 118.92 | 118.92 | 5,466 | 361.54 | 3.082 | 3.082 | 10.658 | 3,853.2 | 1,114.3 | 2,738.9 |
| .50 | 300 | 600 | 118.92 | 118.92 | 5,045 | 328.31 | 3.133 | 3.133 | 11.293 | 3,707.5 | 1,028.6 | 2,678.8 |
| .50 | 250 | 500 | 118.92 | 118.92 | 4,204 | 264.43 | 3.242 | 3.242 | 12.621 | 3,337.3 | 857.2 | 2,480.2 |
| .50 | 200 | 400 | 118.92 | 118.92 | 3,364 | 204.32 | 3.356 | 3.356 | 14.013 | 2,863.2 | 685.7 | 2,177.5 |
| .50 | 100 | 200 | 118.92 | 118.92 | 1,682 | 95.39 | 3.595 | 3.595 | 16.940 | 1,615.8 | 342.9 | 1,272.9 |
| .50 | 50 | 100 | 118.92 | 118.92 | 841 | 46.13 | 3.716 | 3.716 | 18.456 | 851.5 | 171.4 | 680.0 |
| .50 | 25 | 50 | 118.92 | 118.92 | 420 | 22.69 | 3.777 | 3.777 | 19.225 | 436.3 | 85.7 | 350.6 |
| .50 | 1 | 2 | 118.92 | 118.92 | 17 | .89 | 3.836 | 3.836 | 19.969 | 17.8 | 3.4 | 14.4 |

**TABLE 5.**
**FARMED SALMON RESIDUAL DEMAND (ESCAPEMENT UNMANAGED).**

| MARKET PRICE ($/kg) | SALMON DEMAND (000s of tonnes) GROSS Demand Eqn (1) | WILD SUPPLY Eqns (13) & (6) | RESIDUAL DEMAND [$Q_A$ = (Q - H)] | FARMED SALMON REVENUES ($ millions) ($P*Q_A$) Eqn (6) | COSTS (at $3.084/kg) Eqn (24) | RESOURCE RENTS ($ millions) |
|---|---|---|---|---|---|---|
| $26.00 | .00 | 113.76 | .00 | $.000 | $.000 | $.000 |
| 25.00 | 22.53 | 118.26 | .00 | .000 | .000 | .000 |
| 24.00 | 45.98 | 123.13 | .00 | .000 | .000 | .000 |
| 24.00 | 45.98 | 123.13 | .00 | .000 | .000 | .000 |
| 23.00 | 70.42 | 128.42 | .00 | .000 | .000 | .000 |
| 22.00 | 95.95 | 134.17 | .00 | .000 | .000 | .000 |
| 21.00 | 122.67 | 140.47 | .00 | .000 | .000 | .000 |
| 20.154 | 146.28 | 146.28 | .00 | .060 | .009 | .051 |
| 20.00 | 150.70 | 147.39 | 3.31 | 66.119 | 10.192 | 55.927 |
| 19.00 | 180.16 | 155.02 | 25.13 | 477.557 | 77.490 | 400.067 |
| 18.00 | 211.21 | 163.49 | 47.73 | 859.074 | 147.140 | 711.934 |
| 17.00 | 244.05 | 172.93 | 71.12 | 1,209.023 | 219.260 | 989.763 |
| 16.00 | 278.87 | 183.52 | 95.35 | 1,525.596 | 293.963 | 1,231.633 |
| 15.00 | 315.94 | 195.48 | 120.45 | 1,806.812 | 371.360 | 1,435.452 |
| 14.00 | 355.57 | 209.11 | 146.46 | 2,050.385 | 451.524 | 1,598.861 |
| 13.00 | 398.13 | 224.76 | 173.37 | 2,253.779 | 534.492 | 1,719.287 |
| 12.00 | 444.11 | 242.93 | 201.18 | 2,414.119 | 620.227 | 1,793.892 |
| 11.00 | 494.08 | 264.26 | 229.83 | 2,528.113 | 708.561 | 1,819.552 |
| 10.00 | 548.83 | 289.63 | 259.20 | 2,592.010 | 799.117 | 1,792.893 |
| 9.00 | 609.35 | 320.28 | 289.07 | 2,601.588 | 891.188 | 1,710.400 |
| 8.00 | 677.00 | 357.97 | 319.03 | 2,552.212 | 983.559 | 1,568.654 |
| 7.00 | 753.70 | 405.22 | 348.47 | 2,439.306 | 1,074.340 | 1,364.966 |
| 6.00 | 842.24 | 465.52 | 376.72 | 2,260.333 | 1,161.434 | 1,098.899 |
| 5.00 | 946.96 | 541.98 | 404.99 | 2,024.927 | 1,248.570 | 776.357 |
| 4.75 | 976.42 | 563.05 | 413.37 | 1,963.518 | 1,274.426 | 689.091 |
| 4.50 | 1,007.48 | 583.63 | 423.85 | 1,907.309 | 1,306.718 | 600.590 |
| 4.25 | 1,040.31 | 601.01 | 439.30 | 1,867.009 | 1,354.351 | 512.659 |
| 4.10 | 1,060.95 | 605.37 | 455.57 | 1,867.852 | 1,404.533 | 463.318 |
| 4.076 | 1,064.27 | 606.72 | 457.56 | 1,865.155 | 1,410.643 | 454.512 |
| 3.90 | 1,089.67 | 587.27 | 502.40 | 1,959.355 | 1,548.895 | 410.460 |
| 3.867 | 1,094.53 | 551.30 | 543.23 | 2,100.751 | 1,674.766 | 425.985 |
| 3.866 | 1,094.70 | .00 | 1,094.70 | 4,232.118 | 3,374.966 | 857.152 |
| 3.75 | 1,112.20 | .00 | 1,112.20 | 4,170.751 | 3,428.913 | 741.838 |
| 3.50 | 1,151.83 | .00 | 1,151.83 | 4,031.400 | 3,551.088 | 480.313 |
| 3.25 | 1,194.39 | .00 | 1,194.39 | 3,881.783 | 3,682.320 | 199.464 |
| 3.00 | 1,240.37 | .00 | 1,240.37 | 3,721.110 | 3,824.061 | (102.951) |
| 2.75 | 1,290.35 | .00 | 1,290.35 | 3,548.457 | 3,978.142 | (429.686) |
| 2.50 | 1,345.09 | .00 | 1,345.09 | 3,362.731 | 4,146.920 | (784.189) |
| 2.25 | 1,405.61 | .00 | 1,405.61 | 3,162.622 | 4,333.494 | (1,170.873) |
| 2.00 | 1,473.26 | .00 | 1,473.26 | 2,946.524 | 4,542.067 | (1,595.543) |
| 1.75 | 1,549.96 | .00 | 1,549.96 | 2,712.430 | 4,778.527 | (2,066.097) |
| 1.50 | 1,638.50 | .00 | 1,638.50 | 2,457.753 | 5,051.501 | (2,593.748) |
| 1.25 | 1,743.22 | .00 | 1,743.22 | 2,179.030 | 5,374.360 | (3,195.330) |
| 1.00 | 1,871.39 | .00 | 1,871.39 | 1,871.394 | 5,769.507 | (3,898.113) |
| .75 | 2,036.63 | .00 | 2,036.63 | 1,527.475 | 6,278.941 | (4,751.466) |
| .50 | 2,269.53 | .00 | 2,269.53 | 1,134.763 | 6,996.947 | (5,862.184) |

**TABLE 6.**
**FARMED SALMON RESIDUAL DEMAND (ESCAPEMENT MANAGED).**

| MARKET PRICE ($/kg) | SALMON DEMAND (000s of tonnes) GROSS Demand Eqn (1) | WILD SUPPLY Eqns (13) & (6) | RESIDUAL DEMAND [$Q_A$ = (Q - H)] | FARMED SALMON REVENUES ($ millions) ($P*Q_A$) Eqn (6) | COSTS (at $3.084/kg) Eqn (24) | RESOURCE RENTS ($ millions) |
|---|---|---|---|---|---|---|
| $26.00 | .00 | 400.00 | .00 | $.000 | $.000 | $.000 |
| 25.00 | 22.53 | 400.00 | .00 | .000 | .000 | .000 |
| 24.00 | 45.98 | 400.00 | .00 | .000 | .000 | .000 |
| 23.00 | 70.42 | 400.00 | .00 | .000 | .000 | .000 |
| 22.00 | 95.95 | 400.00 | .00 | .000 | .000 | .000 |
| 21.00 | 122.67 | 400.00 | .00 | .000 | .000 | .000 |
| 20.00 | 150.70 | 400.00 | .00 | .000 | .000 | .000 |
| 19.00 | 180.16 | 400.00 | .00 | .000 | .000 | .000 |
| 18.00 | 211.21 | 400.00 | .00 | .000 | .000 | .000 |
| 17.00 | 244.05 | 400.00 | .00 | .000 | .000 | .000 |
| 16.00 | 278.87 | 400.00 | .00 | .000 | .000 | .000 |
| 15.00 | 315.94 | 400.00 | .00 | .000 | .000 | .000 |
| 14.00 | 355.57 | 400.00 | .00 | .000 | .000 | .000 |
| 13.00 | 398.13 | 400.00 | .00 | .000 | .000 | .000 |
| 12.958 | 400.00 | 400.00 | .00 | .000 | .000 | .000 |
| 12.957 | 400.03 | 400.00 | .03 | .442 | .105 | .337 |
| 12.00 | 444.11 | 400.00 | 44.11 | 529.275 | 135.980 | 393.295 |
| 11.00 | 494.08 | 400.00 | 94.08 | 1,034.925 | 290.061 | 744.863 |
| 10.00 | 548.83 | 400.00 | 148.83 | 1,488.286 | 458.838 | 1,029.447 |
| 9.00 | 609.35 | 400.00 | 209.35 | 1,884.112 | 645.413 | 1,238.699 |
| 8.00 | 677.00 | 400.00 | 277.00 | 2,215.986 | 853.986 | 1,362.001 |
| 7.100 | 745.59 | 400.00 | 345.59 | 2,453.501 | 1,065.440 | 1,388.061 |
| 7.099 | 745.63 | 400.03 | 345.60 | 2,453.420 | 1,065.487 | 1,387.933 |
| 7.00 | 753.70 | 405.22 | 348.47 | 2,439.306 | 1,074.340 | 1,364.966 |
| 6.00 | 842.24 | 465.52 | 376.72 | 2,260.333 | 1,161.434 | 1,098.899 |
| 5.00 | 946.96 | 541.98 | 404.99 | 2,024.927 | 1,248.570 | 776.357 |
| 4.75 | 976.42 | 563.05 | 413.37 | 1,963.518 | 1,274.426 | 689.091 |
| 4.50 | 1,007.48 | 583.63 | 423.85 | 1,907.309 | 1,306.718 | 600.590 |
| 4.25 | 1,040.31 | 601.01 | 439.30 | 1,867.009 | 1,354.351 | 512.659 |
| 4.10 | 1,060.95 | 605.37 | 455.57 | 1,867.852 | 1,404.533 | 463.318 |
| 4.076 | 1,064.27 | 606.72 | 457.56 | 1,865.155 | 1,410.643 | 454.512 |
| 3.90 | 1,089.67 | 587.27 | 502.40 | 1,959.355 | 1,548.895 | 410.460 |
| 3.867 | 1,094.53 | 551.30 | 543.23 | 2,100.751 | 1,674.766 | 425.985 |
| 3.866 | 1,094.70 | .00 | 1,094.70 | 4,232.118 | 3,374.966 | 857.152 |
| 3.75 | 1,112.20 | .00 | 1,112.20 | 4,170.751 | 3,428.913 | 741.838 |
| 3.50 | 1,151.83 | .00 | 1,151.83 | 4,031.400 | 3,551.088 | 480.313 |
| 3.25 | 1,194.39 | .00 | 1,194.39 | 3,881.783 | 3,682.320 | 199.464 |
| 3.00 | 1,240.37 | .00 | 1,240.37 | 3,721.110 | 3,824.061 | (102.951) |
| 2.75 | 1,290.35 | .00 | 1,290.35 | 3,548.457 | 3,978.142 | (429.686) |
| 2.50 | 1,345.09 | .00 | 1,345.09 | 3,362.731 | 4,146.920 | (784.189) |
| 2.25 | 1,405.61 | .00 | 1,405.61 | 3,162.622 | 4,333.494 | (1,170.873) |
| 2.00 | 1,473.26 | .00 | 1,473.26 | 2,946.524 | 4,542.067 | (1,595.543) |
| 1.75 | 1,549.96 | .00 | 1,549.96 | 2,712.430 | 4,778.527 | (2,066.097) |
| 1.50 | 1,638.50 | .00 | 1,638.50 | 2,457.753 | 5,051.501 | (2,593.748) |
| 1.25 | 1,743.22 | .00 | 1,743.22 | 2,179.030 | 5,374.360 | (3,195.330) |
| 1.00 | 1,871.39 | .00 | 1,871.39 | 1,871.394 | 5,769.507 | (3,898.113) |
| .50 | 2,269.53 | .00 | 2,269.53 | 1,134.763 | 6,996.947 | (5,862.184) |

**FIG. 1.**
**THE SALMON MARKET — ALL SALMON IS SUPPLIED BY THE ESCAPEMENT-ALLOWED CATCH OF AN OPEN-ACCESS FISHERY.**

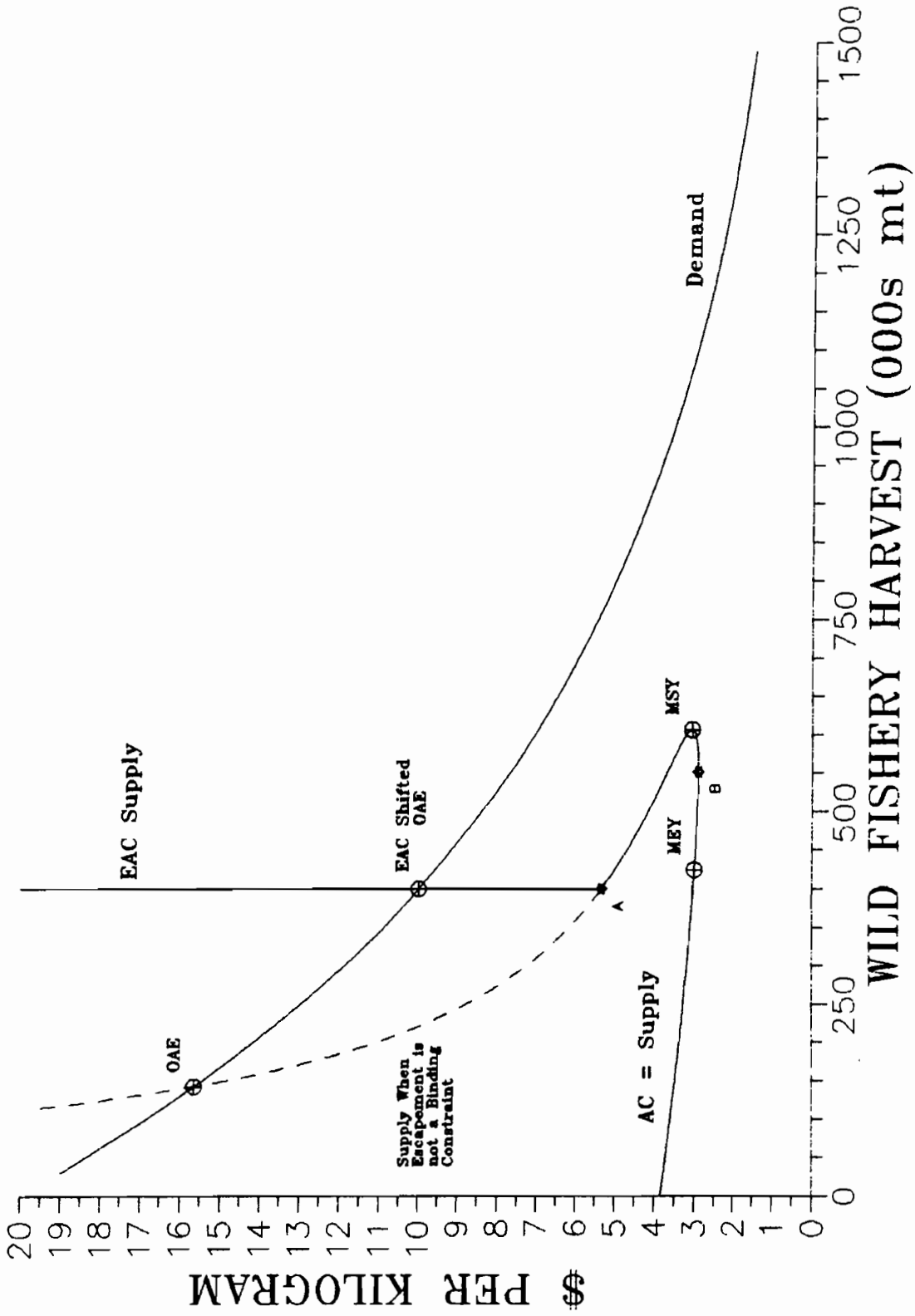


**FIG. 2.**
**THE SALMON MARKET — ALL SALMON IS SUPPLIED BY THE ESCAPEMENT-ALLOWED CATCH OF A LIMITED-ENTRY FISHERY.**

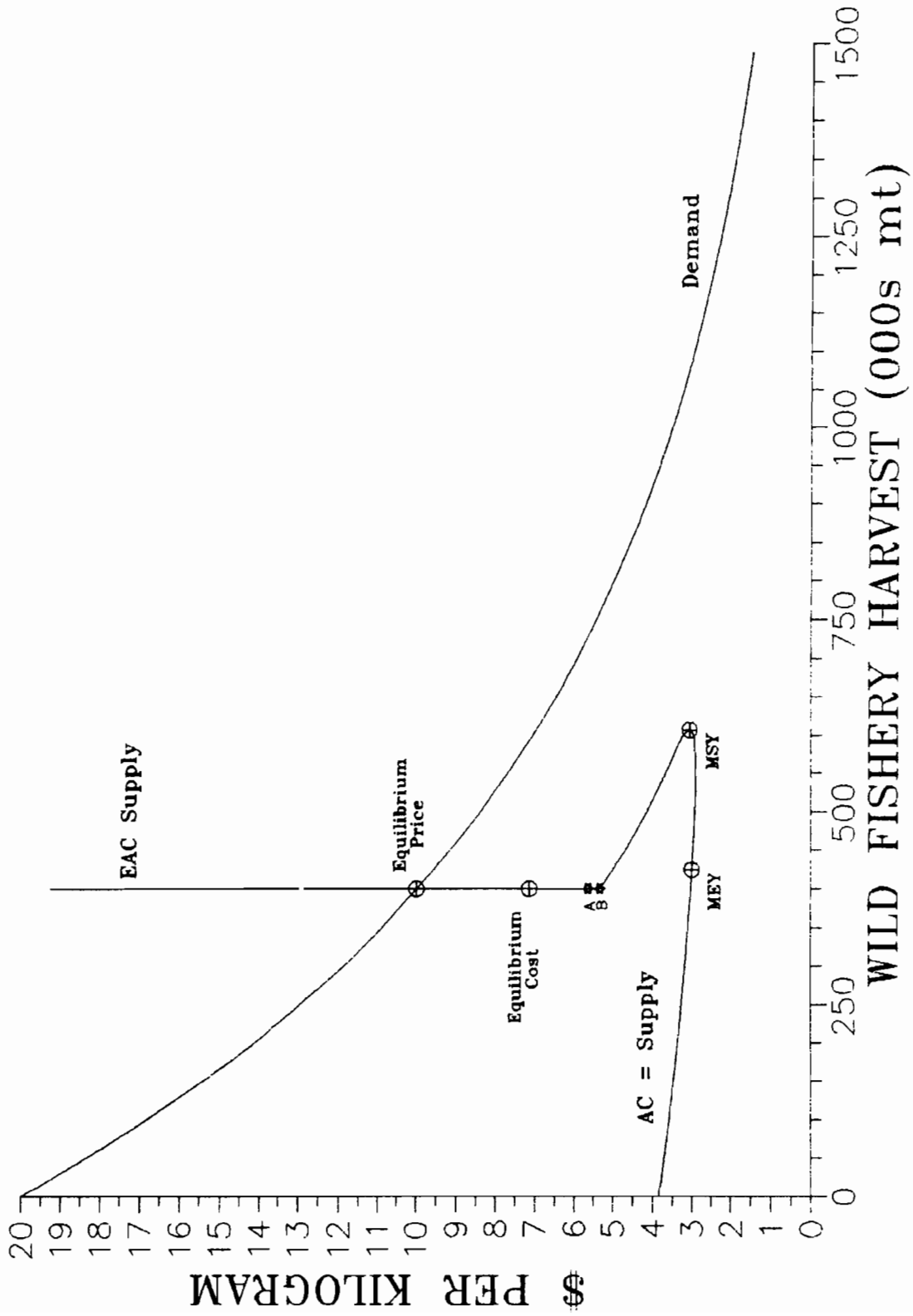
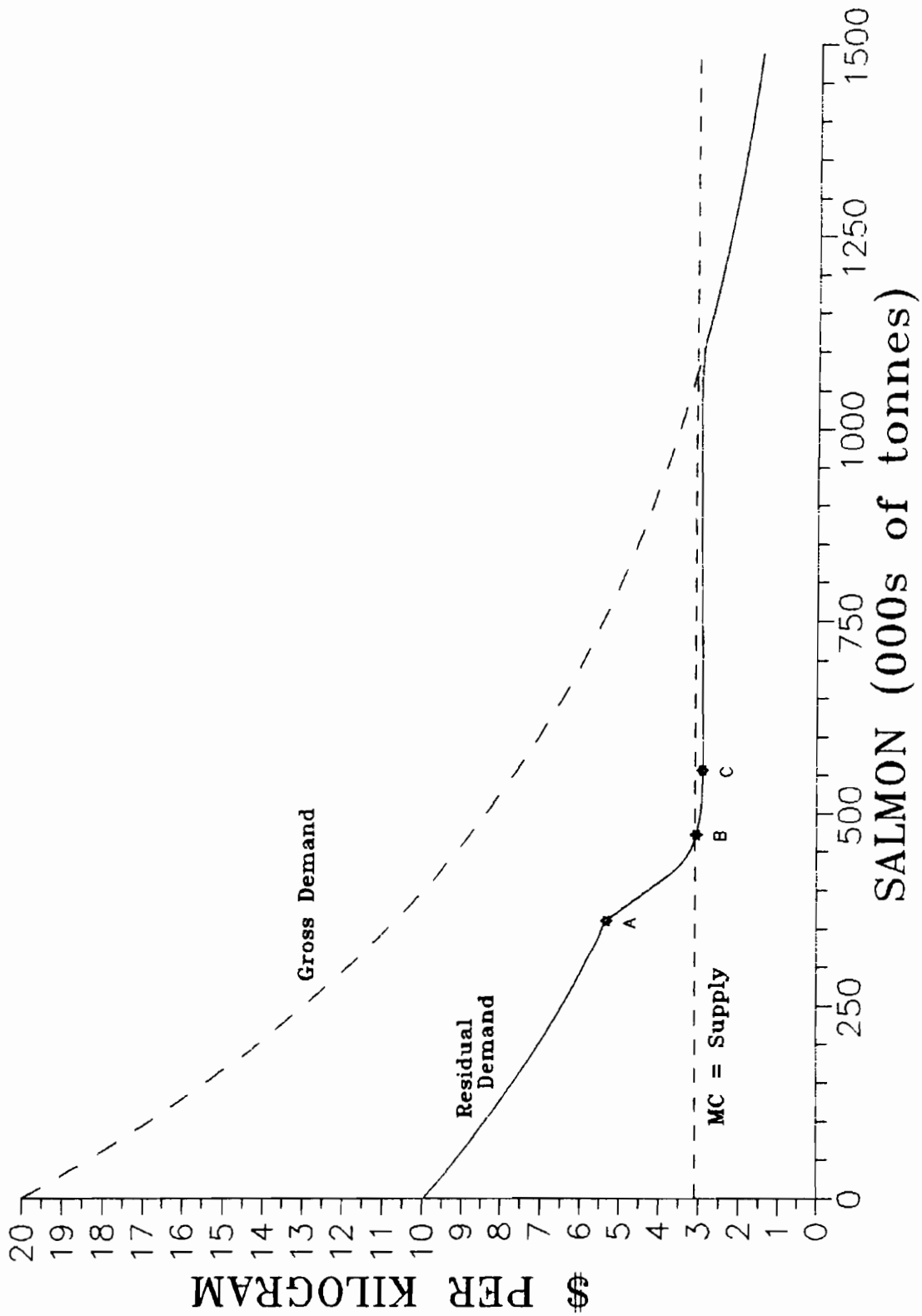


**FIG. 3.**
**THE FARMED SALMON MARKET — PERCEIVED AS BEING RESIDUAL TO THE WILD SALMON FISHERY.**



## A.1 THE WILD FISHERY

In keeping with a simple general model theme, the wild fishery is assumed to be a single stock, that is harvested by a single gear type, that behaves according to the Ricker (1975, pp. 282-283) model where the recruitement to the fishable stock is defined by :

$$R = aSe^{-\beta s} \tag{A1}$$

R = recruits (mt ; 2.5kg / piece
S = spawners = parent stock
$\alpha,\beta$ = parameters

The landed harvest is assumed to be a simple function of the fishing related mortality :

$$H = \delta qER \tag{A2}$$

H = landed harvest
$\delta$ = portion of M that is landed
M = annual harvest related fishing mortality
q = catchabilly coefficient
E = total effort

$$S = R - H / \delta \tag{A3}$$

The equilibrium spawning stock for any given level of fishing effort can be defined by substituting the RHS of (A2) into eqn (A3) and the RHS of eqn (A1) into that result :

$$\overline{S} = ln\,[\alpha(1-qE)] / \beta \tag{A4}$$

$$\overline{E} = ( 1 - e^{\beta s} / a ) / q \tag{A4a}$$

The equilibrium harvest for a given level of effort can be defined by sustituting the RHS of eqns (A1) and (A4) into eqn (A2) :

$$\overline{H} = ( \delta / \beta )\, ln\,[\alpha(1 - qE)] / [1 / (qE) - 1] \tag{A5}$$

$\overline{H}$ = escapment allowed catch (EAC)

which gives an equilibrium gross income in the wild fisheries of :

$$\overline{Y} = P( \delta / \beta )\, ln\,[\alpha(1 - qE)] / [1 / (qE) - 1] \tag{A6}$$

Most salmon fisheries are gauntlet fisheries and the *escapement* (nunber of spawners) is regulated to conserve the stock. Under those conditions, eqn (A4a) becomes :

$$\overline{E}^{\circ} = (1 - e^{\beta s^{\circ}} / \alpha) / q \tag{A4b}$$

$\overline{E}$ = target effort
$\overline{S}^{\circ}$ = target number of spawners

and eqns (A3) and (A1) can be combined and reorganized to define the regulated harvest :

$$\overline{H}^{\circ} = \delta S^{\circ}(\alpha e^{-\beta s^{\circ}} - 1) \tag{A7}$$

## A.2 WILD FISHERY : FISHING EFFORT AND FISHING COSTS

Fishing enterprises combine labour and capital on fishing vessel platforms to produce fishing power - the annual capacity to catch fish - the fishing season length then defines how much effort is applied to the fishery :

$$E = gmfV \tag{A8}$$

$$f = E / gmV \tag{A8a}$$

E = total fishing effort
f = fishinf power per vessel
g = effective fishing season length (part of a year)
V = number of fishing vessels
m = technology parameter

If the fishery managers control escapement then the fishing season is

$$g = \min\{E^{\circ} / (mfV) , g_n\} \tag{A8b}$$

$g_n$ = natural season length

## A.3 WILD FISHERY - FISHING COSTS

The following simple effort cost curve was designed with the idea that fishing inputs have both fixed and variable costs : [6]

$$C_F = V(\Phi + g\Omega)e[g^{.25}\tau f] \tag{A9}$$

$$C_{Fi} = (\Phi + g\Omega)e[g^{.25}\tau f] \tag{A9a}$$

$C_F$ = fishinf annual social cost
$C_{Fi}$ = fishing cost of vessel i
$\Phi$ = fixed cost of a fishing vessel
$\Omega$ = 0season related fixed cost of fishing power
$\tau$ = parameter reflecting economies or diseconomies of scale
e[n] = $e^n$

## B.1 SALMON FARMING : COSTS

DeVoretz et al. (1991b, pp. 3-4) provide a theoretical cost model for Norvegian farmed salmon :

$$AC_{SR} = ce^{hQ} / Q \tag{B1}$$

$AC_{SR}$ = short-run average production cost / kg
c,h = short-run parameters but long-run scale variables

$$MC_{SR} = che^{hQ} \tag{B2}$$

$MC_{SR}$ = short-run marginal production cost / kg

$$MC^{\circ}_{SR} = P = che^{hQ^{\circ}} \tag{B3}$$

$Q^{\circ}$ = output at which $P = MC_{SR}$

6. A more detailed discussion and model of these costs is provided by Wright (1991, pp. 76-77)

$$AC^{\circ} = P / (bQ^{\circ}) \tag{B4}$$

$$h = P / (AC^{\circ}Q^{\circ}) \tag{B5}$$

$$c = Pe^{-hQ^{\circ}} / h \tag{B6}$$

$$\pi_A^{\circ} = PQ^{\circ} - AC(Q^{\circ}) = P(Q^{\circ} - 1/h) \tag{B7}$$

The values that c and h take are determined by the current limits of technology. Salvanes (1988, pp. 91 and 109) provides a way to answer this empirical question (DeVoretz, et al., 1991b, p.1). If P is \$8.24, then :

$$AC = 3.05e^{(.067\ln^2 Q^{\circ} - .599\ln Q)} / 5.34 \tag{B8}$$

When eqn (B4) is set equal to eqn (B8) the result can be reorganized to :

$$c = 5.34P / [3.05e^{(.067\ln^2 Q^{\circ} - .599\ln Q)}] \tag{B9}$$

Equation (B5) can be reorganized to :

$$Q^{\circ} = (\ln [P] - \ln [ch]) / h \tag{B10}$$

The output at which (for a scale of operations – values of c and h) the average cost is minimized can be defined by differentiating eqn (B1) with respect to Q, setting that result equal to nil and reorganizing it to :

$$Q^* = 1 / h \tag{B11}$$

Figure B1 is adapted from DeVoretz et al. (1991b, p. 10) to show what eqns (B1) through (B4) look like when Q* is at the global minimum AC.

Figure B2 is adapted from DeVoretz et al. (1991b, p. 12) to illustrate the long-run AC envelope. Based on the DeVoretz et al. (1991b) values, if :

$$h = 1 / Q^* = 8.707E4 \tag{B12}$$

$$c = P^*Q^*e^{-1} = 1.3029E{-}5 \tag{B13}$$

then :

$$Q^* = 76{,}749 \text{ kg} \tag{B14}$$

$$P^* = MC^* = AC^* = \$3.0838 / \text{kg} \tag{B15}$$

and, in the very long-run, eqn (B15) is the aquaculture supply curve. Howewer, while there is rent available to salmon farms (in the short to intermediate-run) frams will supply salmon based on eqn (B3). If rent is available for a long time, the long-run supply function of a typical salmon farm can be defined by adjusting (for a range of salmon prices) parameter c until the values produced by eqns (B9), (B10) maximize the farm's profit - eqn (B7).

*FIGURE B1: Norwegian Aquaculture Short Run Average Production Costs for an Observed Output (Salvanes, 1988) of 152,183 kg*

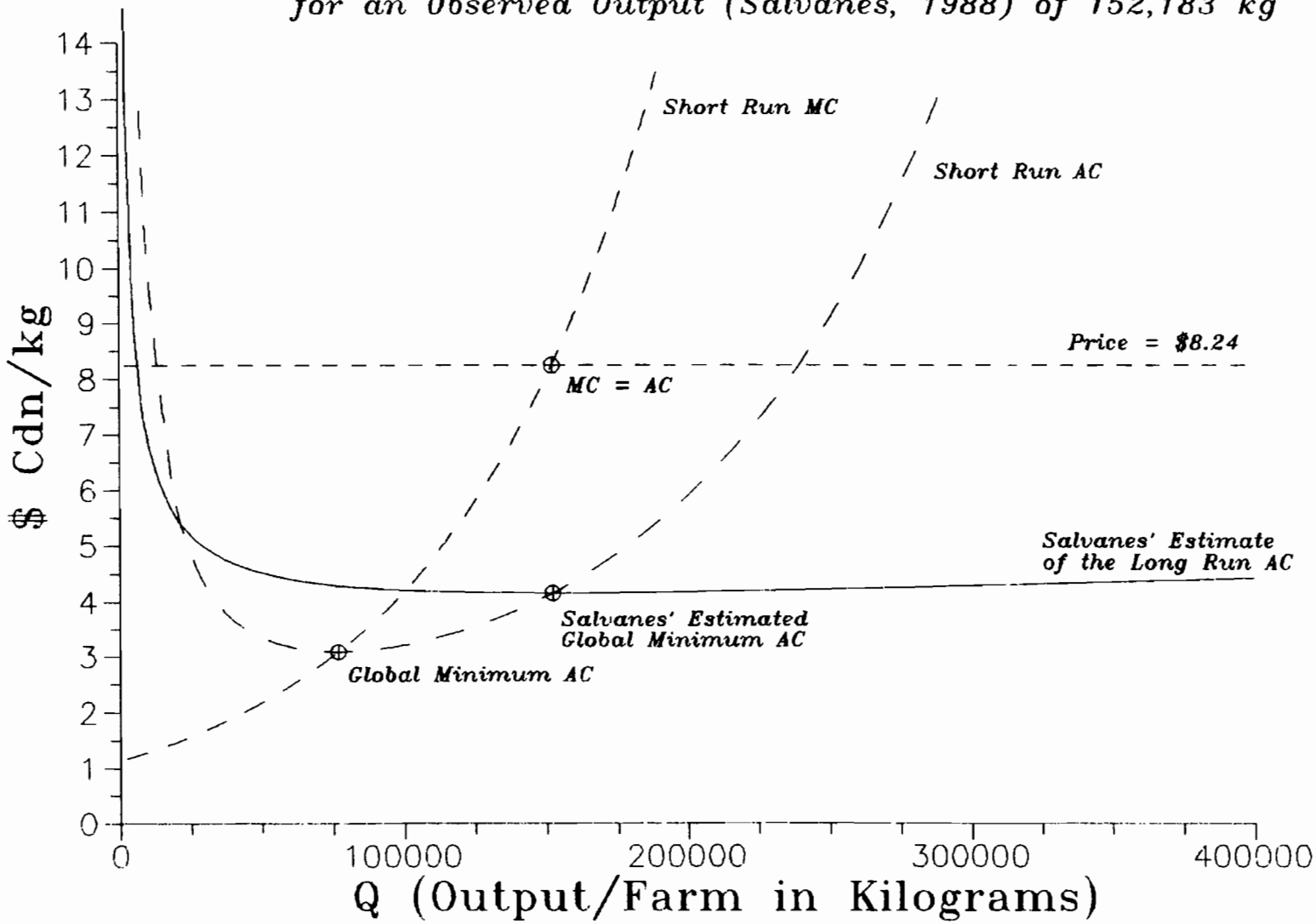
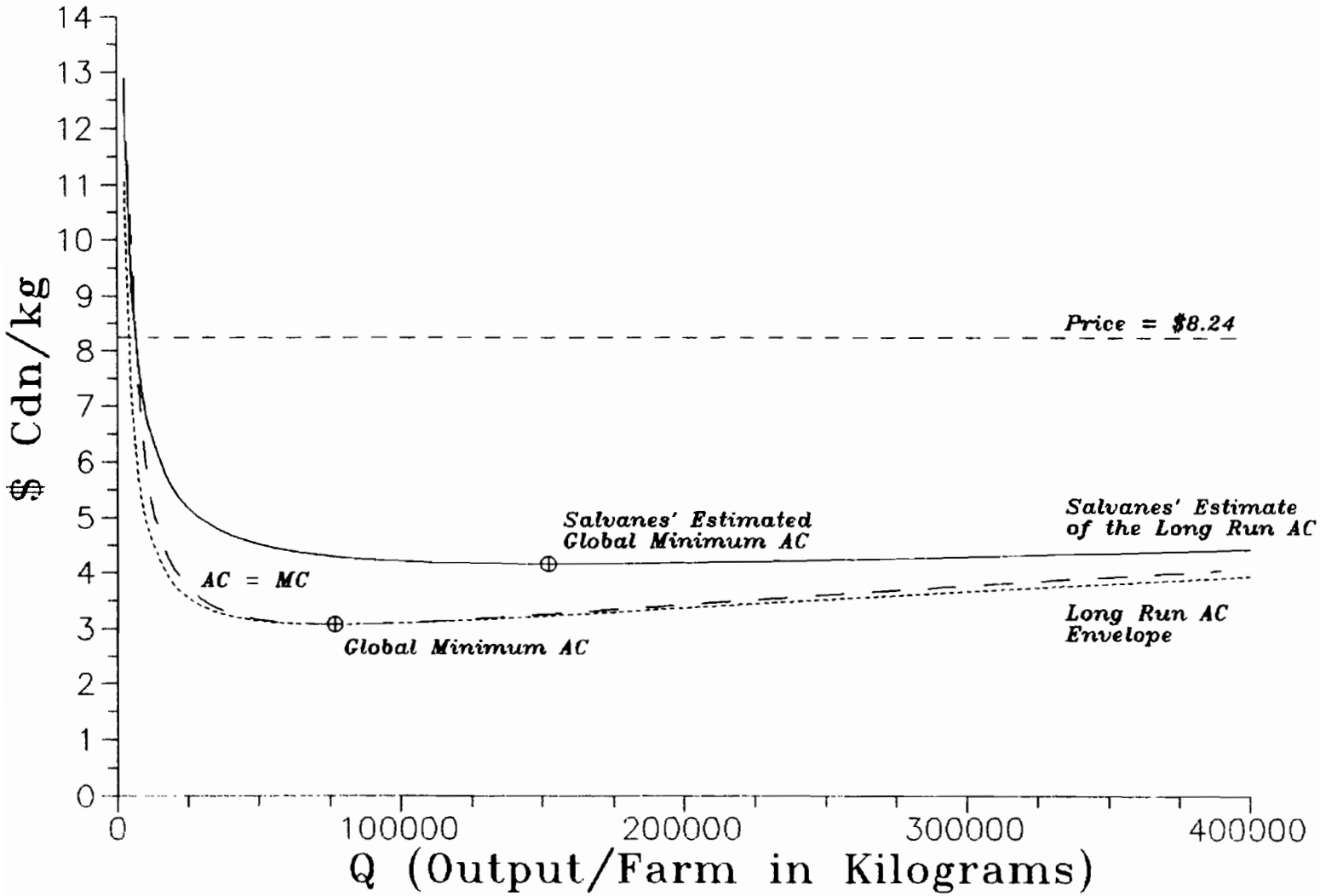


*FIGURE B2: Long-Run AC Envelope Contrasted With a Range of Minimum Short-Run ACs and Salvanes' Esitmate of the Long-Run AC*



# Determinants of Price in the Portland, Maine Fish Auction

**Nida Ty and John M. Gates**

Department of Resource Economics, The University of Rhode Island, Kingston, RI 02881-1630, USA

ABSTRACT

*The Portland fish exchange is an unusual fish market in North America. Fish are segregated by species, size and vessel into lots of up to about 1200 pounds. Fish buyers are able to inspect each lot in advance of the auction. This structure permitted a stratified random design to elicit buyers evaluation of fish quality using standard quality criteria in Food Science but modified on the advice of a panel of buyers. The questionnaire was distributed to buyers on randomly chosen days in July, 1990 for lots of codfish (the largest volume species) chosen randomly but stratified by size category. A panel of buyers agreed to score the quality of these lots using a pretested questionnaire. The results were collated with their transaction prices and other pertinent data such as lot size, total volume on the exchange that day, and buyer characteristics. These data were analyzed using multivariate regression methods to determine the effects of measured variables on the exchange price of each lot. Because each observation involves a known, homogeneous quantity and quality of fish, the data are much more precise than is often the case with fisheries market data. The Portland Fish Exchange is, to all appearances, a reasonable approximation to a purely competitive market, the behavior of buyers is believed to yield good estimates of true market preferences. The results indicate significant price differences with respect to fish size, (some) quality measures, lot size, harvesting technology and fishing grounds. At this time, the results are being discussed with an industry panel to ensure that our interpretations are plausible and not simply statistical quirks. This study does not shed light on the larger question of what would happen if all fish markets were to increase fish quality ; to claim otherwise would be a fallacy of composition.*

## 1. INTRODUCTION

This paper summarizes a study of quality factors affecting fish prices at the open-display auction market in Portland, Maine. Although similar markets exist elsewhere in the world, this one is unique in the United States. Fish quality attributes deemed important by the fish buyers were identified and their effects on bid prices at the Portland auction

market were measured. Cod was chosen as the target species because it ranks among the top five species in terms of consigned weight and value at the Portland fish auction market and is one of the most abundant and commercially important groundfish in the Northeast region.

## 2. BACKGROUND INFORMATION

A literature review and discussion of "Hedonic Price (HP)" models is contained in an appendix available from the authors.

An auction is "a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants" (McAfee and McMillan 1987). Cassady (1967) regarded auctions as an essential marketing device for fresh fish, the price of which is dominated by current supply and demand conditions. Proponents of the auction system for marketing fish such as Nichols *et al.* (1980) maintain that auctions, in general, provide high prices to the fishermen and high quality products to the consumers.

### *2.1 The Portland Fish Exchange* (PFE)

PFE opened in May of 1986 to manage the only all-display fresh fish auction market in the United States. The PFE was premised on the idea that an open marketplace can act as a price-setting mechanism which is fair, accurate, and responsive to product quality. The PFE auctions take place at 1 p.m. on Mondays through Thursdays and 11 a.m. on Sundays. Prior to auction time, the buyers and sellers' representatives receive a "detail" sheet which resembles an auction board listing of species, size classes, date, lot number, boat number and name, and weight. The order of the auction is by species by cull (size). The average running time of one auction round is an hour. Fish are auctioned off using the English (ascending-bid) system. The top bidder chooses "one or all" of the pallets of fish of a cull just bid. A 12,000-pound limit is set to avoid having only one buyer buy all the fish of particular species and cull without giving a second chance to other buyers. If more than ten pallets is desired, the buyer has to continue to bid for additional fish and to succeed must be the top bidder each time. The minimum purchase for each bid is one lot, which may be less than 900 pounds on partial lots. The bidding starts all over if there is more of that cull of that species after the first top bidder has chosen his lots. After the last species and cull have been auctioned off, buyers are allowed a second period of bidding on any items that were not bid on during the original auction. This round lasts for about five to ten minutes only. A seller has the right to refuse or "scratch" the sale (by saying "no sale !") at the time a given species by cull is being auctioned. Any scratched sale allows the buyer one final rebid of any amount. If the sale is still scratched after the rebid, the seller may either leave the scratched lot for next day's auction or remove it from the auction floor. The same options are available for lots which did not receive any bid at all.

This brief characterization is in stark contrast to the auctions at Boston and New Bedford where fish are bid upon without prior inspection by the buyer ("sight unseen"). Further information on these other fish auctions in new England is contained in an appendix available from the authors.

Buying fish sight unseen in the Boston and New Bedford auction markets has caused several problems for both buyers and sellers. Among the complaints aired are price-fixing, cartels, dishonest weights, and back door deals. Buyers have to rely on indirect measures of the fish quality such as the reputation of individual captains, the length of their trips, gear used, catching grounds, and other information. In an all-display fish auction market, as in the PFE, buyers can visually inspect the fish before bidding. The bidding among the buyers allegedly establishes premiums as well as discounts in relation to the product's quality attributes. Even if quality differentials are not revealed automatically, competitive auctions provide a "melting place for buyers and sellers who would benefit from markets for higher quality products" (Peterson and Georgianna 1988).

### *2.2 Price-Level Comparisons*

Conventional wisdom in the New England fishery market holds that the fresh cod, haddock, and pollock round ex-vessel prices are set in the Boston auction. A visual comparison of the Portland and Boston cod prices appears in Figure 1 for

the years 1985-1989. As shown in Figure 1, the price level and gap are compared between the pre-PFE (before June 1986) and the post-PFE (after June 1986) periods. The Portland prices increased from an average of 51.4 cents per pound to 68.9 cents per pound or a 34 percent price jump between the two periods. The Portland average prices were 24.5 percent lower than the Boston prices before PFE opened in June 1986. In the post-PFE period, the Portland prices were only 14.4 percent lower than Boston prices. Using a t-test of difference between means, it was found that the price gap between the Portland and Boston ports has significantly narrowed during the period. The equilibrium price difference between spatially separated competitive markets such as Boston and Portland is the transport cost between them. There has not been much change in the transport cost between these regions ; the narrowing of the Boston- Portland price gap is inferred to have been effected by enhanced competition and better quality of fish landed at the PFE.

## 3. RESEARCH METHODS

Sensory evaluation of fish quality required a panel of "judges". Six fish buyers were chosen on the basis of their experience and reputation as quality-conscious buyers at the auction. Since this study was done at the primary market or first exchange level, only quality characteristics of raw whole fish were measured. After consultation with the panel evaluation members and with food scientists, various parts of the fish were chosen as units of assessment for the quality attributes related to appearance, texture, color, and odor. The flesh is assessed for its firmness or consistency. The fish's skin is examined to note any loose scales and discoloration or bleaching of certain areas. The appearance of the eyes is a good guide to degree of spoilage. Very fresh fish have bright, convex or bulging eyes with a dark pupil. As spoilage proceeds, the eyes turn duller and grayer and become flat, then concave or sunken. In general, off-odors can be detected first in the area around the abdominal cavity. That is because the intestines and the gut cavity of the fish harbor large numbers of spoilage microorganisms and autolytic enzymes (Huss 1988 ; Connell 1980).

The volume of cod landings at PFE vary seasonally with a peak in May or June and trough in January or February. The month of June was purposively sampled as representative of a peak cod-fishing month. Nine auction days within the month of June were randomly selected, spread across from the first to the fourth week. The panel evaluations of cod lots were conducted during the period June 5-21, 1990. Systematic sampling was used to pick the lots for each day. All the large-sized lots were evaluated since the total number of lots under this category rarely exceeded 20. A total of 440 cod lots were sampled for sensory evaluation. Eleven (11) lots, however, did not receive any bid and were removed from the auction floor by their sellers. Assigning zero values for the sale price variable in these cases is unrealistic since these lots would command positive prices if sold in other markets. Consequently, these cases of missing values were dropped which resulted in a final sample size n = 429 lots of cod fish. Buyer inspections of the cod lots were usually done one or two hours before auction time. Each of the judges evaluated the randomly chosen lots independently of the other evaluators. One or two fish are picked from each box within an individual lot. The evaluator held each fish and examined closely the flesh, skin, and the eyes. Then each fish was smelled by bringing it close to the nose comparing the odor with the description on the scoresheet.

For the study, the HP model for cod was specified as :

$$P_i = P( Z_1,..., Z_j, D_1,..., D_k, e_i ) \quad (1)$$

where P or Price is either the actual auction sale price, PR, or a relative price measure, PP, for lot i. The Z's measure the physical quality attributes which were assessed through various parts of the fish for each lot. The D's are non-physical but quality-related attributes representing gear type and fishing grounds and $e_i$ is a stochastic error term.

The auction sale price (PR) represents the actual price paid by the highest bidder for one or more lots (up to maximum of 10 lots) on a given round of bidding. In cases of "scratched" or "no sale" lots, the highest bid is treated as the sale price, even if sale was refused.

An alternative price variable is the percentage price (PP) which is a relative price measure. It is the ratio of the actual sale price (PR) and the average daily auction price for each size category for a given day. By expressing the actual prices received for cod lots as percentages of a daily average price quotation, the influence of supply on price was reduced. In this way, it is possible to arrive at some measure of the average influence of certain quality factors on prices which may be above or below the average market price.

Apart from size and lot weight, all the other physical quality attributes were scored before the auction by the participating buyers. Each part of the fish was scored on a 0 (least acceptable) to 3 (most acceptable) scale. Category scale data are usually considered to be at least ordinal level data. They do not generally provide cardinal measures of value. Thus, on a category scale for odor quality, a product rated a 2 is not necessarily twice as good as a product with a score of 1. It can be noted, however, that there is an underlying continuum being approximated by artificial categories. For example, in the odor scale where 1 is "slight off-odor" and 2 is "trace of off-odor", there is a range of odor types between these two discrete numbers not accounted for by the scale. Only a very sophisticated measuring instrument can reveal the underlying interval scale. In the statistical analysis, all the quality score variables are treated as continuous interval variables. Scores for each part inspected by the four evaluators are averaged.

A higher score for each part inspected signifies better quality grade. The coefficients of the four score variables (FL, SK, EY, and OD) should all be positive since higher values for these variables represent higher grades and price should increase as grade improves.

The bruising characteristic (BR) is measured by a discrete qualitative variable where 0 denotes absence of bruising and 1 means presence of bruising. A price discount, hence a negative coefficient, is expected for this variable.

The only institutionalized grading at the PFE is size grading. This is done visually and manually with the aid of a weighing scale. For size sorting, the size categories follow the PFE cull standards which is as follows : Scrod (or small) cod, which has to be at least 19" long, weighs between 1.5 to 3.5 pounds ; market cod is from 3.5 to 10 pounds ; and large cod is anywhere over 10 pounds in weight. When available, cod weighing more than 22 pounds are classified as "whale" cod. Large fish of a given species generally command the highest prices. The coefficients of the size categorical variables (SZL and SZM) are hypothesized to have positive sign.

It is a common notion that fish buyers like to buy big lots. Other things being equal, a full lot is preferable to a partial lot. Therefore a positive coefficient for the lot weight variable (WT) is expected.

Two qualitative variables representing the gear type and the fishing ground of the boat-suppliers were analyzed. These variables are hypothesized to be important determinants of the value of cod. Gears were classified under two categories : the otter trawl and the gillnet types. The expected sign of the coefficients of the gear type and the fishing ground dummy variables is not definitely known. This is because although fish caught by gillnetters were thought to be of better quality (suggesting a negative coefficient for otter trawl qualitative variable), otter trawlers have been upgrading methods of handling and preserving their catch and have improved the quality of the fish they land (suggesting a positive coefficient for otter trawl dummy). Fishing ground was either offshore (o) or inshore (i). Fish caught from inshore fishing grounds may or may not be better than those from offshore grounds in terms of physical characteristics, even if some consumers maintain that inshore fish taste better.

Generally, any system of price premia and penalties can change with changing supply conditions (Waugh, 1929). To account for day-to-day supply fluctuations during the study period, a quantity consigned variable (QC) was used.

A list and description of all the variables discussed above is shown in Appendix A. They are grouped into categories described by equation 1.

Using the Student's t-test, one can determine if an attribute is an important determinant of the cod price. However, sequential application of the t-test to multiple characteristics within the same sample is not valid since statistical independence is violated.

## 4. ESTIMATION RESULTS

Five alternative functional forms, (linear, log-linear, semilog, inverse semilog, and quadratic) were examined. Several criteria were considered in choosing the final model. The first is consistency of expected signs and magnitudes for the coefficients of the explanatory variables. Then the goodness of fit of the regression equation is evaluated and reliance is placed on the F-statistic which tests the joint hypothesis that all coefficients are zero. To detect multicollinearity, the condition number and the values of the proportions of the coefficient variance were examined. Finally, the residual patterns were examined to see if residuals had patterns or tended to occur randomly. Autocorrelation in the the price variable was examined using the Durbin-Watson (DW) test.

The semi-log model gave the best results in terms of expected signs, magnitude of coefficient values, t-statistics of estimated parameters, condition number, and goodness of fit. Analysis of the residuals using plots and regressions against the explanatory variables did not suggest a significant problem of heteroskedasticity. Serious multicollinearity was not present as evident from a low condition number (equal to 17.45). The Durbin-Watson statistics for autocorrelation were in the inconclusive regions with $d_l < DW < d_u$. Results of the final set of OLS regressions appear in Table 1. The results from semi-log estimation using percentage price (PP) as dependent variable are provided for comparison.

Except for the skin score variable (SK), all the signs of the estimated coefficients were consistent with expectations. Seven (7) out of the total of 11 coefficients have coefficient :standard error ratios in excess of 1.7. Quite unexpectedly, the variables eye score (EY), skin score (SK), and bruising (BR) were not significant determinants of price variation. The coefficients of the skin and eyes score variables consistently showed low t-values and high standard errors in all the functional forms examined. A singular value decomposition was performed which suggested that multicollinearity among the score variables did not appear to be the culprit.

The standard partial regression coefficients, also called beta coefficients are computed from the parameter estimates of the semilog model. For the ith beta coefficient, i = 1, 2,..., k,

$$BC_i = b_i (S_i/S_y) \quad (2)$$

where $b_i$ is the estimated regression coefficient, $S_i$ is the standard deviation of the ith explanatory variable, and $S_y$ is the standard deviation of the dependent variable which is price in this model. As a unitless measure, each of the $BC_i$'s measures the direction and number of standard deviations that price changes for each one standard deviation increase in the explanatory variable. The absolute value of a beta coefficient is indicative of the degree of influence or relative importance of its associated variable on price. The magnitude of the price effect is computed for each standard deviation change in the explanatory variable. Table 2 includes only those variables with estimated coefficients significant at the 5 percent level or better (one-tailed test). The price effect estimates for the dummy categorical variables are interpreted in relation to the reference category.

The size characteristic was the strongest determinant of price. On average, lots in the market size category receive 13.35 cents per pound more than those in the scrod category while those in the large category receive 33.44 cents more than scrod-sized lots.

Examination of the quality score data suggested that the flesh, skin, eyes, and odor scores were all intercorrelated with simple correlation coefficients ranging from 0.37 to 0.58. An alternative measure for adjusting the model would have been to construct a composite quality score variable. This would have required, however, a method of assigning weights to the four rated parts and was deemed to be arbitrary. As it turned out, the flesh and odor quality scores showed significant t-values at the 1 percent level. Discussions with some fish buyers knowledgeable in fish quality and fish processing suggested that fish buyers are more sensitive to flesh and odor conditions than to condition of the skin and the eyes. Food technology experts have, often times, also chosen flesh texture and odor as quality attributes to be rated in conducting sensory evaluations of fish products.

As expected, the coefficient for lot weight has a positive sign perhaps because unit transaction costs are diminished as lot size increases. Fish landed by otter trawls receive a premium of 2.47 cents per pound in comparison with fish landed by gillnetters. This can be indicative of the improvement in the methods of catch storage and handling among trawler-boats. The flesh, skin, and odor condition of trawled catch were found to be significantly better that those of the gillnetted catch. This result was unexpected. However, a meeting at PFE, buyers were not surprised. They attributed the result to the anatomy of cod for which the most valuable cuts are vulnerable to gillnet damage. They felt that this result would not hold for other species and perhaps not for other seasons.

The quantity consigned variable was included to isolate the effect on price of daily supply variability. The magnitude of the quantity effect on price can be considered only within the range of values included in the data. Due to the wide variability of catch levels from month to month and from year to year, it is not possible to infer results for other seasons from this sample which focused on the peak supply month.

## 5. SUMMARY AND CONCLUSIONS

On the basis of several criteria, the overall explanatory power of the final model was considered quite acceptable. Seven out of the eleven coefficients in the regression equation were much larger than their standard errors and accounted for 72 percent of the cod price variation over the period of study. The residual variance can be partially attributed to the fact that buyers possess market information which may not be related to quality factors or local (PFE) supply conditions.

The results indicate that fish buyers take advantage of the open display feature of the Portland auction market to examine other physical quality characteristics deemed important to assure freshness of the fish lot they are bidding for. Physical characteristics pertaining to size, flesh condition, odor and lot weight are important considerations for the fish buyers at the Portland fish auction market. The premium differentials arising from other quality factors related to texture, color, and odor seem insignificant, in practical terms although they they are significant in statistical terms, compared to size-related premiums.

If the magnitudes of the price impacts are meaningful, then these values can provide important informational inputs in the decision-making process of the fishermen, processors, and policy-makers. To some extent, producers have substantial influence on the size mix of their catch through their gear type and/or mesh size decisions. Moreover, selection of methods of handling and preserving the catch on board may be the best way that producers have of affecting the flesh and odor conditions of landed fish. Once the relative values of the quality attributes are known, producers are provided with estimates of the possible value gains to be had from certain actions, thereby enabling reliable estimates of cost-effectiveness or cost-benefit to be made.

The efficient performance of the Portland Fish exchange, especially in its size-grading function, has resulted in some payoffs. The current sorting system which is based solely on size was found to explain 62 percent of the variation in cod prices. The important role played by the open-display type of fish auction is undeniable. As competition among buyers for high-quality fish intensifies, a fair and accurate system of pricing will eventually prevail and Portland could emerge as the price leader in the fresh fish market of the region. Where price premia exist for high-quality fish, fishermen have the economic incentive to improve quality. Market based standards of quality would diminish the need for mandatory federal inspection for the fishing industry.

## REFERENCES

**Cassady R. Jr.** (1967). *Auctions and Auctioneering*. Berkeley : University of California Press.

**Connell J.J.** (1980). *Control of Fish Quality*. 2nd ed. Farnham, Surrey, UK : Fishing News (Books) Ltd..

**Huss H.H.** (1988). *Fresh Fish - Quality and Quality Changes*. A Training Manual Prepared for the FAO/DANIDA Training Programme on Fish Technology and Quality Control. (FAO Fisheries Series, No.29). Rome : FAO.

**McAfee R. P. and J. McMillan** (1987). Auctions and Bidding. *Journal of Economic Literature*, **25 :** 699-738.

**Nichols J.P., J. Cato, W. Lesser, F. Olsen, F. Prochaska, F. Smith and J. Wilson** (1980). *Marketing Alternatives for Fishermen*. College Station : Texas A & M University, SSG S80-204, May 1980.

**Peterson S. and D. Georgianna** (1988). New Bedford's Fish Auction : A Study in Auction Method and Power. *Human Organization*, **47 :** 235-241.

**Waugh F.V.** (1929). *Quality as a Determinant of Vegetable Prices*. New York : Columbia University Press.

TABLE 1.
PARAMETER ESTIMATES FOR HEDONIC PRICE EQUATION FOR COD.

| Independent Variable | Symbol | Dependent Variable PR (Actual Price) | PP (Relative Price) |
|---|---|---|---|
| Flesh score | FL | 1.97* (0.75)[b] | 3.23* (1.10) |
| Skin score | SK | -0.66 (1.11) | -0.83 (1.64) |
| Eyes score | EY | 0.82 (0.87) | 1.52 (1.28) |
| Odor score | OS | 2.51* (0.83) | 3.95* (1.22) |
| Bruising | BR | -0.92 (1.06) | -1.81 (1.55) |
| Size(large) | SZL | 33.44* (1.15) | 7.93* (1.69) |
| Size(market) | SZM | 13.35* (1.25) | 5.60* (1.67) |
| Lot weight | WT | 1.26* (0.38) | 2.03* (0.54) |
| Gear type (otter trawl) | OTR | 2.47* (0.98) | 3.43* (1.44) |
| Fishing ground (inshore) | IN | 0.53 (0.96) | -0.54 (1.41) |
| Qty. consigned | QC | -5.74* (0.59) | ——— |
| Intercept | | 48.64* (2.27) | 75.19* (3.16) |
| adj $R^2$ | | 0.72 | 0.24 |
| F-value | | 101.72 | 14.78 |
| DW | | 1.56 | 1.56 |

[a]A semi-log regression where all explanatory variables, except the dummy variables, are in natural logs. Sample size, n = 429.

[b]Standard errors are in parentheses. Asterisk (*) denotes significance at the 1 percent level.

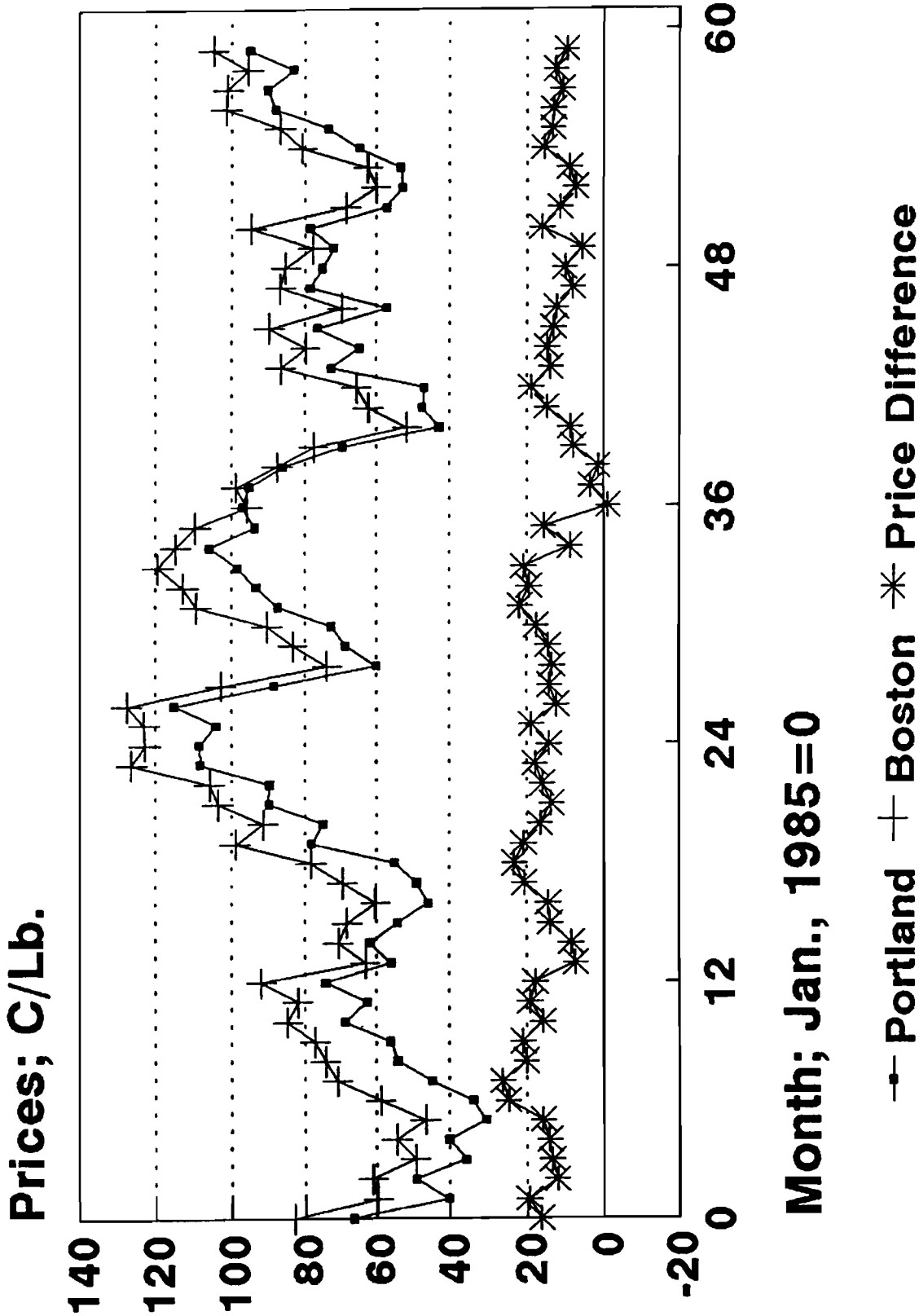
TABLE 2.
ESTIMATED BETA COEFFICIENTS AND PRICE EFFECTS.[a]

| Variable | Change | | Beta Coefficient | Effect on Price[b] |
|---|---|---|---|---|
| Flesh score | increase of 1 s.d. | | 0.090 | 1.49 |
| Odor score | increase of 1 s.d. | | 0.093 | 1.55 |
| Lot weight | increase of 1 s.d. | | 0.113 | 1.88 |
| Qty. consigned | increase of 1 s.d. | | 0.311 | 5.17 |
| Size effect relative to Scrod size | | Market | | 13.35 |
| | | Large | | 33.44 |
| Gear type effect relative to gillnet | | Trawl | | 2.47 |
| Intercept | | | | 48.64 |

[a]Sale price (PR) as dependent variable. For non-dummy variables, price effects are based on the beta coefficients shown above. For dummy variables and the intercept, price effects are the estimated regression coefficients.

[b]In cents per pound.

FIG. 1.
COD PRICES-JAN., 1985–DEC., 1990 PORTLAND & BOSTON.



Appendix A. Descriptions of Variables in the Hedonic Price Model for Cod

| Variable | | Definition |
|---|---|---|
| Price | | |
| PR | = | Auction sale price in cents per pound of cod for lot i |
| PP | = | Percentage price which is the ratio of the auction sale price for lot i and the average price of cod for that day |
| $z_j$ | | |
| FL | = | Flesh score [a] |
| FL | = | Skin score [a] |
| EY | = | Eyes score [a] |
| OD | = | Abdominal odor score [a] |
| BR | = | Dummy variable for bruising, where BR = 1 if bruising is present, BR = 0 if bruising is absent. |
| SZ | = | Categorical variable for size or cull, where SZL = 1 if size is large, SZM = 1 if size is market, and SZS = 1 if size is srod (reference category) |
| WT | = | Lot weight of dressed/gilled cod (in pounds) |
| $D_k$ | | |
| GR | = | Categorical variable for the boat's gear type, where OTR = 1 if gear type otter trawl and NET = 1 if gear is gillnet (reference category) |
| FG | = | Categorical variable for fishing ground, where IN = 1 if inshore and OFF = 1 if offshore (reference category). |

[a] Scores are averaged across evaluators.

## Appendix B. Conceptual Framework : Hedonic Prices and Product Characteristics

Waugh (1929) criticized economic theories of value for the neglect of "quality factors which determine whether the particular sale in question will be made at prices above or below [the] general level". Since that time several theories dealing directly with quality evolved. Most of the earlier works is in the hedonic price (HP) index literature, the earliest of which dates back to Court's paper in 1939. Adelman and Griliches (1961) proposed that "the quality of a commodity is a composite of different characteristics". Lancaster (1966a, 1971) did a pioneering work on the characteristics approach to consumer demand. Lancaster's theory is that utility or satisfaction is derived from the properties or characteristics which goods possess rather than goods themselves. Lancaster asserted that the relevant characteristics should be defined not in terms of people's reaction to the good, but rather in terms of objective measurement. Thus, to Lancaster, a characteristic must be defined in terms of properties of the good itself, such as calorie content of food or cooling power of an air conditioner. Lucas (1975) formulated a HP function as a regression of the observed price of a commodity against its quality attributes. The underlying hedonic hypothesis states that goods are valued for their utility-bearing characteristics and that the prices of goods vary directly with the specific amounts of each characteristic the product contains. The observed product prices are viewed as a composite of the values of the product's characteristics. A generalized HP equation is a regression of the form :

$$P_i = P ( V_{i1} ,..., V_{iJ}, u_i )$$

where $P_i$ is the observed price of the commodity i, $V_{ij}$, j = 1,..., J measures the amount of some "intrinsic quality" per unit of commodity i, and $u_i$ is a stochastic error term. The partial derivative with respect to any of the characteristics is the HP or the implicit marginal price of that characteristic. According to Rosen (1974), an estimated HP function does not typically identify a supply or a demand function since it is defined only over the characteristic space and its arguments consist exclusively of characteristics.

Early applications of HP methods involved the value of quality change in consumer goods or of quality in price indices (Adelman and Griliches 1961 ; Griliches 1971). Rosen (1974) used the HP concept to analyze the supply and demand of the characteristics which differentiate products in competitive markets. These studies were based on the idea that variations in the prices of different brands or models of a product reflect differences in the amount of certain basic attributes that they possess. Most of the early empirical applications have dealt with industrial products such as consumer capital goods such as automobiles and electrical apparatus. Hedonic values of residential property have been used to measure environmental benefits.

In the agricultural sector, hedonic studies were done to explain variations in prices of cotton and deer hunting leases and more recently for rough rice bid/acceptance markets (Brorsen *et al.* 1984), beef carcass auction markets (Porter and Todd 1985), and lamb carcass whosesale market (O'Connell 1986). The hedonic study of rough rice by Brorsen *et al.* (1984) led to identification of quality factors such as head yield, mill yield, and test weight which are also important in determining rice's value. These factors are not included in the present system of establishing federal grades for rough rice. In his hedonic model of the Paris lamb carcass market in Paris, France, O'Connell extended the price equation to include country of origin, which is a non-quality attribute. The results showed that supplying countries aside from France "suffer a substantial country-of-origin discount which is not justified on quality considerations". Porter and Todd's model of the beef carcass auction markets in Perth, Australia identified eight quality factors which significantly affect beef prices. Five of these factors, namely ; meat color, fat color, trim, length, and grain feeding, were suggested to be included in the Australian carcass classification system.

## REFERENCES

**Adelman I. and Z. Griliches** (1961). On an Index of Quality Change. *Journal of the American Statistical Association*, **56 :** 535-548.

**Belsley D.A., E. Kuh and R.E. Welsch** (1980). *Regression Diagnostics, Identifying Influential Data and Sources of Collinearity*. New York : John Wiley and Sons, Inc.

**Bigelow H.B. and W.C. Schroeder** (1953). *Fishes of the Gulf of Maine*. Fishery Bulletin of the Fish and Wildlife Service. (No.74), Washington D.C. : Government Printing Office.

**Brorsen B. Wade, W.R. Grant and M.E. Rister** (1984). A Hedonic Price Model for Rough Rice Bid/Acceptance Markets. *American Journal of Agricultural Economics*, **66 :** 156-163.

**Cassady R., Jr.** (1967). *Auctions and Auctioneering* . Berkely : University of California Press.

**Connell J.J.** (1980). *Control of Fish Quality*. 2nd ed. Farnham, Surrey, UK : Fishing News (Books) Ltd..

**Connell J.J.** (1972). *Quality Control in the Fish Industry* . Torry Research Station Advisory Note No. 58. Edinburgh, Scotland : Her Majesty's Stationery Office.

**Court A.T.** (1939). Hedonic Price Indexes With Automotive Examples. In *The Dynamics of Automobile Demand*, 99-117. New York : General Motors Corporation.

**Griffin N.** (1988). Auctions Face Transition in Boston and New Bedford. *National Fisherman*. June 1988, 16-19.

**Griffin N.** (1988). Seafood Auctions : Finding a Successful Formula Can Be a Difficult Task. *National Fisherman*. May 1988, 12-15.

**Griliches Z.,** ed. (1971). Price Indexes and Quality Change. Cambridge, Mass. : Harvard University Press.

**Guaspar J.** (1985). *I Know It When I See It (A Modern Fable About Quality)*. New York : American Management Association.

**Huss H.H.** (1988). *Fresh Fish - Quality and Quality Changes*. A Training Manual Prepared for the FAO/DANIDA Training Programme on Fish Technology and Quality Control. (FAO Fisheries Series, No.29). Rome : FAO.

**Judge G.G., R. Carter Hill, W.E. Griffiths, H. Lutkepohl and L. Tsoung-Chao** (1982). *Introduction to the Theory and Practice of Econometrics*. New York : John Wiley and Sons, Inc.

**Lancaster K.J.** (1966a). A New Approach to Consumer Theory. *Journal of Political Economy*, **74 :** 32-57.

**Lancaster K.J.** (1966b). Change and Innovation in the Technology of Consumption. *American Economic Review*, **56 :** 14-23.

# The Price Equalization Fund of the Fisheries in Iceland A Descriptive Study

**Olafur Örn Klemensson**

Central Bank of Iceland

ABSTRACT

*The objective of this paper is to illuminate and discuss the system of stabilizing the export prices of the fisheries' sector. The paper is divided into five sections. In the first section, it is be shown how important the fisheries are for the Icelandic economy. In the second section the rational behind efforts to reduce economic fluctuation caused by changes in export prices of the fisheries' sector is discussed. Thirdly the price development of the main fish products is shown. Next the main features of the Price Equalization Fund, its implementation and how it works are described and in the fifth section, the experience of the price equalization policy is discussed including how it can contribute to the stabilization of the economy.*

## 1. THE IMPORTANCE OF THE FISHERIES' SECTOR

The Fisheries' sector is of fundamental importance to the Icelandic economy, as it has been for most of this century. Fish products account for more than 75% of the merchandise exported, contributes directly 17% of the GDP and employes 13% of the workforce. This fundamental role of the fisheries on the economic development can be seen in Fig. 1.

With a simple regression it can also be shown that 75% of the total variation in the growth rate of the GDP can be explained by these factors.

The equation is:

DGDP 0.23*DCATCH + 0.13*DCATCH(-1) + 0.10*DTOT + 0.18*DTOT(-1) + 0.077*DTOT(-2) + 066*DUMMY1971*0.030

(4.33) (2.46) (1.75) (3.56) (1.39) (2.63) (7.07)

These facts make the Icelandic economy unique in comparison with other European countries. The size and importance of the fisheries' sector put Iceland among the few countries of the world where fisheries are the pillar of monetary and fiscal system.

The Icelandic economy has been relatively unstable as shown in Fig.2. The main reasons for this volatility are the annual changes in the catch of the main fish species and fluctuations in the price level on fish products of foreign markets. The economy is very open through its high dependency on foreign trade which accounts for some 35% of GDP. All these facts makes the economy highly exposed to exogenous factors.

It must be one of the prime objectives of any government to reduce fluctuations in economic activity and thus diminish uncertainty and instability in the economy. It is not in the power of Icelandic authorities to influence developments outside the Icelandic economy such as fluctuations in the price level of fish products, but it is possible to reduce adverse effects of these fluctuations on other factors of the economy. With the right economic policy mix it ought to be possible to adjust the economic development toward more stability, reduced inflation and make the way for continuous economic growth.

It has been shown above that there is an overwhelming influence which the fisheries' sector has on the economic performance in Iceland. All major fluctuations in the economic activity have been caused by changes in the output or in the export prices of the fisheries' sector. To illuminate this a typical business cycle in Iceland can be described as follow.

The upswing usually begins with either increases in fish catches or in price level of fish products or even both at the same time. This leads to a rise in income, first within the fisheries' sector, but then also in other sectors as most of the increases in income within the fisheries' sector will spill over to other sectors. The overall level of demand then rises and the demand for labour will push up the rate of real income. The net result on the fishery industry is that only a marginal part of the higher income is retained within the fisheries' sector as most of it flows to other sectors as has been described. In the meantime the higher level of demand and money supply has led to a demand-induced inflation, and production costs increase accordingly. With subsequent decline in export prices or in the fish catch, the firms in the fisheries' sector must face a higher level of production costs but at a lower level of income. These firms have serious difficulties adjusting to the adverse effects of lower prices and higher productions costs. This usually induces great pressure on the exchange rate which ultimately leads to devaluation of the currency.

This model describes exactly what happened in the years 1986-1990. The price level of most fish products began to move upwards in the second half of 1986 and continued on till the peak was reached in late 1987. The catch was rather good in these years as were other factors affecting the fisheries. As has been described above, the higher level of income in the fisheries' sector led to higher costs and, ultimately, a much higher level of real income the other sectors of the economy. This resulted in a sharp rise in the real exchange rate of the currency and very serious difficulties within the fisheries' sector. In spite of greatly increased turnover an higher net income, most of the fishery businesses were not able to build up reserves during this period of two very favourable years. The adjustment process was a very difficult and a costly one. The currency had to be devaluated and this led to higher inflation and the Government had to write out state-guaranteed loans on a big scale, and at least some of them, eventually, must be redeemed by the state.

This experience led to renewed discussion about a new and more effective price equalization fund to replace an older fund which had been established in 1969.

## 2. THE NECESSITY OF ECONOMIC STABILITY

In Iceland it has been the prime objective of the economic policy to reduce the inherent instability of the economy. The core of the stabilization policy is to slow down the expansion by withholding a part of the excessive monetary supply. Theoretically it can be accomplished with either general policy tools, like fiscal, monetary or exchange rate policy or with selective methods like the price equalization scheme i.e. withholding part of the income of the dominant sectors of the economy.

There is a good cause to believe that fiscal and monetary policy methods are too general to be sufficient to ensure stability in the Icelandic economy. Other policy methods, more selective, should be of great help in the stabilization process.

Changes in the exchange rate of the Icelandic Króna have often been used in the past to secure the competitiveness of the fishery industry but the experience indicates that a stable exchange rate is a prerequisite to bring forth moderate wage agreements and low inflation.

The economies of Europe are in a transition towards a more unified economic system and Iceland will be a part of the EEA agreement as from 1993. This transition to economic unification will dramatically reduce the policy alternatives at hand. Closer economic ties will also make it imperative to increase stability in the economy.

This development will greatly restrict the possibilities of the monetary authorities to use a discretionary exchange rate or monetary policy to stabilise the fluctuations. This tighter economic co-operation also calls for more stability in the Icelandic economy and the same overall economic performance as per European standards.

This development can be used to point out the necessity of using custom made policy tools for the implementation of the stabilisation policy.

Two other arguments for the case of an active price equalization scheme have been brought forward. The first argument is built on the assumption that it is necessary to ensure equity between the competing economic sectors by letting the dominant fisheries sector take part in an obligatory saving scheme in the form of a price equalization fund. The second argument rests on the usefulness for the businesses in the fisheries' sector in building up reserves to meet unforeseen fluctuations in income caused by changes in export prices.

## 3. PRICE DEVELOPMENT OF MAIN THE FISH PRODUCTS

To illustrate the effects of the price fluctuations of fish products on the economic development, it is helpful to draw up graphically the price development of the main fish products during the past 20 years.

In Fig. 3.a) the prices of groundfish products and fish meal and oil are plotted for the period 1964-1991 and in Fig. 3.b) the prices of crustaceans are shown, calculated in SDR at current and fixed prices.

The price fluctuations are distinctly different between fish products. The price of frozen fish has been relatively stable compared with the price of fresh and salted fish. Fish meal and oil prices are the most unstable of all fisheries products.

The intensity of the fluctuations have been evaluated with help of standard deviation of changes between yearly averages of fixed prices in SDR.

Standard deviation of yearly changes in SDR-prices

| | |
|---|---|
| Frozen fish | 7.6% |
| Fresh fish | 18.3% |
| Lobster | 13.4% |
| Shrimps | 16.5% |
| Scallops | 19.5% |
| Salted fish | 18.7% |
| Fish meal and oil | 22.9% |

## 4. THE PRICE EQUALIZATION FUND

### *4.1 New Legislation*

The old Price Equalization Fund of the Fishery Industry from 1969 had been only partly active for some years as the main activity was limited to crustacean species and salted fish. The Fund had deliberatly been put out of action regarding frozen fish products during the years of very high prices, i.e. between 1986-1988.

The role and usefulness of price equalization of the export prices of fish products was very much in debate during the drastic fall in prices during 1988 and 1989. The general consensus was that only two alternatives were possible: to abandon totally the idea of stabilazing the prices of fish products and to improve the price stabilization system.

After prolonged discussion, a government-appointed committee of politicians and representatives from the interested groups came out with a proposal for a new and improved price equalization fund in spring 1990.

In May 1990 the Parliament passed a law on the new Price Equalization Fund of the Fisheries (P.E.F.).

### *4.2 The Characteristics of the New Fund*

The main characteristics of the P.E.F. are the following.

i) The main purpose of the Fund is to diminish the effects of fluctuation in prices of fish products on the economy.

ii) According the new law the price equalization is to cover all fish products exported from Iceland.

iii) The fund is divided into sections according to the lines that divide the Icelandic fisheries sector: these are the sections for processed and unprocessed groundfish; sections for lobster, shrimps and scallops; the section for fishmeal and oil and the section for herring.

iv) Payments into the Fund are treaded as taxes. Inpayments are therefore not direct property of the fisheries companies concerned. The companies are only entitled to compensation payments (outpayments) when the prices fall.

v) The accrued capital of the Fund must be invested outside Iceland, which is necessary to ensure the targetted economic effects.

vi) Participation in the Fund is obligatory but all companies taking part in the Fund have an individual account in each of the seven sections of the Fund. Inpayments of duties are therefore earmarked the individual company. Outpayments to compensate for any fall in prices are restricted to the amount which each company has on its individual account at the Fund.

To achieve the objectives of the Fund, the following prerequisites have to be met.

i) The implementation must be as simple and transparent as possible. All calculation will be made at the office of the P.E.F. on the basis of information retrieved from the exporters. The proportional inpayments and outpayments are on a monthly basis and will be announced several days before they take effect. It is therefore known to all subjects concerned some days in advance what the proportion of inpayments and outpayments will be.

ii) To restrict the function of the Fund to smooth out fluctuation in prices but not to take into account other factors such as volume of catch or net business results in the fisheries' sector.

iii) The functioning must be as self regulating as possible with a minimal number of parameters to decide upon.

### *4.3 The Formulas for Calculation*

The main function of the price equalization scheme is to levy percentage duties on fish products when the marked price is over a certain average and pay out compensation when the actual marked price is under the calculated average.

In detail, the features of the system are as follows.

The calculation of price equalization is kept very simple. The law of the Fund prescribes precise rules for deciding in-or outpayments.

The Board of the Fund has five members, three of whom are directly appointed by the Minister of Fisheries and the other two being appointed after suggestions from shipowners, fishermen unions and the processors. It means that the Minister

always has the majority on the Board. The Board has to decide the percentage of inpayments or outpayments of the export value in each of the seven sections. The percentages are to be decided for each month in advance. The decisions of the Board must be publicly announced.

The calculation is made in several steps. First, for every month the average marked price for the products in each of seven sections of the Fund must be calculated, the necessary information being retrieved from the producers. In the second step the marked price is then adjusted for inflation (CPI indices for the five biggest industrial countries in OECD). The third step is to calculate the so called basic price, i.e. 60 months moving average price for each of the sections. The final step is to calculate the proportional difference between the inflation-adjusted marked price and the basic price. If the difference is positive the producers must make inpayments to the Fund and if the difference is negative the Fund has to pay compensation to the producers. The formulas behind the calculations are shown in Appendix 1.

## 5. THE EXPERIENCE OF PRICE EQUALIZATION

The price of groundfish products rose rapidly during the year 1990. In August of 1990 the groundfish sections of the new Fund became active. An inpayment of 1% of f.o.b. of the export value was decided for that month for all groundfish. The prices in other sections of the Fund did not give rise to inpayments or outpayments at that time.

In spring 1991 the price of groundfish came to a new historic peak. In May that year the average price of frozen fish was 20% higher in real terms than in 1987 when the price was on a previous record level.

The proportional inpayments went up to 5% in April 1991. These high inpayments coincided with the main fishing season and consequently this high inpayment met a profound discontent among the subjects concerned. During the summer months of 1991 the high prices leveled out and began to fall again in August 1991. High inpayments were paid to the Fund during these months of very high prices. But at the same time signs of overheating of the economy became evident. Upward pressure was on prices, wages and interest rates. But in a rather short period of time, nearly 1.5 billion Icelandic Krönas (U.S.$ 260 million) were paid into the Fund and neutralised. This reduced the money supply to a certain extent and curbed inflationary expectations. The labour unions agreed to postpone wage increases which they were entitled to, according to previous labour market agreement. This was done to allow the fisheries sector to improve its international competitiveness and to build up reserves to use during periods of low prices. All this made the necessary preconditions for more stability in the Icelandic economy.

For the period from July 1990 to January 1992 when inpayments to the Fund were stopped, the total income of the groundfish sections of the Fund accrued to 2.5 billion Icelandic Krönas (U.S.$ 430 million) or equivalent to 5% of the total export income of groundfish products in 1991. In Fig.4. the effects of the price equalization system can be seen.

The general consensus among economists and representatives from the various interests groups in Iceland has been rather univocal. The price equalization system has been successful. It has been proven that such an additional policy-tool is very helpful, if not a necessary part of the stabilization policy.

## APPENDIX 1.

The law of the new Fund prescribes that in each month the average market price in SDR for the products of the different sections are to be calculated. Let MPt stand for this average price for a specific section. Then t stands for the month when the board of the Fund makes its decision which will be effective for the next month, i.e. month = (t + 1). This price is adjusted for inflation with an index which shows changes in the purchasing power of SDR against prices measured by the consumer price indices in the five biggest industrial countries. The respective weights used are the same as those used to calculate the exchange rate of SDR. Let CPIt stand for this price index in month t and let RPt stand for the inflation adjusted price. It follows, therefore:

$$RPt = MPt/CPIt \tag{1}$$

Mathematically the formula for the basic price is the arithmetic mean of inflation adjusted marked prices for the last 60 months. Let BPt stand for the basic price then:

$$BP = (RP + RP\text{-}1 + ....+ RP\text{-}59)/60 \tag{2}$$

The next step is to evaluate the marked price MPt which is retrieved from data supplied by the exporters.

Next, the percentage difference between the inflation adjusted marked price and the basic price is to be calculated. Let PD stand for this difference:

$$PD = 1 - PD/RP \tag{3}$$

It is stated in the law of the Fund that 50% of this difference shall be the proportion of inpayment or outpayment. Now one parameter must be decided upon. This parameter is the so called price gap that can be, according to the law of the Fund, anywhere between 3% and 5% . The larger the price gap is, the less sensitive are inpayments and outpayments to changes in prices.

If we let PGt stand for the price gap and let PEt + 1 stand for the percentage of the f.o.b. value of export during next month, which is to be paid as inpayments or outpayments, then these payments are decided by the following formula:

$$\begin{aligned} &0.5(PDt - PGt) \text{ if } PDt \text{ is } > PGt \Rightarrow \text{outpayment} \\ &PEt + 1 = 0 \text{ if } -PGt < PDt < PGt \Rightarrow \text{neutral} \\ &0.5(PDt + PGt) \text{ if } PDt < -PGt \Rightarrow \text{outpayment} \end{aligned} \tag{4}$$

If PEt + 1 > 0 the firms should pay into the Fund in the month (t+1), while PEt + 1 0 the Fund has to pay price supplements out of each individual company's account, as long as that company has a positive balance in its account.

## APPENDIX 2.

During the active period of the Fund the following decisions concerning inpayments to the sections of groundfish products (as a percentage of f.o.b. prices) have been:

| | | |
|---|---|---|
| Aug | 1990 | 1.0% |
| Sep. | " | 1.7% |
| Oct. | " | 2.5% |
| Nov. | " | 3.9% |
| Dec. | " | 3.9% |
| Jan | 1991 | 4.5% |
| Feb. | " | 4.2% |
| Mar. | " | 4.5% |
| Apr. | " | 5.0% |
| May. | " | 4.6% |
| Jun. | " | 4.4% |
| Jul. | " | 3.8% |
| Aug. | " | 2.7% |
| Sep. | " | 2.0% |
| Oct. | " | 2.0% |
| Nov. | " | 1.6% |
| Dec. | " | 1.5% |
| Janv | 1992 | nil |

FIGURE 1.
THE TOTAL CATCH, THE TERMS OF TRADE AND GDP AT FIXED PRICES. INDICES, 1960 = 100.

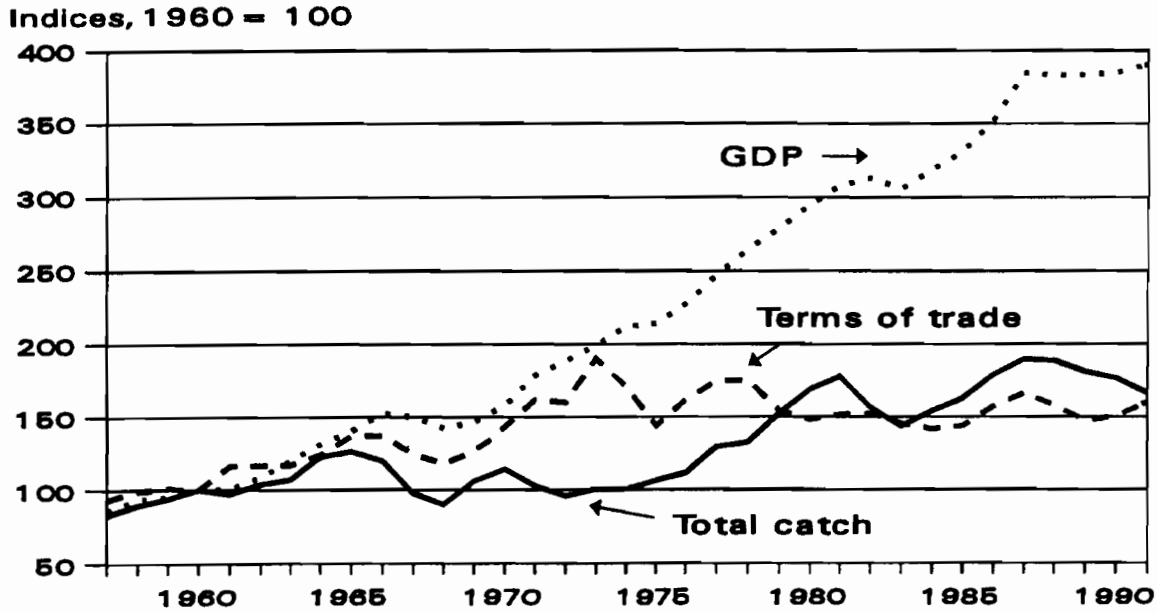



FIGURE 2.
ANNUAL CHANGE IN REAL GDP 1975-1991 IN ICELAND AND THE OECD

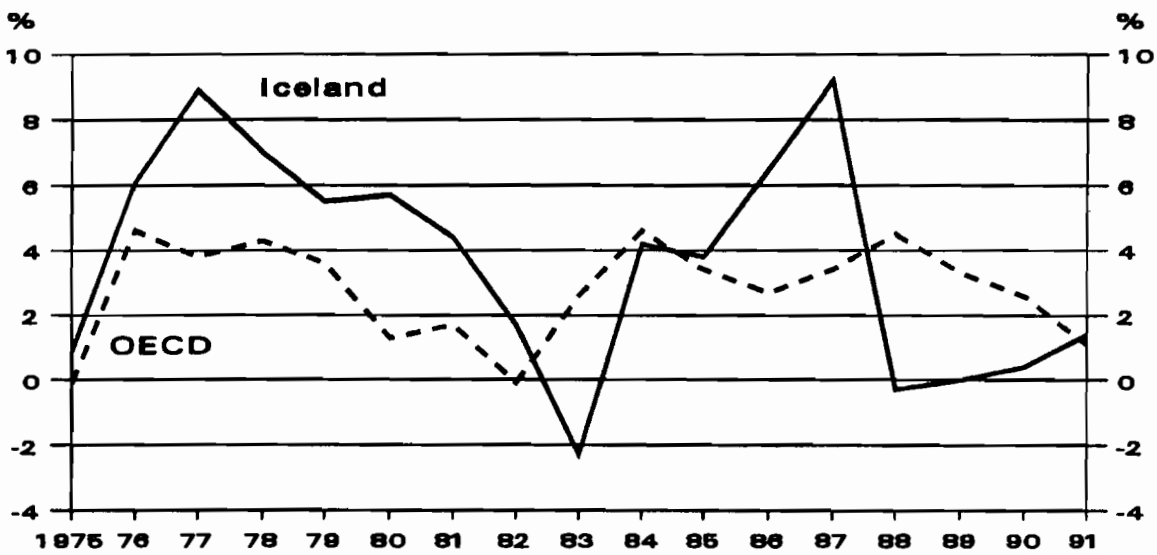


FIGURE 3A.
PRICES OF GROUNDFISH PRODUCTS, AND FISHMEAL AND OIL

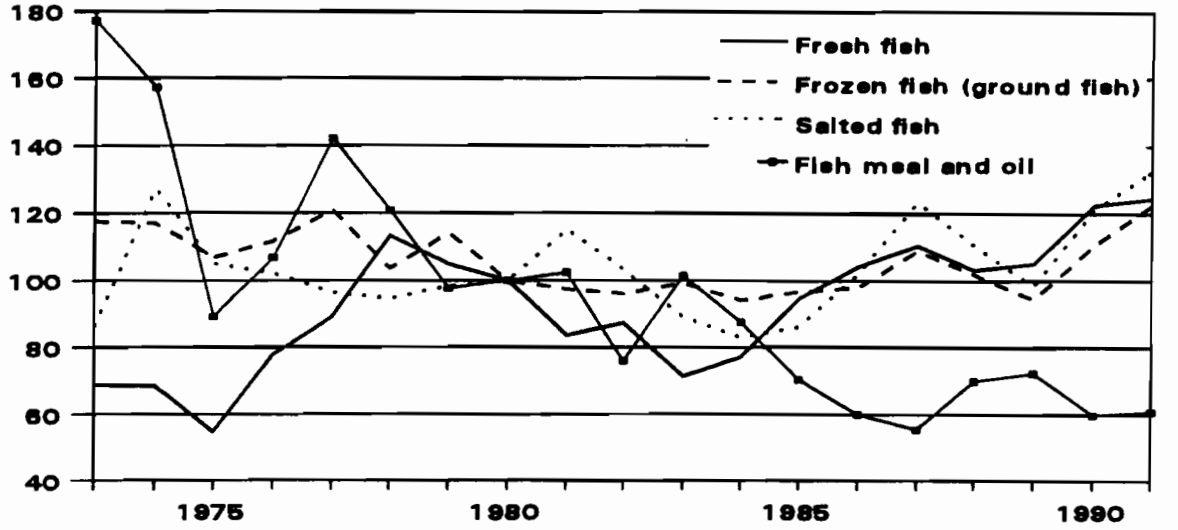



FIGURE 3B.
PRICE OF CRUSTACEANS

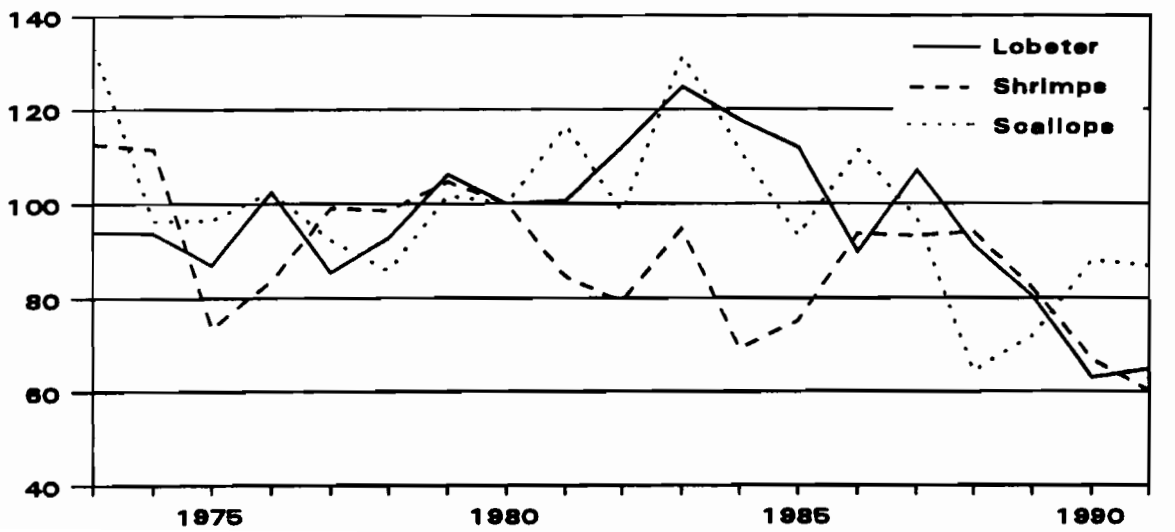
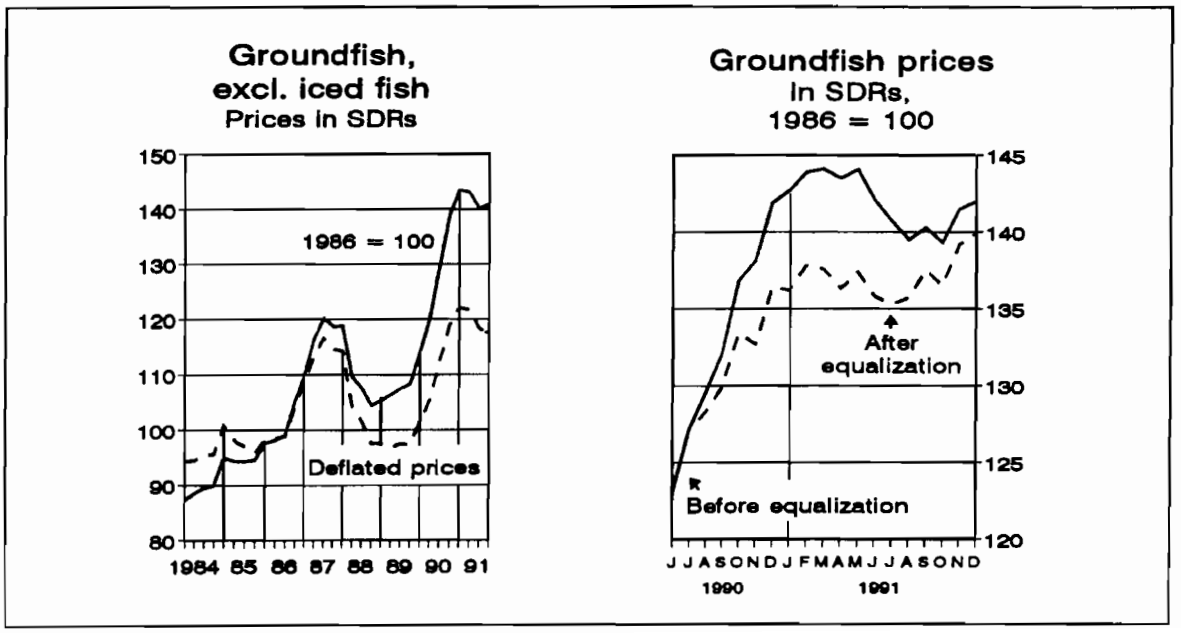


**FIGURE 4.**
**MONTHLY MARKET PRICE OF GROUNDFISH PRODUCTS WITH AND WITHOUT PRICE EQUALIZATION 1990-1991**



# Fish Marketing System Developed in Japan and Price Maintenance Mechanism

**Katsuhiro Miki[a] and Tadashi Yamamoto[b]**

[a]National Research Institute of Fisheries Science, Kachidoki 5-5-1, Chuo-ku, Tokyo 104, Japan

[b]College of Economics, Nihon University, Tokyo Shinjuku 1-23-5-703, Shinjuku-ku, Tokyo 160, Japan

ABSTRACT

*Because of the abundance of fisheries resources around its islands, Japan has been the world number 1 fishing nation, producing more than 10 million metric tons of fish per annum for the past several decades. It is, however, not too much to say that its particular structure of fish marketing system has made it possible to maintain the highest level of fish production in the world and make such a marked growth in Japanese fishery.*

*Unlike many other countries, the Japanese fish marketing system has several channels before fish reaches the consumer. It is, however, quite an effective system, capable of managing a variety of different species caught from different areas as well as certain species sometimes caught in great quantities. In the present paper, the role of the fisheries cooperative association in fish producing areas and the fish wholesale market in fish consuming areas is illustrated.*

*In recent years, fish imports have increased tremendously, and some fisheries products have greatly improved in quality. These fisheries products tend to follow different marketing channels. The paper also touches on these special cases.*

*Unlike the E.C., the Japanese government hardly gives any subsidies to fishermen to compensate for falling fish prices. Instead, the government provides the fishermen's organization with funds for the construction of a cold storage, where fish is stored until prices have recovered.*

## 1. INTRODUCTION

The total supply of fish and fishery products in Japan in recent years has been 14 to 16 million MT in round weight. Of this total supply, about 10 to 12 million MT are supplied by her domestic fishery, and the remaining 3 to 4 million MT are imported.

On the other hand, the total demand of fish and fishery products in round weight is about 12.5 to 13.5 million MT, of which 8.5 to 9.0 million MT are for food use and the remaining 4.0 to 4,5 million MT for non-food use such as fish meal and feed for fish culture.

Japanese fish marketing system has been developed to support such a great deal of supply and demand of fish and fishery products. In the present paper, the existing fish marketing structure which was basically developed as "fresh fish market" is at first illustrated. Then, its recent deviation which took place in relation to change in the form of fishery products transacted will be analyzed.

## 2. JAPANESE PREFERENCE TO FISH

Until Japan officially opened her window to Europe and the United State of America in 1868, eating the meat of animals with four legs was taboo. This was due to the fact that Japan is surrounded by sea, and fish has been plentifully available as the source of animal protein.

In buying and eating fish, Japanese are extremely cautious not only in the taste but also in freshness, appearance, color, etc. Japanese often eat raw fish, i.e., 'Sashimi', to enjoy the original taste of fish. While eating fish, Japanese also appreciate to see the whole fish with head and every fin. Therefore, freshness and appearance are key factors to determine the price of fish.

Existing fish marketing structure in Japan has been developed taking into account these conditions.

## 3. EXISTING FISH MARKETING STRUCTURE

### *3.1 Specific Features of Fish Marketing*

Existing fish marketing structure in Japan is composed of a fish wholesale market in fish producing area and another fish wholesale market in consuming area. How such two tier fish marketing structure was historically developed is not clearly known. However, it is almost sure that the fish wholesale market in consuming area was developed in much earlier stage, whereas those in fish producing area were mostly developed in around 1930 with the encouragement of the government.

It is important to note that existing fish marketing structure in Japan has been developed as a market mainly for "fresh fish". Incidentally this two tier fish market structure satisfies with the following two conditions :

i) Fresh fish are perishable and are quickly spoiled. There fore, fish has to be quickly transacted until it reaches to consumers.

ii) The price realized at the markets must be fair and reason able to both fish producers and consumers.

### *3.2 Existing Fish Marketing Structure*

As referred in 3.1 above, there are two different types of fish wholesale markets. These function as follows : (see Fig.1)

#### 3.2.1 Wholesale Market in Fish Producing Areas

At first a fisherman brings his catch to a fishing port and consigns the catch to a fish wholesaler. Then, with the arrangement of the wholesaler fishes are auctioned to the buyers. In this way, fishes go to the buyer, who offered to pay the highest price. Here, the buyers are fish dealers who intend to ship the fish to another wholesalers in consuming areas, local middlemen who intend to sell the fish to local retailers, fish processors or local fish retailers. (For further detail see Odaka's paper)

It may be very clear from the foregoing that fish bidden by local middleman, local retailer and fish processor are locally consumed. Thus, only fish bidden by fish dealers are shipped at his own risk to another fish wholesaler in fish consuming area.

By 1988, throughout the country there were 1077 fish wholesale markets in fish producing areas, the majority of which are run by unit FCAs. This means that the majority of marine FCAs act as fish wholesalers in fish producing area. However, some of them are prefectural federation of FCAs, fish marketing company or at extreme case individual.

### 3.2.2 Wholesale Market in Fish Consuming Areas

Fish market facilities in consuming areas are normally provided by local governments like the Tokyo Metropolitan Government, Osaka City Government, etc. In a same wholesale market there are, in principle, two fish market companies or more, which act as fish wholesalers in fish consuming areas.

Fish dealers in fish producing areas as referred in (3.2.1) above will ship his fish and consign it to a fish wholesale company in fish consuming area. Similar to fish producing areas, with the arrangement of the fish wholesaler the fishes are auctioned to the middlemen who belong to that fish market and are authorized to attend the auction. In recent years, however, owing to the standardization in the quality of fishery products, some of fishery products are directly sold to the middlemen at a mutually settled price.

Each middle man has own sale lot in the site of fish market, and sell fish bought from the fish wholesaler to fish buyers by negotiation. Here, the buyers are retailer, supermarket, restaurant, "Sushi shop keeper, etc., who come to the fish market every day to buy fishes from the middlemen.

## 4. DIFFERENCE BETWEEN FISH MARKET AND VEGETABLE MARKET

According to a law of wholesale market, both fish and vegetable are regarded as perishable food. However, as for vegetable there is no marketing structure in its producing area. A farmer brings his vegetables to his agricultural cooperative association (ACA). Then, after grading and packing them, the ACA ships the vegetables to a vegetable wholesale market in consuming area. Thus, unlike fish, there is no transaction of vegetable in producing area.

The following are said to be the reasons why a fish wholesale market has been developed even in its producing areas :

i) In comparison with vegetable, fish is treated as more variety of commodities in fish market, as the price of fish is determined not only by species but also by size. Furthermore, fish can be transacted as a commodity, only when it is strictly sorted out by species, size, freshness, appearance, color, etc. Such a sensible assortment of fish is not possible without a wholesale market in fish producing area.

ii) Fish is extremely perishable and requires very fast transaction and shipment to its consuming areas. The existence of a fish wholesale market in fish producing areas, especially that of fish dealer who takes charge of fish shipment, makes this prompt shipment possible.

iii) The price of fish is determined at a fish wholesale market in fish producing area, right after fishes were landed. This makes it possible for fishermen to recover his sale proceeds as quickly as possible, and this will facilitate the continuation of his fishing business.

iv) The fish wholesale market is available all along the coast of Japan. This makes it possible for fishermen to land his catch at the nearest port from his fishing ground and to save his navigation time and cost.

For the above reasons, the fish wholesale market in fish producing areas plays a vital role in the fish marketing.

## 5. SPECIFIC FEATURE OF FISH MARKETING IN RECENT YEARS

### *5.1 Development of Frozen and Other Processed Fish Products*

Since around 1970, the installment of quick freezer into distant water fishing boat, particularly tuna and squid boats, development of fish processing technics for high quality fishery products, enlargement of cold chain system up to consumer's homes and so forth have resulted in considerable change in the form of fishery products from "fresh fish which is perishable" to "frozen and other processed fish products" such as 'Surimi' based products.

In other words, in those days marketing of frozen and other processed fish products has become popular, although marketing in fresh fish still remains. Naturally, these new fishery commodities are of highly preserved and of highly standardized in quality. As these new fishery commodities are not perishable foods, they are not necessary to be auctioned.

With an increase in the volume of these new fishery commodities, auction, which is the basic pattern of fish transaction at fish wholesale market, has been gradually replaced by cross trade between a fish wholesaler and a middleman. (see Fig.2) As a result, a fish wholesale company in consuming area, which was originally a fish consignee, has become a fish trader who buys fish and sells it to others.

On the other hand, marketing of these processed fish commodities outside the existing fish marketing channels has increased. In this respect, it should be mentioned that there is no legal rule that fish and fishery products have to be sold through the existing fish marketing channels.

The following may be some typical diversification of fish marketing patterns, which took place in recent years.

i) Marked increase in the import of shrimp, tunas and salmons by powerful trade companies has created either their own marketing routs for these commodities or routing only through wholesale market in consuming area.

ii) Consumers buy fish more at supermarket than at fish retailer, resulting in a decrease in the number of the retailers. Eating out at a family restaurant, which is, in many instance, a chain store, has also become popular. As a result, these enterprises try to create their own fish marketing channels.

iii) Fish producers, individual fisherman, FCA or the federation of FCAs, also attempt to create their own marketing channels by establishing their fish shipment base close to fish consuming area, by skipping the wholesale market in the fish producing area.

iv) Direct sale of fish and fishery products by FCAs to consummers' cooperative associations, daily meal supply enterprises, a chain of fish retailers, etc. has been also practiced. Sometimes, fish producer or fish dealer in fish producing area sell live Kuruma prawn, prepared puffer 'Sashimi', etc. directly to consumers.

### *5.2 Consumer's Gourmet Preference and Live Fish*

In recent years, marketing live fish has become very popular throughout the country. The share of fresh fish auctioned against the whole fish transacted at Wholesale Fish Markets has followed a steady declining trend (see Fig.3).

Some live fishes are air-lifted to Japan from abroad. Air lift import of sea breams and spiny lobster from New Zealand has been now popular. In many instances, fish are airlifted under the status of winter sleep.

Although tuna can not be kept alive for shipment, in recent years fresh tunas are imported by air with crush ices at ice temperature. In this way, the quality of tuna meat can be best maintained, resulting in higher price.

## 6. PRICE MAINTENANCE OF FISH IN JAPAN

In around 1960 a great fluctuation of fish price in relation to the seasonal change in fish landings was recognized, and a need to expand the capacity of cold storages was keenly stressed. For the period from 1975 to 1990, the number of cold storages increased from 3761 to only 3903. During the same period, however, the capacity of the cold storages doubled from 14 million cubic meter to 26.6 million cubic meter (see Table 1).

Thus, in spite of the oversupply of quality fish due to its increased import, the price of fish seems to have been well stabilized. This is due to the fact that at the time of its oversupply the fish is stored at a cold storage until the price is recovered. Thus, it is well assumed that an ample space of cold storage capacity plays a role of stabilizing the price of fish.

During the past years the cold storage holding of fish has increased from year to year, and in recent years it has always remained at the order of 1.5 million MT, which is equivalent to nearly 20 % of the annual total supply of fish for food use (see Table 2).

During the 1970s the price of fish was generally stagnant. However, in terms of the consumer's price index number, over a period from 1975 to 1990 the price of fish has always followed a slightly higher upward trend than that of meats. (see Fig.4)

## 7. CONCLUSIONS

In recent years, from the viewpoint of Consumers fish and fishery products have been regarded as favorite food items or delicacies rather than the source of animal protein.

The demand of quality fish will last forever. From the viewpoint of fish retailer, supermarket, 'Sushi' shop keeper, etc. existing fish wholesale market needs to be retained as a place to assort a variety of different fish species.

**TABLE 1.**
**CAPACITY OF COLD STORAGES.**

| Year | Number of Cold Storages | Capacity of Cold Storages (million Cubic m) |
|---|---|---|
| 1975 | 3,761 | 14.0 |
| 1980 | 3,968 | 18.9 |
| 81 | 3,908 | 19.2 |
| 82 | 3,876 | 19.3 |
| 83 | 3,842 | 19.5 |
| 84 | 3,807 | 19.6 |
| 85 | 3,774 | 19.9 |
| 86 | 3,777 | 20.6 |
| 87 | 3,804 | 21.8 |
| 88 | 3,829 | 23.3 |
| 89 | 3,866 | 24.7 |
| 90 | 3,903 | 26.6 |

Source: Fisheries Agency

**TABLE 2.**
**COLD STORAGE HOLDINGS OF FISHERY PRODUCTS.**

Unit 1,000 MT

| Year | | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|
| Total | | 1218 | 1331 | 1466 | 1566 | 1440 |
| Fresh | | 2 | 2 | 2 | 2 | 1 |
| Frozen | Sub Total | 1096 | 1204 | 1339 | 1429 | 1308 |
| | Tuna | 47 | 44 | 42 | 44 | 51 |
| | Salmon | 57 | 45 | 39 | 53 | 55 |
| | Sardine | 129 | 106 | 116 | 125 | 122 |
| | Horse Mackerel | 28 | 30 | 43 | 45 | 50 |
| | Mackerel | 78 | 84 | 72 | 94 | 56 |
| | Pacific Saury | 36 | 39 | 49 | 75 | 59 |
| | Shrimp | 56 | 67 | 85 | 92 | 85 |
| | Squid | 125 | 170 | 215 | 246 | 229 |
| | 'Surimi' | 106 | 140 | 121 | 102 | 101 |
| | Others | 434 | 479 | 557 | 553 | 500 |
| Salted | | 66 | 68 | 66 | 76 | 72 |
| Cured | | 53 | 57 | 58 | 59 | 60 |

Source: The Ministry of Agriculture, Forestry and Fisheries

**FIG. 1.**
**FISH MARKSETING CHANNELS IN JAPAN.**

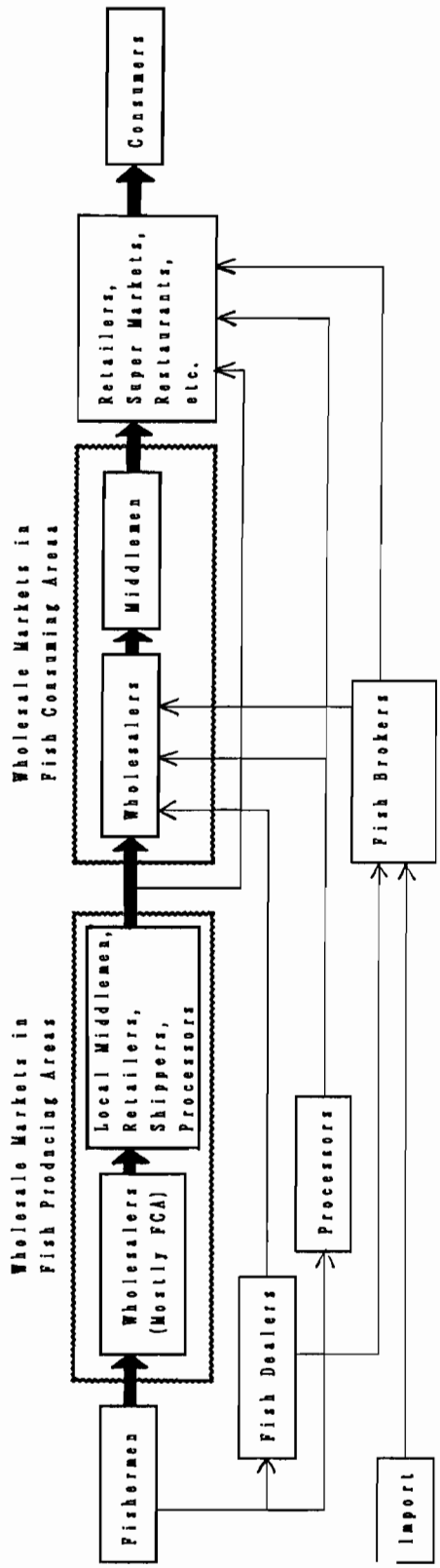
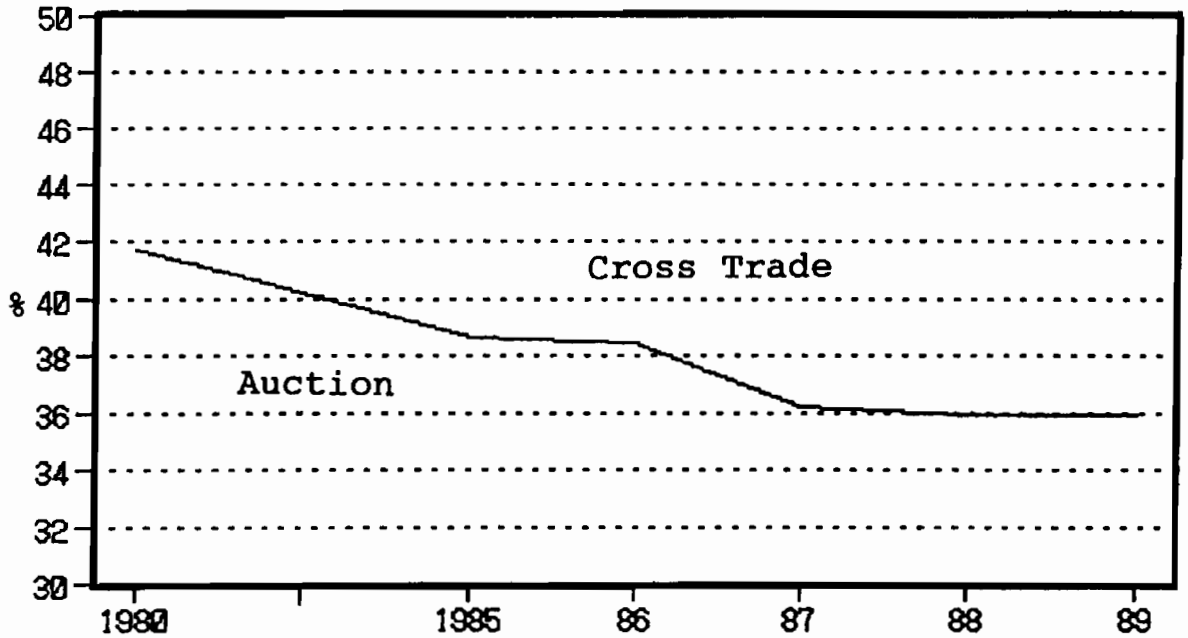
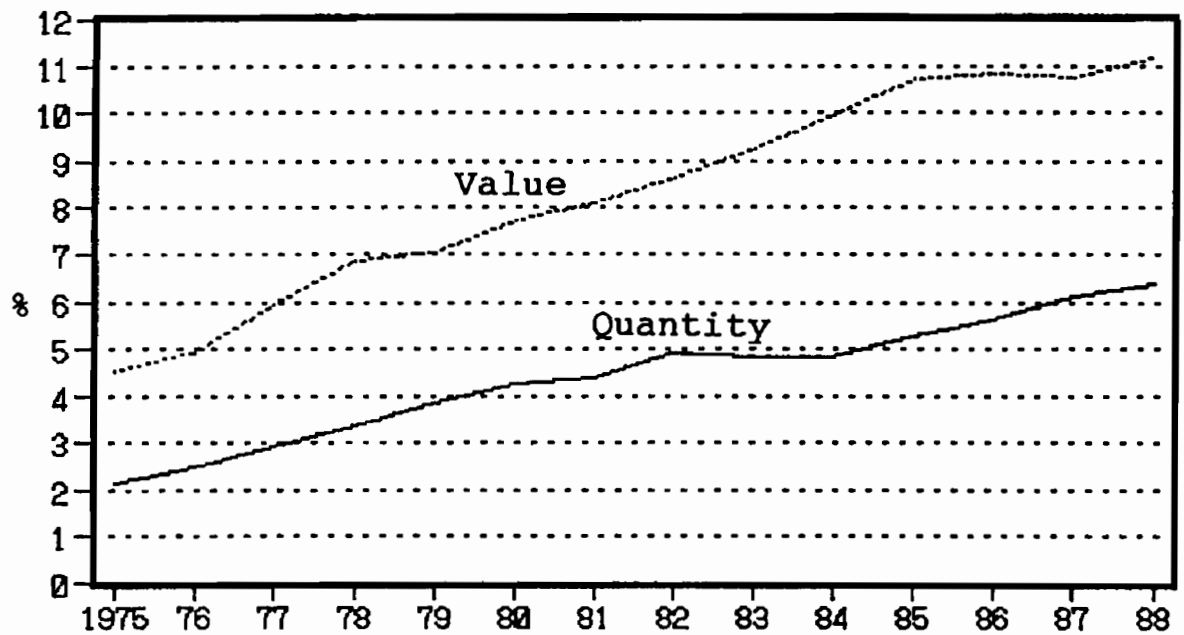


FIG. 2.
% SHARE OF FISH AUCTIONED TO TOTAL QUANTITY OF FISH TRANSACTED.



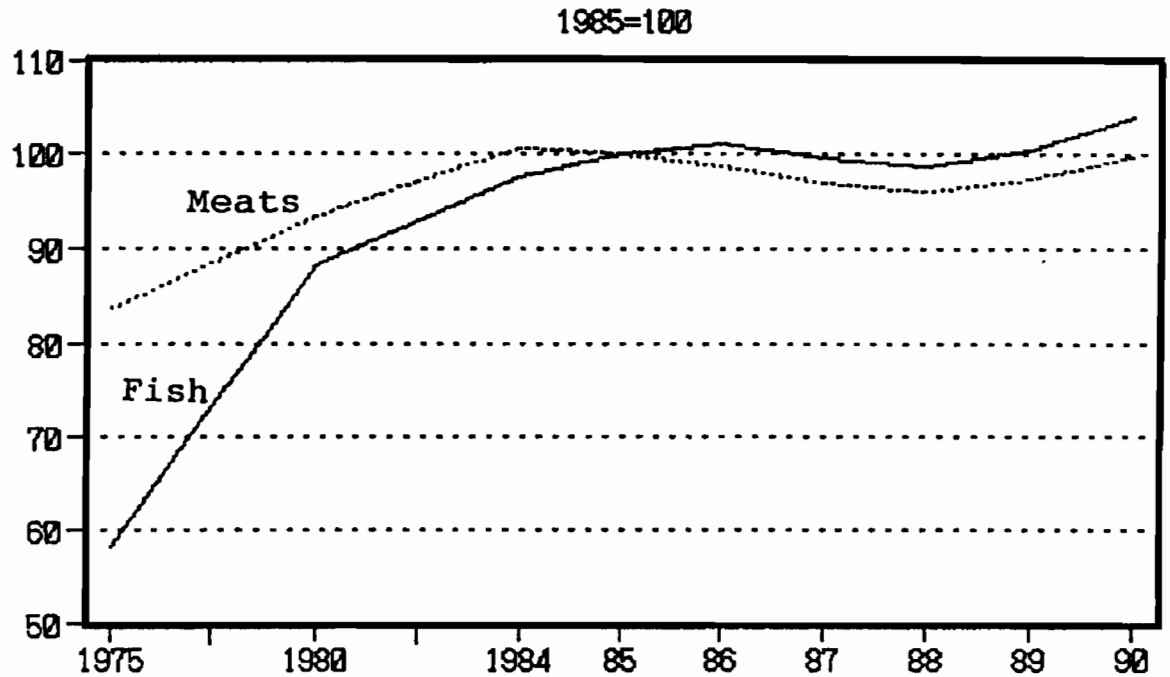

Source : Tokyo Metropolitan Government Wholesale Markets.

FIG. 3.
% SHARE OF LIVE FISH TO TOTAL QUANTITY OR VALUE OF FISH TRANSACTED.




Source : Tokyo Metropolitan Government Wholesale Markets.

**FIG. 4.**
**CONSUMER PRICE INDEXES OF FISH AND MEATS.**




Source : "Report on Consumer Index Number, Central Statistics Bureau"

# Fishery Cooperative Association in Japan and its Vital Role in Fish Marketing

**Natsuko Odaka[a] and Tadashi Yamamoto[b]**

[a]RA43, Kamihirama 1254, Nakahara-Ku, Kawasaki, Kanagawa Z11, Japan

[b]College of Economics, Nihon University, Tokyo Shinjuku 1-23-5-703, Shinjuku-ku, Tokyo 160, Japan

ABSTRACT

*Japan has an unique fishermen's organization in the world, as almost all fishermen in Japan are organized into a fishery cooperative association (FCA). There is a FCA at every fishing village. As a result, Japan has a complete network of FCAs throughout the country.*

*Japan's FCAs are involved in fish marketing activity, through which fishes caught by member fishermen are sold by means of auction.*

*Out of its all economic activities, FCA's fish marketing activity plays a key role for the economic stability of both FCA and its members.*

## 1. DEVELOPMENT OF FISHERMEN'S ORGANIZATION IN JAPAN

During feudal era of Japan which lasted until 1867, a fishing right was granted to a fishing community. Although there was a tie among fishermen in the community, during this period there was no fishermen's organization.

In 1901, the first fishery law was promulgated in Japan, stipulating that a fishing right was to be granted to a fishery association (FA). This implied that fishermen are not allowed to operate in fishery, unless they become the members of FA. In this way, throughout the country all fishermen were organized into FA. In those day, the FA was responsible only for the management of fishery based on the fishing right granted to them.

In 1910 the fishery law was revised, allowing FA to engage in economic activity for the benefit of fishermen. With this revision, some FAs began to operate in fishing marketing. By 1920 there were a total of 3,646 FAs, of which those engaged in fishing marketing were only 744 or 20 % of total.

In 1933 the fishery law was again revised. As a result, the FA was converted into the form of a fishermen's cooperative association (FCA) with a capital shared by members and started to involve, in addition to fish marketing, in saving and credit business to the members. At the same time, the government began to provide the FCAs with fisheries facilities such as fishing port, fish landing pier, fish marketing shelter, ice making factory, etc.. This was the occasion, when many Japanese FCAs began to involve in fish marketing by eliminating a direct fish transaction between fishermen and fish merchants.

## 2. FISHERY COOPERATIVE STRUCTURE IN JAPAN

Japan's fisheries cooperative structure is composed of three tiers,i.e., an unit FCA at a fishing village level, a prefectural federation of FCAs at a prefectural level and a national federation of FCAs at national level.

As of March, 1990, the total number of unit FCAs throughout the country accounts for 2,118. Some 535,000 fishermen belong to these FCAs either as full or associated member.Above unit FCAs there is a prefectural federation of FCAs at each prefecture, which accounts for 43 federations throughout the country. Above these 43 prefecture federations of FCAs there is a national federation of FCAs in Tokyo, which is known as Zengyoren.

## 3. FISH MARKETING CHANNEL IN JAPAN

Japan's fish marketing channel is basically composed of : (See Fig.1 of Miki's Paper)

i) Fish wholesale markets in fish producing areas, and

ii) Fish wholesale markets in fish consuming areas.

In most cases, FCA acts as fish wholesalers in fish producing areas, as FCAs are developed all along the sea coast and have their own fish landing facilities and market shelters. In contrast to fish producing areas, facilities for fish wholesale market at consuming areas are provided by local governments, and in most cases private fish marketing companies act as fish wholesalers.

Fishes are transacted by means of auction at both level of fish wholesale markets. However, this paper deals with mainly how FCA acts as fish wholesaler in fish producing areas.

## 4. ACTIVITIES OF THE FISHERY COOPERATIVE ASSOCIATION (FCA)

Fisheries Cooperatives is a non-profit making organization. It is an economic and social entity with its main purpose to improve their social and economic well being. It is organized by pooling their resources and efforts together to achieve a common goal. The FCAs are mainly multi-purpose and full service organizations which are engaged in a wide variety of services for the interest of its members. Generally, the fisheries cooperatives are engaged in economic and non-economic activities as listed below :

### *4.1 Economic Activity*

(i) Fish Marketing Business

This is one of the most important economic activities of the FCA. It assumes responsibility in selling the members' catch through auction or bidding. FCA's fish marketing helps to strengthen the financial status of the FCA, and at the same time assures the income of members by a fair price of their catch, which is realized through auction.

(ii) Credit Business

Saving accounts are opened for every members, and the proceeds from the auction, after deducting FCA commission, is saved at their own account. The surplus of such savings are used for fisheries loan to other members.

(iii) Supply Business

The FCA supplies, in many instances, the fishermen with fishing materials and also household daily necessities at reasonable prices. The payment is automatically deducted from the savings account of the fisherman.

(iv) Utilization Business

This is referred to the use of FCA owned facilities such as cold storage, warehouse, boat parking lots and other facilities. The fishermen pays a certain amount of fee for the use of such facilities.

### *4.2 Non-economic Activities*

#### 4.2.1 Fisheries Management based on Fishing Right

This includes (i) Establishment of closed season, closed sea area, restriction of fishing gears, minimum size of fish to be caught, catch limit, etc. for the conservation of fisheries resources, (ii) fair allocation of fishing grounds. (iii) Stocking fish seeds into sea to increase the productivity of natural fisheries resources, (iv) surveillance of fishing grounds, and so forth.

#### 4.2.2 Guidance and Education of Member Fishermen

This includes improvement of fishing/aquaculture technics, improvement of home management, encouragement of youth activities, and so forth.

## 5. FCA'S FISH MARKETING ACTIVITIES IN DETAIL

Fish is landed at one of over 2,000 fishing ports, and it is at this very point that Japan's fish marketing channels starts.

### *5.1 Japan's Fish Marketing in the past*

Japanese fishermen have had a long and bitter experience of being exploited by fish merchants or middlemen who dominated and controlled fish trade for many centuries. The marked development in establishment of FCA's fish marketing activity in around 1933 therefore liberated Japanese Fishermen from economic slavery to economic freedom.

### *5.2 FCA's Fish Marketing Practice*

The system operates in such a way that the member fishermen hand over/consign their catch to FCA for sale. At this point, it is important to note that the FCA does not buy the fish but act as consignee.

With fish consigned by fishermen, the FCA holds fish auction at its fish marketing shelter by inviting fish buyers once or twice a day depending on the timing of fish landing. On this occasion the FCA acts as auctioneer, and fishes go to the buyer who bid the highest price. Then, the FCA collects the payment from fish buyers on behalf of fishermen.

It is important to note that, although Japanese fish marketing system was transferred from "direct transaction between fishermen and fish merchants" to "FCA fish marketing system", these fish merchants were allowed to attend at FCA fish auction and were able to continue their business.

In return to this service, the FCA charge the member fishermen a commission which may vary from 3 to 5 %. Through this FCA fish marketing system, a fair price for their fish is assured. On the other hands, the revenue received as the commission assists to strengthen the financial position of the FCA. On the average, about 39 % of total revenue made by FCA is from this fish marketing business ( see Table 1 ).

At present, throughout the country there are more than 700 fish wholesale markets in fish producing area, of which more than 80 % are FCAs. FCAs deal with more than half of the total catch landed throughout the country.

### *5.3 Significance of FCA Fish Marketing System*

In general the importance of FCA marketing business can be summarized as follows ;

(i) It provides the FCA with a stable and steady income, as such fish marketing practice lasts forever.

(ii) The costs for fish marketing business are small, but the profits are high.

(iii) There are very little risks involved, since the buyers take all risks until fish reaches to another buyer.

(iv) Since the FCA takes charge of collecting the proceeds from the buyers, it has an opportunity to deduct its dues from the members income before depositing it on their accounts.

(v) It offers a good opportunity to fishermen to meet together every day during the time of auction and exchange ideas about their common problems and interests.

**TABLE 1.**
**TOTAL REVENUE REALIZED BY ALL UNIT FCAS.**

| Kind of business | Total | % |
|---|---|---|
| Total | 140,185 | 100.0 |
| a. Marketing business | 55,445 | 39.6 |
| b. Credit business | 24,625 | 17.6 |
| c. Supply business | 18,030 | 12.7 |
| d. Utilization business | 9,052 | 6.5 |
| e. Others | | |
| i. FCA own fishing business | 13,267 | 9.5 |
| ii. Processing business | 3,563 | 2.5 |
| iii. Insurance business | 2,077 | 1.5 |
| iv. Other Business | 14,124 | 10.0 |

Source: Fishery Agency

# Supply and Demand of Fish and Fisheries Products in Japan

**Guylaine Bourguignon**

Fisheries Management and Economy Division, National Research Institute of Fisheries Science, 2-12-4 Fukuura, Kanazawa-Ku, 236 Yokohama, Japan

ENSA-Rennes, DEERN, 65, rue de Saint-Brieuc, 35042 Rennes, France

RÉSUMÉ

*Après la 2nde guerre mondiale, en reconstruisant son industrie de pêche, le Japon devint le plus grand producteur de produits halieutiques dès les années 60 - une position qu'il détient toujours bien que le tonnage de sa production en pêche baisse ; moins de 10 millions de tonnes en 1991. Le développement de la capacité de capture en pêche a permis au Japon d'avoir une spécialisation à l'exportation jusqu'en 1971, année durant laquelle les importations furent supérieures en valeur aux exportations. L'augmentation du pouvoir d'achat des japonais, grâce à la croissance économique, a entraîné une disponibilité d'achat pour les produits alimentaires, dont les produits halieutiques. Le déficit de la balance commerciale pour les produits de la mer n'a cessé de croître. De nos jours les exportations représentent à peine 5 % des échanges mondiaux en valeur, tandis que les importations sont à plus de 30 %. Plus qu'une préférence de l'alimentation à base de poisson, toute l'historique du développement de l'industrie halieutique japonaise témoigne de la stratégie d'un pays pauvre en ressource alimentaire se dotant de facteurs pour produire les protéines les plus accessibles. C'est ainsi, que les protéines de poisson entre pour 21,5 % dans l'alimentation au Japon, alors qu'au Etats Unis seulement 2,5 % y prennent part.*

## 1. INTRODUCTION

After the 2nd world war by rebuilding its production capability Japan became the world's largest fish producer in the later 1960's - a position it still holds, though its production is decreasing ; less than 10 million tons in 1991. The build-up of the Japanese fishing industry led to the country becoming the world's largest fish exporter in the 1960's. Early 70's Japan began to experience high economic growth which had a corresponding rise in the nation's standard for food products.

This brought an increase in the country's consumption of its own catch and a rise in imports of medium and high grade fisheries products. Imports exceeded exports in value for the first time in 1971. This trade deficit has quickly grown, exports have decreased to 5 % of the world fishery trade, whereas imports have increased to about 30 %.

Of course, one of the major reason for the size of Japanese fish market is the preference for fish in Japan. Fish protein is an important component of Japanese daily diet. For example, in the U.S. only about 2.5 % of protein is from fish whereas in Japan 21,5 % of protein consumed is from fish (Fig.1).

## 2. TRENDS IN JAPANESE FISHERY PRODUCTION

Japan's fishery production has continued to increase even after 1977 (Exclusive Economic Zone's establishement). Since 1972, production has exceeded 10 million tons annually. However, since 1989 it is on a decreasing trend, and has fallen at 9.8 million tons in 1991.

### *2.1 By fishery zones*

The establishment of 200-mile zones by most coastal nations and the reduction in fishery allocations to Japanese fishermen forced major change in distant-water fishery. Production within foreign 200-mile zones has decreased dramatically, mostly within U.S. and ex-USSR zones ; from 2.2 million tons in 1978 to 1.5 in 1990 ; and concerns principally high-seas fishery. However, production value has been declining since 1984, by the loss of allocations for higher valuable species within foreign 200-mile zones. Production in offshore fishery, which operate mainly in the waters off Japan 12 miles, accounts for more than half of total Japanese fisheries production, but its value has decreased since 1982, because of overproduction of non-valuable species like sardine. Coastal fishery production has been stable around 3.3 million tons since 1980, including marine aquaculture.

It is the most important component of Japanese fisheries considering is value due to higher valued target species. Marine aquaculture accounts for about 11 % of total production and 25 % of total value. Inland-water fishery, including aquaculture, is a minor component of the fishery sector (Fig.2).

### *2.2 By major species group*

Since 1960, the composition of the Japanese fisheries has changed, with the increase of non-valuable species. In 1990, 38,9 % of the production was made up by sardine, catched in offshore fishery. Sardine production depends on periodic natural fluctuations, and in a close future production might decrease (Fig. 3).

## 3. DOMESTIC FISHERY PRODUCTION BY FOOD USE AND NON-FOOD USE

The production's drop in distant-waters fishery, as well as the production's rise of lower valuable species in offshore fishery, have resulted in a break down in the domestic production of fisheries products for food. In a whole, Japan supplies is market at 79 %, when it was at more than 100 % in 1970. In 1975, 78 % of the production was dedicated to food use, in 1990, only 63 % (Fig. 4).

### *3.1 Use of fishery production for non-food*

Growth in fishery production for non-food correlates with the development of mariculture and the big increase in sardine production. Aquaculture sector requires reduction for fish culture. Export trade concerns mainly fish meal and oil.

### *3.2 Use of fishery production for food*

By catching less and less valuable species, the use for fresh consumption of Japanese production has declined, and conversely production of salted and smoked products has increased. Production of fish paste has decreased since the loss in 1988, of Cod's allocations in U.S. fishery zone. The canned industry concerns canned sardine, and has decreased after competition with countries like Thailand, Korea... in canned tuna and salmon (Fig. 5).

## 4. SUPPLY AND DEMAND OF FISHERIES PRODUCTS FOR FOOD

### *4.1 Trends in import and export*

In early 70s, with the rise in household income, flourishing Japanese fisheries industry's aim was to supply its domestic market. Anyhow, Japanese products were too expensive to be exported, futhermore economic growth has enable to meet the growing demand by importing.

Since 1985, import has increased by 30 %, export has decreased by 39 %, while demand goes up sligthly by 4,5 %, opposite to that, production has decreased by 15 %. Rise in import will steadily continue, instead demand is stagnant, with an insufficient production in quantity and valuable species. Export might decrease more, considering fluctuation in sardine production, which generate export of canned sardine and feedstuff products (Fig. 6).

### *4.2 Structural change in import*

(1) **Products group** (Fig.7) : Japan has always purchased fresh, chilled...fisheries products. But since its production can not meet the domestic demand, import of fresh, chilled... fisheries products has increased to account for 83 % of total import fisheries products in volume in 1990 (table 1). In 1985, import of fish paste became significant after the terminating of allocations in U.S. Cod's fishery zone.

(2) **Major species** (Fig. 8) : Five species, shrimp, salmon, tuna, squid and octopus are target in Japanese import. But, imports are more and more diversified, when sharing 49 % of import volume in 1975, this five items compose 38 % of import volume in 1990 (table 1).

## 5. TRENDS IN FISHERIES PRODUCTS CONSUMPTION

The demand for direct human consumption increase slightly A large variety of fisheries products are consumed by the Japanese people. The preference for fresh, chilled... products is still there, 37,5 % of consumption, but consumption of salted, smoked, dried products is increasing (more than 35 % in 1990, when it was at 29 % in 1985) (Fig. 9). General trend is that processed fish and shellfish products are popular in cities, whereas unprocessed products is preferred in rural areas. Salted, smoked and dried products is a part of Japanese traditional fish processing industry and eating habits, particularly with salted salmon. The largest amounts of fresh fisheries products purchased in order of volume were squid, shrimp, tuna, jack mackerel, saury, sardine, yellowtail and mackerel. Oyester, shortnecked clams and other shellfish are also consumed in larges volumes.

### *5.1 Yearly consumption by quantity*

Fisheries products were the first source of animal protein for the Japanese people. Since 1960s, fundamental changes have taken place in their dietary patterns. The average calorie intake per person has grown from 2200 calories a day in 1960 to around 2600 nowaday. When consumption of meat was increasing by 6.5 % annually, seafood consumption grew

at slower rate (1,5 % per year). In 1990, per capita consumption is about 72 kg on a round weight basis (Fig. 10). This accounts for 42 % of the total daily animal protein supply of 45.1 grams per person. Japan's exceptionally high per capita consumption of fisheries products differs significantly from that of other developed nations which depend upon livestock products for their protein supply.

### *5.2 Annual price rank between main food items*

In 1985, seafood products have become with beef the most expensive food items (Fig. 11). Within the meat sector the consumption of pork and chicken has risen faster than of beef, untill 1980. Instead of been the most expensive food item, consumption of beef still rises, because of low level of consumption. This is to correlate with the expansion in domestic consumption of that were once luxury and expensive fish like tuna, salmon, shrimp... The tendency of selective consumption result in a price inflation for target species like flatfish more expensive than beef (Table 2). In 1970, only tuna and yellowtail were ranging between beef and pork price.

In 1988, eight species were on this side, and most fish were more expensive than chicken, except for the fish caught in bulk such as codfish, saury and mackerel.

Consumer price index shows a higher growth in fish and shellfish price than for other food items (Fig. 12). Rising income has strengthened Japanese demand for higher quality and expensive marine products types as salmon, shrimp, tuna...

## 6. CONCLUSION

In the past twenty years, Japan has moved from been the world's largest exporter to the largest single importer of fisheries products. Marine products account for the largest single component of Japanese food imports. This revearsal in trading position can be attributed to various factors : decreased domestic production resulting from stock depletion and the introduction of EEZ, strengthened domestic demand for high valued mainly imported species, and declined competitiveness of Japanese fisheries products on export due to the appreciation of Yen.

Japan Fisheries Agency has pronosticated for year 2000, a production of 11,600,000 tons, a domestic demand of 16,050,000 tons. That means an annual growth less than 1 %. Has Japanese demand has reached contentment ?

## REFERENCES

**Taya K.** (1991). Supply and Demand of Fisheries Products in Japan - with an Emphasis on Shrimps and Salmons - Paper for Presentation at the *IAAE Symposium on Aquaculture Economics,* Tokyo 91/08.

**Kingstone A., T. Battaglene, P. Smith and S. Beare** (1991). Changes in the Japanese Seafood market - Discussion paper 91-3, Australia Bureau of Agricultural and Resource Economics, Project 9323-101.

**OECD** (1991). Review of Fisheries in OECD member countries - OECD Paris.

**OECD** (1989). Trade and access to Resources - OECD Paris.

**Annual Report on the Family Income and Expenditure Survey.** Statistics Bureau, Japan.

**Annual Statistics of Fisheries Products Marketing.** Ministry of Agriculture, Forestry and Fisheries, Japan.

**Statistics by the National Federation of Fisheries Co-operative Association (Zengyoren).** Japan.

**JETRO** (1991). "Japan food imports in 1990" - AG-41, Jetro Japan.

**TABLE 1.**
**STRUCTURE OF IMPORTS .**

| Main items | 1975 | 1980 | 1990 |
|---|---|---|---|
| Shrimp | 114 | 148 | 304 |
| Salmon, trout | 7 | 39 | 169 |
| Tuna, ... | 100 | 96 | 252 |
| Squid | 59 | 94 | 114 |
| Octopus | 75 | 63 | 92 |
| **Subtotal (A)** | 350 | 440 | 931 |
| **FCF Subtotal (B)** | 583 | 735 | 2024 |
| **TOTAL (C)** | 710 | 1037 | 2437 |
| Ratio% A/C | 49 | 43 | 38 |
| Ratio% B/C | 82 | 71 | 83 |

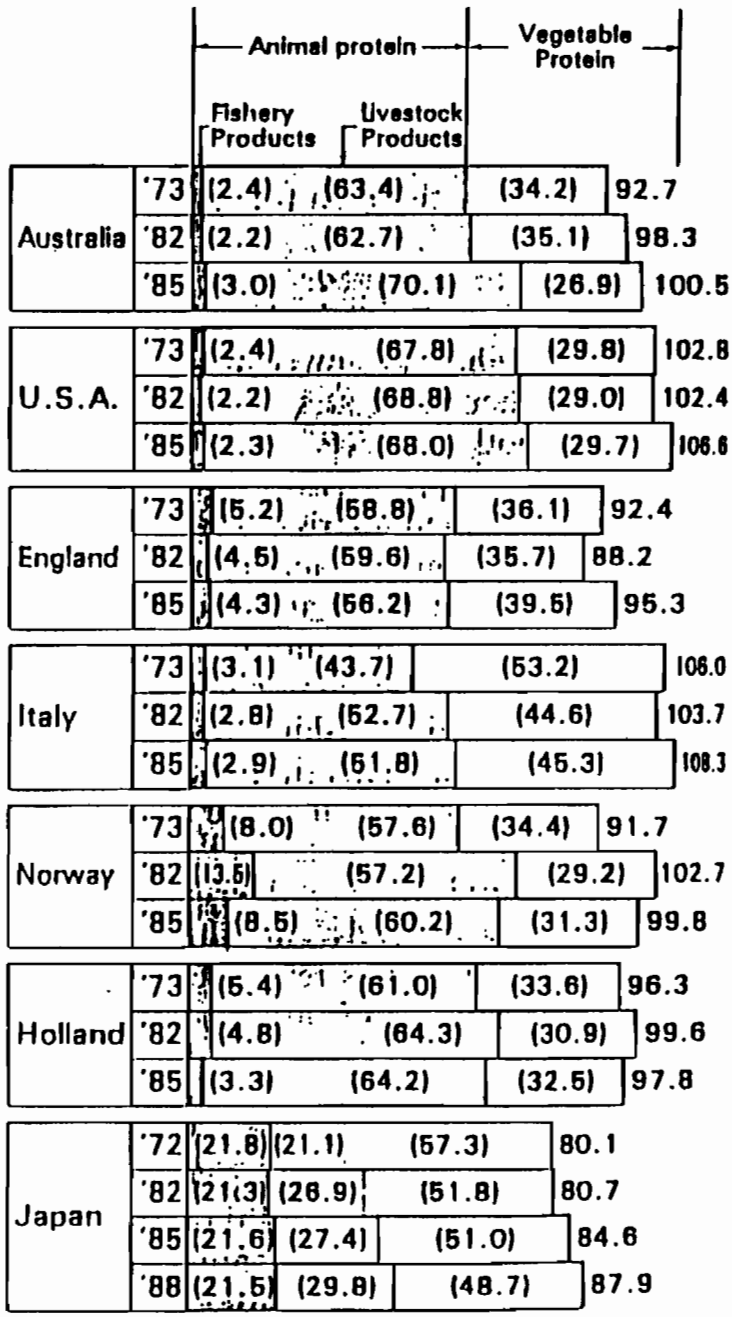
Quantity 1000 tons (round weight), FCF : Fresh, Chilled, Frozen

**TABLE 2.**
**ANNUAL PRICE RANK OF LIVESTOCK AND MARINE PRODUCTS.**

| Year | 1970 | 1975 | 1980 | 1985 | 1989 |
|---|---|---|---|---|---|
| High price | Beef | Beef | Beef | Beef | Flatfish |
| | Tuna | Tuna | Tuna | Tuna | Beef |
| | Yellowtail | Yellowtail | Flatfish | Flatfish | Tuna |
| | Pork | Seabream | Seabream | Seabream | Seabream |
| | S.Salmon | Pork | Yellowtail | Yellowt. | Yellowt. |
| | Seabream | S.Salmon | S.Salmon | S.Salmon | S.Salmon |
| | Chicken | Flatfish | Octopus | Bonito | Salmon |
| | Bonito | Bonito | Bonito | Octopus | Bonito |
| | Salmon | Octopus | Salmon | Pork | Octopus |
| | Flatfish | Chicken | Pork | Salmon | Flounder |
| | Octopus | Salmon | Horse m. | Flounder | Pork |
| | Saury | Cuttlefish | Flounder | Cuttlef. | Horse m. |
| | Flounder | Flounder | Chicken | Horse m. | Cuttlef. |
| | Horse m. | Horse m. | Cuttlef. | Chicken | Chicken |
| | Cuttlef. | Saury | Cod | Cod | Saury |
| | Sardine | Cod | Saury | Saury | Cod |
| | Cod | Sardine | Mackerel | Mackerel | Mackerel |
| Low price | Eggs | Eggs | Sardine | Sardine | Sardine |
| | Mackerel | Mackerel | Eggs | Eggs | Eggs |

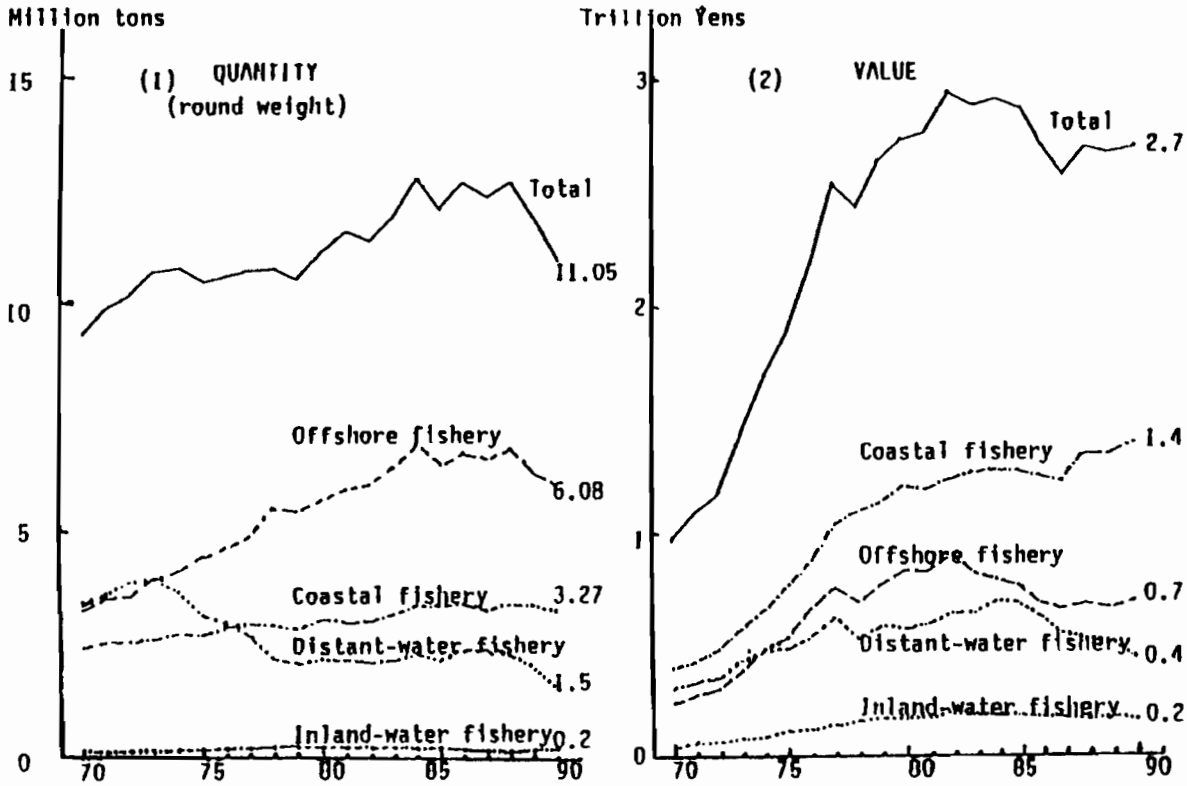
Source : Annual report on the family income and expenditure survey, Statistics Bureau

FIG. 1.
PROTEIN INTAKE IN MAJOR COUNTRIES OF THE WORLD.
(unit; gm per person per day - figures in () are structured percentages, %)



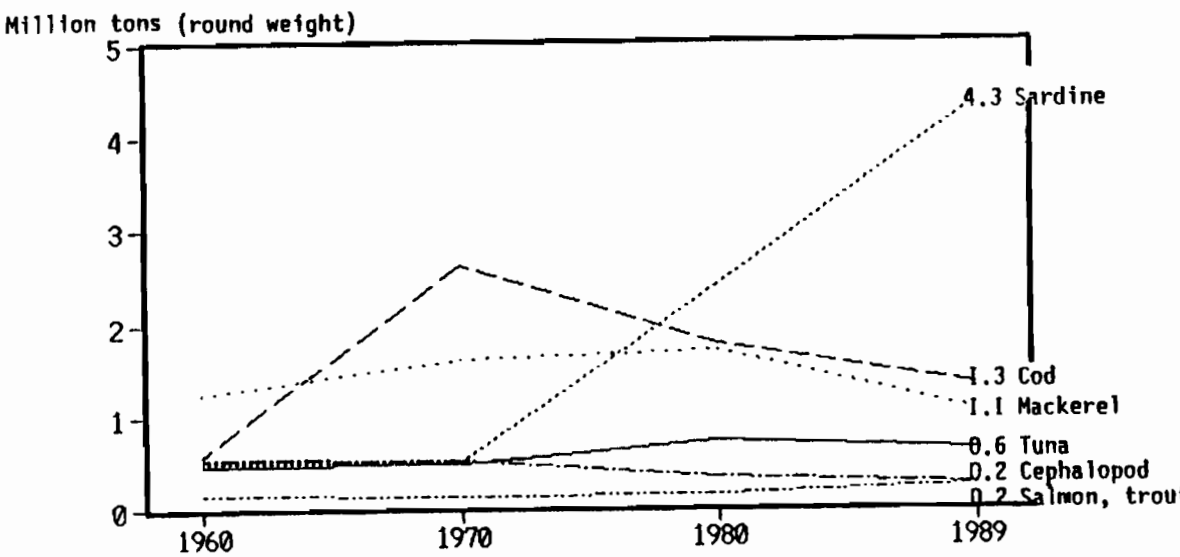

Reference materials:
Food balance sheet of the Ministry of Agriculture, Forestry and Fisheries and OECD's Food Consumption Ststistics

**FIG. 2.**
**TRENDS IN FISHERIES PRODUCTION IN JAPAN (including aquaculture).**




Source : Ministry of Agriculture, Forestry and Fisheries - Annual Report of Fisheries and Aquaculture - Japan

**FIG. 3.**
**TRENDS IN FISHERIES PRODUCTION BY MAJOR SPECIES GROUP.**




Source : Ministry of Agriculture, Forestry and Fisheries - Annual Report of Fisheries and Aquaculture - Japan

FIG. 4.
DOMESTIC FISHERIES PRODUCTION BY FOOD AND NON-FOOD USE.

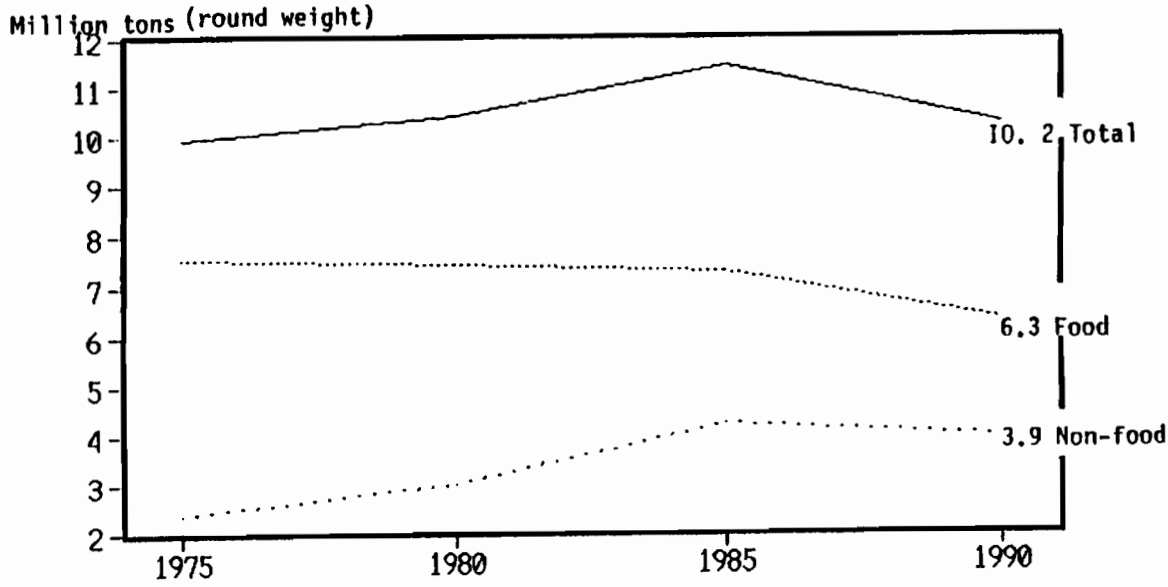
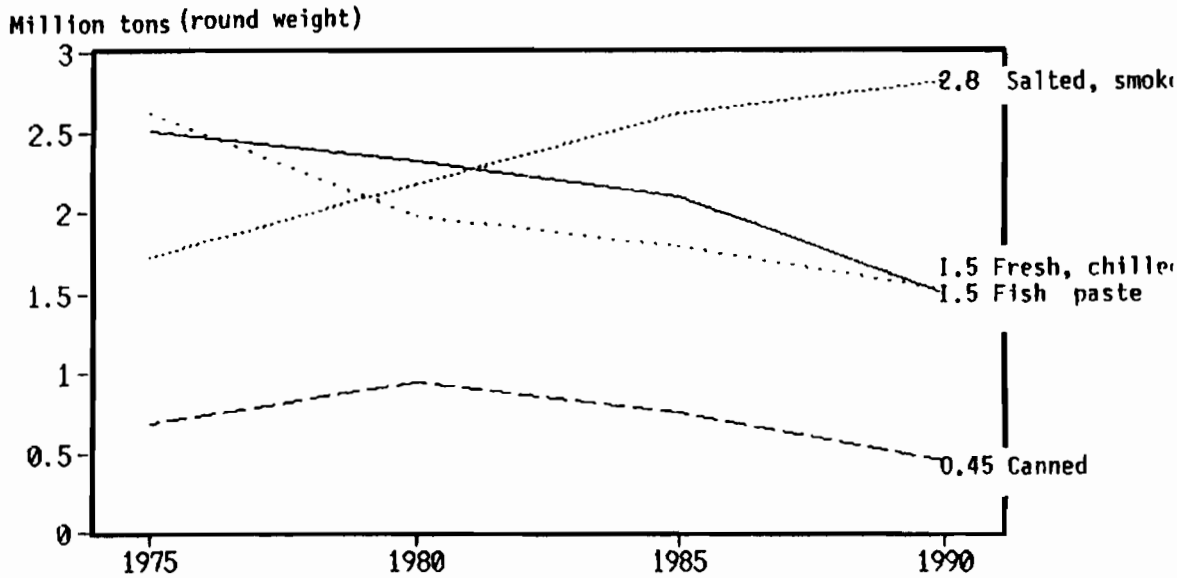



FIG. 5.
USE OF DOMESTIC FISHERIES PRODUCTION FOR FOOD.




Source : Ministry of Agriculture, Forestry and Fisheries - Annual Report of Fisheries products marketing - Japan

FIG. 6.
SUPPLY OF FISHERIES PRODUCTS FOR FOOD USE.

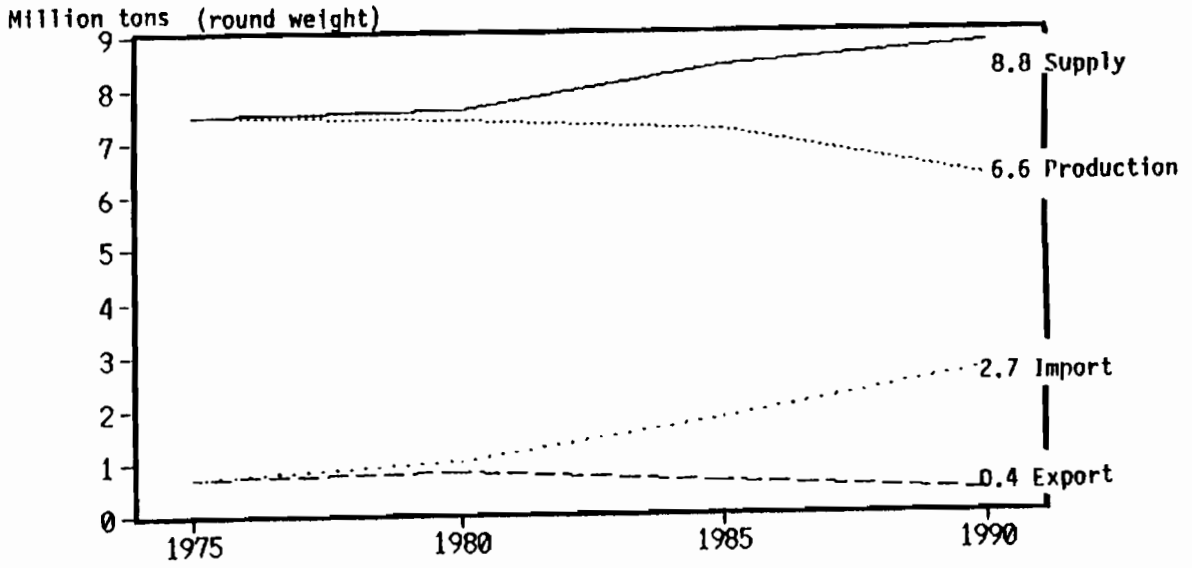
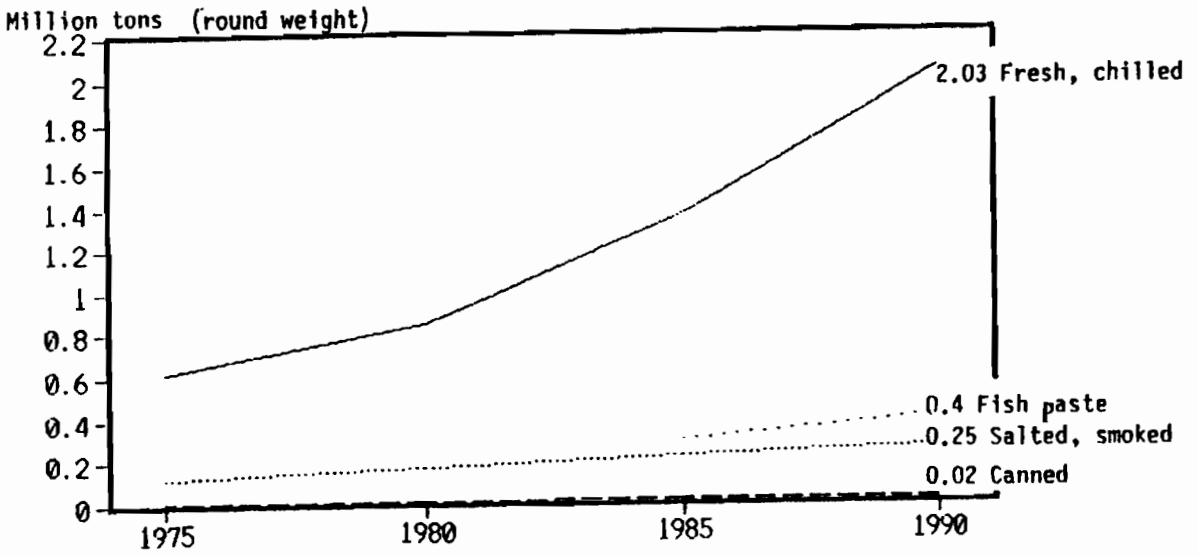
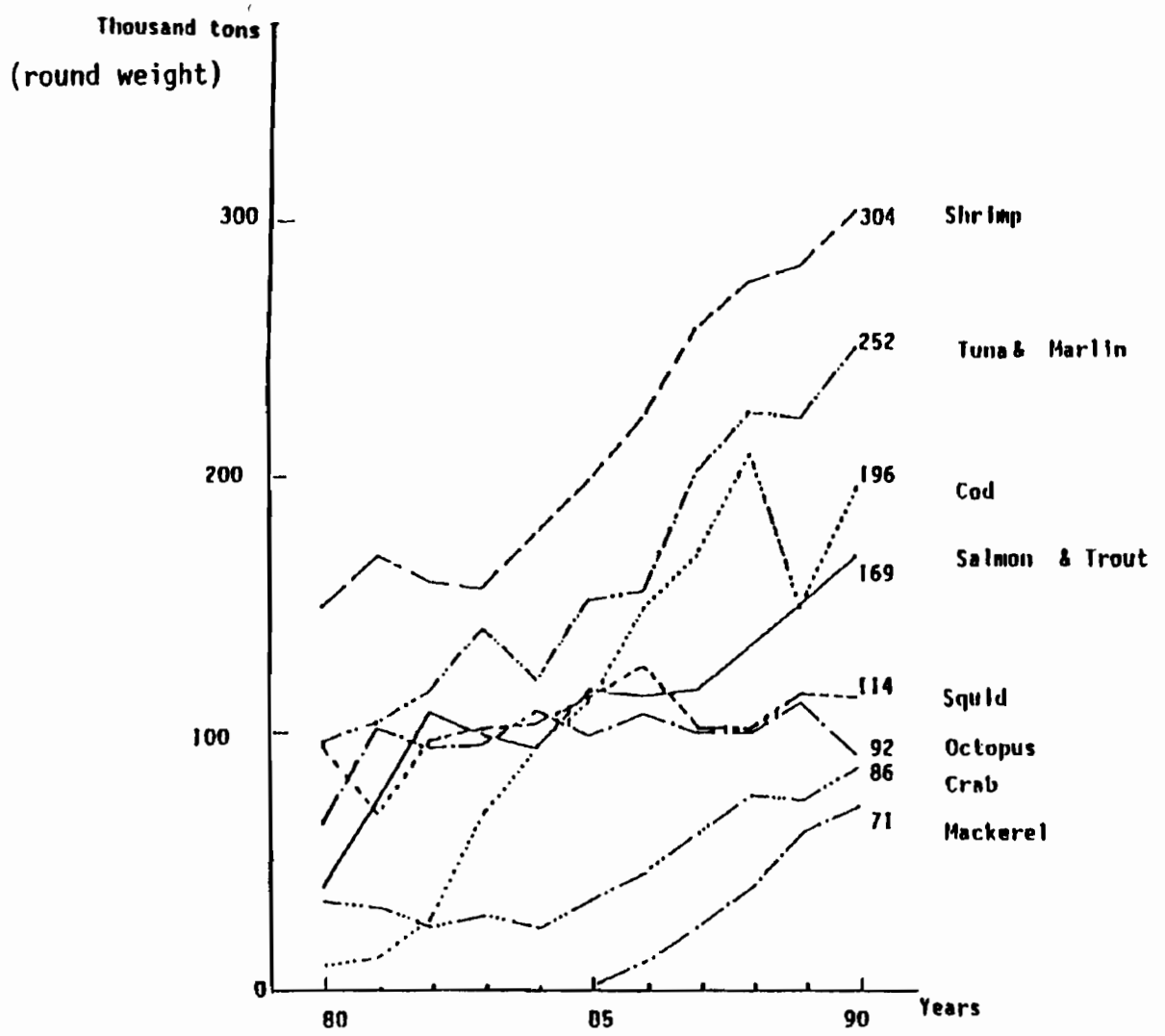



FIG. 7.
TRENDS IN IMPORT FISHERIES PRODUCTS FOR FOOD.



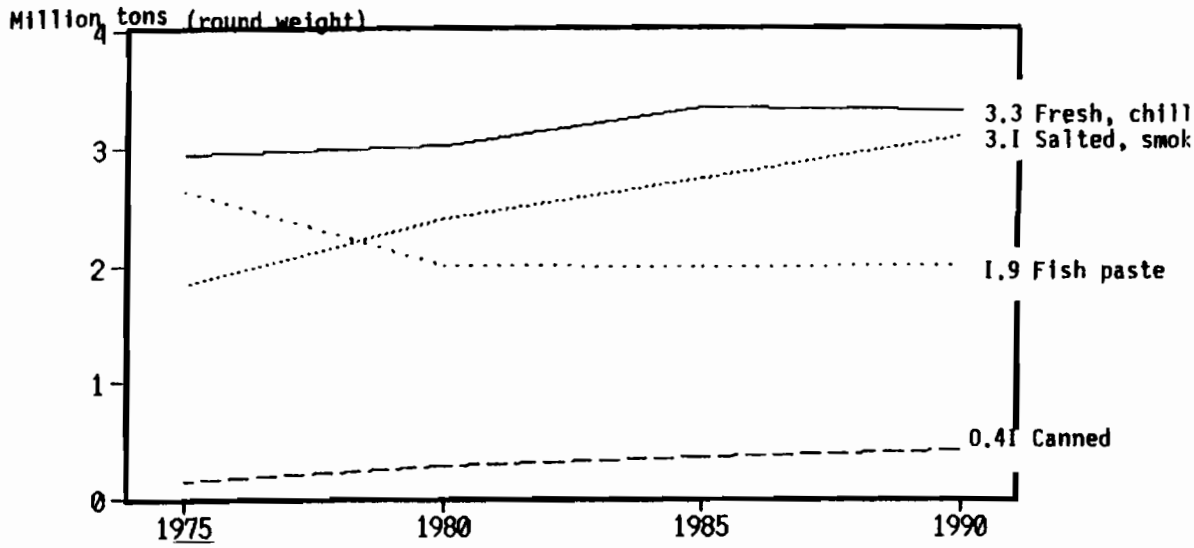

Source : Ministry of Agriculture, Forestry and Fisheries - Annual Report of Fisheries products marketing - Japan

FIG. 8.
TRENDS IN IMPORTS OF MAJOR FISHERY PRODUCTS (MAJOR SPECIES).




Source : Ministry of Finances - Trade Statistics of Fisheries products

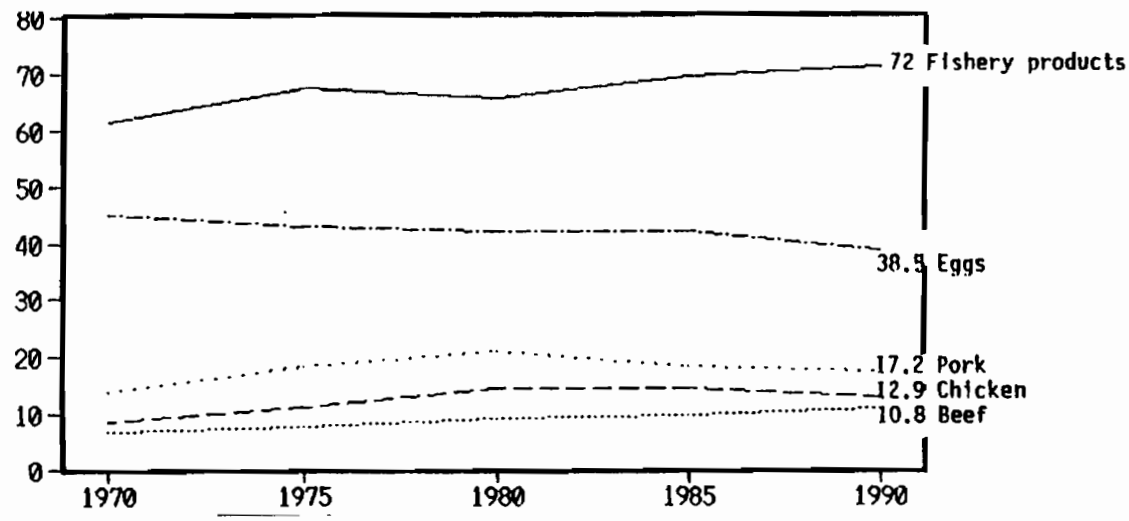
**FIG. 9.**
**TRENDS IN FISHERIES PRODUCTS CONSUMPTION.**




Source : Ministry of Agriculture, Forestry and Fisheries - Annual Report of Fisheries products marketing

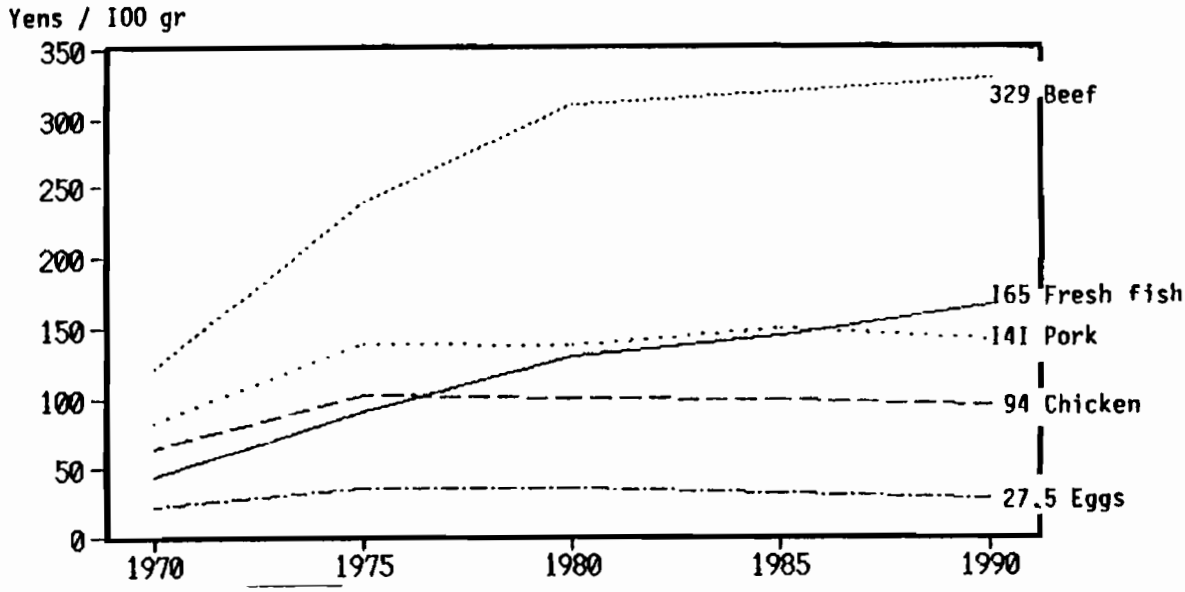
**FIG. 10.**
**YEARLY CONSUMPTION QUANTITY OF MAIN FOOD ITEMS PER CAPITA.**

Kilogram



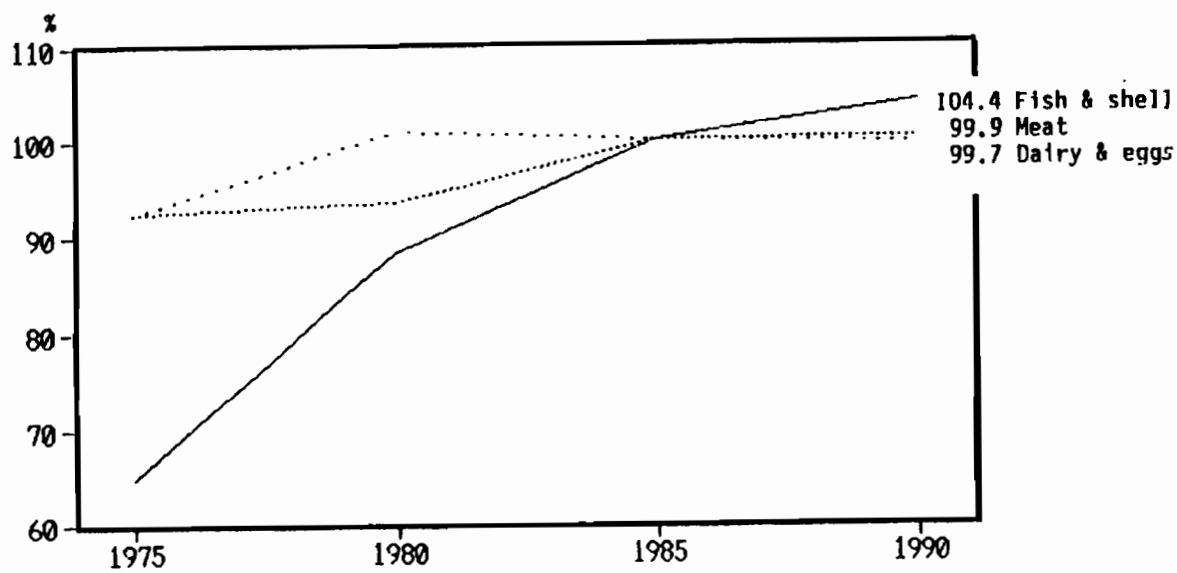

Source : Statistics Bureau - Annual report on the family income and expenditure Survey - Japan

FIG. 11.
YEARLY AVERAGE PRICE OF MAIN FOOD ITEMS.




Source : Statistics Bureau - Annual report on the family income and expenditure Survey - Japan

FIG. 12.
CONSUMER PRICE INDEXES.




Source : Statistics Bureau - Annual report on the family income and expenditure Survey - Japan

# Dual Structure of Japanese Marine Fisheries and Role of Fisheries Statistics in Fisheries Administration

**Tadashi Yamamoto**

College of Economics, Nihon University, Shinjuku 1-23-5-703, Shinjuku-ku, Tokyo 160, Japan

ABSTRACT

*Statistics are basically utilised for the economic analysis of the national economy or a certain sector of the national economy. However, only fishery statistics are utilized for two different purposes as follows : (1) Statistics needed for the economic analyses of fishery and (2) Statistics needed for the biological analysis of fisheries resources.*

*This is due to the fact that fisheries resources are renewable and annual change in its abundance has to be assessed from year to year in connection with fisheries' management. When emphasis is given to fishery statistics for biological use, those needed for economic analysis are apt to be ignored.*

*Fishery statistics needed for the biological analysis are catch and fishing effort data broken down according to the fishing areas.*

*In the present paper, therefore, the author will try to clarify, based on his past experiences, the following points :*

*1) the type of statistics needed for economic analyses of fisheries ;*
*2) the type of basic analyses to be made based on fisheries data as specified in (1) above ; and*
*3) the most effective way of collecting fisheries data as defined in (1) above.*

## 1. INTRODUCTION

### *1.1 Place of Fisheries out of National Economy*

Before World War II, agriculture and fisheries were major sectors of Japanese national economy. In those days, fishery products like canned salmon and crab and dried abalone and kelp, etc. were the important export commodities subsequent to silk.

After World War II, owing to the marked progress of secondary and tertiary industries, however, Japanese fishery has been a small sector of the national economy, being only 0.35 % of her GDP by 1990.

Owing to an increased income of Japanese people, demand for quality fish and fishery products began to increase since around 1970. Thus, Japan has been now the world largest fish import country. By 1989, Japan's import of fish and fishery product amounted to US $ 10.1 billion, which was 28.1 % of the world total import of fishery commodities.

### *1.2 Place of Marine Fisheries out of the Whole Fisheries*

Japan is an island country. Although it has some inland water fisheries, its production is insignificant in quantity term. With the exception of fresh water culture for eel, smelt fish, carp and rainbow trout, commercial capture fisheries are seldom practiced in the rivers.

For the above mentioned reason, discussions hereunder will be limited to marine fisheries, unless otherwise stated.

## 2. DUAL STRUCTURE OF MARINE FISHERIES

### *2.1 The Meanings of Dual Structure in Marine Fishery*

From socio-economic viewpoint, marine fisheries in Japan is divided into two categories as follows :

(1) Household Fishery

This fishery is undertaken to maintain the livelihood of the fishing household and is operated, in most instances, by its family members. The size of fishing boat in use is powered boat of less than 10 gross tons, non-powered boat or without boat. The household fishery is more or less equivalent to "coastal fishery" in Japan.

(2) Capitalistic Fishery

This fishery is undertaken to pursue a profit, and is operated, in most instances, by hired fishermen. The size of fishing boat in use is inboard powered boat of 10 gross ton and above. In general, offshore and distant water fisheries in Japan are regarded as capitalistic fishery.

Marine fishery in Asian countries also forms "dual structure". In Asian countries the household fishery is called "small scale fishery", whereas the capitalistic fishery is called "industrial fishery".

An economic unit engaged in fishery is statistically called "fishing establishment". In Japan and even in many Asian countries, the majority of fishing establishments are fishing households, which engage in the household fishery (see Table 1).

Even in EC countries such fishing household are likely to have existed. However, the fact has been hardly recognized due to the absence of statistical data on fishing households, which are normally obtained through a fishery census. It is important to note that the fishing households are also the objects of fisheries administration.

### *2.2 Dual Structure of Fishery and Role of the Government*

To clarify the dual structure of marine fishery is quite important for the government in the following respects :

(1) In general the income of fishing households is low, and hence their living condition is miserable. Needless to say, the role of the government is to improve the income and living level of fishing households.

For doing so, a variety of measures may have to be taken by the government. One of them may be to reduce the number of fishermen, although a question may remain how to reduce.

(2) In general the business of the capitalistic fishery is not always stable due mainly to price fluctuation of fish caught. In many instances, fisheries are seasonal. During a peak season of a particular fish the price goes down, whereas during the off season the price goes up.

One of the ways to prevent from the fall of fish price would be to store the surplus of fish at the cold storage until the price is recovered to a normal level.

## 3. NATIONAL FISHERIES STATISTICAL SYSTEM IN JAPAN

National fishery statistical system in Japan has been developed after World War II.

### *3.1 Statistical Items to Be Covered*

Fishery statistics are primarily utilized (i) for the evaluation on the progress achieved by the current fisheries development program and also (ii) for the planning of future fisheries development programs, although catch and effort data are required for stock assessment. So far, much emphases have been given to the collection of catch/effort statistics, leaving behind fishery statistics needed for the fisheries administration.

To meet the above two objectives, national fishery statistical system should cover at least statistical items as listed in Fig. 1a. These statistical items have been selected in accordance with "a principle of economic circulation".

(1) Number of fishing establishments by size and nature

Fishing establishment is an economic unit, which has an intention of doing fishing business. It is important to note that fishing establishments are the right object of fishery administration. The government should be aware of the number of such economic units by size and economic nature and their annual changes. These statistics are seldom available in developed countries.

(1') Number of fishing employee's households

The fishing employee's household is a household, that provides fishing laborer to other fishing establishment(s). Although it does not involve in fisheries production, it is also part of the objects of fisheries administration in terms of welfare of fishermen.

(2) Number of fishing boats

This statistics represent the size/capacity of fisheries production means. In many countries these statistics are available from the registration record of fishing boats, but they are not always very reliable.

(3) Number of fishermen

This statistics are indispensable as denominator to measure crude productivity of fishermen. The reduction in the number of fishermen is, in many countries, essential so as to increase the income of small scale fishermen, which ultimately improve their income and living condition.

(4) Number of fishing units

A fishing unit is composed of fishing boat, fishing gear and fishermen, and it is a technical unit to operate in fishing. Number of fishing units is counted by type of fishing gear employed. This statistics are useful for the planning of a fishery development program, and can be used as the substitute of fishing effort data in a country, where catch and fishing effort survey is not yet implemented.

(5) Statistics for the above (2), (3) and (4) are input data in the fishery, whereas catch statistics in quantity and value are output data. The latter statistics are quite important to assess the extent in the development of a fishery.

*3.2 Type of Fishery Statistical Surveys Required*

(1) Primary Phase of Fishery(see (1), (2) and (3) of Fig.1b)

To clarify the economic structure of a fishery, a fishery census is required at the interval of 5 or 10 years. To see the growth of a fishery, fishery production survey is required as a current survey. Fishery economy surveys are required for fishing households and fishing enterprises with objectives as given in Fig. 1b.

(2) Secondary and Tertiary Phases of Fishery (see (4) and (5) of Fig. 1b)

The fall of fish price greatly affects the operation of fishing business. To secure data needed to protect the fish producer from the fall of fish prices, fish marketing survey and fish cold storage survey are being undertaken Japan on monthly basis. However, the volume of fish and fishery products stored at cold storages at the end of every month has been indispensable information to international fish traders as well as fish producers abroad.

## 4. JAPANESE FISHERIES : CURRENT STATUS AND ISSUES

Japanese fishery statistics are being collected along the lines as illustrated in the above chapter. Based on these fisheries statistics the following can be clarified :

(1) Number of Fishing Establishments (see Table 1)

The total number of fishing establishments declined from 227 thousand in 1975 to 185 thousand in 1990 at an annual decreasing rate of 1.4 %. During the same period the number of fishing households decreased faster than that of fishing enterprises.

Japanese marine fisheries has a typical dual structure in terms of the number of fishing establishments, 95 % being fishing households and the remaining 5 % fishing enterprises.

(2) Number of Fishing Boats by Sizes (see Fig. 2)

The number of fishing boats declined from 327 thousand in 1975 to 277 thousand in 1990 at an annual decreasing rate of 1.1 %. During the same period the number of both inboard powered boats of any size and non-powered boats considerably decreased, whereas that of outboard powered boats slightly increased.

(3) Number of Fishermen (see Fig. 3)

For about ten years after World War II agriculture and fishery were the sanctuaries, which absorbed many unemployment and underemployment people. With the marked economic growth of the secondary and tertiary industries in the 1960s, quite many people in rural area moved into urban areas, resulting in sharp decline in the number of both farmers and fishermen.

Thus, the number of fishermen decreased from 780 thousand in 1954 to 370 thousand in 1990 at annual decreasing rate of 2 %.

(4) Fisheries Production (see Fig. 4a and 4b)

During the past about 30 years, Japanese fisheries production tremendously increased from 4.9 million MT in 1956 to 12.2 million MT in 1988 at annual in creasing rate of 2.9 %. The advent of new EEZ regime in 1977 greatly affected her distant water fishery, reducing its production from 4 million MT in 1973 to only 1.5 million MT in 1990. However, a marked increase in the catch of sardine due to the recovery of its resources made it possible to increase its total fisheries production at least until 1988 (see Fig. 4a).

Since 1988, however, the total fishery production has began to decline due to the decrease in the catch of sardine and Alaska pollack. (see Fig. 4b) Nevertheless, the total fishery production in value terms has not followed significant declining trend, as the fishery production from coastal fishery including coastal aquaculture in value

terms has followed a slightly increasing trend since 1988. (see Fig. 4c) This implies that fishermen's labour's productivity, i.e., average catch per fisherman per year in value terms have not declined even after 1988, as the number of fishermen still follow a clear declining trend.

(5) Species Composition of Marine Capture Fishery and Coastal Aquaculture

In recent years, Japan's marine capture fishery maintains high fishery production level, being around 10 million MT. Nevertheless, nearly 40 % of the total marine catch is occupied by sardine. The catch of fishes popularly consumed at home such as mackerel, squids, salmons, tunas, etc. are at the order of around 300 to 500 thousand MT per year. (see Fig. 5a) In order to fulfill the short supply of quality fish from marine capture fishery, coastal aquaculture has been developed for scallop, yellowtail, red sea bream, horse mackerel, coho salmon, etc. (see Fig. 5b)

(6) Economy of Fishing Households and Fishing Enterprises

(i) Fishing Household (see Table 2)

A fishing household has generally several income sources including the income from its own fishing. Average income of fishing household in recent years is around 6 million Yen, which is comparable with those of farm household in rural area and salary man's household in urban area. With this income level, the fishing household is able to find about one million Yen as surplus, which goes for his saving.

(ii) Fishing Enterprise (see Table 3)

Unlike fishing household, a fishing enterprise is seldom involved in side business. For this fishing enterprise, therefore, a cost and earning survey has been applied to see the size of profit realized from its own fishery business. During the past 15 years, the total fishing operational cost has been always close to the total earning due mainly to high labor and fuel costs. Therefore, in those days the size of profit achieved by fishing enterprise has been always marginal.

**TABLE 1.**
**NUMBER OF FISHING ESTABLISHMENTS, 1975–1990.**

(1) ACTUAL FIGURE

| TYPE OF FISHERIES ENGAGED | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| T O T A L | 227,452 | 216.433 | 202,818 | 184,954 |
| HOUSEHOLD FISHERY *1 | 217,266 | 204,837 | 192,059 | 175,444 |
| CAPITALISTIC FISHERY *2 | 10,186 | 11,596 | 10,759 | 9,510 |

*1 : All fishing households using powered boat of less than 10 gross ton, non-powered boat or without using any boat, those which engaged set nets or beach seine, and those which engaged in any type of coastal aquaculture are included.

*2 : All fishing establishments using a powered boat of 10 gross tons and above.

(2) RELATIVE IMPORTANCE BETWEEN HOUSEHOLD AND CAPITALISTIC FISHERIES

| TYPE OF FISHERIES ENGAGED | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| T O T A L | 100.0 | 100.0 | 100.0 | 100.0 |
| HOUSEHOLD FISHERY *1 | 95.5 | 94.6 | 94.7 | 94.9 |
| CAPITALISTIC FISHERY *2 | 4.5 | 5.4 | 5.3 | 5.1 |

(3) ANNUAL CHANGE IN NUMBER OF FISHING ESTABLISHMENTS

| TYPE OF FISHERIES ENGAGED | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| T O T A L | 100.0 | 95.1 | 89.2 | 81.3 |
| HOUSEHOLD FISHERY *1 | 100.0 | 94.3 | 88.4 | 80.8 |
| CAPITALISTIC FISHERY *2 | 100.0 | 113.8 | 105.6 | 93.4 |

TABLE 2.
CHANGES IN THE ECONOMY OF FISHING HOUSEHOLD *1, AVERAGE PER FISHING HOUSEHOLD.

UNIT : MILLION YEN

| ITEMS | | YEAR | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1975 | 1980 | 1985 | 1988 | 1989 | 1990 |
| - FISHING HOUSEHOLD - | | | | | | | |
| TOTAL INCOME (1) = A + B + C *2 | | 3.4 | 4.8 | 5.3 | 5.8 | 6.3 | 5.9 |
| OWN FISHERY | A | 1.9 | 2.8 | 2.8 | 2.8 | 3.3 | 2.8 |
| SALARY/WAGE AS WORKERS | B | 0.7 | 1.1 | 1.2 | 1.5 | 1.5 | 1.5 |
| OTHER INCOMES | C | 0.7 | 0.9 | 1.4 | 1.5 | 1.5 | 1.6 |
| DISPOSABLE INCOME (1) - TAXES - | (2) | 3.2 | 4.3 | 4.5 | 4.8 | 5.2 | 4.8 |
| TOTAL FAMILY EXPENDITURE | (3) | 2.1 | 3.3 | 3.7 | 3.8 | 4.0 | 4.0 |
| SURPLUS (2) — (3) = | (4) | 1.0 | 1.0 | 0.7 | 1.0 | 1.2 | 0.8 |
| DEPENDENCY ON FISHERY (%) a/(1) x 100 = | (5) | 59.0 | 57.3 | 51.4 | 48.7 | 52.1 | 47.3 |
| AVERAGE NUMBER OF HOUSEHOLD MEMBERS | (6) | 4.7 | 4.4 | 4.2 | 4.1 | 4.0 | 4.0 |
| TOTAL INCOME OF : FARM HOUSEHOLD | | 3.9 | 5.6 | 6.9 | 7.5 | 8.0 | 8.4 |
| SALARY MAN'S HOUSEHOLD IN URBAN AREA | | 2.8 | 4.2 | 5.3 | 5.8 | 6.0 | 6.3 |

*1 : Fishing household engaged in coastal fishery using non-powered boat and po wered boat of less than 10 gross tons.

*2 : The income of a fishing household is generated not only from own fishery but also from salary/wage earned by some of its family members. Other incomes such as pension, interest, dividend, gift, etc. are also regarded as the income of a fishing household. These icomes are classified into as follows :

A = Total sale from own fishery — Total expense spent for own fishery.
B = The sum of salaries and wages which were earned by all members of the fishing household.
C = Any income other than the above A and B such as pension, interests, gifts, etc.

(Data Source) Fishery Economy Survey for Fishing Household, Ministry of Agri., Forestry & Fishery.

TABLE 3.
COST AND EARNING OF SMALL & MEDIUM SIZE CAPITALISTIC FISHERY. AVERAGE PER FISHING ESTABLISHMENT.

UNIT : MILLION YEN

| ITEMS | | YEAR | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1975 | 1980 | 1985 | 1988 | 1989 | 1990 |
| TOTAL EARNING (SALE) | (1) | 101.0 | 131.0 | 135.0 | 127.0 | 133.0 | 136.0 |
| TOTAL COST = (A + B + C + D) | (2) | 100.4 (100) | 134.2 (199) | 134.3 (100) | 124.4 (100) | 129.2 (100) | 133.1 (100) |
| LABOR COST | A | 38.0 (38) | 47.0 (34) | 47.0 (36) | 47.0 (39) | 49.0 (39) | 50.0 (38) |
| FUEL COST | B | 14.0 (14) | 28.0 (21) | 25.0 (19) | 13.0 (11) | 13.0 (10) | 15.0 (11) |
| OTHER COST | C | 35.4 (34) | 44.2 (33) | 47.3 (34) | 48.4 (38) | 51.2 (39) | 52.1 (39) |
| DEPRECIATION COSTS | D | 13.0 (13) | 15.0 (11) | 15.0 (11) | 16.0 (13) | 16.0 (13) | 16.0 (12) |
| PROFIT | (3) = (1) — (2) | 0.6 | —3.2 | 0.7 | 2.6 | 3.8 | 2.9 |
| RATE OF PROFIT TO TOTAL REVENUE (%) (4) = (3)/(1) x 100 | | 0.6 | —2.4 | 0.5 | 2.0 | 2.9 | 2.1 |

(Note)
Small & medium size fisheries refer to those, which uses fishing boat of 10 to 1,000 gross tons.

(Data Source) Fishery Economy Survey for Fishing Household, Ministry of Agri., Forestry & Fishery.

**FIG 1a.**
**STATISTICAL ITEMS TO BE COVERED FOR PRIMARY PHASE OF FISHERY.**

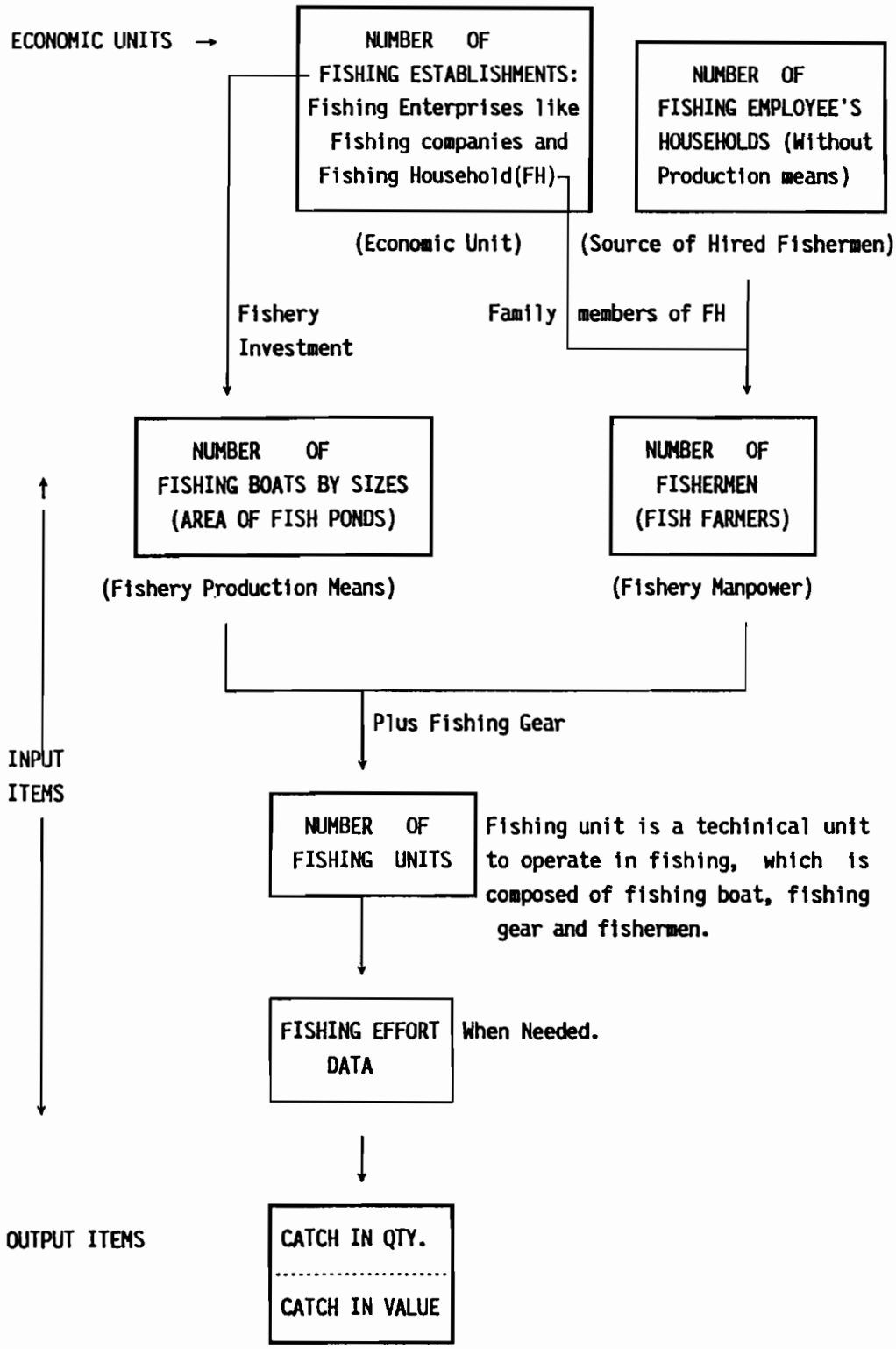


FIG. 1b.
NATIONAL FISHERY STATISTICAL SYSTEM DEVELOPED IN JAPAN.

| NAME OF SURVEY | OBJECTIVES | SURVEY ITEMS | SURVEY METHOD | SURVEY FREQUENCY |
|---|---|---|---|---|
| (1) FISHERY CENSUS | TO CLARIFY THE ECONOMIC STRUCTURE OF THE FISHING INDUSTRY AS WELL AS TO COUNT THE NUMBER OF FISHERY INVENTORY ITEMS. | ALL FISHERY INPUT ITEMS AS GIVEN IN Fig. 2. | COMPLETE ENUMERATION OF FISHING ESTABLISHMENTS | EVERY 5 YEARS |
| (2) FISHERY PRODUCTION SURVEY | TO EVALUATE THE PROGRESS OF FISHERY DEVELOPMENT AS WELL AS TO ASSESS THE STATUS OF THE RESOURCES. | NUMBER OF FISHING UNITS, CATCH IN QTY. & VALUE AND FISHING EFFORT DATA FOR SOME FISHERIES | MOSTLY BASED ON FISH MARKETING RECORD AND SOME TIMES FISHING LOG BOOK | MONTHLY, QUARTERLY OR YEARLY<br>AT LEAST YEARLY |
| (3) FISHERY ECONOMY SURVEY | | | | |
| 3.1 FISHING HOUSEHOLD ECONOMY SURVEY | TO MEASURE THE INCOME AND LIVING LEVEL OF THE FISHING HOUSEHOLDS. | INCOMES FROM ALL INCOME SOURCES OF FISHING HOUSEHOLD AND ALL FAMILY EXPENDITURES OF THE HOUSE HOLD | BOOK-KEEPING BY SAMPLE FISHING HOUSEHOLDS. | MONTHLY AND YEARLY |
| 3.2 FISHING ENTERPRISE ECONOMY SURVEY | TO MEASURE THE SIZE OF PROFIT GENERATED FROM FISHING BUSINESS. | TOTAL COST OF FISHING OPERATION AND CORRESPONDING TOTAL SALE OF CATCH SOLD. | BOOK-KEEPING BY SAMPLE FISHING ENTERPRISES. | MONTHLY AND YEARLY |
| (4) FISH PROCESSING SURVEY | TO ASSESS THE SIZE OF FISH PROCESSING INDUSTRY. | NO. OF PROCESSING PLANTS, NO. OF WORKERS AND THE QTY. OF FISHERY PRODUCTS PRODUCED. | INTERVIEWS | YEARLY |
| (5) FISH MARKETING SURVEY | TO PROVIDE DATA NECESSARY TO STABILIZE THE PRICE OF FISH, WHICH WILL ULTIMATELY STABILIZE FISHING BUSINESS. | MONTHLY WEIGHTED PRICE OF FISH PER KG. AND CORRESPONDING QTY. OF FISH TRANSACTED | BASED ON THE FISH MARKET RECORDS | MONTHLY |
| (6) FISH COLD STORAGE SURVEY | DITTO | FISH AND FISHERY PRODUCTS STORED AT THE END OF EACH MONTH AND CARRIED OVER TO THE FOLLOWING MONTH. | BASED ON THE COLD STORAGE RECORDS. | MONTHLY |

Fig. 1.2 NATIONAL FISHERY STATISTICAL SYSTEM DEVELOPED IN JAPAN

FIG. 2.
NUMBER OF FISHING BOASTS BY SIZES, 1975–1990.

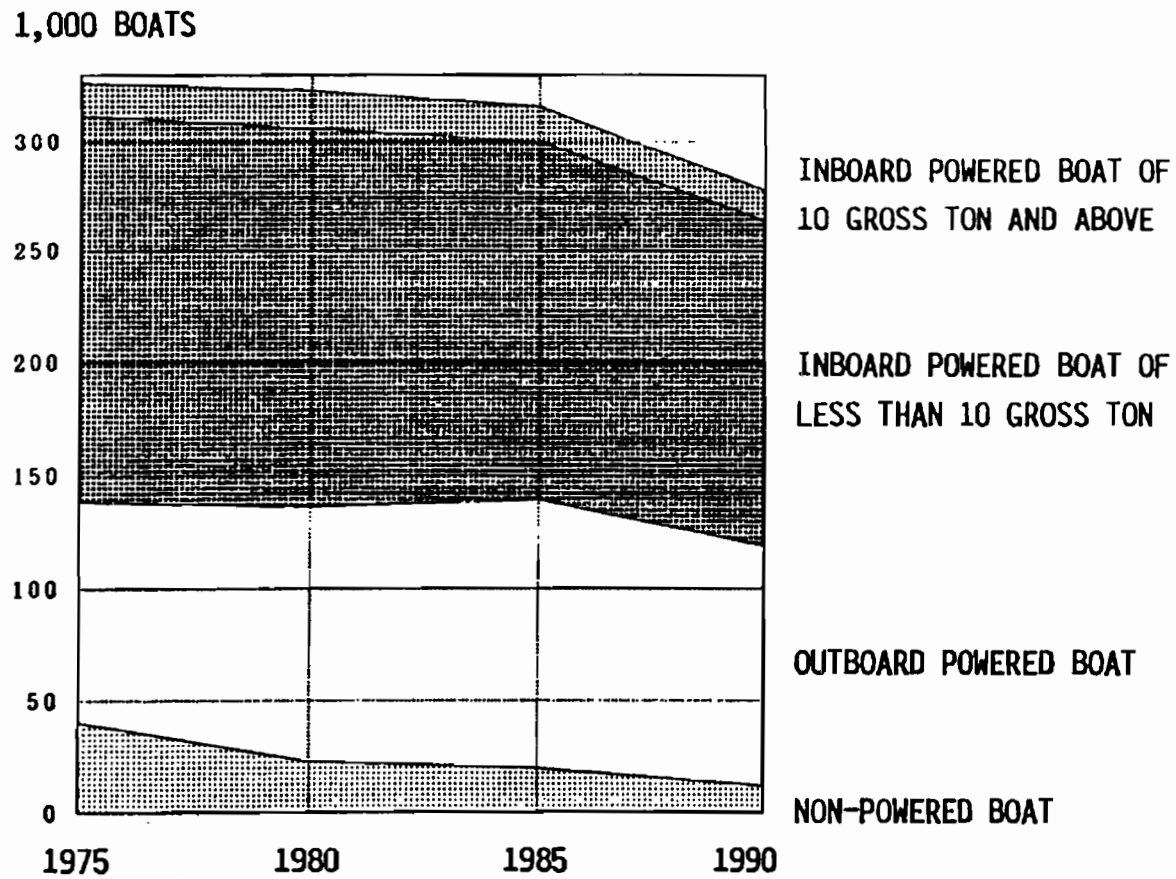


FIG. 3.
NUMBER OF FISHERMEN.

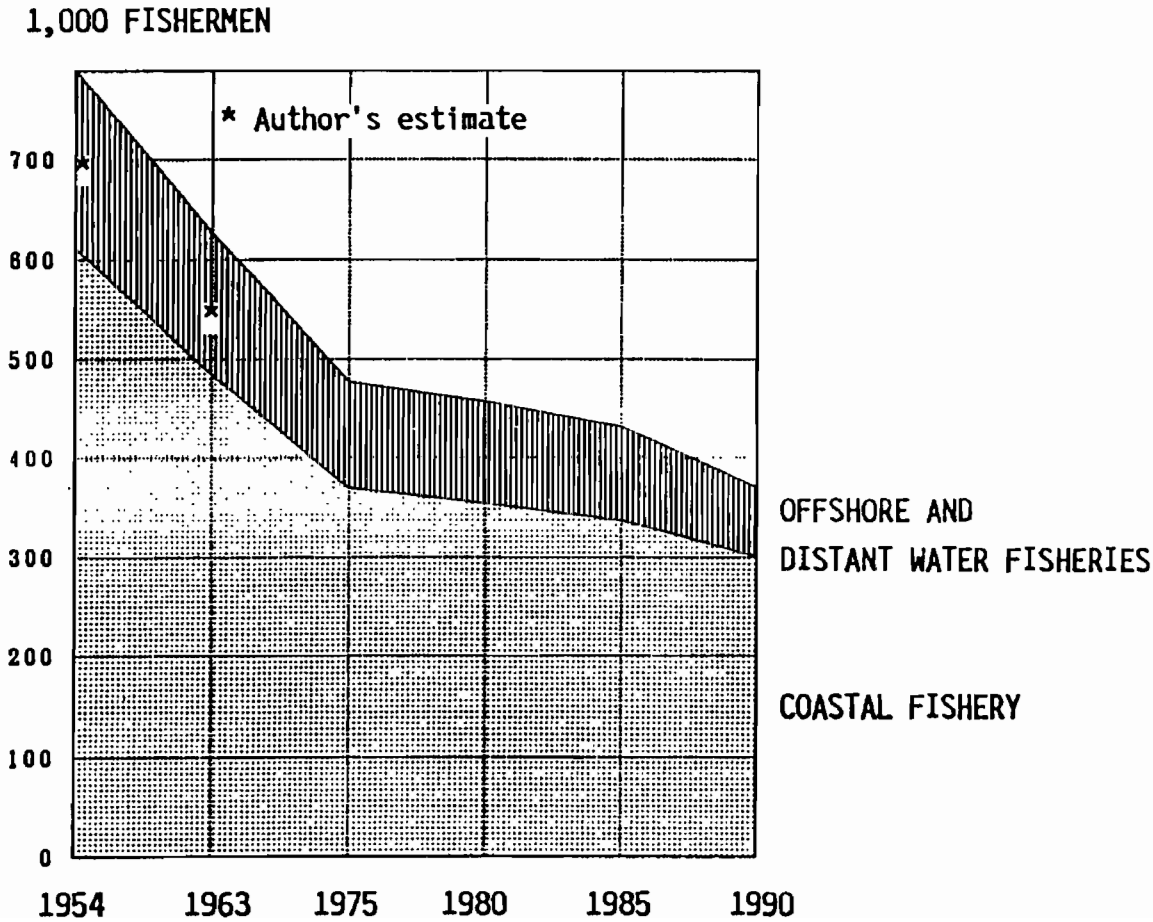


**FIG. 4a.**
**YEARLY TREND OF FISHERIES PRODUCTION BY SECTORS.**

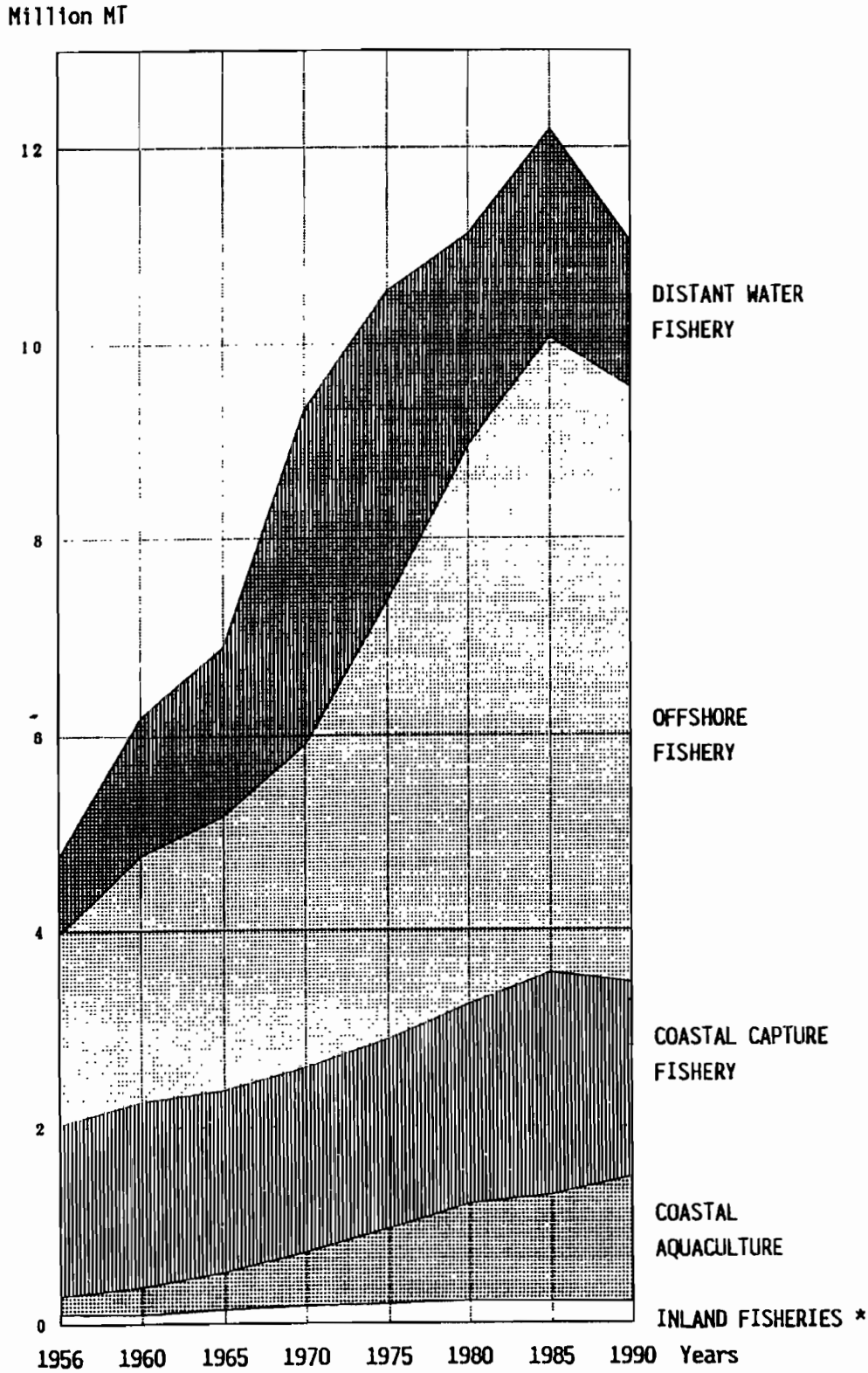


FIG. 4b.
MARINE FISHERY PRODUCTION IN QUANTITY, 1975–91.

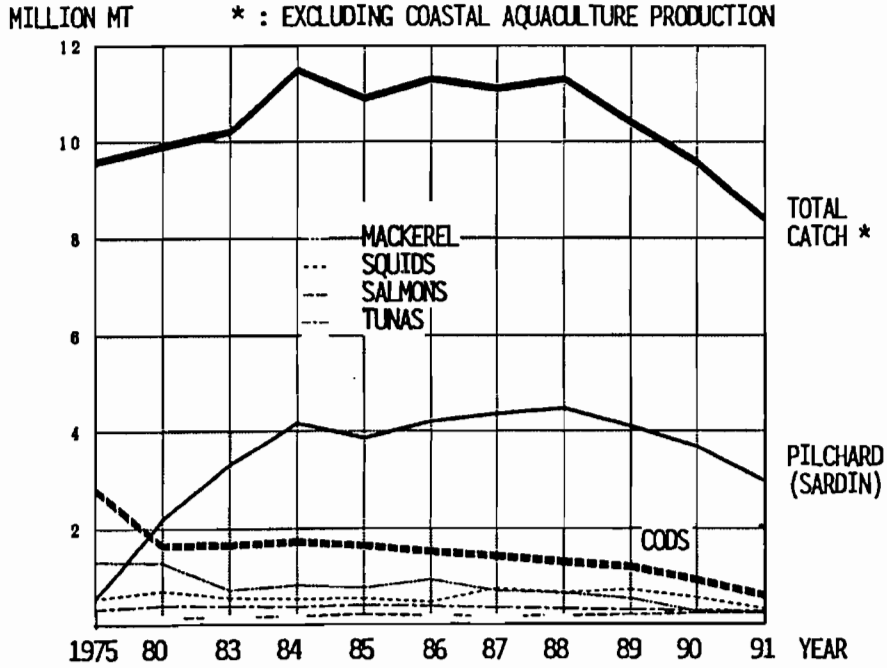



FIG. 4c.
COASTAL AQUACULTURE PRODUCTION BY MAJOR SPECIES, 1975-91.

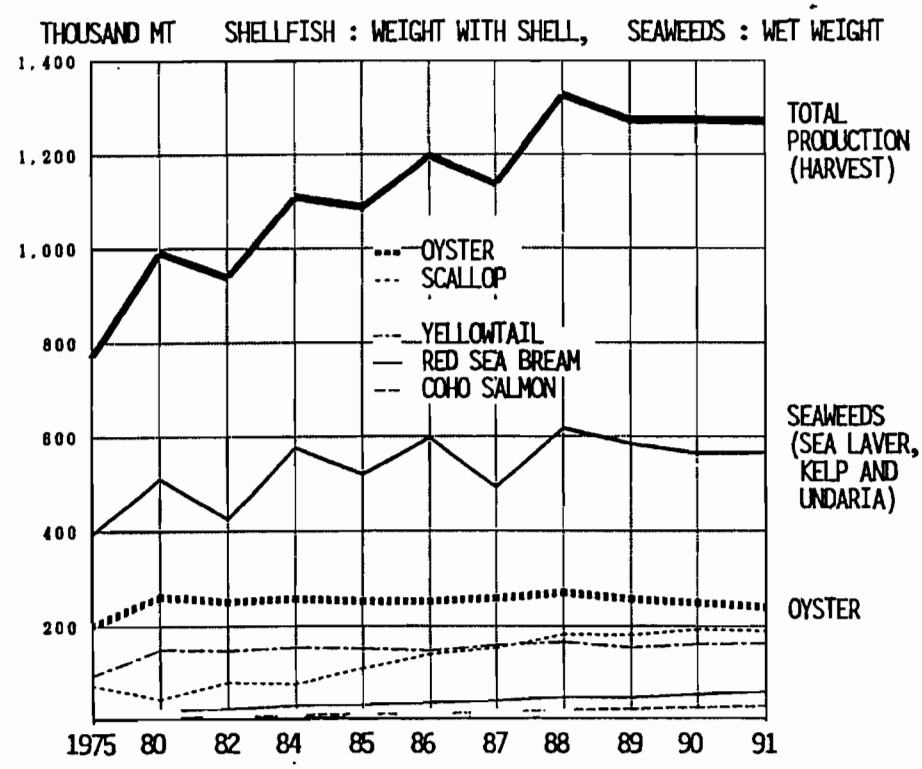


FIG. 5a.
MARINE FISHERIES PRODUCTION BY SECTORS IN QUANTITY, 1975-91.

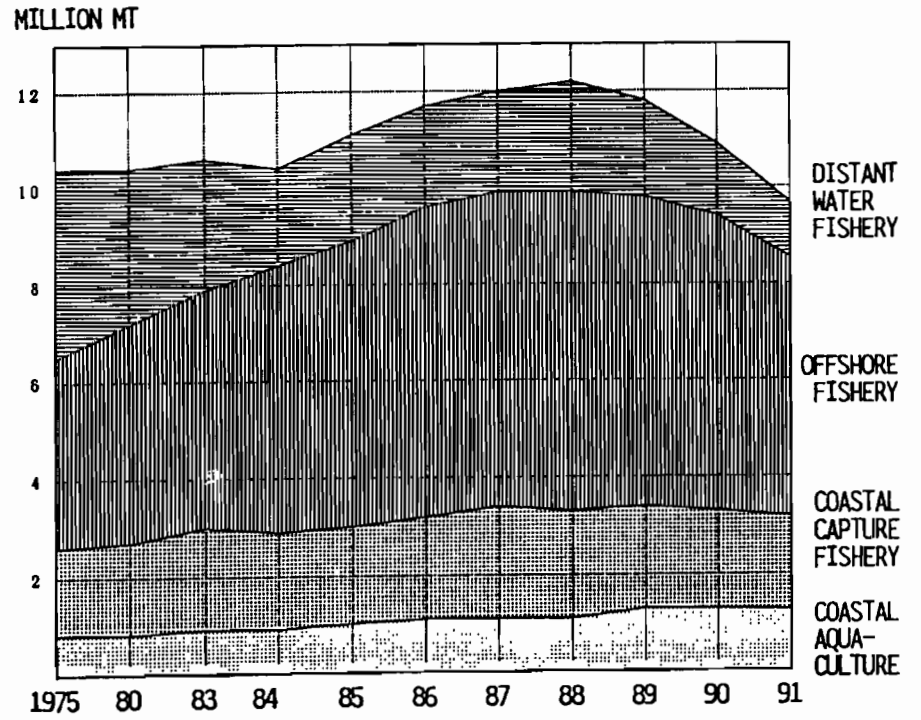
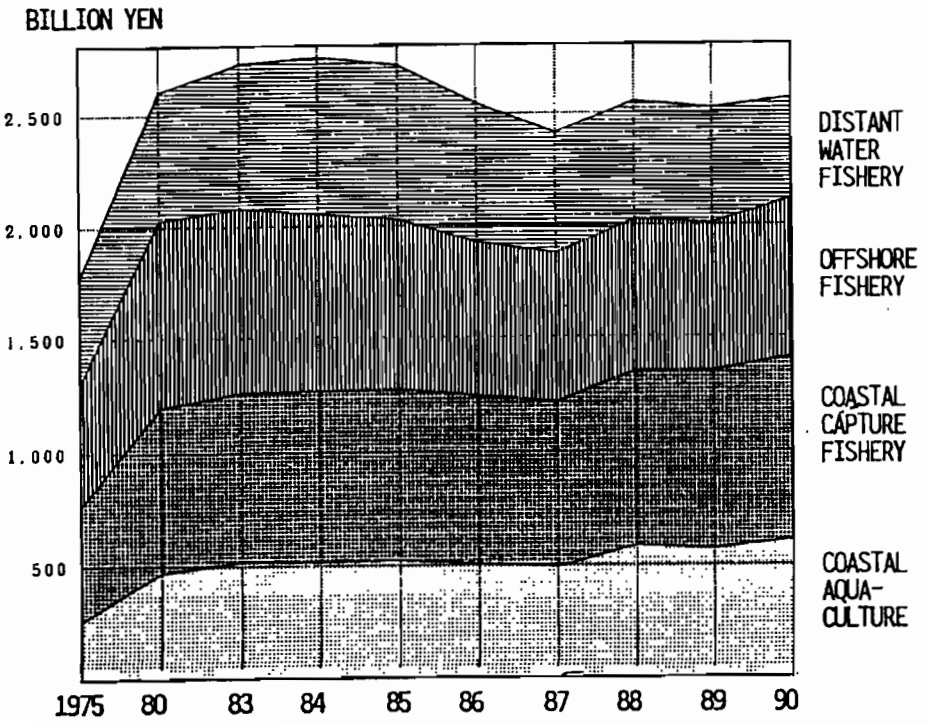



FIG. 5b.
MARINE FISHERY PRODUCTION BY SECTORS IN VALUE, 1975-90.



# Resource Valuation and Conflict
# by
# A. T. Charles and J. Catanzano

Deux des caractéristiques majeures du monde de la pêche sont (a) un état de surexploitation des ressources (utilisation excessive pouvant conduire à une destruction des ressources), et (b) l'existence de conflits pour l'usage des ressources halieutiques. Ces deux problèmes résultent de processus complexes, mais l'une des causes qui leur est certainement commune tient à l'inadéquation des politiques de gestion basées sur des « signaux » économiques dérivés des méthodes actuelles de détermination de la valeur des ressources. Un nombre croissant d'auteurs expriment des réserves sur l'aptitude de ces méthodes à déterminer la valeur intrinséque d'une ressource pour une société considérée dans ses différents usages potentiels, du fait du haut niveau d'incertitude et de l'état encore embryonnaire des méthodes utilisées.

Construits à partir de l'évocation de cas conflictuels, les textes rassemblés ici montrent tout l'intérêt de nouvelles approches des usages concurrentiels qui se côtoient pour l'accès aux ressources. Une évaluation des papiers contenus dans cette session offre l'opportunité de comparer les cas issus de pêcheries africaines, japonaises, des régions nord-américaines, d'espaces européens. Une telle comparaison nous permet d'entrevoir :

- des similitudes s'agissant des problèmes générés par les usages de nature multiple de la ressource;
- des zones d'ombre restant à aborder et pour lesquelles les fondements théoriques sont à repenser. On y perçoit les interrogations encore en suspens sur le rôle des institutions (dont les marchés), ainsi que celles sur le comportement des acteurs et les fondements de leurs choix et celles enfin relatives à la détermination de la valeur économique totale (valeur d'usage et valeur intrinsèque) des ressources halieutiques considérées comme un tout et notamment sans distinction d'usage.

Pour illustrer ces développements on trouvera ici l'évocation de conflits entre pêche récréative, pêche commer-

Two predominate characteristics of the world's fisheries are (a) resource over-exploitation (excessive stock depletion) and (b) the existence of conflicts in the use of resources. These two problems arise through complex processes, but surely one common cause is the inadequacy of management policies based on economic "signals" derived from present methods of resource valuation. An increasing number of authors are expressing reservations about the validity of these methods for determining the intrinsinc value of a resource to society in its possible alternative uses, given the high level of uncertainty and the embryonic nature of the methods involved.

With respect to conflict in fisheries, the papers assembled here demonstrate the interesting new approaches to the problem of handling competition among marine resource uses. An assessment of the papers compiled herein provides the opportunity to compare across a number of conflict situations in African, Japanese, North-American and European fisheries. Such a comparison indicates :

- similarities in problems due to the multi-use nature of the resources;
- a number of research areas in which theoretical foundations must be further elaborated. These "pending" questions deal with the role of institutions (particularly the formation of markets), the behaviour of individuals and the foundations of their choices, and determination of a total economic value (including use value and intrinsic value) aggregated across all uses.

To illustrate these points, this compilation includes a variety of conflict situations existing among recreational, commercial and subsistence fisheries or between domestic and foreign fisheries. The three papers of Potten *et al.*, Kusakawa, and Johnston and Emami all deal with what is perhaps the major area of conflict, at least in developed nations, that arising between commercial and recreational fishing.

ciale et pêche de subsistance ou encore entre pêcheries nationales et pêcheries étrangères. Potten *et al.*, Kusakawa ainsi que Johnston et Emami s'intéressent au cas de conflit peut-être le plus répandu, au moins dans les pays développés, qui met en jeu les concurrences entre pêche récréative et pêche professionnelle.

Le lien entre de tels conflits et la détermination de la valeur de ces ressources est clair ; les efforts pour la résolution de ces conflits et en fait les débats sur ce thème, doivent prendre en compte la compréhension des paramètres socio-économiques en jeu, en intégrant leur évolution selon les différents usages potentiels mis en concurrence. Potten *et al.* évoquent à ce propos la question relative aux coûts de la gestion et à leur prise en charge. Qui paye et qui doit payer ? Comment se répartissent les coûts de la gestion ?

On perçoit clairement à travers ces quelques cas les limites de la connaissance de ces ressources. Ces connaissances se développent le plus souvent encore à partir d'une prise en compte prioritaire voire exclusive des usages commerciaux. De fait, même lorsque les pêches non commerciales en viennent à dominer les pêches commerciales par l'effet qu'elles ont sur la ressource, il semble que les gestionnaires et les chercheurs restent attentifs quasi exclusivement aux pêches commerciales.

Les interactions et conflits entre pêches commerciales et pêches non commerciales – plutôt entre pêches récréatives et pêches commerciales comme il est fait référence dans le papier cité précédemment, ou entre pêche de subsistence et pêche commerciale (comme dans Geier *et al.* à propos des pêches de l'Alaska) – , ajoutent seulement quelques controverses sur la question de l'évaluation des flux économiques générés dans ces pêcheries. Ceci ressort également dans le travail de Queirolo et Johnston à partir des conflits potentiels entre pêches nationales et pêches étrangères impliquées dans des accords de coopération. Globalement, cela semble être l'une des deux plus importantes voies de travail identifiées par les auteurs sur ce sujet.

L'autre point fondamental abordé tient à l'incapacité des mécanismes de marché à permettre la détermination correcte de la valeur des ressources, puisque en plusieurs cas, notamment pour les pêches récréatives, et pêche de subsistence des populations indigènes d'origine maritime, les échanges se font sans référence au marché. En particulier la valeur de la ressource doit intégrer pas seulement les mesures monétaires de la valeur immédiate d'usage, mais aussi, (a) un ensemble complexe de facteurs socioéconomiques et culturels, et (b) les aspects dynamiques, considérant la ressource comme une forme de capital. On retrouve là par rapport à ce point particu-

The link between such conflicts and the matter of resource valuation is clear ; efforts at conflict resolution, and indeed any intelligent debate on the topic, must be based on some understanding of the socioeconomic values involved, and how these vary across the different uses. Potten *et al.* mention in this respect the question of management costs and their reimbursement. Who should pay and who actually does pay ? How are the management costs allocated ?

These papers note the limits of current knowledge concerning fishery resources, and the frequent focus on commercial uses in place of a balanced approach across all use categories. Indeed, even when non-commercial fisheries come to dominate resource use and resource impacts, it seems that management and research attention can sometimes remain focused on the commercial sector.

Interaction and conflict between commercial and non-commercial fishing – whether between commercial and recreational sectors, noted in the papers above, or between subsistence and commercial fisheries (as in Geier *et al.* for the case of Alaska) – only adds to controversies over how economic flows in the fishery sector are evaluated. This is reflected as well in the examination by Queirolo and Johnston of potential conflict between domestic and foreign fishing involved in "cooperative" arrangements. Overall, it appears to be one of the two most important fields for further exploration identified by the authors in this collection.

A second fundamental point is the inability of market-based mechanisms to properly evaluate fishery resources, since so many uses, notably recreational and subsistence/indigenous/Native fisheries, lie outside the normal market system. In particular, fishery resource valuation must incorporate not just monetized measures of immediate use value, but also (a) a complex package of socioeconomic and cultural factors, and (b) a dynamic aspect, namely the resource as a form of capital. We might suggest that underlying this point are a number of more general concerns, related to (i) the measure of utility and of non-use values for environmental goods (cf. the work of R.K. Turner), and (ii) the choice between immediate and long-term benefits, and the related matter of inter-generational natural capital flows.

In this context, some subjects are still subject to debate. While past research on recreational fisheries often measured "value" simply as a sum of expenditures by the fishers, Potten *et al.* note that the correct item to measure is the net economic value, including elements of both consumer and producer surplus. In this regard, it has been popular to use travel cost and contingent valuation methods which attempt to calculate what the market valuation "would be" if markets for recreational fishing in fact existed.

lier, un nombre de points plus généraux, reliés (i) à la mesure de l'utilité et la mesure de la valeur de non-usage pour les biens environnementaux (cf les travaux de R. K. Turner), ainsi que (ii) la question du choix entre les bénéfices immédiats et les bénéfices de long terme, et les liens intergénérationnels relatif aux flux de capital naturel.

A ce propos, quelques thèmes se voient remis en débat. Alors que les travaux anciens sur les pêcheries récréatives mesuraient souvent la valeur simplement comme la somme des dépenses engagées par les pêcheurs, Potten *et al.* font remarquer que la façon correcte de mesurer cette valeur revient à mesurer la valeur économique nette incluant à la fois des éléments du surplus du consommateur et du producteur.

Par rapport à cela, se sont développées des applications de la méthode des coûts de transport ainsi que des méthodes d'évaluation contingente qui consiste en fait à simuler ce que serait la valeur s'il existait un marché pour les pêches récréatives.

L'utilisation de telles méthodes, qui peuvent aussi bien s'appliquer aux activités de subsistence (par exemple le cas des pêcheurs de l'Alaska), reste fortement discutable. Des incertitudes dans les méthodes utilisées pour les biens relatifs aux pêcheries non commerciales doivent raisonnablement nous conduire à reconsidérer les régulations économiques mises en place sur la base de la simple théorie néo-classique. En outre, de telles méthodes ne devraient pas manquer d'intégrer les éléments clés du comportement du pêcheur non professionnel. Larson et Johnston notent à ce propos que le comportement décrit par l'effet Giffen « une augmentation de la quantité demandée d'un bien en réponse à l'augmentation de sa valeur monétaire », pourrait bien se produire.

En recherchant des méthodes plus complètes, plus propices à l'intégration des différents facteurs du comportement que celles en liaison avec les signaux économiques classiques, l'attention s'est portée sur un nombre d'alternatives possibles. Cependant, celles-ci ont été tracées plus en référence aux analyses spécifiques à l'environnement qu'aux ressources marines, et leur applicabilité aux pêcheries devrait inévitablement augmenter, en partie du fait des besoins pour de nouvelles approches aptes à résoudre les problèmes de disponibilité limitée des informations et de complexité des mécanismes institutionnels.

Trois approches sont privilégiées dans cette session :

(i) L'approche comptable des ressources naturelles (Webster) qui vise à l'évaluation du capital naturel total considérant les ressources halieutiques comme une forme d'actif aux variations duquel

The use of such methods, which in theory can also be applied to subsistence activities (for example Alaska fishermen), remains highly debatable. Uncertainties in the very procedure to be used in valuing non-market fishery "goods" may reasonably lead one to re-evaluate economic regulations designed on the basis of simple neo-classical theory. Furthermore, such methods may miss key elements of recreational fishing behaviour ; Larson and Johnston note that Giffen behaviour, "an increase in quantity of a good demanded in response to an increase in its money price", could well occur.

In searching for methodologies more complete and more inclusive than that reliant on standard economic signals, a number of alternatives are gaining attention. While these are drawn more from environmental analysis than from marine resource studies, their applicability in fisheries will inevitably increase, in part due to the need for new approaches to deal with limited availability of information and complexity of the institutional mechanisms. Three approaches discussed in the papers of this section are as follows :

(i) Natural resource accounting approaches (Webster) take a perspective of evaluating the total natural capital in the fishery as a form of asset, and measuring changes in this asset. Such approaches are becoming increasingly popular in evaluations of "sustainable development" policy options.

(ii) Multi-criteria regional impact models, which Geier *et al.* are in the process of developing for the Alaska context, attempt to determine total socioeconomic impacts of policy changes. This concept has also been used elsewhere, as in the so-called Five Account Model that formed the basis for evaluating salmonid enhancement in British Columbia.

(iii) Perspectives based on "New Institutional Economics", emphasize the fundamental importance of institutions, and move beyond the simplistic assumption of pure and perfect competition. The NIE viewpoint is highlighted in two papers herein (Failler and Wilson ; Wilson and Lent), and alluded to in Queirolo's reflections on the asymmetry of information and its role in determining the efficiency of rational choices. This perspective represents not so much an alternative methodology as an alternative view of standard fishery concepts (such as rent-seeking), emphasizing the multidimensional nature of "value" and the importance of understanding the dynamics of fishery institutions and of human behaviour.

In conclusion, it must be pointed out that, in the fishery sector and in the environmental arena, a combination of

on s'intéressera. De telles approches sont devenues extrêmement utilisées dans l'évaluation des options de politiques de « développement durable ».

(ii) Les modèles multicritères d'impact régional, que Geier *et al.* tentent de développer à partir du cas des pêcheries en Alaska en essayant de déterminer l'impact socio-économique global de nouvelles politiques. Ce concept a été également utilisé ailleurs et notamment dans le cadre du FAM (Five Account Model), qui donnait les bases d'évaluation du réensemencement de salmonidés en Colombie Britannique.

(iii) Des perpectives basées sur la Nouvelle Economie Institutionnelle, mettent l'accent sur l'importance fondamentale des institutions et tentent de dépasser l'hypothèse simpliste de concurrence pure et parfaite. Le point de vue de la NEI est éclairée ici dans deux communications (Failler et Wilson ainsi que Wilson et Lent), alors que Queirolo fera quant à lui allusion au problème d'assymétrie d'information et au rôle qu'elle joue dans l'efficience des choix rationnels. Ces perspectives ne représentent pas véritablement une alternative méthodologique mais plutôt une alternative de vue des concepts classiques de l'économie des pêches (tel que « rent seeking »), soulignant l'aspect multi-dimensionnel de la mesure de la valeur et l'importance de la compréhension des dynamiques propres aux institutions de la pêche et au comportement des pêcheurs.

En conclusion on peut souligner, tout d'abord, que comme pour la plupart des biens environnementaux, ce sont les défaillances combinées de l'information, du marché et des interventions qui soulèvent la plupart des obstacles au principe d'un développement durable (ici une pêche durable). D'un point de vue plus positif, par conséquent, les papiers qui vont suivre représentent un effort significatif visant à :

(i) construire une approche plus large et plus explicite de la détermination de la valeur des ressources, et de l'évaluation des conflits en prenant en compte aussi bien les facteurs externes que les hauts niveaux de variabilité et d'incertitude ;

(ii) réviser et réévaluer les paradigmes classiques de la théorie des pêches et développer les nouveaux paradigmes et nouvelles méthodologies nécessaires.

En effet, en soulignant les objectifs multiples et les usages divers liés à ces ressources nous sommes amenés à prendre du recul par rapport aux modèles classiques pour aller vers des approches plus nébuleuses, plus multidisciplinaires qui représentent un véritable challenge pour la recherche sur les pêches.

poor information, market failures and inadequate management interventions present serious obstacles to the principle of a sustainable development (sustainable fishing activity in this case). On the positive side, however, the papers herein represent a significant effort to:

(i) build a broader and more comprehensive approach to the valuation of resources and the assessment of conflicts taking into account external factors as well as high levels of variability and of uncertainty.

(ii) review and reassess classical paradigms in the fishery theory and develop new paradigms and new methodologies as needed.

By recognizing the multi-objective and multi-use nature of the fishery, we are taken beyond traditional fishery models, into more nebulous, more multi-disciplinary approaches, that present real challenges to fisheries research.

# On Inferior Goods and Giffen Effects in Recreation Demand Analysis

**Douglas M. Larson[a] and Richard S. Johnston[b]**

[a]Department of Agricultural Economics, University of California, Davis, California 95616-8512, USA

[b]Department of Agricultural and Resource Economics, Oregon State University, Ballard Extension Hall 213, Corvallis, Oregon 97331-3601, USA

ABSTRACT

*Time-intensive goods like outdoor recreation are likely candidates for Giffen behavior when money price changes. For choices with binding money and time constraints, observable conditions for a good to be Giffen are developed. Model specifications and omitted variable biases are likely reasons why no Giffen recreation goods have been found.*

## 1. INTRODUCTION

The Giffen "paradox" has long intrigued students of economic theory. Put as a query, the phenomenon of interest is : "All else constant, under what circumstances will it be true that the quantity of a good demanded will move in the same direction as its price, thereby violating the first law of demand ?" The conventional explanation for Giffen behavior, in the neoclassical theory of consumer choice subject to a constraint on money income, relies on unusually-shaped preference. The strong inferiority of a good outweighs the negative substitution effect, so that the real income increase produced by a fall in its price results in a decline in its consumption. This story for the possible "existence" of Giffen behavior at the individual level has generally been dismissed as remote (George J. Stigler ; John R. Hicks) or "pathological" (Eugene Silberberg and Donald A. Walker) ; furthermore, William R. Dougan has argued that one cannot expect to find the behavior at the market level, as it is ruled out by the Walrasian stability conditions.

Recently interest in the phenomenon of Giffen behavior at the individual level has been renewed by both empirical evidence and theoretical developments. Raymond C. Battalio et al. reported the first experimental confirmation of Giffen behavior, in studies of the behavior of "poor" rat consumers. Otis W. Gilley and Gordon V. Karels (GK hereafter) developed a theoretical framework that provides an explanation for Giffen behavior consistent with the experimental

evidence. They showed that the presence of a second (minimum) constraint on consumption required for sustenance leads to Giffen behavior when both constraints are binding, because the consumer's response to a price increase consists only of an income effect. Both of these papers sound the same theme of the earlier literature, though : Giffen behavior is a relatively rare phenomenon, confined to poor consumers who have limited choice among staple items.

This paper's purpose is to suggest that Giffen behavior may be much more common than either the recent papers or earlier literature suggest, if only we know where and how to look for it. To develop this argument, we consider consumption of a commodity more common to consumers in rich, well-developed countries rather than in poor, less-developed ones : outdoor recreation.

A focus on outdoor recreation is useful for several reasons. First, outdoor recreation usually involves travel to a site distant from home, and consumption of the good itself involves spending time at the distant site ; thus, the time-intensiveness is a characteristic often associated with outdoor recreation. This illustrates well the case of consumption subject to two binding upper constraints, on time and money, rather than one upper (money) and one lower (nutrition) constraint as GK used. The idea that time constrains choice is well-developed in economics (e.g., Gary Becker ; Anthony DeSerpa). Both casual observation and empirical research point to the fact that in today's society many people wish they had more free time and more total time ; an example is a recent study which found "...almost half of American workers say that they would give up a day's pay to get an extra day off" (John P. Robinson).

A second reason for the focus on outdoor recreation is that its time-intensiveness makes recreation a commodity especially likely to exhibit Giffen behavior. Third, finding evidence that outdoor recreation may be Giffen puts the lie to the contention that Giffen behavior is most likely among poor consumers. Finally, because it is a nonmarket good, the Dougan argument concerning impossibility of the behavior in the aggregate is moot since recreation is not traded in markets within which Walrasian stability conditions must hold. Thus, we argue that not only is Giffen behavior potentially much more widespread than currently believed, but also that there is nothing to prevent it from being observed in the aggregate when the good in question is not marketed.

Having demonstrated the plausibility, indeed perhaps even the likelihood, of recreation giving rise to Giffen behavior, we turn to the empirical question of why such behavior has not been reported at all in the literature. While part of the reason is undoubtedly the strong self-selection against publishing such "unusual" results, we provide an econometric explanation for this absence of results confirming Giffen behavior for recreation. Despite long recognition of the importance of time in recreation choices, most empirical models in the literature are one-constraint models, explaining recreation trips as a function of money prices and budget, either because the time parameters are omitted or because a priori reasoning is used to collapse the two constraint problem into a single constraint problem. In either case, the likely effect is to mask possible Giffen behavior or to render the model incapable of testing for it. Thus existing empirical evidence in the recreation demand literature is largely unable to address the question of whether recreation is a Giffen good.

## 2. THE CHOICE MODEL

Consider an individual who allocates scarce time and money income in choosing consumption of three goods x, y, and z in order to maximize the utility function u(x, y, z). Each of the goods i, i=x, y, z, has a money ($p_i$) and a time ($t_i$) price of consumption, both of which are parametric to the individual, and the total amount of money income and time available are M and T, respectively. Given the focus of this paper, it is useful to think of x (and sometimes y) as a recreation good, such as trips of a fixed duration to a recreation site. It is necessary to incur both money and time costs of gaining access to recreation areas outside the home, and for recreation goods the time price is likely higher relative to the money price than for most other goods. For many non-recreation goods, the time price of consumption is low in relation to the money price, though some time must be spent in all consumption. Both constraints are assumed to bind throughout the analysis.

The constraints for the general model are written

$$M = p_x x + p_y y + z \qquad \text{(money)} \tag{1}$$

$$T = t_x x + t_y y + t_z z \qquad \text{(time)} \tag{2}$$

where the constraints are taken to be independent in order to have a two-constraint model, and both have been normalized over the money price of z, $p_z$. The choice problem is

$$\max_{x,y,z} U(x,y,z) \qquad \text{s.t. (1), (2)} \tag{3}$$

which yields (Marshallian) demands of the form $x^* = x(\alpha)$, $y^* = y(\alpha)$, $z^* = z(\alpha)$, where for notational convenience is the vector of all parameters of the problem : $\alpha = (p_x, p_y, t_x, t_y, t_z, M, T)$.

Consider an equivalent, indirect representation of the problem which first optimizes out the consumption of good z and then considers the remaining choice of x and y given the (prior) choice of optimal z. This version of the problem is useful because, by properly accounting for how the optimal choice of z conditions the feasible choice set for x and y, the optimal choices of x and y are apparent immediately in x-y space from the intersection of the two conditional constraints. This simplifies the visual understanding of relationships between goods in the two-constraint model and how they interact to give rise to inferior and Giffen good effects, without direct reference to the preference map.

Substituting $z^*(\alpha)$ obtained from (3) above into the preference function, and noting that the time and money available for choice of x and y are reduced because of the choice of $z^*$, the choice problem can also be written as

$$\max_{x,y} U(x,y,z(\alpha)) \quad \text{subject to the conditional budgets} \tag{4}$$

$$M_{xy} \equiv M - z^* = p_x x + p_y y \tag{5}$$

$$T_{xy} \equiv T - t_z z^* = t_x x + t_y y \tag{6}$$

Since the constraints are independent, a single x-y combination solves the conditional problem (4) since there are two unknowns and two equalities to be satisfied. The solution to this problem yields conditional demands of the form

$$x = \hat{x}(p_x, p_y, t_x, t_y, M_{xy}, T_{xy}) \tag{7}$$

$$y = \hat{y}(p_x, p_y, t_x, t_y, M_{xy}, T_{xy}) \tag{8}$$

which are identical to the unconditional demands that solve (3). That is, the same first order conditions hold for the conditional choice functions $\hat{x}(\cdot)$ and $\hat{y}(\cdot)$ in (7) and (8) and for the unconditional $x(\alpha)$ and $y(\alpha)$ that solve (3). In particular, no separability assumptions about preferences are required to obtain (7) and (8), unless z is treated as a composite commodity[1]. However, by solving the conditional budget constraints for $\hat{x}(\cdot)$ and $\hat{y}(\cdot)$, a convenient visual depiction of comparative statics results.

Figure 1 gives the visual setup for analyzing the comparative statics of changes in goods x and y. The two conditional budget constraints, $M_{xy}$ and $T_{xy}$, represent possible allocations of money and time expenditure between x and y, conditional on the optimal choice of the third good, $z^*$. The optimal choices of x and y, $x^*$ and $y^*$, are identified by the intersection of the two conditional constraints ; there is no need to introduce the preference map to find them. As opposed to the standard analysis, though, both conditional budgets depend on all parameters of the problem, so each will shift when any parameter changes.

### *2.1 Classifying Time- and Money-Intensive Goods*

As a preliminary to comparative statics, some relationships that prove important to the analysis of the two-constraint model are developed. The first is the notion of whether a good is relatively more time- or money-intensive in relation to other good(s), which is determined by the relative slopes of the time and money budget lines for pairs of goods. Good x is time-intensive relative to good y if the ratio of its time to money price is higher ; i.e., if

1. In general, if there were degrees of freedom for choosing $\hat{x}$ and $\hat{y}$ (as would be the case, for example, if there were only one constraint instead of two), they would also depend on $z^*$ directly as it affects the shape of the preference map, in addition to its indirect effect through M and T ; that is, $x = \hat{x}(p_x, p_y, t_x, t_y, z^*, M_{xy}, T_{xy})$ and $y = \hat{y}(p_x, p_y, t_x, t_y, z^*, M_{xy}, T_{xy})$. However, since the conditional budgets solve directly for $\hat{x}$ and $\hat{y}$, there is no opportunity for variations in z to affect the choice of x and y when the conditional budgets are fixed.

$$\frac{t_x}{p_x} > \frac{t_y}{p_y} \tag{9}$$

x is relatively more time-intensive than y[2]. Figure 1 is drawn so that x is time-intensive relative to y, in keeping with the interpretation of x as a recreation good and y and z as other non-recreation goods.

Two other characteristics of the time-intensive (x) and money-intensive (y) goods can be noted from Figure 1. Good x is referred to as *time-constrained,* because

$$\frac{M_{xy}}{p_x} > \frac{T_{xy}}{t_x}; \tag{10}$$

that is, the maximal quantity of x feasible under the (conditional) time budget is less than under the money budget, given the relative money and time prices of x. Similarly, good y is termed *money-constrained* because

$$\frac{T_{xy}}{t_y} > \frac{M_{xy}}{p_y}, \tag{11}$$

and the conditional money budget relative to money price is more binding on maximum y than is the conditional time budget.

## 3. CONDITIONS FOR THE TIME-INTENSIVE GOOD TO BE GIFFEN

By solving the two constraints (5) and (6), the conditional demands $\hat{x}$ and $\hat{y}$ can be written as

$$x = \hat{x}(p_x, p_y, t_x, t_y, M_{xy}, T_{xy}) = \frac{\frac{T_{xy}}{t_y} - \frac{M_{xy}}{p_y}}{\frac{t_x}{t_y} - \frac{p_x}{p_y}} \tag{12}$$

and

$$y = \hat{y}(p_x, p_y, t_x, t_y, M_{xy}, T_{xy}) = \frac{\frac{M_{xy}}{p_x} - \frac{T_{xy}}{t_x}}{\frac{p_y}{p_x} - \frac{t_y}{t_x}} \tag{13}$$

where the pre-conditioned optimal consumption of z enters through the conditional budgets $M_{xy} \equiv M - z^*$ and $T_{xy} \equiv T - t_z z^*$. Equations (9)-(11) imply that the numerators and denominators in (12) and (13) are all positive.

Consider a *ceteris paribus* change in $p_x$. The effects on consumption of x can be separated into a direct effect, holding z constant, and an indirect effect as $z^*$ adjusts given the new level of $p_x$ and both conditional budgets shift. The direct effect, from (12), is

2. Using the same logic to define the notion of relatively money-intensive, it follows immediately that if x is time-intensive relative to y, y is money-intensive relative to x, since (9) can also be written as $(p_y/t_y) > (p_x/t_x)$.

$$\left.\frac{\partial x}{\partial p_x}\right|_z = \frac{x/p_y}{D_y} > 0\,, \tag{14}$$

where $D_x \equiv (t_x/t_y - p_x/p_y) > 0$ is the denominator of the expression for x in (12), and is positive by (9). This is illustrated in Figure 2, where initial consumption is $(x_0, y_0)$ at the intersection of the conditional budgets $M^0_{xy}$ and $T^0_{xy}$. As the price of x falls, the direct effect is given by the counterclockwise rotation of the money budget from $M^0_{xy}$ to $M^*_{xy}$ ; consumption of x falls to $x_1$ while consumption of y increases to $y_1$. The intuition behind this is that as the price of the time-intensive good, x, increases, its relative time-intensiveness decreases, so that more is demanded. If the indirect effect is small relative to this direct effect, consumption of x will tend to increase with an increase in own price. The indirect effect, as changes in z* cause $M_{xy}$ and $T_{xy}$ to adjust, is

$$\left(\frac{\partial x}{\partial z}\cdot\frac{\partial z}{\partial p_x}\right) = \frac{\dfrac{-t_z\dfrac{\partial z}{\partial p_x}}{t_y} - \left(\dfrac{-\dfrac{\partial z}{\partial p_x}}{p_y}\right)}{D_x} = \frac{\left(\dfrac{1}{p_y} - \dfrac{t_z}{t_y}\right)\dfrac{\partial z}{\partial p_x}}{D_x}\,. \tag{15}$$

In Figure 2 this is the shift in budget lines from $M^*_{xy}$ and $T^0_{xy}$ to $M^1_{xy}$ and $T^1_{xy}$, respectively, which induces a further shift in consumption to $(x_2, y_2)$. Thus the indirect effect depends on whether x and z are Marshallian substitutes or complements (i.e., on the sign of $\partial z/\partial p_x$) and on whether z or y is the more time-intensive (i.e., on the sign of $(1/p_y - t_z/t_y)$. Recalling that $p_z \equiv 1$ and using (9), $(1/p_y - t_z/t_y)$ is positive (negative) if y is more (less) time-intensive than z. Thus, several sets of sufficient conditions for x to be Giffen can be identified from (14) and (15). They are

a) x and z are substitutes ($\partial z/\partial p_x > 0$) and y is more time-intensive than z

$$\frac{1}{p_y} - \frac{t_z}{t_y} > 0\,;$$

b) x and z are complements and z is more time-intensive than y ; or

c) z is strongly separable from x and y in the preference function ($\partial z / \partial p_x = 0$) ; or

d) y and z are equally time-intensive.

If either (a) or (b) holds, both the direct and indirect effects of the change in $p_x$ are positive, reinforcing the Giffen effect ; while for (c) and (d), the indirect effect is zero.

The time-intensiveness conditions are easily checked in applied studies from knowledge of the parameters (prices and budgets) an individual faces and their optimal consumption quantities [3]. The substitution relationship between x and z is a matter of conjecture, but a reasonable hypothesis would be that x and z are substitutes. The same intuition that explains the positive own-price response through the direct effect for x also suggests this. The increase in money price of the time-intensive good x also decreases the money-intensiveness of the money-intensive good, z ; therefore one could expect an increase in z, implying $\partial z / \partial p_x > 0$.

Condition (c) is a special case of the general analysis where z doesn't change as parameters concerning x and y change ; this corresponds to the two-good analysis of the GK paper. Condition (d) is another special case where changes in expenditures on z and y exactly offset each other as the price of x changes, so the indirect effect is zero and x is Giffen because of the positive direct effect. This corresponds to the comparative statics analysis of the three-good case in the GK paper[4]. While restrictive, this condition is useful in identifying generic commodities likely to exhibit Giffen behavior

3. In particular, because of the normalization over $p_z$, $p_z = 1$ and $t_z = (T - T_{xy})/(M - M_{xy})$ ; these can be compared with $p_y$ and $t_y$ to determine whether y or z is more time-intensive.

such as outdoor recreation, which is particularly time-intensive. For example, if all other goods are of approximately equal time-intensiveness, condition (d) indicates that outdoor recreation will be a Giffen good regardless of its substitution relationships with those goods, because of its greater time-intensiveness.

### *3.1 Observable Sufficient Conditions for x to be Giffen*

Directly observable, and weaker, sufficient conditions for x to be Giffen can be expressed by taking account of relative magnitudes of both the direct and indirect effects. This eliminates the need to appeal to intuition about the changes in the third good z as prices of x or y change.

The largest possible reduction in x through the indirect effect is $x^{min} - x$, where x is the initial quantity and $x^{min}$ is the lowest possible consumption of x given prevailing relative prices and budgets. Thus, we seek the conditions for which

$$\frac{x/p_y}{D_x} + (x^{min} - x) > 0 ; \tag{16}$$

and if these hold, x is necessarily Giffen.

Note from (16) that if $(1 / p_y) > D_x$ x is necessarily Giffen, since quantities of all goods are taken to be positive initially and $x^{min}$ is non-negative[5]. A little algebraic manipulation reveals that this is an easily checked condition : $(1/p_y) > D_x$ implies that

$$t_x/p_x < (1 + 1/p_x)\, t_y/p_y . \tag{17}$$

This is the condition on relative prices implicitly assumed by GK when they graphically illustrated the three good case and argued that "consumption of potatoes necessarily rises" when the price of potatoes increases (p. 186). The remaining case to be investigated, therefore, is where $(1/p_y) < D_x$.

The value of $x^{min}$ is determined by, and will vary with, the relative prices and the budget constraints for the problem. Consistent with the earlier discussion, consider, for example, three goods for which the following relative prices and budgets apply :

$$\begin{cases} \text{x is time constrained } (M/p_x > T/t_x) ; \\ \text{y and z are money-constrained } (M/p_y > T/t_y,\ M > T/t_z) ; \text{ and} \\ t_x/p_x > t_y/p_y > t_z . \end{cases} \tag{18}$$

Using (1) and (2) to write y and z parametrically in terms of x,

$$z = \frac{t_y\, p_y \left\{ \frac{M}{p_y} - \frac{T}{t_y} \right\} - \left\{ \frac{t_y}{p_y} - \frac{t_x}{p_x} \right\} p_x\, x}{t_z \{t_y/t_z - p_y\}} \qquad \begin{matrix} \{-\} \quad \{-\} \\ \\ \{+\} \end{matrix} \tag{19}$$

and the signs of the terms, given in braces, are implied by conditions (18). The signs on the numerator of (19) imply that a minimum for x is given by z = 0 :

4. Though they don't address the issue directly, for GK's statement that when the price of potatoes increases, "consumption of potatoes necessarily rises" (p. 186) to be correct without qualification requires that there be no change in potato consumption as the consumer substitutes among meat and their third good (x in their analysis) along the line segment AD. They are referring to the direct effect only in this passage.

5. This can also be expressed as $t_x /t_y < p_x/p_y + 1/p_y$ ; but also, by assumption $P_x /p_y < t_x/t_y$, so the two conditions together are $p_x /p_y < t_x /t_y < /p_x\ p_y + 1/p_y$. Thus, if x is only slightly more time-intensive than y, x is necessarily Giffen for this case.

$$x^{min} = \frac{t_y p_y \left\{ \frac{T}{t_y} - \frac{M}{p_y} \right\}}{p_x \left\{ \frac{t_x}{p_x} - \frac{t_y}{p_y} \right\}} \tag{20}$$

Using (20) in (16), with some rearrangement, gives

$$x \frac{(1/p_y) - D_x}{D_x} > - \frac{p_y \left\{ \frac{T}{t_y} - \frac{M}{p_y} \right\}}{D_x},$$

which leads to an upper bound on the quantity of x that implies x is Giffen :

$$x < \frac{(p_y / t_y)T - M}{D_x - 1/p_y} \quad \text{when} \quad D_x - 1/p_y > 0. \tag{21}$$

Conditions (17), (18), and (21) are easily checked from data on relative prices and budgets, and eliminate the need for conjecture about the relationship between x and the third good z. In this particular case, only prices of the two primary goods of interest (x and y) alone are needed. Conditions such as (17) and (21) will vary with the actual price relationships among goods, but are easily derived. Table 1 presents a summary of observable conditions which imply that a good is Giffen with respect to money price changes.

### *3.2 Outdoor Recreation As a Potential Giffen Good*

The preceding analysis demonstrates that time-intensive goods seem especially likely to exhibit Giffen behavior with respect to money price changes, when both constraints bind[6]. One of the key features which distinguishes outdoor recreation from other goods is the prominence of time in decisions concerning its consumption. Indeed, its consumption is often denominated in time units (days or hours spent at a site), and plays an important role in its cost as well because outdoor recreation is typically consumed at sites distant from the home. Thus, trips to engage in outdoor recreation (the x in the present model) usually require a substantially higher commitment of time relative to money than do other consumption goods, so outdoor recreation is relatively time-intensive.

A couple of examples of the model's predictions will help to illustrate the point. Suppose that x is an outdoor recreation activity such as a day hike in the nearby woods or mountains, or a day at the park downtown ; this is a relatively time-intensive activity. Let y and z be indoor activities such as housework and indoor recreation. Because y and z both require housing services, they are approximately equal in money-intensiveness and are more money-intensive (less time-intensive) than x. Because of their equal money-intensiveness, the indirect effect of a change in $p_x$ is zero because $(1/p_y - t_z/t_y)$ in (15) is zero ; thus an increase in the money price of the outdoor recreation (because, say, of an increase in gasoline prices) should, all else equal, lead to an increase in trips to the woods or local parks.

As a second example, suppose that x and y are two types of outdoor recreation activities, with x representing trips to the beach and y being a relatively expensive outdoor activity such as hot air ballooning, glider flying, or backcountry skiing ; z is consumption of all other goods. Beach-going is the good x in the analysis since it is more time-intensive than ballooning (y), and both are more time-intensive than z. It is likely that x and z are substitutes, since an increase in the price of a beach visit reduces the money-intensiveness of z relative to x and leads to more of z being consumed.

6. Likewise, the money-intensive good is especially likely to have a positive response to changes in its time price, though this effect has not traditionally been labeled "Giffen."

According to condition (a) in section II, the amount of beachgoing one does will also increase as the money price of a beach visit increases[7] ; the quantity of ballooning will decrease and purchases of all other goods will increase.

## 4. WHY HASN'T A GIFFEN RECREATION GOOD BEEN FOUND ?

The foregoing analysis shows that time-intensive goods appear to be especially susceptible to being Giffen goods ; that in response to an increase in own money-price (own time-price and all else constant), an increase in consumption should be observed for at least some time-intensive goods. Given this bold prediction, and the fact that outdoor recreation offers a prominent example of time-intensive goods, one might well ask, Why it is that no evidence of Giffen behavior in outdoor recreation has been reported ? [7]

One reason is that no recreation demand studies in the empirical literature have yet fully implemented the demand models implied by the choice problem (3)[8]. While recent empirical recreation demand models are more comprehensive and sophisticated than those in earlier studies, data limitations have usually prevented the estimation of separate time and money price and time and money budget effects on the demand for recreation.

A substantial literature recognizes that omission of time prices from estimated outdoor recreation demand functions will lead to a downward bias in the estimated money price parameter. This has two consequences, the first of which is widely recognized : that consumer's surplus associated with the good will be underestimated (Clawson ; Knetsch ; Cesario).

The second consequence is of particular interest to the question of uncovering Giffen behavior for recreation goods. If x is a Giffen good, its true money price coefficient is positive. However, the downward bias in the estimated money price coefficient will reduce its statistical significance, or even change its sign (from positive to negative) ; the effect, in either case, will be to mask the Giffen behavior.

The recognition of the first consequence of omitting time parameters has led to a number of suggestions about how to value travel time, in order to collapse the two-constraint problem into a standard, one constraint problem. This usually results in an empirical specification of the following type :

$$x_i = \hat{\alpha} + \hat{\beta}(p_i + k w_i t_i) + \hat{\delta} M_i + v_i , \tag{22}$$

where $w_i$ is the individual's wage rate and k is a fraction between 0 and 1 (Cesario ; McConnell and Strand ; Smith et al. SEJ ; Bockstael et al.). The justification for these specifications is that the individual is making a labor-leisure choice which identifies an observable exogenous parameter as the value of time.

These specifications are essentially incapable of testing for Giffen behavior because they impose the a priori assumption that the own-time price and own-money price effects are of the same (usually negative) sign. By differentiating (12) with respect to $t_x$, it can be seen that if x is Giffen with respect to changes in $p_x$, it will most likely have opposite signs on the money- and time-price coefficients : positive for the former and negative for the latter. Thus, imposing the assumption in (22) that time and money price have the same sign (through the common $\beta$ ) virtually rules out the prospect of finding Giffen behavior.

To sum up, the reason no empirical evidence of Giffen recreation goods has yet been found is that existing empirical estimates of recreation demand are based on estimation frameworks that, because of omitted variables or a priori reasoning, are not sufficiently flexible to enable the behavior to be observed.

7. The only examples we have found in the published literature of positive own-price elasticities is in the paper by Smith et al., who report positive own-price elasticities for two of 22 ordinary least squares estimates of recreation demand models ; neither is statistically significant at the 5 % level. The authors do not suggest that Giffen behavior is responsible for these results.

8. The best empirical study to date is the work of Bockstael, Strand, and Hanemann, who estimate utility-theoretic demand functions for recreation that depend on both time and money budget parameters. They obtained a significant negative own-time price effect, which is expected for time-intensive goods (see (16)), and a negative (but very small in magnitude) own-money price effect which, in their specification, is tied to the (statistically insignificant) money income effect. Because three parameters are estimated for the two price and two money effects, their study does not appear to offer any evidence one way or the other regarding possible Giffen behavior.

## 5. CONCLUSIONS

Giffen behavior, i.e., an increase in quantity of a good demanded in response to an increase in its money price, may well be more widespread than is currently believed, if only we know where and how to look for it. To make this point, we develop a general three-good model where choices are made subject to money and time constraints, and show how the optimal choices can be conveniently represented graphically in two-space by analyzing an equivalent conditional choice problem. We develop easily-checked sufficient conditions for a good to be Giffen, involving relative time-intensiveness and budgets.

The intuition behind the results lies in the notion of time- and money-intensiveness : as the money price of the time-intensive good increases, its *time-intensiveness decreases,* and this tends through the direct effect to lead to a substitution toward the time-intensive good to achieve the highest possible level of utility. Analogously, increases in the own time-price of the money-intensive good leads to an increase in its consumption : a Giffen-like phenomenon with respect to time.

Given the suggestion that time-intensive goods such as outdoor recreation may be prone to Giffen behavior, the question of empirical verification arises. Virtually no published study has come up with a positive own-money price coefficient, with a couple of statistically-insignificant exceptions. However, the specifications estimated in existing recreation demand studies are not capable of reflecting such behavior, for reasons either of variable omission or a priori judgments about the nature of the individual's decision problem.

Perhaps the framework and results in this paper will stimulate a closer look at the empirical possibilities for finding Giffen behavior in recreation demand and other commodities for which choice is made subject to multiple constraints.

## REFERENCES

**Battalio R.C., J.H. Kagel and C.A. Kogut** (1991). "Experimental Confirmation of the Existence of a Giffen Good." *American Economic Review,* September 1991 : 961-970.

**Becker G.** (1965). "A Theory of the Allocation of Time," *Economic Journal,* September 1965 : 493-517.

**Bockstael N. E., I.E. Strand and W.M. Hanemann** (1987). "Time and the Recreation Demand Model." *American Journal of Agricultural Economics,* May 1987 : 293-302.

**Cesario F.J** (1976). "Value of Time in Recreation Benefit Studies." *Land Economics* **52 :** 32-41.

**Clawson M.** (1959). "Methods of Measuring the Demand for and Value of Outdoor Recreation." Washington, D.C. : Resources for the Future, Reprint No. 10.

**DeSerpa A.C.** (1971). "A Theory of the Economics of Time," *Economic Journal,* December 1971 : 828-846.

**Dougan W.R** (1982). "Giffen Goods and the Law of Demand." *Journal of Political Economy,* August 1982 : 809-815.

**Gilley O.W. and G.V. Karels** (1991). "In Search of Giffen Behavior." *Economic Inquiry,* January 1991 : 182-189.

**Hicks J.R.** (1956). *A Revision of Demand Theory.* London : Oxford University Press.

**Judge G.G., W.E. Griffiths, R. Carter Hill, H. Lutkepohl and T.C. Lee** (1985). *The Theory and Practice of Econometrics,* 2nd ed., New York :John Wiley and Sons.

**Knetsch J.L.** (1963).. "Outdoor Recreation Demands and Benefits." *Land Economics* **39 :** 387-96.

**Robinson J.P.** (1991). "Your Money or Your Time." *American Demographics* **13 :** 21-26.

**Silberberg E. and D.A. Walker** (1984). "A Modern Analysis of Giffen's Paradox." *International Economic Review,* October 1984 : 687-694.

**Stigler G.J.** (1947). "Notes on the History of the Giffen Paradox." *Journal of Political Economy,* April 1947 : 152-156.

**Smith V.K and W.H. Desvousges** (1985). "The Generalized Travel Cost Model and Water Quality Benefits : A Reconsideration." *Southern Economic Journal,* October 1985 : 371-381.

**Smith V.K., W.H. Desvousges and M.P. McGivney** (1983). "The Opportunity Cost of Travel Time in Recreation Demand Models." *Land Economics,* August 1983 : 259-277.

**Smith V.K., W.H. Desvousges and M.P. McGivney** (1983). Estimating Water Quality Benefits : an Econometric analysis, *Southern Economic Journal,* Oct. : 422-437.

**TABLE 1.**
**SUFFICIENT CONDITIONS FOR THE TIME-CONSTRAINED GOOD TO BE GIFFEN.**

| Time Intensiveness of x Relative to y | Range where x is Giffen[a] | |
|---|---|---|
| | $t_y/t_z > p_y$ | $p_y > t_y/t_z$ |
| $\frac{t_y}{p_y} < \frac{t_x}{p_x} < (1+\frac{1}{p_x})\frac{t_y}{p_y}$ | all x | all x |
| $(1+\frac{1}{p_x})\frac{t_y}{p_y} < \frac{t_x}{p_x}$ | $x < \frac{(p_y/t_y) - M}{D_x - 1/p_y}$ | $x < \frac{(M - T/t_z)\, D_x}{(t_x/t_z - p_x)\,(D_x - 1/p_y)}$ |

[a]The term $D_x \equiv t_x/t_y - p_x/p_y$, and $D_x - 1/p_y$ is positive when $t_x/p_x > (1+1/p_x)t_y/p_y$.

**FIGURE 1.**
**THE OPTIMAL CHOICE OF X AND Y IN THE THREE-GOOD, TWO-CONSTRAINT MODEL**

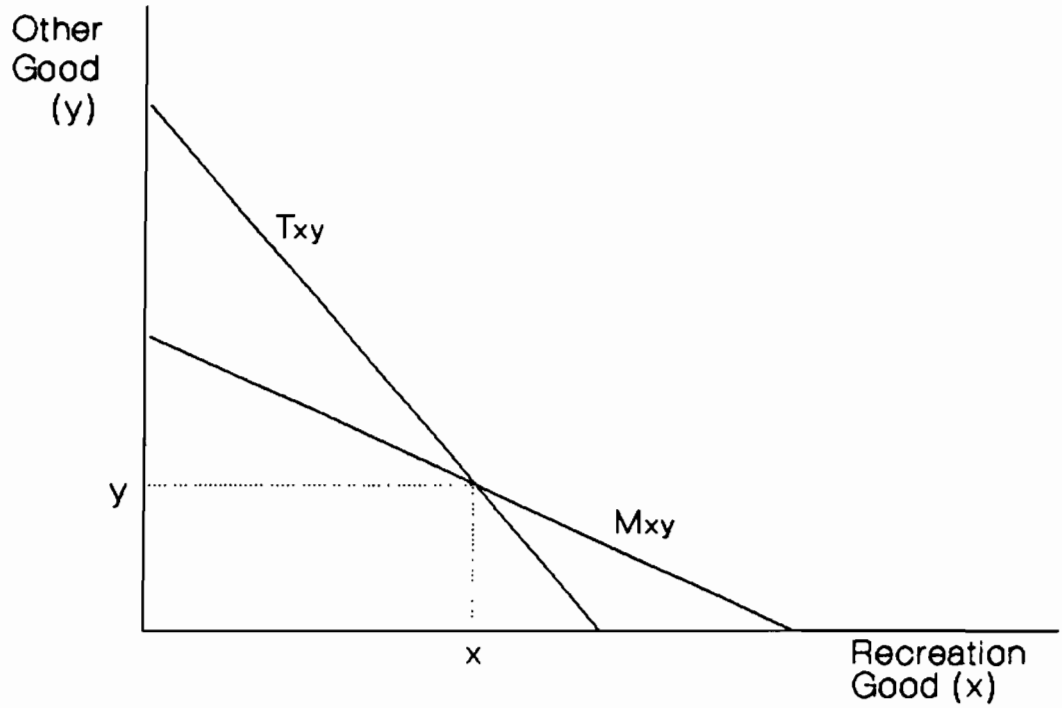
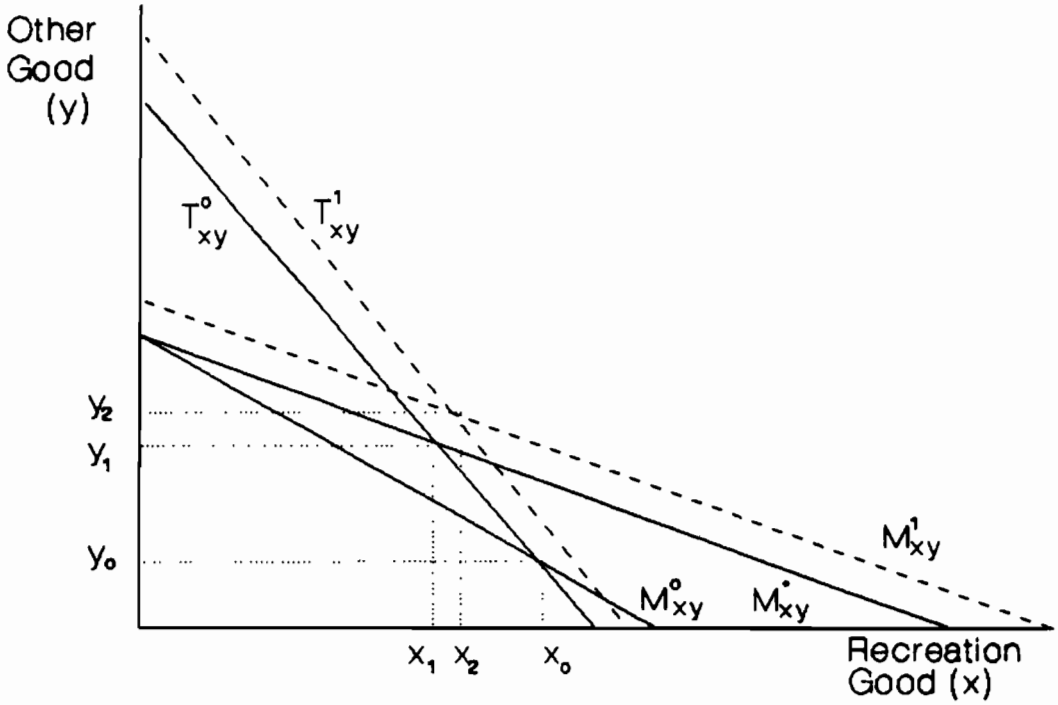



**FIGURE 2.**
**THE TIME-INTENSIVE (RECREATION) GOOD AS A GIFFEN GOOD.**



# International Issues in Valuation of Commercial and Recreational Fisheries

**Richard S. Johnston and Ali Emami ***

Department of Agricultural and Resource Economics, Oregon State University,
Ballard Extension Hall 213, Corvallis, OR 97331-3601, USA

ABSTRACT

*In principle, a competitive economy allocates its resources among conflicting uses such that the marginal net return to any given resource is equal across all uses of that resource. For a fishery resource, this principle has been adopted as a norm against which to judge government policy. While the notion has not gone unchallenged, economists have, largely, accepted its basic premise and, indeed, have devoted considerable effort to the question of how to measure net economic value. Measurement problems have been particularly troublesome where markets do not exist and where externalities are large. In the case of the fishery, for example, there are both conceptual difficulties and corresponding empirical problems. These stem principally from the "open-access" nature of the fishery and the "non-market" nature of the good/service combination produced and consumed in the recreational fishery.*

*These issues are complicated considerably when it is recognized that both inputs and outputs in several fishery sectors are traded in international markets. Not only do measurement problems increase but one is faced with how to make allocation decisions when resulting additions to or reductions in economic value are realized in foreign countries.*

*This paper advances three arguments :*

*i) Events in international markets can have enormous consequences in domestic markets. Attempts to implement the equi-marginal rule may, therefore, require reallocation in response to those events.*

*ii) Failure to recognize interdependencies between international trade policy and resource management may lead to unexpected results.*

* This paper draws heavily on a draft manuscript prepared for A.T. Kearney. The authors are grateful to Steve Edwards for helpful comments on that draft. Discussions with Grant Thompson, Jim Hastie, Lewis Queirolo, and Dave Colpo have also been valuable. Partial support for the research reported here has been provided by the Cooperative State Research Service, U.S. Department of Agriculture (Agreement No. 92-34276-7140) and by the OSU Sea Grant program.

*iii) Whether or not the equi-marginal principle is adopted by fishery managers, it may offer guidance for potentially useful research. For fishery managers, this suggests a better understanding of the markets into which the resources they manage move.*

## 1. INTRODUCTION

According to a generally-accepted principle of economics, a competitive economy allocates its resources among conflicting uses such that the marginal net return to any given resource is equal across all uses of that resource. In welfare economics, this principle has been adopted as a norm against which to judge — or prescribe — government policy. For example, in the case of a fishery resource, Edwards argues that "in order to maximize the total net economic value from using fish for food and sport, an allocation must equate *marginal* net economic values from each conflicting use of the fish stock." (italics in original) (Edwards, p. 20). While use of the equi-marginal principle as the sole prescriptive tool for resource management has not gone unchallenged (Bromley), economists have, largely, accepted its basic premise and, indeed, have devoted considerable effort to the question of how to measure net economic value. Measurement problems have been particularly troublesome where markets do not exist and where externalities are large. In the case of the fishery, for example, there are both conceptual difficulties (e.g., Bockstael and Strand ; Just, et al., append. B) and corresponding empirical problems (Bergstrom, et al.). These stem principally from the "open-access" nature of the fishery — especially, but not only, the commercial sector — and the "non-market" nature of the good/service combination produced and consumed in the recreational fishery.

These issues are complicated considerably when it is recognized that both inputs and outputs in several fishery sectors are traded in international markets. Not only do measurement problems increase but one is faced with how to make allocation decisions when resulting additions to or reductions in economic value are realized in foreign countries.

This paper advances three arguments :

iv) Events in international markets can have enormous consequences in domestic markets and, hence, may importantly affect the relationship between fish landings and marginal net economic value. Attempts to implement the equi-marginal rule may, therefore, require re-allocation in response to those events.

v) Failure to recognize interdependencies between international trade policy and resource management may lead to unexpected results. Collaboration between fishery managers and trade policymakers may reduce this problem.

vi) Whether or not the equi-marginal principle, as a norm, is adopted by fishery managers, who must consider political and other "non-economic" criteria, assuming that it does, at least as a first approximation, may offer guidance for potentially useful research.

None of these arguments sounds particularly profound or insightful. The principal contribution of the paper, however, is to suggest a framework within which trade and natural resource issues can be considered simultaneously.

## 2.. THE MODEL

We begin with a diagram, first proposed by Schaeffer, depicting the growth of a stock of fish over time. In Figure 1, the size of the stock, measured on the vertical axis, follows a sigmoid curve, increasing initially at an increasing rate, followed by a growth pattern along which the stock approaches a maximum, F*, (the "carrying capacity" of the stock's environment) asymptotically. This is only one of several models of how a fish stock grows but it is commonly used by both biologists and fishery economists and, in any event, provides all of the ingredients needed for the present discussion.

Bioeconomic models begin with a formulation such as that of Figure 1. From there policy makers can design "socially optimum" exploitation strategies : fishing patterns over time that maximize the net present value of the resource (Clark). These optima are highly sensitive to assumptions about the relevant interest rate, fishing costs and demand patterns. Recent extensions have examined the issue in the context of a multi-species fishery and have introduced elements of uncertainty (e.g., Kirkley and Strand).

The model of this paper is offered in a similar spirit. In particular, the early bioeconomic model is modified to permit the coexistence of both a commercial and a recreational fishery on a given stock and to allow sales of the commercially-harvested fish in both domestic and international markets. In the paper we make a simple point: occurrences in international markets may place enormous pressure on fishery managers to change allocations to the recreational sector. This is not an unexpected result, although there are a few surprises en route to its development.

The argument can be most easily demonstrated through expanding on an analytical model developed by McInerney and later used by Just, et al. Its highly simplified assumptions permit the use of two-dimensional graphs and allow the simultaneous consideration of market and resource management issues. Use of the model in any practical setting would, of course, require much more complexity than is employed here. Nonetheless, the model does generate useful insights and suggests testable hypotheses.

The model looks at only two time periods. This means that, from the many dates represented on the horizontal axis in Figure 1, only dates $t_0$ and $t_1$ are considered. That is, in the first period, the economy has the option of harvesting all, some, or none of the stock, whose size then is $F_0$. Any amount of $F_0$ not harvested can grow at the rate g (the slope of the line connecting $F_0$ to $F_1$ in Figure 1 is $1 + g$) and becomes available for harvest during the second time period. Looking at the issue this way obviates the necessity of distinguishing between stocks and flows : stocks are reduced by harvest and increased by growth, both flow measures. The analysis begins with only a commercial fishery and a domestic market.

Figure 2 is a four-quadrant diagram depicting supply and demand conditions for fish from this stock in each of the two time periods. In the upper right quadrant, $MCB_0$ measures the marginal social benefits associated with different levels of commercial harvest during the current period, $t_0$. It can be thought of as a "general equilibrium" demand curve at the ex-vessel level, assuming no externalities in the markets for fish, other than those reflected in prices. The area under this curve embraces all of the consumer and producer surpluses along the market channel to the final consumer, except for the producer surplus associated with commercial harvesting this period. This last surplus is reflected in $MXC_0$, which is the marginal cost of harvesting ("extraction") in the current period. It represents the additional costs of harvesting associated with catching larger and larger quantities of fish, out to a maximum harvest of $F_0$, the stock size in $t_0$. It has a positive slope, reflecting the presence of "highliners" in the commercial fleet and the decline in the catch per unit effort with increased harvests.

The curve labeled $AXC_0$ depicts the average costs that fishermen would incur during the current period, at various harvest levels. This curve does not appear in the original McInerney and Just, et al. diagrams, presumably because those authors focus on the user cost issue and not the short run "open access" phenomenon. Curve $AXC_0$ is simply the "average" curve corresponding to $MXC_0$.

At this point it is worthwhile commenting on the slope of the $MCB_0$ curve. In the case of many fish stocks it may be appropriate to think of prices (at all levels of the market channel) as being independent of the level of harvest from those stocks. That is, a given stock may make such a small contribution to the total supply of the species that the volume harvested from that stock has no effect on market price. In that case the $MCB_0$ curve will contain no consumer surplus and its slope will reflect only whatever producer surpluses accrue along the marketing channel.

However, in these days of the "niche-market," such an assumption may be incorrect. In the case of west coast salmon, for example, there appear to be numerous such markets. Buyers of salmon for restaurants in Southern California seldom know the origin of the fish they purchase, especially if the fishing occurs in Alaskan waters, but they demand a consistent quality that processors can supply only from selected runs. Similarly, Columbia River gillnetters report a premium for their fish by delivering directly to smaller fish markets in the Portland, Oregon, area. Some restaurants in the Puget Sound include on their menus the names of the fishermen from whom they buy salmon. Thus, even where the management question pertains to individual stocks, it may not be inappropriate to assume negatively-sloped final demand curves.

Return to Figure 2. In the lower left quadrant, $MCB_1^*$ shows the marginal social benefits of harvesting and marketing different quantities of fish in the second period, $t_1$ ; $MXC_1^*$ shows the marginal extraction costs for those fish harvested in $t_1$ ; and $AXC_1^*$ is the corresponding average harvesting cost. In the upper right quadrant $F_0$ is the size of the fish stock at the beginning of time period $t_0$. If none of $F_0$ is utilized in $t_0$ the stock can grow to $(1 + g)F_0$ by time $t_1$. For ease of presentation, g is assumed to be stock (density)-independent, although the analysis does not rely on this. Thus the line from $F_0$ to $(1 + g)F_0$ in the lower right quadrant represents alternative combinations of $t_0$ and $t_1$ harvests available from the initial stock.

The line in the upper left quadrant has the slope $(1 + g)/(1 + r)$, where r is the appropriate social discount rate between the two time periods. Thus $MCB_1$ in the upper right quadrant is derived "by deflating the marginal social benefit... in the lower left quadrant by the social discount rate of r but then inflating by a rate of g because nonuse of 1 quantity unit at time $t_0$ supports consumption of $1 + g$ units at time $t_1$" (Just, et al., p. 323). The marginal and average extraction cost curves, $MXC_1$ and $AXC_1$, are derived similarly. Note that these curves are drawn independently of the stock size in $t_0$. This is not an inappropriate assumption for processing and marketing costs. It is questionable in the case of fishing costs, however, which are likely to rise as the stock size falls.

Note that no consideration is given yet to the recreational fishery. This is introduced below, as is the international market.

At the "open access" equilibrium in the first period, price $p_0$ would prevail and $\underline{f}_0$ units of fish would be harvested. This is where fishing effort is employed to the point at which the average cost of fish equals the ex-vessel price of fish. Similarly, the open access equilibrium in the second period would yield $p_1$ and $F_0 - \underline{f}_1$, measured in $t_0$ units, (or p measured in $t_1$ units) requiring that no more than $f_1$ be utilized this period. Thus, the available stock of fish in $t_0$, $F_0$, does not permit realization of both open access equilibria. If $\underline{f}_0$ units of fish were harvested in this period, only $(F_0 - \underline{f}_0)$ units would remain to grow in the next period to $f_1^*$.

To correct this externality, the equi-marginal principle discussed earlier is applied, with all costs and revenues being expressed in current dollars and quantities expressed in terms of the available stock of fish at the beginning of the first period. The "social optimum" is obtained by equating the marginal net benefit curves, $MNCB_0$ and $MNCB_1$, for the two periods. These curves are derived as the vertical differences between their respective MCB and MXC curves and express, in current period dollars, the incremental net benefits, after accounting for all costs but including any consumer and producer surpluses along the market channel, associated with different levels of harvest. As depicted, the "social optimum" is found at harvest levels of $f_0^*$ and $f_1^*$, with corresponding prices of $P_0^*$ and $P_1^*$ for the first and second periods, respectively. (A more complete model would, of course, consider more than two periods.)

## 3. INCLUDING A RECREATIONAL FISHING SECTOR

This model can be expanded to include consideration of a recreational fishery. In the following discussion, however, the distinction between the MXC and AXC curves is dropped. While the distinction is important, it is not needed to make the intended points and dropping it simplifies the diagrams enormously. Further, the distinction is not used by either McInerney or Just, et al. Thus we move from considering "open access" equilibria to considering "free market" equilibria in which only current benefits and costs are considered (i.e., user costs are ignored) but where other fishing externalities are not considered explicitly. Such an equilibrium is found at the intersection of the benefit and cost curves for the current period.

Figure 3, then, retains the MCB and MXC curves of Figure 2 and adds three new curves : $MNRB_0$, MNRB and $MNRB_1$. The first of these is the "general equilibrium demand" for recreational fishing on this fish stock in the current time period, net of the cost of fishing. Curve MNRB is the counterpart curve for recreational fishing that occurs in $t_1$ , with $MNRB_1$ being its translation into current period dollars and fish stocks. These, then, are "marginal net recreational benefits" curves. By using them, some elements of the open access nature of the recreational fishery are ignored, as in the commercial fishery. Nonetheless, the primary insights are retained. One significant limitation of the analysis, however, is the assumption of independence of the commercial and recreational fishing sectors in both demand and cost of harvest. Recognizing such interdependencies would be important for empirical work in any fishery but would add unnecessary complication to this discussion.

If the fishery is not managed to obtain the "social optimum," the "free market" commercial catch in this period is $f_0$ (determined by the intersect of $MXC_0$ and $MCB_0$). Now, however, there is also a current period harvest of $\underline{Rf}_0$ in the recreational fishery. At these levels, an even more insufficient stock of fish is left for harvest by the two user groups in $t_1$.

With fishery management, the social optimum is achieved at the intersection of $MNV_0$ and $MNV_1$, where each MNV curve is the horizontal sum of its corresponding MNRB and MNCB curves. At this point the "marginal net economic values from each conflicting use of the fish stock" are equal (Edwards, p. 53). To achieve this result, the fishery managers

will design instruments that result in a total harvest of $f_0^*$ in $t_0$. This consists of $f_0$ units of fish being harvested by the commercial fleet at the price of $P_0^{'}$ and a recreational catch of $Rf_0$. This permits a total harvest of $f_1^{''}$ units of fish in $t_1$, consisting of a commercial harvest of $f_1^*$ units at the price of $P_1$ in $t_0$ dollars (or $P_1^*$ in $t_1$ dollars) and a recreational catch of $Rf_1^*$.

This result will change in response to a change in the interest rate, r. This period's harvest, both commercial and recreational, are favored with a higher r. Similarly, if g were to increase or if $F_0$ were larger — perhaps through fishery enhancement programs — more fish would be available. The cost of programs that increased either g or $F_0$ would have to be considered in deriving the new optimum. And, of course, any change in a variable that affects one or more of the marginal benefit and marginal cost curves may also shift that optimum.

Expanded by more appropriate representations of the relevant biological and economic relationships, this kind of model underlies the goals articulated by economists with a normative orientation. Much of the fishery economics literature, then, has focused on how well various policy instruments can do to realize these goals. Tax schemes, subsidy schemes, various quota arrangements, and limitations on inputs are among the policy arrangements considered and, in some cases, implemented.

One set of policy instruments has, in general, not been considered : those that focus away from the ex-vessel level and on conditions in the markets for seafood (or other fish/shellfish product) elsewhere in the market channel, including the wholesale and retail levels. If there are monopoly or monopsony elements at one or more of these levels and if this is not recognized in the design of management policies, the desired objective may be far from realized. With some exceptions (e.g., Bradley ; Capalbo and Howitt ; Clark and Munro) this issue has received little attention in the literature. Perhaps the reason for this is that, in many cases, as indicated above, a given stock of fish supplies only a small portion of a market so that price is invariant with respect to the level of harvest on that stock. Thus, no matter what policy is adopted by fishery managers, it is assumed that there will be no effect on price, irrespective of the structure of the market.

For many fishery management decisions, however, such an assumption cannot be sustained. Because of the contribution of Alaska pollock to world groundfish, including surimi, markets, decisions in that fishery could affect prices and the product forms into which the fish is processed and marketed. When allocation decisions among gear types and user groups affect the entire West Coast salmon fishery, market effects may be significant. "Market niche" arguments are presented above. In all such cases market structure and pricing behavior along the market channel will affect the nature of the MCB curves and could complicate their estimation.

Thus, decisions at various stages of the market channel may change the "optimal" levels of harvest and allocation among gear types and user groups. One particular set of decisions merits attention because of the large potential impacts on resource utilization and because such decisions are often made with no consideration of those impacts. These decisions fall under the general heading of "international trade policy." Policies designed to promote exports or to restrict imports may have consequences for resource use that steer utilization away from its "optimal" level. Consequently, resource managers may find that their policies run counter to those adopted by trade policy-makers. This is an issue that may be especially important to coastal nations that, since extending their fishery jurisdiction, find themselves in possession of a resource capable of generating significant benefits through expanded exports.

## 4. INTERNATIONAL MARKETS

Elements of the interdependencies between trade policy and resource utilization are depicted in Figure 4. The principal difference between this figure and Figure 3 is that a trade sector has been added. In the upper right quadrant the needed (appropriately transformed) curves from the lower left quadrant are shown. The trade sector is represented by (1) the perfectly price-elastic line emanating from $p_{w0}$ in the upper right quadrant, reflecting the opportunity to export F at that price in the current period and (2) the perfectly price-elastic line emanating from $p_{w1}$ in the lower left quadrant, reflecting the opportunity to export fish at that price in the next period. The "export demand" curves are assumed to be perfectly price-elastic under the assumption that fish from this stock compete with so many others in international markets that they have no effect on price. As suggested above, this assumption is unrealistic for many managed fisheries in the U.S. and, thus, it is dropped in the later discussion.

The addition of export opportunities can change both the temporal and user group allocations. In the case depicted, the new optimum is found where the AMNV curves for the two periods intersect in the upper right quadrant. These "aggregate marginal net value" curves are the MNV curves augmented by the benefits that can be realized by exports. As before, both curves are expressed in terms of current period dollars and fish stocks.

The socially optimum levels of the model's variables in $t_0$ and $t_1$ are respectively shown as $\hat{f}_0$, $\hat{f}_1$ for total harvest, as $f_0^{\#}$, $f_1^{\#}$ for the commercial harvest, as $rf_0^{\#}$, $rf_1^{\#}$ for the recreational catch, as $X_0^{\#}$, $X_1^{\#}$ for total domestic utilization, and as $(\hat{f}_0 - X_0^{\#})$, $(\hat{f}_1 - X_1^{\#})$ for exports.

Note that the desired commercial harvest level in the current period, in the absence of management would be at a higher level than with management ($f_0^0$). Even without, when added to the desired recreational harvest, it exceeds the total stock of fish available in $t_0$ and, thus, nothing is left for period $t_1$. With explicit consideration of the stock and crowding externalities (so that the open access equilibrium would be determined by average, not marginal, cost curves) the divergence would be even more exaggerated.

Now consider the impact of an export enhancement program imposed in $t_0$ only on the optimum allocation. The results are depicted in Figure 5, where "s" is a subsidy per unit of F exported. The "social optimum" is obtained at the intersection of the $AMNV'_0$ and $AMNV_1$ curves, where the (') indicates that the $AMNV_0$ curve is adjusted to reflect the reduction in social benefits that accompany the subsidy program. For the particular circumstances depicted, the optimal allocation does not change. While exporters realize a gain in their incomes, domestic consumers experience losses in consumer surplus. Beyond this, payment of the subsidy imposes a welfare loss on the taxpayers of this exporting country in $t_0$.

If the $AMNV_0$ curve was not adjusted to reflect these losses, and if, instead, fishery managers used the subsidized export price in calculating domestic social benefits, the resulting "optimum" corresponding to the intersection of $AMNV_0$ and $AMNV_1$ could significantly deviate from that described in the previous paragraph. Note, also, that the export enhancement program exacerbates the "open access" problem in an unmanaged fishery ($f_0^{\#}$). Indeed, in this case, the activities of commercial harvesters in the current period would leave nothing for harvesting during the later period.

On the other hand, this diagrammatic presentation also suggests that trade policy can be used to augment fishery management. If a country is an importer of F or of close substitutes for F, subsidizing those imports should reduce the demand from domestic stocks, at least for the commercial product. In the case of an unmanaged fishery, the result could be a net increase in net social welfare, even when the cost of the subsidy is included. Whether or not there will be such an increase is, for any particular fishery, an empirical question. In any event, it is clear that there are interdependencies between trade policy and fishery management policy. An understanding of the policies of one sector by the policy-makers in the other should reduce frustrated expectations for both.

Similarly, there are good reasons for fishery managers to be sensitive to changes in the policies of trading partners. A country that subsidizes its exports of seafood may generate results comparable to those of resource management in the importing country. A similar role may be played by countries that restrict imports of seafood from exporters. It is interesting that, for goods produced under conditions of strong property rights and few externalities (e.g., agricultural products), such practices by trading partners would be viewed as operating against domestic interests. In the case of an unmanaged resource at home — or one that is costly to manage — they may, instead, serve to benefit the country against which the policies are, or are intended to be, directed. In any event, fishery managers can certainly justify keeping informed of developments in the international arena.

## 5. DISTRIBUTION OF GAINS

Suppose the fishery in question is an important supplier of fish in the international market and that, therefore, the export demand, instead of being perfectly price-elastic, as in Figure 4, is negatively sloped. How would this affect the socially optimum allocation of fish between periods and among user groups ? At first glance, it would appear that the added dimension could be treated in a fashion similar to the situation in which the domestic consumer demand is negatively-sloped. Indeed Edwards provides a clear demonstration of how this can be accomplished, illustrating how consumer surplus can be accommodated in a general equilibrium ex-vessel demand equation (Edwards, Appendix C).

However, such surplus is assumed to accrue to domestic, not foreign, consumers. In international trade theory, efficient resource allocation calls for maximum global benefits, not distinguishing among producers and consumers with respect to place of residence. However, if a country is large enough in world markets to affect its terms of trade, it may be possible to devise an "optimum tariff" that generates net benefits to the importing country. Similarly, a policy that gives zero weight to the well-being of foreign consumers may yield a domestic "social optimum" similar to that resulting from the assumption that the exporting country was practicing monopoly pricing (although in a many-commodity world, this would have to be modified to include the role of "surpluses" in other markets and the possibility of retaliation by trading partners, either directly or indirectly).

In their discussion of general equilibrium demand curves in the presence of international markets, Just et al. suggest treating world prices of traded goods as exogenous variables, indicating that "...conditioning of supply and demand estimates on external prices of traded goods will result in measuring equilibrium welfare for only the constituents of the economy in question" (Just et al., p. 208). In the case of a negatively-sloped export demand curve, however, this begs the question, since the world price itself is affected by the domestic allocation policy. Once again, it is clear that trade policy decisions and resource allocation decisions are not independent.

In addition, some inputs used by the fishing industry may be imported and, thus, associated producer surpluses may leave the country. How are such surpluses to "count" in calculating the social optimum ? And the same question arises when substitutes for the domestic product are imported from abroad and when the domestic country is a significant importer of these substitutes, able to affect world prices by its actions.

Finally, it must be observed that many fishery management decisions are made with regional interests in mind. Thus, the above discussion of the role of international markets could be extended to include the role of consumer and producer surpluses that accrue to individuals outside of the management region. In such cases, again, knowledge of markets may be helpful to fishery managers.

## 6. INCREMENTAL DECISION-MAKING

The discussion to this point has dealt exclusively with "either/or" decisions : either the fishery is managed to be at the "social optimum" or it is not. In fact, most fishery management decision-making processes are of a much more incremental nature ; that is, most decisions are designed to adjust seasons, landings, etc., in response to changing conditions, such as health of the stock, oceanographic conditions, and the like. In such cases, it is tempting to argue that because effects along the market channel are likely to be small they can be ignored. Ex-vessel prices, then, can be assumed to be constant and costs and benefits of management changes can be estimated by calculating their likely impacts on revenues to commercial fishermen and recreational benefits to sports fishermen and women.

A difficulty with this argument is that decisions along the market channel are also made "at the margin," so that even small changes can have market impacts. This is particularly true in the case of those fisheries in which an important product is fresh seafood. Management decisions that affect the stability of supply may dramatically affect prices, especially if there are seasonal patterns in consumer demand. Recent analysis of the Japanese market for seafood, an important market for U.S. exports, suggests that there is a significant seasonal component to demand there.

Similarly, allocation among gear types may importantly determine product form and the market segments to which the product travels. For the Pacific Fishery Management Council of the U.S., this has been a central issue in allocating coho and chinook salmon among troll and net fishermen.

Many management decisions are made in response to changes in biological conditions. Some of these, including restrictions on mesh size or on location of fishing activity, may determine sizes of individual fish supplied to the market and, in the extreme, may lead to supplying those sizes and qualities demanded least, with corresponding effects on prices.

These are a few examples of how incremental management decisions in a fishery may have significant marketing impacts that importantly affect the economic well-being of the various user groups. Analogously, it is possible for relatively "small" marketing decisions to have enormous resource use impacts and, hence, to create a need for changing allocation decisions by fishery managers. A famous U.S. example is that of a popular Louisiana restaurant whose chef developed a recipe for blackened redfish that enormously increased the demand for red drum from the Gulf of Mexico. The result was tremendous pressure on red drum stocks that led to indefinite closure of the commercial offshore fishery.

Clearly, even for incremental changes, decisions made at the various market levels, including international markets, may have significant impacts on variables of interest to fishery managers. Similarly, adjustments in fishery management that appear to be relatively minor may have market impacts which, in turn, feed back to those variables — especially, prices — of interest to fishery managers. Application of the equi-marginal principles outlined above provides guidance regarding the information it is necessary to have in order to predict the likely consequences of management/policy changes.

## 7. RECOMMENDATIONS

This reasoning leads to three sets of recommendations :

i) Fishery managers may benefit from being aware of what is occurring in the markets for the resources they are managing. This includes an understanding of factors affecting supply and demand conditions for seafoods and other products produced from the relevant fish stocks, as well as an appreciation of the institutional/market structure within which market decisions are made.

ii) Fishery managers and those involved in trade (and, perhaps domestic market) policy may benefit from working together as they design and use management/policy instruments. Such collaboration may reduce the incidence of unexpected consequences. Similar benefits may accrue to researchers. Specialists in fishery management and specialists in international seafood trade could benefit from cooperation, a point made with respect to natural resource issues in general at a 1987 meeting cosponsored by the U.S. Department of Agriculture and Resources for the Future (Sutton ; see also Ervin and Tobey).

iii) Much more needs to be known about seafood markets. While the U.S. has a long history of research on the characteristics of domestic and foreign markets for agricultural products, seafood markets are poorly understood. Techniques used to understand markets in the agricultural sector have been used successfully in conducting research on the markets for seafood. This could profitably be expanded. There is much to know about seafood demand, pricing strategies, market structure, and supply factors.

## REFERENCES

**Bergstrom J.C., J.R. Stoll and A. Randall** (1989). Information Effects in Contingent Markets. *American Journal of Agricultural Economics* **71** (3) : 685-691.

**Bockstael N.E. and I.E. Strand** (1985). Distributional Issues and Nonmarket Benefit Measurement. *Western Journal of Agricultural Economics* **10** (2) : 162-169.

**Bradley P.G.** (1970). Some Seasonal Models of the Fishing Industry. In A.D. Scott (editor), *Economics of Fisheries Management : A Symposium* : 33-46. Institute of Animal Resource Ecology, The University of British Columbia. Vancouver, Canada.

**Bromley D.W.** (1977). Distributional Implications of the Extended Economic Zone : Some Policy and Research Issues in the Fishery. *American Journal of Agricultural Economics* **59** (5) : 887-892.

**Capalbo S.M. and R.E. Howitt** (1985). Imperfect Competition and Transboundary Renewable Resources : The Implications for Fishery Control Policies. In *Proceedings of the Second Conference of the International Institute of Fisheries Economics and Trade, Volume 2 : A Compendium of Papers on Seafood Trade and Markets* : 111-125. Oregon State University Sea Grant College Program, ORESU-W-84-001.

**Clark C.W.** (1976). *Mathematical Bioeconomics*. New York : Wiley.

**Clark C.W. and G.R. Munro** (1980). Fisheries and the Processing Sector : Some Implications for Management Policy. *The Bell Journal of Economics* **11** (2) : 603-616.

**Edwards S.F.** (1989). Allocating Fish Stocks Between Commercial and Recreational Fisheries : An Economics Primer. Unpublished. National Marine Fisheries Service, Woods Hole, MA.

**Ervin D.E. and J.A. Tobey** (1990). European Agriculture and Environmental Policies : Sorting Through Incentives. Draft paper. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture.

**Just R.E., D.L. Hueth and A. Schmitz** (1982). *Applied Welfare Economics and Public Policy*. Englewood Cliffs, NJ : Prentice-Hall, Inc.

**Kirkley J.E. and I.E. Strand** (1988). "The Technology and Management of Multi-species Fisheries." *Applied Economics* **20 :** 1279-92.

**McInerney J.** (1976). "The Simple Analytics of Natural Resource Economics." *Journal of Agricultural Economics* **27** (1) : 31-52.

**Sutton J.D.** (editor) (1988). *Agricultural Trade and Natural Resources*. Boulder and London : Lynne Rienner Publishers.

FIG. 1.

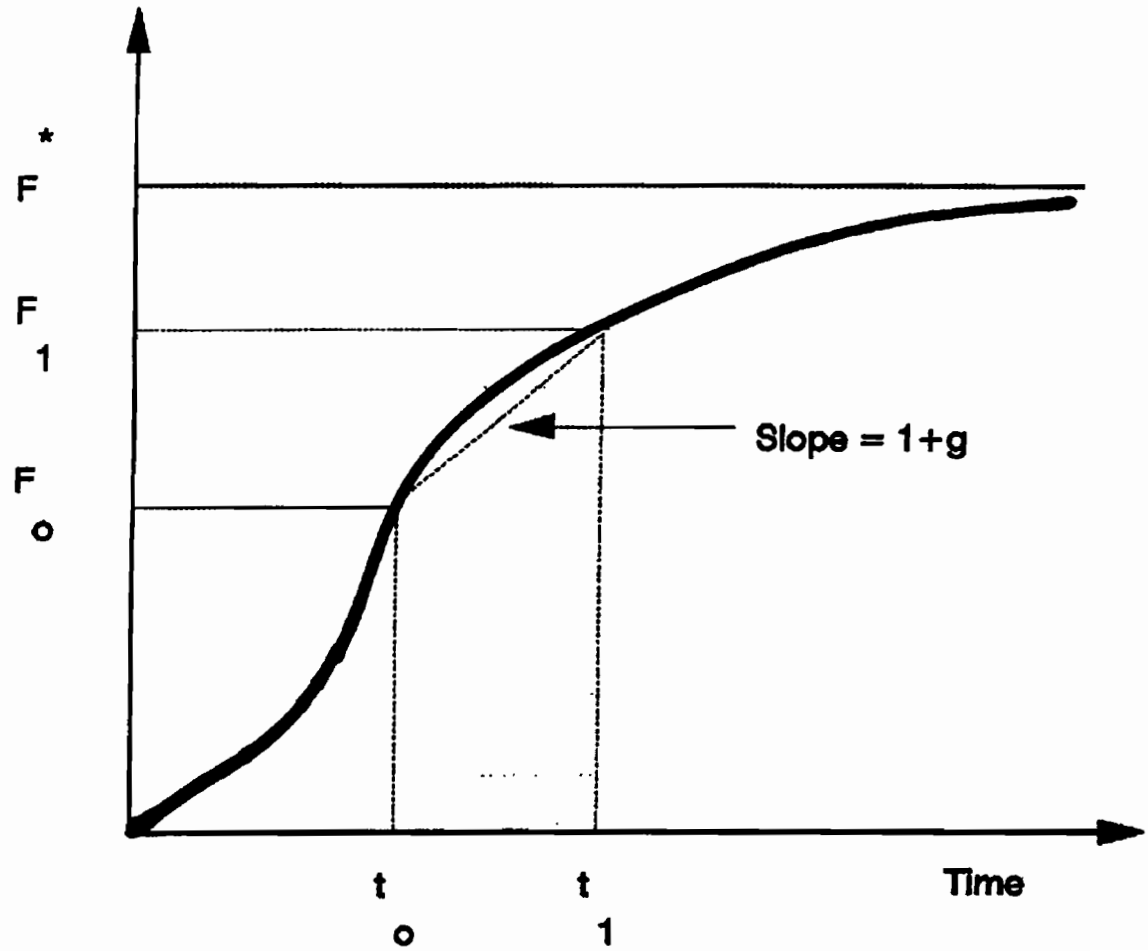


FIG. 2.

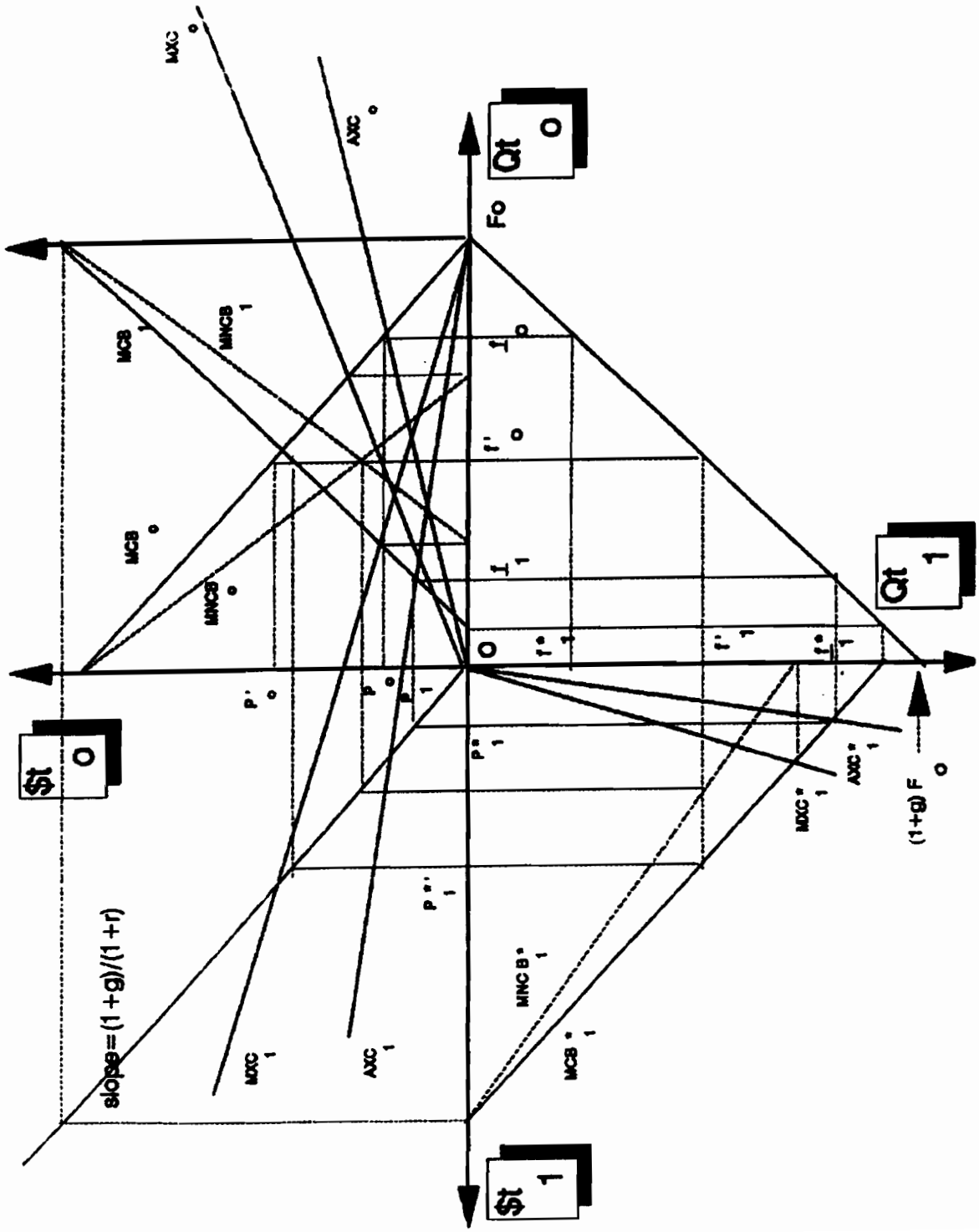

MXC 0
AXC 0
Qt 0
Fo
MCB 1
MINCB 1
MCB 0
MINCB 0
Qt 1
$t 0
$t 1
slope=(1+g)/(1+r)
MXC 1
AXC 1
MINC B* 1
MCB * 1
MXC* 1
AXC* 1
(1+g) F 0

FIG. 3.

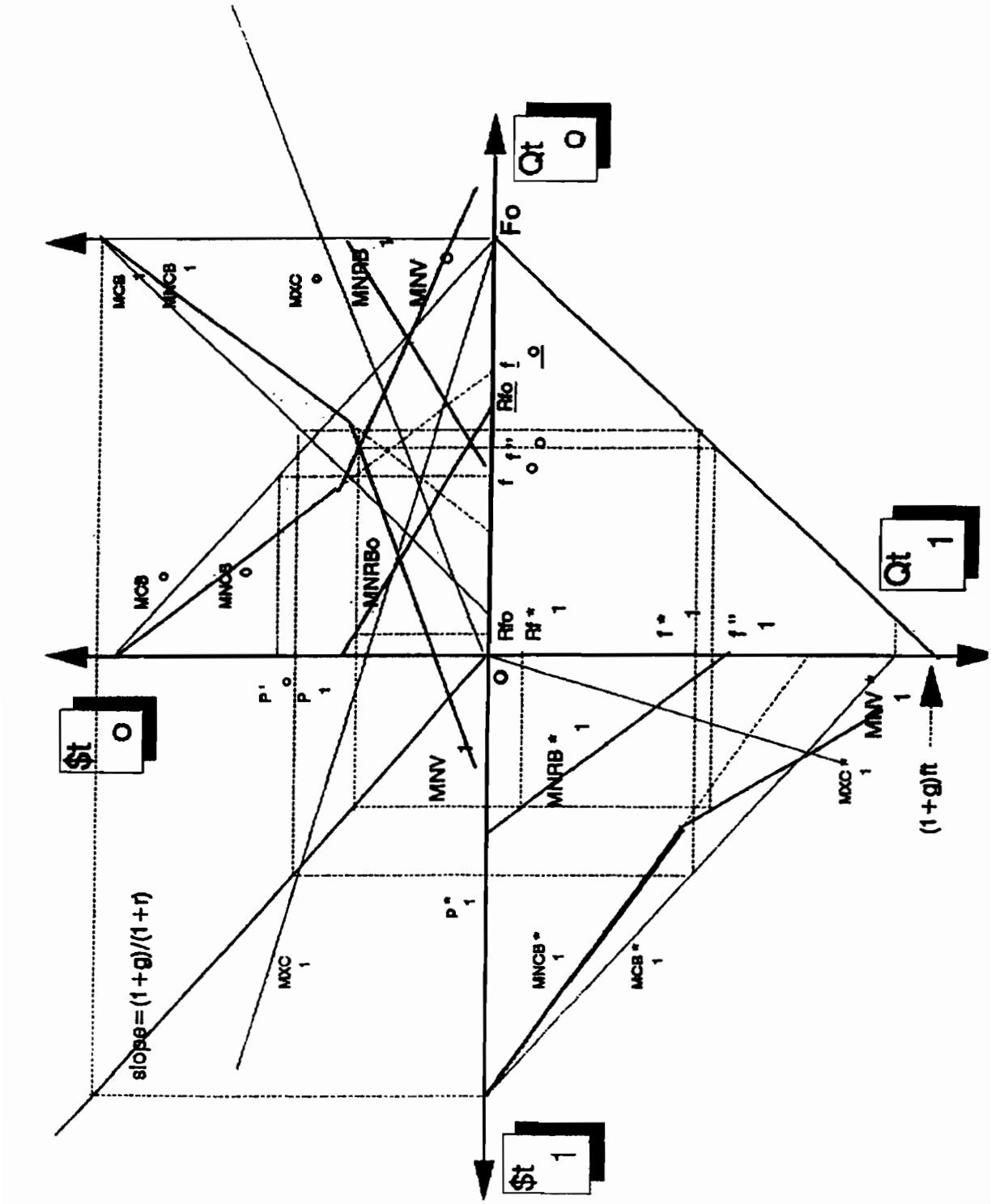

Qt 0
Fo
MCB 1
MNCB 1
MXC 0
MNRB 1
MNV 0
Rfo f 0
f f'' 0 0
MCB 0
MNCB 0
MNRBo
Rfo
Rf* 1
f* 1
f'' 1
Qt 1
$t 0
P' 0
P 1
0
MNV 1
MNRB* 1
MXC* 1
MNV 1
(1+g)ft
P* 1
MXC 1
MNCB* 1
MCB* 1
slope=(1+g)/(1+r)
$t 1

FIG. 4.

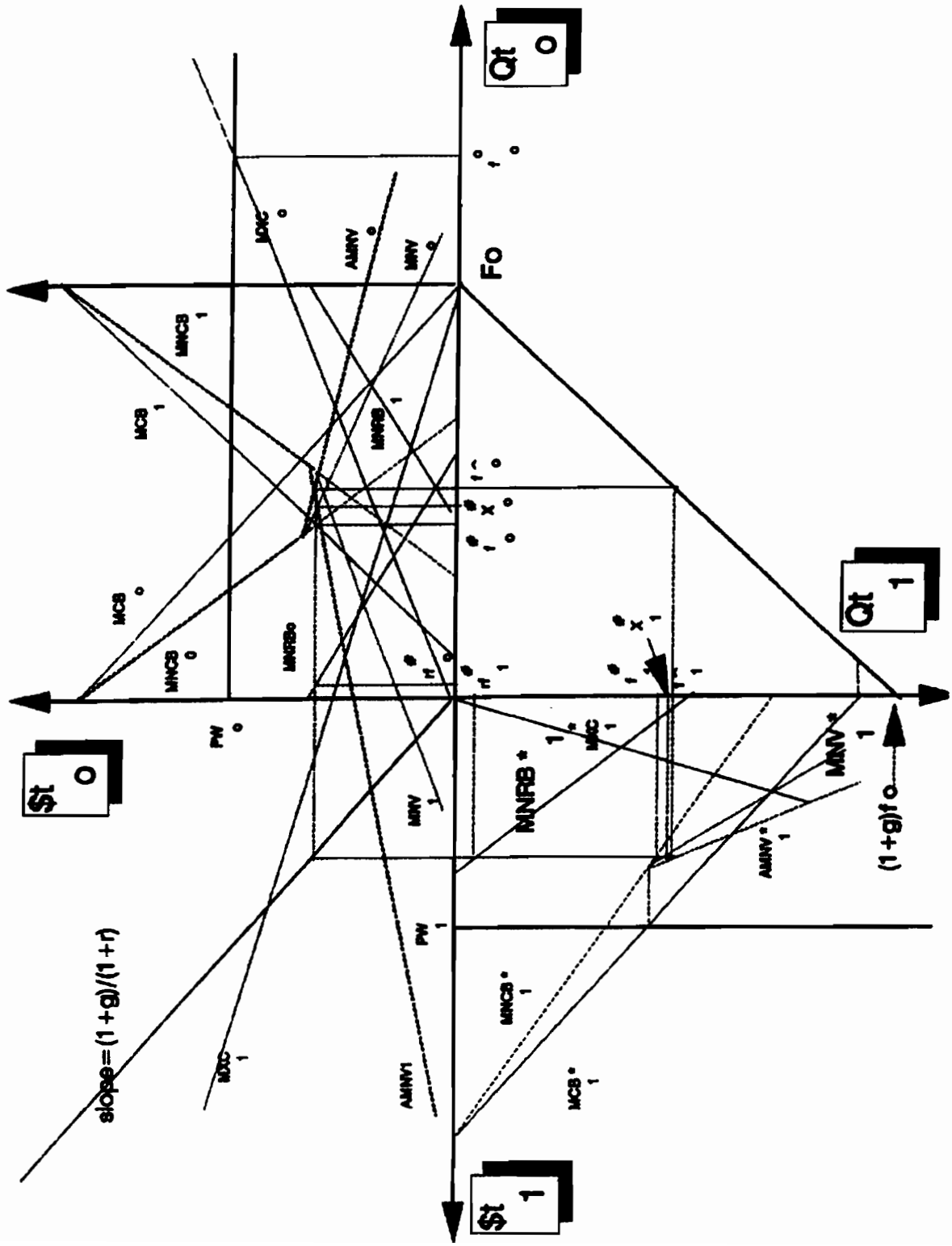
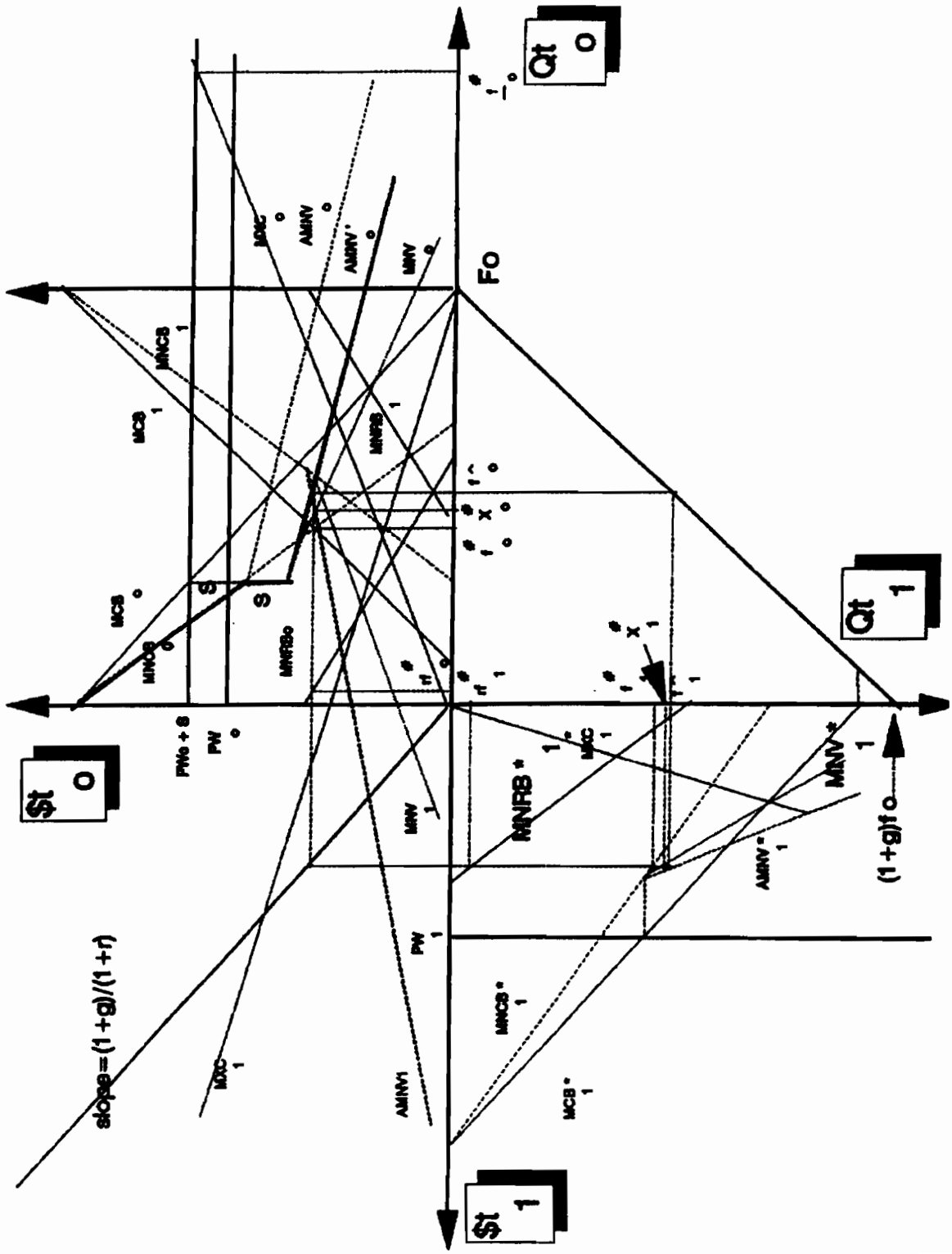

Qt 0
Fo
Qt 1
$t 0
$t 1
MNRB*
(1+g)f o
slope=(1+g)/(1+r)
MMC
AMNV
MNV
MNCB
MCB
MNRBo
PW
MMC*
MNV*
AMNV*
MNCB*
MCB*
AMNV1

FIG. 5.


Qt 0
Fo
Qt 1
$t 0
$t 1
MNRB*
MNV*
(1+g)f o
slope=(1+g)/(1+r)
MCB
MNCB
MNRB
MNV
AMNV
AMNV'
MCC
PW
PW0 + B
S
MCB*
MNCB*
AMNV1
MCC*
AMNV*

# Production Domestique, Absence de Marchés et Marchés Manquants dans les Economies en Développement : Analyse d'Impact de Projet dans le Secteur des Pêches

**Pierre Failler et James R. Wilson**

Département Economie et Gestion des Ressources Maritimes, Université du Québec à Rimouski,
300 allée des Ursulines, 65L 3A1 Québec, Canada.

ABSTRACT

*Cost-Benefit Analysis, like the empirical tool developed in France called Méthode des effets, tend to discount welfare changes arising from non-market or missing market phenomena. Examples in developed economies of such measurement problems, are often found in the environmental resource economics literature on non-market measurement. However, in developing economies, where transactions costs might militate against the formation of explicit markets, the household is often regarded as the principal economic unit. Thus, changes in household production and consumption, which may have no market analog in the neoclassical sense, would reflect both individual and aggregate welfare changes in terms of changing surplus conditions.*

*However, these project evaluation methods are still widely used, for example by the World Bank and the Coopération française, to quantify benefits and costs, and to identify the gainers and losers which result from a given policy, even though it is not clear that these measures capture the economic and social realities observed. In communities where subsistence and non-market activities are evident, resorting to other techniques for impact measurement is necessary.*

*The purpose of this paper is to examine the application of household production theory in conjunction with standard project evaluation technics. The development of such an approach could aid in measuring changes in non-market economic goods held within families and communities. This conceptual approach is studied within the context of Impact evaluation of a small-scale fishery project in the Tanganyika lake district of Zaire. Household-production theory applied to this case places in perspective the implicit measurement difficulties engendered by the assumption of well-functioning markets. A secondary aim of this work is to explore the dynamics of growth and change in household well-being, as a result of proposed development projects.*

## 1. INTRODUCTION

L'aide au développement, amorcée sous forme de projet, doit subir, dans la plupart des cas, une évaluation financière et socio-économique. La théorie néoclassique, construite autour des institutions de marché et d'un système de prix continu, propose à cet égard les concepts de base pour la mesure des changements en bien-être. Mais, cette mesure doit toujours être reliée, de façon directe, à un marché en décrivant une fonction d'offre, et, de demande et de façon indirecte, en établissant un prix fictif pour les marchés manquants et les non-marchés. Auquel cas, on émet les hypothèses appropriées sur : la séparabilité de la fonction d'utilité et de la fonction de production ; la continuité des contraintes de budget ; les conditions de complémentarité entre le marché et le non-marché. Cette approche théorique est largement développée dans la littérature économique qui traite de l'économie des ressources naturelles et environnementales [V. Adamovitz ; 1991] et de l'estimation des marchés parallèles ou *missing market* [(T. A. Cameron ; 1988)(E. L. Feige ; 1990)(J. Gaudin et M. Schiray ; 1984)(M. Penouil ; 1990)].

Dans la plupart des travaux appliqués, les biens non-marchands et les effets des marchés manquants sont considérés comme des phénomènes non-mesurables, du fait de raffinements conceptuels rarement utilisés. L'analyse *coût-bénéfice*, tout comme la méthode empirique développée en France sous le nom de *méthode des effets*, mesure les changements en bien-être provenant des phénomènes marchand, mais ne mentionne que de manière allusive l'existence d'activités non marchandes [(M. Bridier et S. Michaïlof ; 1990)(M. Chervel et M. Le Gall ; 1981)(J. Price Gittinger ; 1985)(L. Squire et G. Van Der Tak ; 1985)].

Malheureusement pour les praticiens comme pour les théoriciens, plus nous utilisons les hypothèses fondamentales du modèle néo-classique, notamment la prédominance du marché, moins crédibles deviennent les mesures. Et ce, malgré la littérature courante faisant état du foisonnement de marchés informels, notamment en Afrique : cet informel à la place du formel présente des problèmes de mesurage. La littérature des Droits de propriété [Coase ; 1960] nous enseigne que les coûts de transactions élevés sont responsables du type de structure des institutions autres que le marché. Ceux-ci peuvent empêcher la formulation de marchés explicites. Les innovations publiques qui doivent normalement réduire les coûts de transaction, se heurtent au problème des ressources (humaines, technologiques, etc.) limitées, et de ce fait ne peuvent assurer un rôle prédominant. Des institutions en marge de ces circuits publics et privés se développent pour assurer la distribution des ressources parmi la population. Les institutions parallèles, où les formes structurelles de famille et de communauté dominent, apparaissent comme des palliatifs à ces carences flagrantes.

En Afrique, la famille peut se concevoir comme une unité économique à part entière, voire comme la principale entité économique [P. Hugon ; 1991]. Aussi les changements dans la production et la consommation domestiques des familles, par définition non marchandes, traduiront-ils les modifications de bien-être au niveau de la structure familiale en terme de changements des conditions de surplus. Cela signifie que les fondements théoriques issus de la mesure du bien-être doivent être capables de traiter de manière cohérente la famille dans un contexte de coûts de transactions très élevés.

Il convient donc de compléter les analyses basées sur la "New Institutional Economics" par les extensions théoriques qui expliquent le comportement des populations concernées. Pour ce faire, la Théorie de Production des Ménages (TPM), comme support théorique, peut se révéler pertinente pour l'appréciation des changements en bien-être. Les modèles de production domestique développés dans les PVD au début des années 80 se sont attachés à examiner les activités agricoles avec en toile de fond les phénomènes d'autoconsommation [(L. Squire et al. ; 1986)(A. De Janvry et al. ; 1990)]. Et cela, bien que la production domestique ait intéressé dès les années 30 les économistes comme S. Kuznets, L. Esptein et d'autres. Néanmoins, trente années s'écouleront avant que celle-ci n'acquière ses premières lettres de noblesse sous l'impulsion des Gary S. Becker, Lancaster... La *nouvelle théorie du consommateur* a mis en évidence un processus de production domestique : à l'activité de consommation des ménages se substitue une activité de production des satisfactions [J. P. Faugère ; 1980]. Cette nouvelle approche combinée aux travaux de T. P. Schultz et R. Pollack sur l'allocation du temps des individus a permis d'appréhender le problème de la mesure de la production domestique dans une optique plus élargie.

Le premier objectif de cette communication est d'utiliser les différentes approches de la théorie économique pour développer des fondements théoriques en vue de mesurer les changements de bien-être dans un contexte de coûts de transaction élevés où la famille joue un rôle dominant.

Nous essayerons ensuite d'explorer les questions relatives à la perception du bénéfice entre les receveurs et les donateurs, et les difficultés de mesurage qu'implique une injection de dollars ou de francs dans un tel contexte. En étudiant, notamment, l'efficience inter-temporelle des projets face à la stabilité du panier de consommation de la famille, même

s'il apparait comme évident que celui-ci change durant la période étudiée [(M. Bridier et S. Michaïof ; 1990)(M. Chervel et M. Le Gall ; 1981)]. Si, à la fin du projet, les infrastructures économiques existantes ne peuvent supporter les nouvelles habitudes de consommation de la population affectée, les impacts à long terme d'une telle initiative de développement se manifesteront par une dépréciation accrue de l'économie.

De plus, les conclusions des analyses de projet se révèlent incomplètes : elles focalisent leur attention sur les seuls aspects financiers et économiques et ne traduisent qu'une relation unilatérale projet-population concernée, sans mentionner la relation inverse population concernée-projet. Le comportement des individus va en effet affecter la vie du projet et donc influencer les résultats financiers escomptés.

Un survol de la littérature touchant les aspects d'évaluation de projet, de production non marchande, de production domestique et de comportement humain révèle une connaissance approfondie dans chacune de ces approches où psychologie et économie s'enrichissent de leur apports respectifs. Une recension a révélé l'absence d'une synthèse des savoirs propres à chaque spécialité pour mesurer les changements en bien-être des populations affectées par un projet. Il va donc sans dire qu'une étude approfondie dans ce domaine, étude qui peut au premier abord sembler marginale, devrait toutefois permettre de combler une lacune et d'améliorer par conséquent les outils de prise de décision pour la mise en place de projets ou de politiques de développement (en particulier dans les PVD).

Le cadre de référence de cet article est l'Afrique, et plus particulièrement la région du lac Tanganyika (Est du Zaïre) où le premier auteur a séjourné pendant l'été 1991 pour recueillir les données nécessaires à la réalisation de l'étude de faisabilité financière et socio-économique d'un projet de pêche artisanale [P. Failler ; 1991]. L'Afrique, de par la complexité de ses structures familiales, communautaires et sociétaires en général, projette une image ambiguë où la rationalité néoclassique perd pied rapidement. Il sied donc d'appréhender ces différentes structures pour comprendre la façon dont elles interfèrent avec la mise en place et la vie d'un projet.

La démarche suivie tout au long de cette communication consistera donc à développer une esquisse théorique sur la famille étendue en Afrique dans l'optique néo-institutionaliste avec comme support la TPM, et ce, dans un effort pour formuler des conclusions concernant la validité des mesures du surplus dans ce contexte d'évaluation de faisabilité de projets. L'approche néo-institutionaliste consiste à tirer ses concepts théoriques des observations faites sur le terrain. Nous commencerons donc par une description de la structure économique et sociale des communautés africaines. La deuxième partie viendra renforcer cette description par une explication théorique des concepts de famille et de communautés villageoise et ethnique, en regard des relations et des contrats qui régissent les comportement des individus entre eux. La troisième partie reprendra, dans un premier temps, les formulations de la firme chez Coase et la notion d'altruisme définie par Becker pour, dans un second temps, tenter d'appuyer sur des fondements théoriques notre perception de la mesure du surplus dans de telles entités économiques.

## 2. DESCRIPTION DES INSTITUTIONS ÉCONOMIQUES DES VILLAGES DE PÊCHE AU BORD DU TANGANYIKA

Le projet de pêche artisanale commandité par le Comité Catholique contre la Faim et pour le Développement (CCFD, Paris) avait pour objectif de former un Groupement d'Intérêt Économique (GIE), où les pêcheurs seraient partie prenante [P. Failler et M. Kamitenga ; 1991]. Ces pêcheurs partagent leur temps entre une pêche de subsistance et une agriculture de même nature. L'agriculture, dans la région bordant le lac Tanganyika, pour 94 % des pêcheurs interrogés par la FAO, constitue une importante source de revenu et seulement 3 % d'entre eux dépendent entièrement de la pêche [K. Leenderste et B. Horemans ; 1991].

Trois localités zaïroises avaient été sélectionnées en raison de leur proximité des meilleurs lieux de pêche et de l'accessibilité de leurs berges : Baraka, Kazimia et Dine. Les observations suivantes ont été recueillies d'après des constatations de visu appuyées par une maigre littérature, produite localement sous forme de rapports d'activité pour le Gouvernement zaïrois. Ces trois localités qui s'apparentent davantage, de par leur population importante, à des villes qu'à des villages présentent cependant les mêmes caractéristiques d'infrastructure que ces derniers. Aucun de ces lieux n'est alimenté en électricité, et seuls Baraka et Kazimia possèdent l'eau courante. Les communications se caractérisent par : un réseau routier difficilement praticable en saison sèche (il faut six heures pour parcourir les quatre-vingt-dix kilomètres séparant Uvira de Baraka) et inutilisable pendant la saison des pluies ; un transport maritime important mais très dangereux en raison de normes de sécurité inexistantes. Un tel système occasionne des coûts très élevés de transport pour les marchandises et les déplacements humains.

Les coûts de transport associés aux profits réalisés par les nombreux intermédiaires peuvent multiplier le prix d'un sac de poisson séché (45 kg) par quatre sur une distance de deux cents kilomètres. En règle générale, on peut mentionner que plus l'on s'éloigne du lieu de production et l'on s'enfonce dans les terres, plus les coûts unitaires par kilomètre parcouru augmentent. Ceci rend très difficile le commerce sur de longues distances et explique, entre autres, l'absence de diffusion de certains produits dans des villages de taille réduite qui ne sont pas situés près des routes principales ou sur le trajet fluvial. Les coûts de transactions ne permettent donc pas à tout un chacun de disposer à sa guise d'un éventail de biens. Le recours à la production domestique s'avère de ce fait une nécessité à laquelle les populations ne peuvent se soustraire.

Un système de phonie qui palie médiocrement l'absence de téléphone assure une liaison minimale entre les autorités des différentes localités de la région. L'absence d'électricité interdit toute information télévisée et limite l'information retransmise par radio. La diffusion de la presse est inexistante : les journaux sont imprimés à Kinshasa (Capitale), située à quelque deux mille kilomètres du Tanganyika. Il est donc clair que, même si le Burundi diffuse sa presse et ses émissions de télévision dans la ville d'Uvira (proche de la frontière), dès que l'on descend vers le sud la propagation de toutes ces informations s'interrompt. Le système d'information dans sa généralité présente donc des déficiences handicapantes pour une région si riche en ressources naturelles [stock halieutique important ; essences précieuses (Teck, ébène, acajou) ; or, diamants et minerais convoités].

La localité de Baraka représente un centre économique dû au simple fait que le transport fluvial alimente deux fois par semaine son marché, principalement en produits de consommation courante comme le poisson, le manioc, l'essence, les médicaments et la bière. Tous les producteurs de poissons séchés et frais viennent de Dime, de Kazimia (au sud) vendre leur poisson aux grossistes venus du nord du lac. Le marché se définit comme le lieu de rencontre des producteurs, des commerçants et des particuliers. Les prix sont, pour le poisson par exemple, fixés en fonction de la qualité, du rapport entre l'offre et la demande, et de l'éloignement par rapport au lieu de production. Les fluctuations sont très fortes dans un intervalle mensuel. L'instabilité des volumes de capture est amplifiée par les mécanismes de marché en vigueur.

Une chute de la production provoque un goulot d'étranglement à l'accès des produits : le nombre de grossistes en présence devient faible, car peu d'entre eux ont les moyens de se fournir à des prix très élevés. Le nombre d'intervenants sur le marché de gros comme de détail étant réduit, le jeu de la libre concurrence ne s'établit pas correctement car le besoin de la population est toujours le même mais avec une disponibilité réduite.

Cette localité qui abrite environ 30.000 personnes (les recensements datent et sont très imprécis) a connu son ère de prospérité sous la colonisation belge, alors qu'il existait des usines de transformation du coton. Il y avait à cette époque, avant l'indépendance du Zaïre en 1960, un réseau routier entretenu, de l'électricité, des stations d'essence, etc.. Aujourd'hui, il ne reste qu'un hôpital, une mission catholique, des écoles de niveau primaire et quelques magasins peu achalandés. Seul le marché bi-hebdomadaire assure à Baraka une dynamique économique qui suffit à lui maintenir un rôle manifeste au niveau régional. La pêche n'est cependant plus qu'une activité de subsistance dans la majorité des cas. Un recensement des unités de pêche zaïroises effectué par la FAO en mai 1991 a révélé une forte diminution de la pêche artisanale au détriment de la pêche coutumière entre 1984 et 1991 (respectivement : -48 % et +32 %).

La localité de Dime présente des conditions plus précaires que Baraka. Elle rassemble une vaste communauté de pêcheurs actifs tout au long de l'année. Les conditions de vie sont véritablement précaires : pas de dispensaire, d'hôpital, de route, etc.. L'unique vocation de ce village réside dans l'activité de pêche artisanale et coutumière. Kasimia offre des conditions moins hostiles mais, hormis une coopérative de pêcheurs et d'agriculteurs, aucune activité industrielle n'est recensée. Elle possède cependant des dispensaires et des écoles. La population d'environ 10.000 habitants en 1988 se concentre autour de l'activité de pêche artisanale.

Quatre ethnies composent la population des nombreux villages qui jalonnent les rives du lac et les localités visées par le projet : les Babembe, les Bavira, les Barundi et les Bachi. La coexistence de plusieurs ethnies dans un même village est courante. On peut cependant mentionner que les Babembe et les Bavira sont les plus nombreux et les plus anciennement implantés. Les Barundi et les Bachi ont commencé à fuir le régime ségrégationniste du Burundi depuis 1971 et se sont installés massivement sur la rive zaïroise [M. Maes et al. ; 1991], non sans heurts avec les communautés des Babembe et des Bavira. Ces derniers vont même jusqu'à constituer 80 % de la population de certains villages. L'appartenance à une communauté est ressentie très fortement par les individus qui, avant toute chose s'y identifient. A l'intérieur de chaque communauté il existe un système de droit qui régit les actions de ses membres. A titre d'exemple, on a pu assister àl'arrestation et au jugement d'un militaire en fonction par les représentants de la communauté des Bavira parce que celui-ci avait volé un cochon à un membre de la même appartenance ethnique que lui ! Le rôle attribué généralement à la police est ainsi substitué par un code de conduite et de répression communautaire qui veille au respect de certaines règles.

On peut s'imaginer à partir de cet exemple l'ampleur du processus communautaire. Il réglemente la vie de ses membres en ne tenant que peu compte du système juridique mis en place par l'état et appliqué par la police locale.

Le système judiciaire, policier, militaire, toute comme l'ensemble des institutions publiques, opèrent une ponction importante sur l'ensemble du système économique, que ce soit au niveau de la circulation des biens marchands entre les différentes zones (délimitation politique des régions) ou au niveau des marchés directement. Au vu de leur salaire, le phénomène de corruption peut trouver une explication : un employé de bureau gagne un dixième du revenu qu'il lui faudrait pour nourrir sa famille ; il faut donc qu'il se procure les neuf dixièmes quelque part ! Le fonctionnaire assimile son travail à un travail de gestionnaire ; il faut en effet qu'il gère au mieux son périmètre de juridiction qui dépend directement de sa fonction et de son grade. Les droits de passage et autres prélèvements se concrétisent par une augmentation sensible des coûts de transaction, ce qui ne fait qu'accentuer la pression sur les familles qui recourent au marché. Les impôts ne représentent qu'une part de plus en plus faible du revenu car ils ne sont pas indexés sur l'inflation depuis 1989 (inflation galopante de 50 %, par exemple, pour le mois de juillet 1991).

La famille, face à de tels coûts, est repliée sur elle-même dans le but de produire les biens qui lui sont indispensables. Le type de famille rencontré dans les localités du projet peut se schématiser ainsi : un tronc composé du pêcheur, de son épouse ou de ses épouses dans les cas de polygamie, de ses enfants, et de branches composées de vieillards, d'inactifs, des proches parents, de leurs enfants, etc.. Ces familles de vingt individus et plus vivent dans un espace très restreint, souvent sous le même toit.

Un recensement effectué dans le cadre du projet de pêche artisanale auprès des pêcheurs a permis de mettre en lumière la nature des revenus, la ventilation des dépenses, et l'identification des personnes qui génèrent un revenu au sein de telles familles élargies. On a pu constater ainsi que le revenu principal provient de l'activité de pêche du chef de famille et que l'activité principale de sa ou de ses femmes est l'agriculture. Les principales dépenses peuvent globalement se ventiler comme suit : achat de biens alimentaires pour 75 % du revenu, acquisition de vêtements pour 15 % et santé pour les derniers 10 % [P. Failler ; 1991].

A partir de cette description sommaire des fonctions des villages, de la place de la famille et de la communauté, il est intéressant d'analyser la nature des relations qui régissent ces deux institutions, maîtresses du paysage social zaïrois et africain.

## 3. OBSERVATIONS PLUS APPROFONDIES DE LA FAMILLE ET DE LA COMMUNAUTÉ

### *3.1 La famille élargie*

Comme il a été souligné ci-haut, le concept de famille ne revêt pas la même signification en Occident qu'en Afrique. En Europe la famille peut se définir comme une cellule nucléaire relativement hermétique, presque exclusivement constituée des deux parents et de leurs enfants. L'Afrique fait éclater ce concept de famille mononucléaire pour apparaître sous une forme plus élargie, où un ensemble de personnes cohabitent sans avoir des liens filiaux ou une parenté directe.

Dans ce contexte de famille élargie, les centres de décisions correspondent rarement aux centres de procréation et peuvent en outre différer des centres de prise en charge [P. Hugon ; 1991]. Les familles sont regroupées autour d'un chef de famille ou de quelques personnes qui garantissent, par leur travail marchand, un revenu monétaire permanent. On peut donc scinder la famille en deux fractions distinctes : le noyau et la périphérie. Le noyau apporte un revenu monétaire qui lui permet d'assumer la prise en charge de la famille périphérique, ce qui lui confère une certaine autorité sur le reste de la famille. En contrepartie, la périphérie consacre le plus clair de son temps à rendre des services divers au noyau et à l'ensemble de la famille. Ces services ou activités assumés par la périphérie sont chronophages. Ils consistent à élever et éduquer les enfants (oncle, grand frère), àassurer le ramassage du bois, les activités de cueillette, etc. On peut, dans ces conditions, attribuer une valeur fictive aux activités assurées par la périphérie, exprimable en termes de temps. Un taux de salaire fictif pourrait être attribué en référence au taux de salaire marchand.

La famille africaine se doit de comporter plusieurs enfants. C'est à la fois un signe de richesse et de bonne santé mais les enfants représentent aussi un capital humain important qu'il convient de faire fructifier. Les enfants sont en effet une

source non négligeable de main d'oeuvre non marchande, disponible au sein de la famille. Mais ils constituent également une forme d'assurance-retraite : les parents seront pris en charge par leurs enfants lors de leur cessation d'activité. On peut rapprocher le comportement des parents avec celui du propriétaire d'un portefeuille de titres négociables. Cet investissement, comme dans un portefeuille d'action, rapporte quelque bénéfice qui, dans notre cas, peut se concevoir comme de la main-d'oeuvre non marchande et un régime d'assurance retraite. Cela suggère que la structure familiale peut être étudiée dans un contexte de *risk management*. Becker (1981) souligne par ailleurs que, dans les familles modernes occidentales, l'investissement en capital humain et non-humain des parents pour leurs enfants se traduit simplement en terme de satisfaction, en fonction entre autres de la qualité des enfants.

### *3.2 La communauté villageoise*

La communauté villageoise gère la vie sociale et économique de l'ensemble des familles appartenant au même groupe ethnique. Cette structure se caractérise par des règles assimilables àun code de conduite communautaire qui apparaît sous les formes suivantes :

- Les individus doivent consacrer une partie de leur temps journalier aux activités communautaires. Ce temps communautaire est voué à la gestion des affaires courantes de la tribu ou du groupe ethnique.
- Un système de donations-obligations régit les relations des individus ou des représentants familiaux avec le reste de la communauté.

Le temps communautaire est pris non seulement sur les temps de loisir mais aussi de travail. Certaines dates, certaines manifestations météorologiques et d'autres événements obligent les individus à ne se consacrer qu'aux seules activités et palabres communautaires [F. R. Mahieu ; 1989]. Le temps communautaire est donc fonction des temps de travail marchand, de travail domestique et de loisir.

Le système de donations-obligations constitue un garde-fou pour l'ensemble de la communauté villageoise ou ethnique. Il assure en effet un rôle de redistribution des ressources des plus nantis vers les plus dépourvus. Cette fonction sociale permet le maintien d'une certaine homogénéité parmi le groupe communautaire. En contrepartie, les individus à la solde de la communauté et donc redevables de sa bienveillance se doivent de fournir du temps pour vaquer aux nombreuses taches communautaires. Les familles doivent s'acquitter de leurs obligations pour être en observance avec la communauté et ne doivent surtout pas y déroger sous peine de s'en voir exclues. Les obligations, en plus du caractère d'entraide incessant, possèdent un caractère ponctuel, notamment, lors des décès, des fêtes, des achats onéreux de certaines familles de la communauté. Les donations, constituées principalement de dons alimentaires, vestimentaires et quelquefois monétaires, sont perçues par les individus les plus défavorisés financièrement.

Les obligations et les donations sont fonction du revenu de la famille, en considérant que les obligations lui sont proportionnelles et les donations inversement proportionnelles.

On peut arguer que ce système communautaire concourt, à l'instar de la famille élargie, à la dissipation de la rente. Les individus qui gagnent les meilleurs salaires se voient affligés d'une famille très nombreuse, proportionnelle à leurs salaires, et de plus, se voient contraints par le système d'obligation de céder une partie de leur revenu à la communauté, sous quelque forme que ce soit, pour entretenir la solidarité. Les individus ayant un revenu monétaire suffisant s'acquittent de leurs obligations en terme de biens incluant des inputs monétaires plus ou moins importants ; les individus défavorisés quant à eux, sont obligés de consacrer leur temps pour se libérer de leurs obligations.

Le temps peut donc s'échanger contre des biens produits par la famille, voire de l'argent dans certaines occasions. On peut sur ce simple fait présager des modifications de la nature des obligations des individus impliqués par un projet de pêche.

Les concepts de famille élargie, de communauté ont permis de dresser un panorama qui ne se veut pas exhaustif, mais qui présente les caractéristiques principales de la société africaine observée. Un des points importants concerne justement la relation entre la famille étendue, la mesure du bien-être et la dissipation du surplus. Cette relation est traitée de façon théorique dans la section qui suit.

## 4. UNE CONCEPTION BECKER/COASE DE LA FAMILLE AFRICAINE

La description précédente du contexte institutionnel de la famille africaine nous a permis de voir clairement la "nature de la famille" dans son contexte. Rappelons-nous maintenant le fameux article de Coase en 1937 intitulé "The nature of

the firm" : de nombreux parallèles semblent surgir entre ces deux institutions. Il est raisonnable d'affirmer que les coûts de transactions limitent le développement du marché dans un tel contexte. L'impact d'un tel développement est double car une part relativement importante des biens de consommation n'est pas achetée mais produite par la famille, ce qui en retour, sur une plus large échelle, limite des occasions d'emploi hors de la famille.

Dans une situation extrême où les coûts de transactions sont très élevés, le commerce entre familles est faible, voire inexistant. Tout le monde se trouve dans une situation de vie précaire proche de l'autarcie. Dans de telles économies de subsistance, la famille peut être assimilée à la firme au sens de Coase, et vice-versa.

Dans l'analyse de la firme par Coase, la première motivation pour créer une telle entité est de réaliser des profits. En formant une organisation, avec une autorité centrale (entrepreneur), la famille se dispense de certains coûts de transactions en évitant le recours au marché [R. C. Coase ; 1937]. Cheung (1983) propose d'autres raisons pour l'émergence d'une firme : division du travail, diminution du risque et coordination des activités de production. De par les hypothèses implicites du modèle néoclassique (information parfaite et absence de coûts de transaction [T. Eggertsson ; 1991]), il ne semble pas évident de justifier l'existence des firmes qui ont pour raison d'être la maximisation des profits, en exploitant l'information imparfaite à la fois à l'intérieur de la firme, et à l'extérieur de la firme au niveau du marché. C'est dans ce contexte d'information imparfaite que le phénomène de quasi-rente existe. Avec un nombre de marchés suffisant, le surplus peut être appréhendé en termes monétaires. Et parce que l'entrepreneur cherche à maximiser sa quasi-rente, celle-ci devient une mesure pertinente du bien-être.

La Nouvelle Économie Institutionnelle, basée sur les travaux de Coase (1937), Alchian (1950) et Cheung (1983) s'intéresse principalement à la logique des arrangements contractuels, entre autres à la question : pourquoi une forme contractuelle domine-t-elle l'autre [T. Eggertsson ; 1991] ? La firme peut se concevoir comme un lieu de connexion des contrats, en fonction de la compétence de l'entrepreneur et des coûts de transaction environnementaux. Cette définition, admise pour les firmes classiques, est aussi vraie pour les autres entités de production organisée. Nous pensons, àcet égard, qu'il est justifié de regarder l'unité familiale du contexte africain comme une forme particulière de firme.

Pourquoi un pont doit-il être construit entre les travaux de Coase sur la firme et ceux de de Becker sur l'altruisme ? Dans une firme typique, comme nous l'avons décrite, l'entrepreneur met en suspens quelques aspects du marché, parce qu'il dirige lui même l'allocation des ressources àl'intérieur de la firme avec des formes de contrats particuliers. Les facteurs de production sont ainsi ordonnés de façon à obtenir une quasi-rente ou une rente, en fonction de la structure de temps. Dans un environnement où les coûts de transaction sont manifestes, les arrangements contractuels ne demandent pas une rigidité aussi soutenue que le marché l'exige pour produire une quasi-rente. Mais l'ensemble de toutes les composantes de la fonction de production doit être déterminé pour placer cette production à un niveau supérieur au coût variable moyen. Dans une firme altruiste, le profit ne constitue pas la forme première de motivation des individus, il est substitué par le maintien des contrats entre les différents facteurs de production. Le raisonnement doit être en fait le même que celui qui est décrit par Becker, mais augmenté de la connaissance suivante : la faible opportunité d'emploi oblige les personnes qui ont un travail à le conserver. Les familles altruistes selon Becker (1981) possèdent plus d'assurance que les autres car elles assurent leurs membres contre les aléas et les vicissitudes de la vie.

Nous pouvons définir une firme altruiste comme une entreprise multi-extrants avec au moins un extrant destiné au marché $m_j$ (j = 1 - k), et un extrant non destiné au marché $Z_i$ (i = 1 - n). Tous les outputs sont produits par une combinaison du temps T et d'argent M. Dans le cas où la firme vend du temps à un taux de salaire w, on peut écrire les deux principales contraintes comme suit :

$$T = T_w + T_n$$

$$M = g(w, T_w)$$

Où $T_n$ est le temps de travail non rémunéré de la firme, $T_w$ le temps de travail rémunéré et w le taux de salaire. La firme va en général vendre plus d'unités de temps rémunéré si w augmente, bien que les coûts d'opportunité de telles ventes croissent. La simplification exprimée dans la formulation $T_w = m_j$ ne met pas en défaut la généralité de l'analyse, $T_w$ étant le seul extrant destiné au marché.

Le facteur $T_n$ est ainsi dirigé dans son activité par le fournisseur de M. En utilisant le cadre théorique de Lancaster/Becker, les $Z_i$ - élaborés par les combinaisons de $T_n$ et M - sont des produits non marchands consommés à l'intérieur de la famille. Par contre, dans un contexte de firme classique ou, dans d'autres regroupements de production, les $Z_i$ sont des extrants marchands, résultats des contrats internes entre le gestionnaire et les facteurs de production. Dans notre cas, les $Z_i$ sont produits de manière interne sous des conditions standard que l'on retrouve dans la théorie Consommateur/Producteur traitant des biens non-marchands : ce qui leur confère des prix fictifs bien définis.

Il semble que dans les nations en développement le népotisme définisse la firme classique et que la subsistance définisse la famille-firme. Les coûts associés aux contrats implicites et forcés au sein de la famille, même avec une parenté éloignée, associés avec l'obligation sociale de redistribution au sein de la famille (altruisme) conduisent à une organisation familiale très large par rapport à que l'on rencontre dans les nations développées.

Nous pouvons introduire, pour objet de présentation, une fonction d'utilité des biens non-marchands $Z_1$ et $Z_2$, pour un niveau minimum acceptable, nécessaire au maintien en vie des individus en question : {Min $Z_1$ ; Min $Z_2$ }. Pour l'intégrité et le réalisme de notre analyse, nous considérons que c'est une "decision-making unit" qui détermine le minimum acceptable standard de consommation, par exemple, de produits alimentaires et d'habillement (ces standards peuvent toutefois différer selon les familles). Considérant un espace où la fonction de production est continue pour les $Z_i$, on peut définir une frontière des possibilités de production. Aux fins d'illustration, supposons que $Z_1$ a nécessité dans sa composition plus d'argent que $Z_2$. L'équilibre initial A (*cf.* figure) suggère que tous les acteurs ont juste de quoi se maintenir dans la firme. La quasi-rente est donc réduite à rien. Supposons maintenant que le taux de salaire horaire $T_w$ subit une augmentation imposée des facteurs externes. Selon les hypothèses énoncées, ceci entraînera un déplacement vers l'extérieur de la frontière de production initiale (nouvelle frontière similaire à celle décrite plus haut). La production de $Z_1$, à forte intensité de capital, augmentera davantage que la production de $Z_2$ qui nécessite plus de travail.

Dans une firme, chaque barrière à la transaction représente des coûts réels ; la taille de la firme dépendra de ces coûts de transaction en fonction de la compétence de l'entrepreneur à commander et à régir ses facteurs de production. La distance de A à B, mesurant les changements en surplus de la famille, de la firme et donc de la société, suivant les hypothèses émises, se traduira à coup sûr en termes monétaires. Lorsque les familles constituent des unités économiques de la sorte, avec des coûts de transaction environnementaux, les changements à l'équilibre dans les taux de salaire ou dans les prix des biens marchands se reflètent sur le surplus, en termes d'externalités physiques ou de variation du revenu monétaire.

Cependant, compte tenu de la réalité du contexte africain, les augmentations exogènes de revenu peuvent étendre le périmètre de la famille par un déplacement vers l'extérieur de la courbe de frontière des possibilités de production, celle-ci caractérisant des changements dans les besoins minimums en $Z_i$ requis pour le fonctionnement de la firme-famille. Les prises de décisions humaines de cette firme vont se manifester au niveau des contrats internes, notamment par une modification de $T_n$ , dans le but de garantir la viabilité de l'unité économique. Les contrats portant sur $T_n$ sont conclus lorsque (min $Z_1$ ; min $Z_2$) est tangente à la courbe des possibilités de production, au point C. La firme s'agrandit et la production d'output doit augmenter.

La quasi-rente a donc disparu au sens monétaire du terme, mais se trouve présente sous forme déguisée dans le capital humain et les qualités que l'on peut lui attribuer.

Ainsi se pose un problème pour les praticiens qui cherchent le moyen par lequel appréhender les changements de surplus. La dissipation de la rente n'implique pas une absence de manifestation concrète, ni des changements non bénéfiques pour les populations concernées. Les biens non marchands peuvent être évalués d'après les conditions décrites *supra*, mais une fois la rente fixée dans sa forme de capital humain, il semble absurde d'insister avec des mesures monétaires du bien-être, spécialement lorsque la structure institutionnelle de la firme ne se manifeste pas par la formation d'un surplus, mais plutôt par la recherche, la capture et la dissipation de la rente dans le but de maintenir le capital humain. Dans ces cas, il semble que les mesurages directs des changements dans les biens et l'amélioration de la qualité de la vie seront plus appropriés que les mesures monétaires. Cela suggère, pour le mesurage de la santé des organismes, d'opter pour des approches de type systèmes écologiques, en complément d'une révision des notions de bénéfice économique et enfin, d'une définition de ce qui doit être réellement pris en compte.

## 5. CONCLUSION

La complexité des structures institutionnelles africaines oblige une révision des concepts développés par les économistes néoclassiques. Ces concepts, adaptés au système économique des pays développés rencontrent bon nombre de difficultés lorsqu'il s'agit de les transposer en Afrique. Un examen approfondi et une remise en question des méthodes de mesure de surplus, de bien-être en général permettra de pallier les inepties actuelles des évaluations de projet. La panoplie d'outils àla disposition des praticiens devra entre autres inclure les approches néo-institutionnelles et les approches de l'économie des systèmes écologiques.

Dans le cas des projets de pêche, la substitution en terme de temps des activités jadis pratiquées par la seule activité de pêche ne provoque pas toujours l'effet escompté dans les analyses de projet. Celles-ci supposent en effet qu'une augmentation du revenu se traduira par un recours plus important au marché, par des dépenses plus élevées pour des produits de consommation durables. Mais c'est oublier le coût d'opportunité associé au renoncement de l'activité secondaire agricole : la famille du pêcheur ne peut pas se passer de la culture de son lopin de terre. Le recours àd'autres personnes sous contrat monétaire n'étant pas envisageable, l'incorporation au sein de la famille de nouveaux membres demeure la solution envisageable : le déplacement du point B au point C peut, notamment, s'expliquer par ce fait.

Une augmentation des revenus des pêcheurs se traduira par un agrandissement de la taille de la communauté au même titre que la famille. Il semble cependant présomptueux de vouloir décrire *a priori* des changements dans les obligations et les donations. Cependant, selon la logique communautaire, le système d'équité sociale permettra aux individus et aux familles qui ne bénéficient pas directement du projet d'en percevoir les effets bénéfiques sous la forme de donations. Mais là aussi, la mesure monétaire rencontre les mêmes difficultés que pour l'unité familiale, les échanges communautaires revêtant, rappelons-le, les formes de temps, de biens divers produits de façon domestique et, dans certains cas, monétaires.

Les populations de pêcheurs ont développé au fil des projets des comportements que l'on pourrait qualifier d'opportunistes. Un projet de pêche signifie très clairement un apport de capitaux, de matériel, de savoir-faire étranger... Il n'est aujourd'hui plus perçu de la même façon qu'il y a vingt ans. Le pêcheur sait que, même si le projet dans lequel il est inscrit ne fonctionne que quelque années, il en tirera un bénéfice substantiel et ponctuel, soit sous forme monétaire (revenus), soit sous forme de matériel de pêche. Le pêcheur perçoit clairement qu'il a tout intérêt à se manifester dans le plus grand nombre possible de projets car, quoiqu'il advienne, il se considère gagnant, n'ayant investi que son temps. Il peut être assimilé à un chasseur de rente qui cherche à maximiser ses gains sur un espace de temps le plus restreint possible. Le phénomène de *rent-seeking* peut se définir, selon Eggertsson, comme la tentative, pour les individus, d'augmenter leur richesse personnelle, tout en contribuant en même temps, mais de façon négative à la création de la richesse nette de leur communauté. Cette définition, au vu de la réalité du contexte africain, doit être reconsidérée, car dans le cas d'un apport monétaire extérieur, la communauté étudiée représente un ensemble de familles, impliquées de près ou de loin dans le projet, auquel cas le phénomène de *rent-seeking* peut se concevoir comme une augmentation de la richesse des familles de pêcheurs et de leur communauté au détriment de l'organisme responsable, et, dans une plus large mesure, de la communauté occidentale.

A cet égard, on pourrait appliquer les analyses de comportements des individus face au risque pour raffiner l'analyse des changements dans les préférences. . Un projet peut être appréhendé en terme de gain ou de perte : la perception d'un projet peut donc s'analyser à la lumière de la théorie des jeux. Il apparaît que les pêcheurs ont pour objectif de maximiser leurs gains en saisissant toutes les occasions offertes. D'autres travaux, comme ceux de M. Willinger, montrent l'aversion des agents vis-à-vis de l'ambiguïté, et ce dans une fonction d'Utilité Espérée. Les travaux de D. Bromley soulignent - en économie de l'environnement - l'aversion des agents envers une incertitude en termes de gain mais un comportement de *risk-lover* vis-à-vis d'une incertitude en termes de perte.

Une application de ces théories permettra sans aucun doute de mieux expliquer la dynamique des changements de comportement des agents en regard d'un projet.

Pour éviter la dissipation de la rente, de nombreux projets de pêche ou de développement en général mettent en place un système d'épargne forcée. Cette épargne est prélevée sur le salaire des pêcheurs (cas du projet de pêche sur le lac Tanganyika). Mais on peut se demander si les efforts pour arrêter la dissipation de la rente sont bien réfléchis, et si oui pourquoi ? Tant que le problème de la société sera la minimisation du nombre d'individus qui tombent au dessous de Min $Z_i$, il semble que les problèmes de la dissipation de la rente ne soient pas pertinents.

Enfin, selon Gary S. Becker, la substitution d'un emploi rémunéré à un emploi domestique provoque une augmentation du coût "d'élevage" des enfants à cause d'une augmentation des coûts associés à une heure de travail (coûts d'opportunité). Dans le cas d'un projet de pêche, la substitution de l'activité de pêche de subsistance par une activité artisanale voire plus industrielle engendre le même type d'effets que ceux mentionnés par Becker. Pour la famille, cela se manifestera par une augmentation des coûts associés au maintien de la famille élargie. Comment considérer ces effets induits ? Un pas vers le progrès ou un frein au développement harmonieux d'une société dans son environnement institutionnel, culturel et écologique. Question posée avec beaucoup d'acuité par un monde occidental qui s'aperçoit d'une dichotomie grandissante entre ses institutions et leurs mécanismes et son environnement écologique. Le débat est ouvert...

## REFERENCES

**Adamovitz W. L.** (1991). Valuation of environmental amenities, communication *Interdisciplinary Symposium on Agriculture and Water Quality,* University of Guelph, Ontario, 23-24 avril.

**Alchian A.A.** (1950). Uncertainty, evolution and economics theory, *Journal of Political Economy*, **58** (3) : 211-221.

**Azam J.-P.** (1991). Marchés parallèles et convertibilité, analyse théorique avec références aux économies africaines, *Revue Economique,* **1** : 75-94.

**Becker G.S.** (1965). The theory of allocation of time, *The Economic Journal*, **vol. LXXV**, (299) : 494-517.

**Becker G.S.** (1981). *A treatise on the family*, Havard University Press, Cambridge.

**Bridier M. et S. Michaïlof** (1990). *Guide pratique d'analyse de projets*, Economica, Paris.

**Bromley W.D.** (1989). Entitlements, missing markets and environmental uncertainty, *Journal of Environmental Economics and Management*, **17** : 181-194.

**Cameron T.A.** (1988). A new paradigm for valuing non-market goods using referundum data : maximum likelihood estimation by censored logistic regression, *Journal of Environmental Economics and Management*, **15** : 355-379.

**Chervel M. et M. Le Gall** (1981). *Manuel d'évaluation économique des projets*, , Ministère de la Coopération et du Développement, Paris.

**Cheung S.N.S.** The contractual nature of the firm, *Journal of Law and Economics* 26 : 1-21.

**Coase R.C.** (1937). The nature of the firm, *Economica* 4 : 386-405.

**Coase R.C.** (1960). The problem of social cost, *Journal of Law and Economics,* **3** (1) : 1-44.

**Deaton A.S. et J. Muellbauer** (1986). *Economics and consumer behavior*, Cambridge University Press, Cambridge.

**De Janry A. et al.** (1990). Why do peasants appear sluggish in spite of a hectic life ?, Berkeley University, California.

**Eggertsson T.** (1990). *Economic behavior and institutions* , Cambridge University Press.

**Failler P.** (1991). *Etude de faisabilité financière et économique du projet de pêche sur le Tanganyika*, document CCFD, Paris.

**Failler P. et M. Kamitenga** (1991). *Fiche d'Identification du projet de pêche sur le lac Tanganyika*, document CCFD, Paris.

**Faugère J.–P.** (1980). L'allocation du temps entre travail domestique et travail marchand, *Revue économique* (**2**) : 313-346.

**Feige E.L.** (1990). Defining et estimating underground and informal economies : the new institutional economics approach, *World Development*, **18** (70) : 989-1002.

**Gittinger J. P.** (1985). *Analyse économique des projets agricoles* , , 2e édition, éd. Economica, Paris.

**Glewwe P.** (1991). Investigating the determinants of household welfare in Côte d'Ivoire, *Journal of Developpement Economics*, 35 : 307-337.

**Leendertse K. et B. Horemans** (1991). *Socio-economic characteristics of the artisanal fishery in Kigoma region, Tanzania,* UNDP/FAO Regional Project for Inland Fisheries Planing (IFIP), RAF/87/099-TD/22/91.

**Maes M. et al.** (1991). *Recensement des unités de pêche zaïroise dans la partie nord du lac Tanganyika,* Projet régional PNUD/FAO sur la Planification des Pêches Continentales (PPEC), RAF/87/099-WP/09/91.

**Penouil M.** (1990). " Les activités informelles : réalités méconnues..., espérances illusoires ? ", *Economie et Humanisme,* **314** : 29-40.

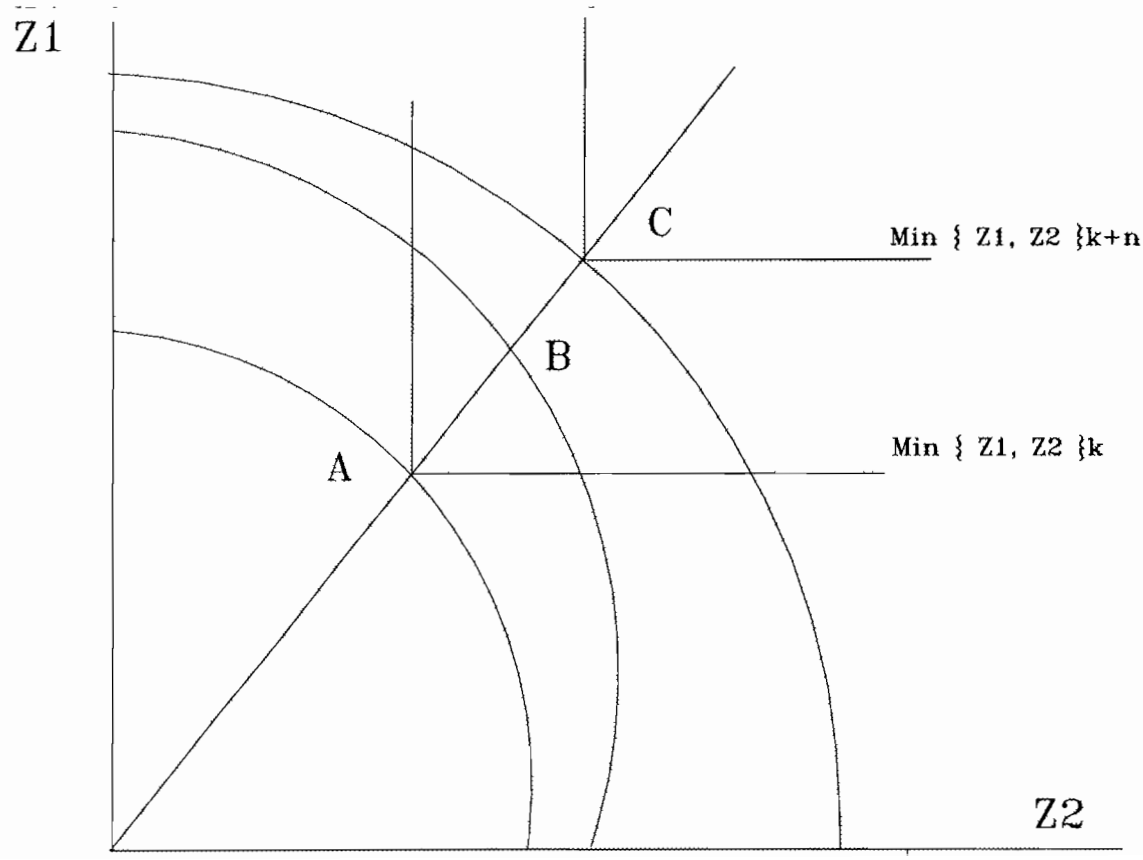
**Pollak R.A. et M.L. Wachter** (1975). The relevance of the household production function and its implications for the allocation of time, *Journal of Political Economy*, **83** (2) : 255-277.

**Schultz T.W.** (1974). *Economics of the family*, National Bureau of Economic Research, p. 527-565.

**Squire L. et H.G. Van der Tak** (1985). *Analyse économique des projets*, éd. Economica, Paris.

**Squire L. et al.** (1986), *Agricultural households models : Extensions, applications, and policy*, Baltimore, London, The John Hopkins University Press.

**FIGURE.**
**LE SURPLUS ET SA DISSIPATION DANS LES FIRMES "ALTRUISTES" PAR EXTENSION DU PÉRIMÈTRE DE LA FAMILLE.**



# Commercial Fisheries and Sport Fishing: Conflict and Cooperation

**Tsunenori Kusakawa**

Faculty of Marine Science and Technology, Tokai University, 3-20-1 Orido, Shimizu, Shizuoka, 424 Japan

ABSTRACT

*Conflicts between commercial fisheries and sport fishing are now becoming a serious problem, because they take the same renewable resources, especially in coastal waters of developed countries.*

*In Japan, the popularization of sport fishing with the improvement of incomes, the reduction in working hours and the advancement of resources-management-type fisheries based on the propagation of fisheries resources and etc., have caused complicated problems between them.*

*Sport fishing, however, makes a contribution to the economic vitalization of fisheries communities with commercial fishermen acting as guides for sport fishermen, running guest-houses, etc.*

*Such competition and cooperation imply not only underlying issues between commercial fisheries and sport fishing, but also more basic issues such as how to coordinate the fisheries use and other uses of waters, or how to position fisheries management into coastal zone management.*

*The present status and the regimes of commercial fisheries and sport fishing in Japan, and the recent development of coordination schemes are firstly reviewed in this paper. Then coordination mechanisms under the initiatives of the parties concerned are analyzed through case studies. Finally rational relationships between coastal zone management and fisheries management in such new situations are considered.*

## 1. PRESENT STATUS OF COASTAL FISHERIES AND SPORT FISHING

Japan is one of world leading fishing nations and the industrial fisheries for offshore and far sea are very common in the world. In 1989, 71 % of the marine fisheries production in volume came from offshore and far sea fisheries, as shown in Table 1.

In terms of value, however, coastal fisheries, defined as operations conducted in local waters with boat less than 10 tons or without boat, accounted for 53.6 % of the total harvest of 2,520.8 billion yen, including aquaculture in the same year, as shown in Table 2. This is mainly due that coastal fisheries harvest high-value species at the form of fresh or live.

The importance of coastal fisheries is more evident in terms of No. of commercial fishermen. As shown in Table 3, coastal fishermen accounted for 80.4 % of the total 382.7 thousand commercial fishermen in 1989.

Japanese fisheries is faced with the difficult problems. Table 1 also shows the decreasing catch of far sea fisheries and the stagnant harvest of offshore and coastal fisheries. Japanese demand for fishery products is firmly-rooted and about 42 % of the animal protein intake came from fishery products in 1988.(Food Supply and Demand) The gap between the dull domestic production and the increasing demand is covered by the import. The import dependent ratio (import/domestic demand) for edible fishery products increased to 30 % in 1988 from 10 % in 1975. (Food Supply and Demand)

Table 2 also shows the decrease of the production value due to the competition with other substitute foods and import. Table 4 shows the relative decline of the income of fishery household compared with other households and the declining ratio of income from fishery in the total income of fishery household. In such conditions, No. of commercial fishermen shows the decrease and the age composition are becoming older due to the declining recruitment of young aged as shown in Table 3. In short, fisheries in Japan are losing its attraction.

To cope with these problems, central and local governments, and fishermen theirselves under the initiative of FCAs (fishermen's cooperative association), intend to revitalize coastal fisheries through the propagation of resources, the improvement of fishing grounds, the introduction of marine recreations into fishery business and so on.

On the other hand, water dependent recreations are becoming popular through the improvement of incomes and the reduction in working hours. Sport fishing is typical water dependent recreations in Japan and the total man-days of sport fishing accounted for 35 million in sea and over 11 million in inland in 1988, and is expected the more future growth. Table 5 shows the man-days of marine sport fishing by category. Total man-days of marine sport fishing increased 56 % during ten years. As shown in this Table, angling took 80 % and next came shellfish gathering.

Table 6 shows the total man-days of marine sport anglers by use of guide and boat. In 1988, 19.2 % enjoyed angling with commercial fishermen who were sport angling guides as avocation, and 11.8 % went with guide other than commercial fishermen, mostly as vocation. In terms of the use of boat, 40.2 % of the total went angling with boat. Of them, 40 % went angling with commercial fishermen who were engaged in sport fishing guide as side business used their own fishing vessels, and 18 % used guide boats which owners were other than commercial fishermen. And remaining 42 % went angling mainly with private boats. Private boat anglers are now showing the increase.

Table 7 shows No. of sport fishing guide by operation. About 88 % of the total were commercial fishermen or FCAs which were organized by local commercial fishermen.

As the No. of coastal fishery households were 180.4 thousands in 1988 (Fishery Census), 13.6 % of them were engaged in sport fishing guide as side business. (It is estimated that almost of all sport fishing guide operated by fishermen are coastal fishery household.)

## 2. REGIMES OF COMMERCIAL FISHERIES AND SPORT FISHING

Japan's fishery regime is unique mainly based on Fishery Law and Fishery Resources Conservation Law. In Japan commercial fisheries are classified into three categories; Free Fishery, Fishing Right Fishery and Fishing License Fishery. Free Fishery which is available for all peoples, is limited the use of fishing gears, only for hook and line and etc., and has not so large effect on the resources. Fishing Right Fishery which can use a certain water area exclusively, is subdivided into Common Fishing Right, Aquaculture Right and Set Net Right. Of them Common Fishing Right is granted only to local FCAs and Set Net Right and some kinds of Aquaculture Right are granted to local FCAs preferentially. That is, local FCAs are permitted to a large degree to manage coastal fisheries which occupy the coastal fishing grounds, such as capture of coastal demersal species, aquaculture and set net fisheries, to assure the life of small scale coastal fishermen.

Local FCA is also pivot for economic activities of fisheries communities through fish marketing business, supply business, banking business and so on. Thus local FCAs are nucleus of coastal fishermen, and only members of FCAs can operate coastal fisheries in fact.

Fishery License Fisheries are for offshore and far sea fisheries, and the licenses are issued by the Minister or prefectural governor, under certain conditions defined for each type of fisheries, such as No. of fishing vessels, vessel size, fishing area, fishing season and etc.

Thus basic fishery management system in Japan is differ from other developed countries. Fishery regime in many developed countries put emphasis on the optimum utilization of the resources based on free access and catch limit, but that in Japan give priority to the management of fishing grounds. For this purpose, the management for the utilization and the conservation in near shore waters is mainly entrusted to local FCAs, and in offshore and far sea waters the emphasis is put on not only the conservation of resources but also the stabilization of fisheries operation and the coordination among fisheries. Further fisheries regime in Japan intends to keep its dual structure, coastal fisheries by households and capitalized fisheries in offshore and far sea waters.

On the other hand, there is no law originally aiming at sport fishing in Japan. But through the popularization of sport fishing and the increase of conflicts between commercial fisheries and sport fishing, it has been taken measures from the side of commercial fishery regime. These measures can be divided into three, measures to regulate sport fishing or to coordinate with commercial fisheries, measures to introduce sport fishing business into commercial fishery, and measures for the safety of vessels which are used to sport fishing guides.

### *2.1 Measures to regulate sport fishing or to coordinate with commercial fisheries*

(i) Prefectural Fisheries Regulation

This Regulation which are set by prefectural governor under the provisions of Fishery Law and Fishery Resources Conservation Law, are originally stipulated to commercial fisheries, but also applicable to sport fishing. By this, sport fishermen are regulated the use of many gears and the catch of demersal inshore resources such as lobster and abalone, but in brief anglings used hook and line are not regulated in sea waters.

(ii) Indication by Fishery Regulatory Commission

This Commission are established by Fishery Law for the coordination between commercial fisheries, but can indicate the coordination scheme between commercial fisheries and sport fishing.

(iii) Notification by the Secretary of Fishery Agency in 1970

The Secretary notified in 1970 to establish Fishing Ground Utilization Coordination Council, composed of commercial fishermen, sport fishermen and academic experts, as an arm of Fishery Regulatory Commission, to deliberate on problems between commercial fisheries and sport fishing for the prevention of conflicts and the peaceful use of fishing grounds. By this notification, each prefecture established the Council.

(iv) Notification by the Secretary of Fishery Agency in 1972

The Secretary notified in 1972 the standard examples to be coordinated by prefectural Fisheries Regulation and Fishery Regulatory Commission.

(v) Amendment of Coastal Fishing Ground Improvement and Development Law (CFGIDL) in 1983

The basic purposes of this law are to contribute to the stable development of coastal fisheries and to the increase of the supply through the propagation of fisheries resources and the improvement of the productivity. The amendment in 1983 added provisions of Fishing Ground Utilization Agreement among users including sport fishermen.

(iv) Amendment of Marine Fisheries Resources Development Law in 1990

This law originally aims the establishment of survey system for the exploitation of fisheries resources, the sound development of fisheries, the stable supply of fisheries products and the rational utilization of fisheries resources. The

amendment in 1990 added provisions that commercial fishermen, sport fishermen, FCAs and federated FCAs can initiatively conclude Resources Management Agreement with one another over a certain resources at a certain fishing ground.

### *2.2 Measures to introduce sport fishing business into commercial fisheries*

(i) Amendment of Fisheries Cooperative Association law in 1990

This law is very important, as described before, for the initiative management of coastal fisheries by FCA. The amendment in 1990 permitted that FCA itself can operate sport angling business and other water dependent marine recreational business, and allowed to sport angling guides other than commercial fishermen to participate into FCA as associate member.

(ii)Amendment of Fishing Port Law in 1988

In Japan fishing port are separated from common port by Common Port Law and Fishing Port Law, and there are about 1,000 common ports and about 3,000 fishing ports. Fishing ports are basically utilized for fisheries exclusively. By this amendment, it became possible in fishing ports to construct water dependent marine recreational facilities such as marina and artificial beach and etc., and to moor sport fishing guide boats which owners are not commercial fishermen.

### *2.3 Measures for the safety of boats used for the sport fishing guide*

Enactment of Sport Fishing Guide Vessel Rationalization Law in 1989

This law was enacted for the safety operation of sport fishing guide vessels, the sound development of this business and the improvement of user facilities, after a sad crash accident between a submarine and a sport fishing guide vessel at Tokyo Bay.

## 3. EXAMPLES AT OMAEZAKI, SHIZUOKA PREFECTURE

Author researched many cases about the relations between commercial fisheries and other water dependent activities. This is one of cases to review how the measures described above worked.

Omaezaki located at the western end of Suruga Bay, is one of large bases for commercial fisheries in the prefecture as well as sight-seeing resort and port town. (see Fig.1)

The commercial fisheries is wide from coastal to far sea, and the landings in recent years are 20,000 to 25,000 tons. Of them about 70 % comes from far sea hook and line skipjack fishing. No. of fishery establishment are 128 and 102 of them are coastal fishery establishments that operate boats less than 10 gross tons. Thus the fishery largely depends on far sea fisheries in landing volume, but in terms of establishment, 80 % depends on coastal fisheries.

Kinsu, a shallow water area about 30km south from Omaezaki, has been used as a good fishing ground for commercial anglingfishermen at Omaezaki and the environs.

The conflict occurred in July 1983 when the first sport fishing guide vessels came to this shallows from Izu Peninsula, another side of Suruga Bay. Local fishermen strongly opposed to this invasion and they requested to Shizuoka Fishery Regulatory Commission that the Commission give a guidance to sport fishing guide vessels from Izu to stop the operation at Kinsu. The prefectural Commission tried the coordination between both groups, but the conflict did not settled. Then the Commission entrusted Shizuoka Fishing Ground Utilization Coordination Council with the solution. The Council consulted with representatives of both parties and an agreement was concluded in Nov. 1983. That is, centered to prefectural Fishing Ground Utilization Coordination Council which is established by a notification of Secretary of Fishery Agency, as an arm of prefectural Regulatory Commission, both parties concluded Fishing Ground Utilization Agreement which was provided in the amendment of CFGIDL.

When the first agreement was contracted, the party of sport fishing guide vessels operation was only one group, Izu Fishing Tour Association and the main conditions were as follows.

| | |
|---|---|
| Fishing season | : from June 15 to Sept. 30 (in Sept., only Sunday and holiday were possible) |
| Fishing hours | : from sunrise to sunset |
| Fishing area | : Kinsu shallow than 200m |
| No. of vessels per one day | : less than 14 vessels |

After then the party of sport fishing guide vessel operation increased to eight groups by 1991, and the conditions were modified through yearly renewal of the agreement.

The conditions in 1991 were as follows.

| | |
|---|---|
| Fishing season | : illustrated in Fig.2 |
| Fishing hours | : from 6:00 to 13:00 (Apr. to Oct.)<br>from 7:00 to 13:00 (Nov. to Mar.) |
| Fishing area | : illustrated in Fig.2 |
| No. of vessels per one day | : eliminated from the agreement |

Another change is that coastal commercial fishermen at Omaezaki and the environs who opposed the sport fishing use of Kinsu at the beginning, introduced the sport fishing guide business as side business. In 1991 No. of sport fishing guides at Omaezaki was accounted for 96, and all of them were coastal fisheries establishments using power vessels less than 10 gross tons. This means that most coastal fishery establishments at Omaezaki conduct sport fishing guide business and they become members of both side of parties, coastal commercial fishery and sport fishing guide operation.

Author estimates that about 2.4 million yen, about one third to one fourth of their total annual income, now come from this guide business at Omaezaki

In these situations Omaezaki FCA established Sport Fishing Section in the organization to promote sport fishing business and to discuss problems.

Further Omaezaki FCA began to collect 3 % of sport fishing boat guide fee from the members. This charge is mainly to make up for the cost of released pelagic fish fry such as red sea bream by the FCA, because sport fishermen angled for the adults. Such charges are becoming common where the release of pelagic fish fry is conducted.

## 4. CONCLUSION

Sport fishing is one of, but most popular, water dependent citizen's activities, not industrial activities and competes with commercial fisheries, because they take the same resources and use same fishing grounds. However they can cooperate through the guide and guest-house business and etc.

As investigated above, the conflicts between commercial fisheries and sport fishing have been settled in general under the framework of the fishery regime. And many coastal commercial fishermen, particularly living in urban areas or sight-seeing areas, introduced the guide business as avocation for the economic vitalization. Such competition and cooperation implies not only underlying issues between commercial fisheries and sport fishing, but also more basic issues how to coordinate the fishery use and other uses of waters, or how to position fisheries management into coastal zone management.

In Japan there is no comprehensive law for the coastal zone management such as CZMA (Coastal Zone Management Act) in the U.S. But 4th NCDP(National Comprehensive Development Plan), a basic land use and conservation plan in Japan, provided the formation of CZMP (Coastal Zone Management Program) by prefecture under the guideline by central Government.

The right of coastal fisheries, one of the utilization of coastal waters, have been recognized traditionally as very strong right compared with other rights in Japan. For instance it is necessary the advanced approval by commercial fishermen concerned for the application of other water dependent projects such as land reclamation, mining, draining of warmed water from electric power station and etc., and in most cases an amount of compensation was payed to commercial fishermen in return for lost income to get the approval. It is also fact that commercial fishermen and their FCA have been kept the coastal environment for their livelihood.

But many citizens and environmentalists began to have questions over the privilege of coastal fisheries and about whose is coastal waters and the renewable resources.

On the other hand, there is no way to collect the fee to make up for the releasing cost by FCAs directly from sport fishermen who don't use guide vessels.

It is expected that water dependent activities by citizen will become more popular, and that sport anglings without guide and the release of fish fry will show more future growth. It is very important to sustain coastal fisheries not only for coastal fishermen and for the supply of fishery products, but also for the protection of coastal environment.

To settle questions by citizen and the problems of commercial fisheries, and to root coastal fisheries in CZMP deeply, it is necessary to get consensus from citizens about the force preserving coastal environments by commercial fishermen and their FCAs, and the importance of the utilization and the management of renewable coastal living resources. Finally it will be needed the comprehensive CZM law which places the priority on the use of renewable resources, not based on the traditional right of coastal fisheries, so that citizen can entrust cost-effectively the management of coastal waters to coastal fishermen and their FCAs.

## REFERENCES

**Hasegawa A.** (editor) (1991). *Study on Fishery Management,* Seizando, Tokyo, 366 p.

**Hasegawa A.** (1988). *Fishery Management,* Kouseisha-Kouseikaku, Tokyo, 236 p.

**Kevin S.** (1991). Management of Exclusive Fishing Rights in Japan (In press), JIFRS/IIFET/ZENGYOREN Symposium,.

**Konno S.** (1991). Basic Idea of Coastal Zone Management, *Coastal Zone,* Vol. **4** No.1, 77-83.

**Kusakawa T.** (1991). Fisheries Management and Coastal Zone (in press), Japan Marine Science and Technology Ass.,Tokyo.

**Kusakawa T. and N. Hiroyuki** (1989). Marine Policy and Coastal Zone Management in the U.S., Survey Report on Comprehensive Marine Use, Research Institute for Ocean Economics, Tokyo, 3-96.

**Land Agency** (1987). 4th National Comprehensive Development Plan.

**Ministry of Agriculture, Forestry and Fisheries** (1990). 8th Fishery Census.

**Ministry of Agriculture, Forestry and Fisheries.** Annual Report on Food Supply and Demand.

**Yamamoto T.** (1991). Japanese Fishery : Current Status and Issues (in press), JIFRS/IIFET/ZENGYOREN Symposium.

**TABLE 1.**
**PRODUCTION VOLUME OF MARINE FISHERIES AND AQUACULTURE (unit : 1000t).**

| Year | Total | Far Sea | Off Shore | Coastal | Aquaculture |
|---|---|---|---|---|---|
| 1965 | 6,762 | 1,604 | 2,917 | 1,861 | 380 |
| 1970 | 9,147 | 3,429 | 3,279 | 1,889 | 549 |
| 1975 | 10,346 | 3,168 | 4,469 | 1,935 | 773 |
| 1980 | 10,900 | 2,167 | 5,705 | 2,037 | 992 |
| 1985 | 11,965 | 2,111 | 6,498 | 2,268 | 1,088 |
| 1989 | 11,712 | 1,976 | 6,340 | 2,123 | 1,272 |

Source : Annual Statistics on Fisheries and Aquaculture Production.

**TABLE 2.**
**PRODUCTION VOLUME OF MARINE FISHERIES AND AQUACULTURE (unit : 1 billion yen).**

| Year | Total | Far Sea | Off Shore | Coastal | Aquaculture |
|---|---|---|---|---|---|
| 1965 | 533.2 | 167.0 | 144.2 | 140.4 | 81.6 |
| 1970 | 920.4 | 296.9 | 236.8 | 251.4 | 135.3 |
| 1975 | 1,774.0 | 470.1 | 537.1 | 513.2 | 253.6 |
| 1980 | 2,602.4 | 572.2 | 830.0 | 731.5 | 468.7 |
| 1985 | 2,714.1 | 682.8 | 758.3 | 750.8 | 522.2 |
| 1989 | 2,520.8 | 512.1 | 656.5 | 785.6 | 566.7 |

Source : Annual Statistics on Fisheries and Aquaculture Production.

**TABLE 3.**
**NO. OF COMMERCIAL FISHERMEN BY TYPE OF FISHERIES, SEX AND AGE (unit : 1000 persons).**

| Year | Total | Coastal | Off Shore Far Sea | Male Sub-total | 15-39 | 40-59 | 60- | Female |
|---|---|---|---|---|---|---|---|---|
| 1965 | 612.0 | 440.2 | 171.8 | 502.5 | 254.2 | 175.8 | 72.2 | 109.5 |
| 1970 | 549.4 | 387.3 | 162.1 | 453.9 | 210.3 | 173.2 | 70.4 | 115.8 |
| 1975 | 477.5 | 339.5 | 138.0 | 397.6 | 143.3 | 186.7 | 67.5 | 80.0 |
| 1980 | 457.4 | 358.5 | 98.9 | 376.9 | 118.2 | 193.6 | 65.1 | 80.5 |
| 1985 | 431.9 | 336.6 | 95.3 | 356.5 | 97.8 | 188.9 | 69.9 | 75.4 |
| 1989 | 382.7 | 307.7 | 75.0 | 314.4 | 75.8 | 157.6 | 81.0 | 68.3 |

Source : Annual Dynamic Statistics on Fisheries.

**TABLE 4.**
**COMPARISON OF INCOMES BY TYPE OF HOUSEHOLD (unit : 1000 yens).**

| | 1975 | 1980 | 1985 | 1989 |
|---|---|---|---|---|
| Fishery Household(A) | 3,383 | 4,821 | 5,310 | 6,258 |
| Income from Fishery % | 59 | 57 | 51 | 52 |
| Income from Other Business % | 41 | 43 | 49 | 48 |
| Agriculture Household(B) | 3,967 | 5,603 | 6,926 | 7,985 |
| All Worker's Household(C) | 2,834 | 4,196 | 5,338 | 5,950 |
| A / B % | 85.3 | 86.0 | 76.7 | 78.4 |
| A / C % | 119.4 | 114.9 | 99.5 | 105.2 |

Source : Fishery Economy Survey, Agriculture Economy Survey, and Family Income and Expenditure Survey.

**TABLE 5.**
**TOTAL MAN-DAYS OF MARINE SPORT FISHING BY TYPE (unit : 1000 man-days).**

| | 1978 | | 1983 | | 1988 | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| Angling | 17,613 | 77.6 | 24,817 | 80.2 | 29,455 | 83.3 |
| Catch by Diving | 23 | 0.1 | 9 | 0.0 | 101 | 0.3 |
| Shellfish Gathering | 2,938 | 12.9 | 3,303 | 10.7 | 4,801 | 13.6 |
| Others | 2,114 | 9.3 | 2,804 | 9.1 | 1,005 | 2.8 |
| Total | 22,688 | 100 | 30,933 | 100 | 35,361 | 100 |

Source : Fishery census.

**TABLE 6.**
**TOTAL MAN-DAYS OF MARINE SPORT ANGLING BY USE OF GUIDE AND BOAT (unit : 1000 man-days).**

| | | 1983 | | 1988 | |
|---|---|---|---|---|---|
| Guide | Boat | No. | % | No. | % |
| With Commercial Fishermen as Guide | With Boat | 4,938 | 19.9 | 4,748 | 16.1 |
| | Without Boat | 859 | 3.5 | 911 | 3.5 |
| | Sub-total | 5,798 | 23.4 | 5,658 | 19.2 |
| With guide other than Commercial Fishermen | With Boat | 1,867 | 7.5 | 2,167 | 7.4 |
| | Without Boat | 894 | 3.6 | 1,311 | 4.4 |
| | Sub-total | 2,761 | 11.1 | 3,478 | 11.8 |
| Without Guide | With Boat | 3,195 | 12.9 | 4,935 | 16.8 |
| | Without Boat | 13,063 | 52.6 | 15,383 | 52.2 |
| | Sub-total | 16,258 | 65.5 | 20,318 | 69.0 |
| Total | With Boat | 10,001 | 40.3 | 11,850 | 40.2 |
| | Without Boat | 14,816 | 59.7 | 17,604 | 59.8 |
| | Total | 24,817 | 100 | 29,455 | 100 |

Note : Angling without boat includes angling from beach, wharf and etc.
Source : Fishery census.

**TABLE 7.**
**NO. OF SPORT FISHING GUIDE BY OPERATION (unit : 1 operation).**

| | 1978 | | 1983 | | 1988 | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| FCAs | 255 | 0.7 | 157 | 0.5 | 125 | 0.4 |
| Commercial Fishermen | 32,459 | 86.9 | 29,551 | 87.3 | 24,499 | 87.3 |
| Others | 4,631 | 12.4 | 4,149 | 12.3 | 3,425 | 12.2 |
| Total | 37,345 | 100 | 33,857 | 100 | 28,049 | 100 |

Note : Sport fishing guide by FCAs is mostly guide for shellfish gathering
Source : Fishery census.

**FIGURE 1.**
**FISHING AREA AND SEASON A: FINSU FOR SPORT FISHING IN 1991.**

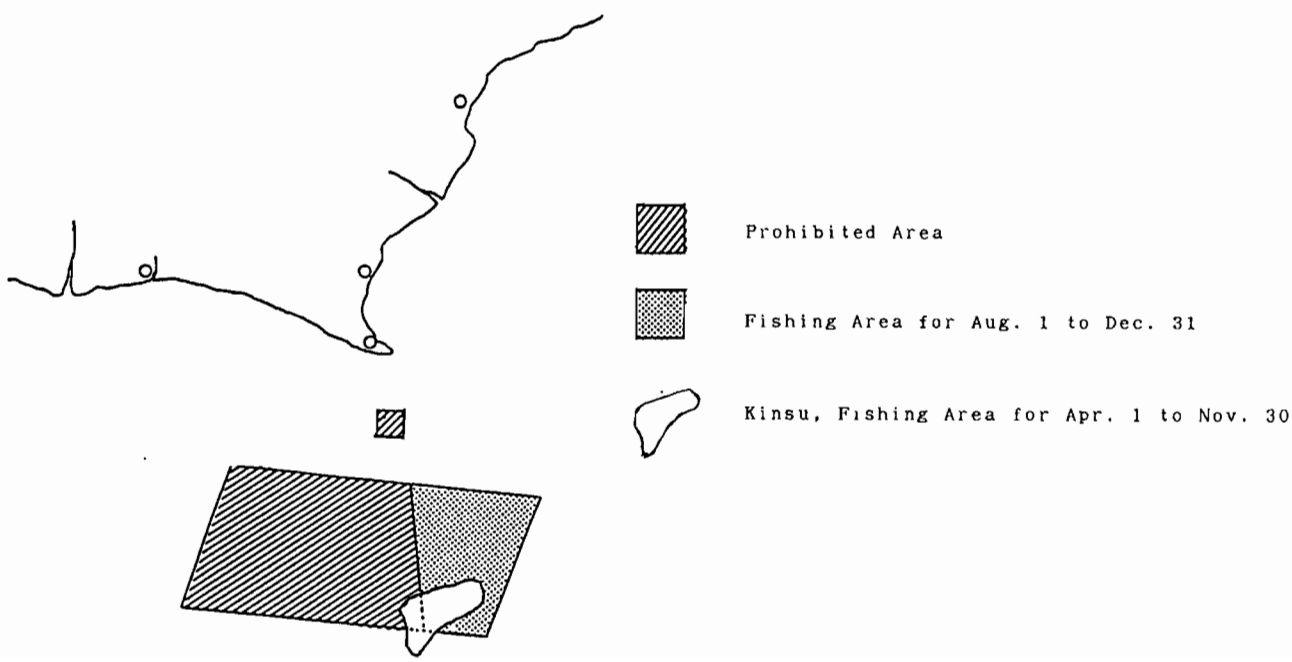
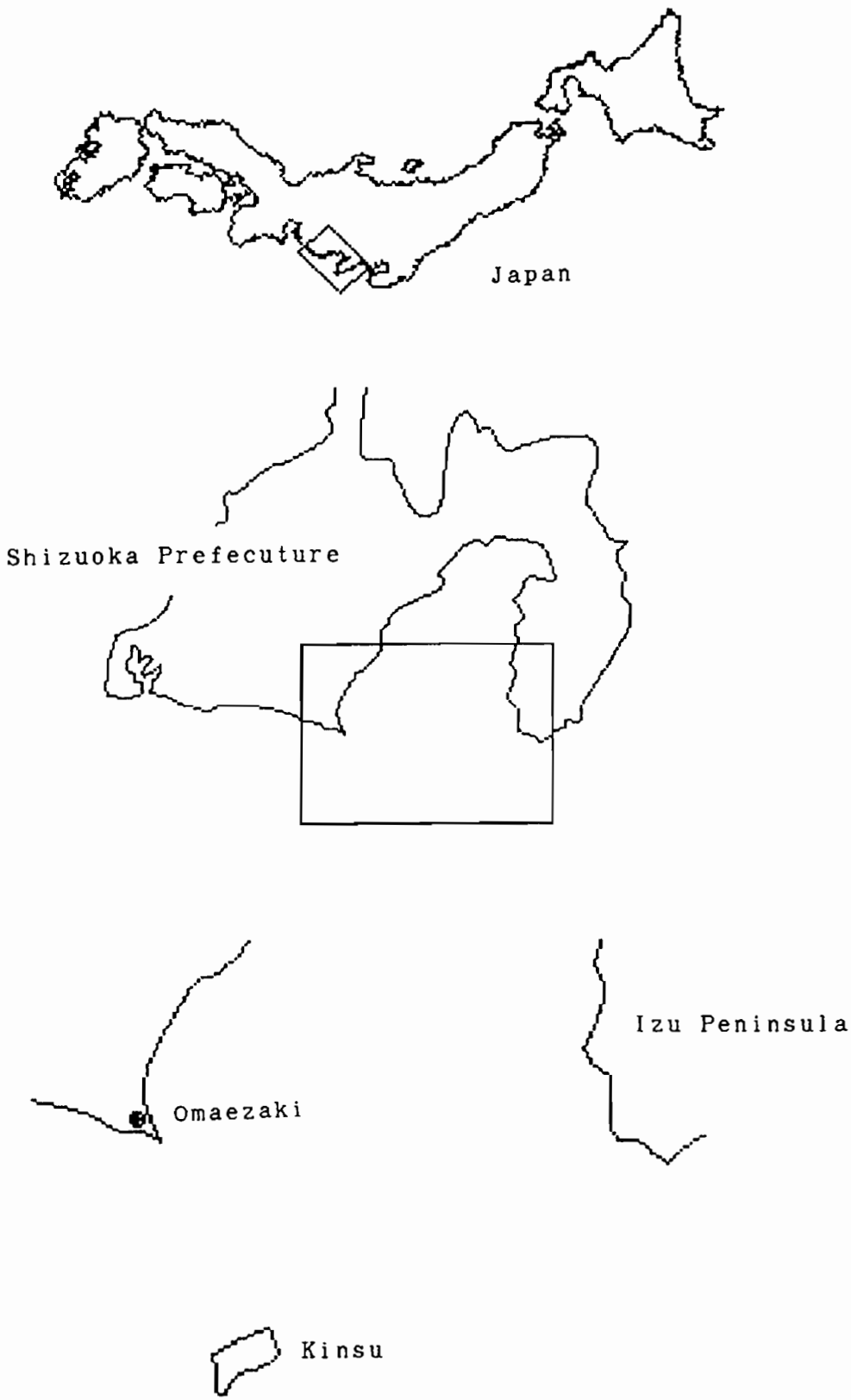


**FIGURE 2.**
**LOCATION OF OMAEZAKI AND KINSU.**



# Subsistence Fisheries in Alaska : Conflicts Within a Multiple Use Resource

**Hans T. Geier, Joshua A. Greenberg and Mark Herrmann** *

Department of Resource Management, University of Alaska Fairbanks, Fairbanks, AK 99775-0100, USA

ABSTRACT

*Subsistence is the customary and traditional noncommercial uses of renewable natural resources in Alaska. Subsistence is seen as a lifestyle, rather than the simple use of resources. The area of focus is the interior terminal chum salmon fishery along the Yukon and Kuskokwim River drainages. Regulation of the fishery by state agencies and regulatory boards is examined with relation to authority granted by state and federal authorities. Conflicts with commercial fisheries, in the Yukon and Kuskokwim River drainages, and particularly with the intercept mixed-stock salmon fleet at False Pass are described. Future valuation and economic analysis of regional activities to describe accurately the contribution to the interior Alaskan economy of the terminal stream chum salmon subsistence and commercial industries in a regional model is discussed.*

## 1. INTRODUCTION

During the 1980s 110,000 people in 225 Alaskan communities participated in subsistence harvest of resources. This F number has been expanded through a recent Alaskan Supreme Court decision (McDowell v. State). Subsistence, defined as the customary and traditional noncommercial uses of natural resources, is an important component of the culture, traditions, and local economies of many Alaskan communities. Subsistence harvests are widely distributed both intra- and inter-community through kinship and non-monetary market networks. As defined under state regulation, subsistence harvest precludes both commercial and sport harvest of natural resources. The purpose of this paper is to investigate economic and political issues surrounding the chum salmon subsistence fishery in the Yukon River drainage in interior Alaska, to analyze the issues with relation to regulating agencies, and to emphasize the impact of current policy on rural economies.

* This report is the result of research sponsored by Alaska Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of the Sea Grant, Department of Commerce, under grant no. NA90AA-D-SG066, Project # M/81-01, and with funds from the University of Alaska with funds appropriated by the state.

## 2. SUBSISTENCE AND FISHERIES REGULATION IN ALASKA

Subsistence in Alaska is stated as a rural preference and is defined as an interest, rather than a native right accompanying aboriginal claims, as in Canada (Feit, 1990). Because there is no right to the resource by certain cultural groups, it is not easy to assign property rights or transfer rights through market mechanisms. Only in the Marine Mammal Protection Act is there a definite recognition of wildlife as a component of the subsistence economy essential to the Native way of life (Marine Mammal Protection Act, 1972). Even here, use of products is strictly governed, allowing only minimal development of markets (Katelnikoff v. U.S. 1991). Subsistence is defined in Alaskan law as :

> *"customary and traditional uses in Alaska of wild renewable resources for direct personal or family consumption, as food, shelter, fuel, clothing, tools, or transportation, for the making and selling of handicraft articles out of non-edible by-products of fish and wildlife resources taken for personal or family consumption, and for the customary trade, barter or sharing for personal or family consumption..." (AS16.05.940(23)).*

Two federal laws are applicable to native rights and subsistence use. The Alaska Native Claims Settlement Act (ANCSA) extinguished native property claims to most of Alaska along with subsistence rights, with lands being given to village and regional native corporations. These lands were not sufficient to provide for native subsistence activities, but provided clear title to the land itself. The Alaska National Interest Lands Conservation Act (ANILCA) defined subsistence practices within a rural context, rather than native context, and provided for them on federal lands.

The Alaska Department of Fish and Game (ADF) regulates subsistence hunting and fishing on lands and waters subject to state management. In 1989, the Alaskan Supreme Court struck down the state rural preference for subsistence as unconstitutional (McDowell, 1989) because of the common use clause in the Alaska State Constitution. ADF management of subsistence practices on federal lands in Alaska has been discontinued when federal agencies decided state management was inconsistent with ANILCA. ADF has continued to manage subsistence, sport, and commercial fishing because the state has jurisdiction over all navigable waters, even on federal lands. Additionally, the jurisdiction is extended 12 miles from the low tide mark offshore (Jacobson et. al., 1985). The stated order of regulation is commercial, sport, and finally subsistence. Where there are natural and healthy populations, according to ANILCA, there can be no regulation of subsistence.

The application of ANILCA to fisheries has not yet been recognized by court cases. However, the same order of preference for management of use of fisheries is recognized by ADF Therefore, subsistence has the highest priority, sport second, and commercial last. Two other sections in the Alaska State Constitution pertaining to the management of fisheries are as follows :

> **Section 4-Sustained Yield.**
>
> *"Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle subject to preferences among beneficial uses."*
>
> **Section 15-No Exclusive Right of Fishery.**
>
> *No exclusive right or special privilege shall be created or authorized in the natural waters of the State. This section does not restrict the power of the State to limit entry into any fishery for purposes of resource conservation, to prevent economic distress among fishers and those dependent upon them for a livelihood and to promote the efficient development of aquaculture in the state. [Amendment approved August 22, 1972-effective October 14, 1972] (Alaska State Constitution).*

Two main conflicts associated with subsistence use of chum salmon in interior Alaska have recently been before the main regulatory body for Alaska State fisheries, the Alaska Board of Fisheries (Board of Fisheries). The two conflicts are : raising the chum cap for the False Pass intercept salmon fishery, and banning of feeding of subsistence salmon to dogs used in commercial endeavors. The subsistence fishery that is threatened is in the Yukon and Kuskokwim River drainages in interior Alaska, extending from the Bering Sea into Canada (Figure 1). While explicitly these conflicts do not directly address the subsistence fishery, the prescribed resolution to these conflicts may weaken subsistence use, and strengthen commercial use.

## 3. COMMERCIAL VS. SUBSISTENCE WITHIN THE FISHERY : DOGS

The largely native subsistence and commercial terminal stream users of chum salmon are located in interior Alaska (and also in Canada) along the Yukon and Kuskokwim rivers, and in the Norton and Kotzebue areas of western Alaska.

Subsistence caught chum salmon are used 70-80 % for dog food, and is appropriately nicknamed "dog salmon". Commercially caught chum salmon in interior fisheries is stripped of its roe for caviar, processed into commercial food goods (McCormick, 1992), and processed as food for dogs (Anderson, 1992).

Dog teams are an integral part of interior Alaskan subsistence lifestyle. They are used for hunting, wood and water hauling, general winter transportation, and also for recreation. Dog racing and trapping are semi-commercial activities that are prevalent in subsistence users' lifestyles (Anderson, 1992).

The use and function of dogs is indicative of how native and subsistence use of resources has changed. Dogs were once the main source of winter transportation and were integral to the subsistence and commercial economy in rural Alaska. Dogs were used to pull sleds for coastal Eskimos up to 1500 years ago and as pack animals by Athabascans in the interior prior to contact by Europeans. Through the fur trading periods, gold rush, and after, dogs served commercial and traditional roles for Natives and non-Natives alike. Starting in the 1930s, airplanes began replacing them for freight and mail. Starting in the 1960s, snowmobiles supplemented and substituted for dog teams, but did not replace them. During the 1970s the limitations and financial obligations of maintaining a snowmachine were realized by some rural residents. It was difficult for those with limited cash income to buy, operate and maintain one. Some residents returned to dogs as a major source of transportation, due to both preference and necessity. Throughout their history, the main food source for dog teams in interior Alaska has been dried fish, of which chum salmon was the most important (Anderson, 1992). Dogs remain an important part of the rural subsistence lifestyle, keeping alive cultural and traditional ways.

A petition to the Alaska Board of Fisheries in late 1990, to prohibit subsistence caught salmon in the Yukon River drainage for dog food in commercial kennels, was initiated in the village of Russian Mission. The initiators of the petition had competing commercial fishery interests. An attorney general opinion cited in the petition held that "feeding subsistence caught fish to dog teams used...primarily for a non-subsistence use, such as commercial racing... probably does not qualify for subsistence use." The Board of Fisheries took action on the petition and broadened its scope in Proposal 396 to include statewide prohibition of the use of subsistence-caught fish to feed dogs used for commercial purposes including dog racing, commercial kennels, and trapping for fur sales (Anderson, 1992).

ADF Division of Subsistence completed a study in January 1992 to collect information on past and present uses of dog teams, and the role that fish play in feeding them, in the Yukon River Drainage. Study results emphasized that "sled dogs remain part of a whole sphere of activities that is actively encouraged as an alternative to idleness, unemployment, and substance abuse" in rural Alaska for communities and individuals. Subsistence caught fish are an important component of the diet of dogs in smaller kennels in most areas. Commercially caught chum salmon for roe are also used for dog food in other areas, as well as the subsistence catch. Large commercial racing kennels were found conclusively to use high protein, high energy commercial dog food as opposed to subsistence fish (Anderson, 1992). The State Board of Fisheries has decided not to enact Proposal 396.

The commercial fishers in the Yukon River drainage fishery were frustrated at the time the petition was filed because of closure of commercial fisheries due to declining salmon stocks. Subsistence permit holders continued to fish. Some of these individuals also held commercial permits. Abuse of the subsistence privilege was perceived to be widespread by commercial terminal stream fishers. Accordingly, there was great frustration among competing users in the same fishery. The petition arose as a consequence of this frustration. After the petition was filed with the Board of Fisheries, it became apparent that most subsistence fishers were also commercial fishers. Frequently, revenues from commercial activities supported subsistence activities. Therefore, the petition to the Board of Fisheries pitted a large portion of the Yukon River drainage fishers with common interests against each other. Reevaluation of the fishery conflict directed the subsistence and commercial terminal stream users to a threat viewed in common, the False Pass commercial intercept fishery (McCormick, 1992 ; Umphenour, 1992).

## 4. THE FALSE PASS COMMERCIAL INTERCEPT FISHERY VS. INTERIOR SUBSISTENCE AND COMMERCIAL TERMINAL STREAM FISHERIES

The False Pass area at the end of the Alaskan Peninsula in Southwest Alaska plays host to an intercept fisheries' fleet. Salmon migrating to western Alaska migrate around Unimak Island off of the Aleutian Peninsula and continue north. Thus, this area near False Pass is a natural congregation point (Figure 1). The False Pass intercept fleet's main target is

sockeye salmon. Sockeye salmon are a high valued species, mainly exported to Japan. In contrast, chum salmon are a relatively low valued salmon species. Chum salmon is a bycatch of the sockeye salmon harvest. The chum salmon cap imposed by the Board of Fisheries forces the False Pass commercial fleet to limit their catches of sockeye salmon. The fishery is closed once the bycatch limit of chum salmon is reached. Therefore, they want the chum salmon cap to be as high as possible to maximize their landings of the more commercially lucrative sockeye salmon.

Commercial salmon fishing at False Pass is by set net (113 permanent permits issued), purse seine (119 permits), and drift gill nets (158 permits). Additional interim use permits were issued. The distribution of the permits for salmon in the False Pass area to non-residents in 1990 were 17, 23, and 44 percent respectively. Permits held by Alaskan residents were concentrated in the less productive set net category. Set net harvests average only about half that of the purse seine and drift gill nets. Non-residents are increasing their share of permits in the fishery (Commercial Fisheries Entry Commission, 1992).

There were 393 total permits fished in 1990 in the False Pass fishery, with reported landings of 51,248,790 pounds. The average harvest per permit was 130,404 pounds (Commercial Fisheries Entry Commission, 1992). The False Pass fishers are heavily capitalized with large investments in vessels and gear. The primary market for harvested sockeye salmon is Japan.

In the commercial Western Alaska interior terminal stream fishery, there was a total of 17,041,796 pounds of fish caught by 1923 permit holders (23, or 1.2 % were non-residents) in 1990 for an average of 8,862 pounds per permit (Commercial Fisheries Entry Commission, 1992). The scale of the commercial fisheries is small and permit holders often have a subsistence permit as well. Subsistence has become increasingly capital intensive as competition for resources increased. The existence of commercial interior fisheries and processing is one of the few entrepreneurial ways for interior Alaskan residents to obtain cash income to purchase gear and equipment for subsistence fishing, hunting, and other activities. Commercially harvested fish from these fisheries is primarily allocated to instate markets, with limited exports, primarily of roe and high quality chum salmon to Japan. Reduction of the terminal stream portion of the harvest of the western Alaskan fishery is feared by residents because the absence of alternative sources of cash income. Rural residents believe this would lead to increased dependence on state and federal welfare and social programs, and impede their ability to participate in subsistence practices.

Thus, the conflict between the False Pass intercept fishery and the terminal stream users shapes up as a "big boys against little boys" conflict (McCormick, 1992). Smaller numbers of highly capitalized commercial fishers on one hand, and traditional, small scale fishers on the other set the stage for a bitter political battle which has been administered by the Board of Fisheries, and is now moving into the courts (Elim v. State, 1992). The interior fishers on the Yukon, Koyukon, and Kuskokwim rivers interest is the chum salmon. They believe the incidental catch by western Alaska mixed-stock intercept fisheries is the reason for recent low harvests. Any chum cap above 400,000 is viewed as detrimental to Yukon River fisheries (Yaska, 1992). Therefore, they are taking action to relieve pressure on the fishery from the False Pass intercept fleet.

The State of Alaska Board of Fisheries, in November 1991 set the 1992 False Pass chum cap at 900,000, 50 % more than the 1991 season allowance of 600,000. The reaction from Yukon and Kuskokwim River fishers was swift and sure. Lawsuits were threatened, and accusations of special interests and politics abounded. Terminal stream users wanted a cap of 400,000, 200,000 less than in 1991. In December it was found that the study the Board of Fisheries based its chum cap on contained a statistical error. The Board decided to reconsider, and on March 16 rolled back the False Pass chum cap to 700,000.

The Alaska Department of Fish and Game Division of Commercial Fisheries published the study that the Board of Fisheries based its initial False Pass 1992 chum cap decision (Eggers, et. al., 1991). The study was roundly criticized for questionable research methodologies in an internal ADF peer review (ADF Memo 121291.MEM, 1991). A statistical inaccuracy was also found. Similar questions were raised by external review (Rexstad, 1991), and in general by resource users and others familiar with the study, its methodologies, and the fisheries.

Even before the statistical error was detected, the study was subject to severe criticism by interior Alaskan Native interests, and commercial and subsistence fisheries interests (Hilsinger, 1991). Questions regarding the efficacy of the study include :

i) The study only covers one year. ADF biologists recommend that to be accurate, a study must cover the entire life cycle of a fish, or at least 4 years for chum salmon.

ii) Fish were tagged by the fleet that fished for them--interior fishers felt this led to a conflict of interests. Objectivity was called into question by this.

iii) Only 40 % (6,300 out of a targeted 15,000) of the desired number of fish were tagged.

iv) The fish were not tagged during the originally planned time frame, and the commercial fishery opening occurred the day after tagging ended. 30 % of the reduced number of tagged fish were caught during the opening.

v) 5.There was no commercial fishing along the Yukon River drainage in 1987. If there was a commercial season, the harvest would have been much higher. Therefore, this sample population was not accounted for.

vi) 6.Fishers in remote areas, including in Canada, were not notified of the study, leading to low return of tags.

Additional questions concerning methodological techniques were raised, including the decision of the author not to use certain tagged fish, combination of several susceptible salmon runs, and inadequate ground surveys by ADF (Hilsinger, 1991 ; McCormick, 1992 ; Umphenour, 1992).

Native subsistence users in the Yukon River drainage were especially critical of the tagging method used in the study, saying that tagged fish that did make it up the Yukon were weak and sickly (Yaska, 1992). The implication was that stress from tagging reduced their ability to return up the river, and thus lowered the return for spawning Yukon River salmon tagged at False Pass. The native fishers in interior Alaska state that they have been able to detect a difference in return in years with high chum caps at False Pass. Graphical examination of ADF data supports this contention, though statistical analysis has not been pursued except in the 1987 ADF study.

The chum stocks in western Alaska and in the Yukon and Kuskokwim River drainages have been in severe decline. Fishers in these areas have been taking severe conservation efforts, but concurrently the intercept fishery has been increasing its take of the bycatch chum. The Native and non-Native community (50,000 people) in western Alaska is represented by The Western Interior Fisheries Coalition. This organization has targeted all future Board of Fisheries proceedings that regulate Alaskan intercept fisheries. It has issued a strong statement of intent against what it sees as a four vote majority representation of the intercept fisheries. The political ramifications of this issue promise to be lengthy and bitter (Naneng, 1992). Additionally, the Alaskan Federation of Natives has filed a countersuit to a state lawsuit against federal government subsistence policies in Alaska. This underscores a distrust of Alaskan Natives for state regulation of subsistence (Hulen, 1992). Subsistence fisheries issues, as well as commercial allocation in interior Alaska will be central to the arguments that the Board of Fisheries will have to consider. The regulation of Alaska's fisheries, dictated first by biological statutes of sustained yield, and second by allocation to subsistence use, will provide the core of the opposition to chum caps in the False Pass intercept fishery.

## 5. TWO THREATS, DIFFERENT ISSUES, A DEPLETED RESOURCE

There are thus two threats to the interests of subsistence fishers in interior Alaskan fisheries posed by Alaska Board of Fisheries decisions. The first is the threat to the predominant subsistence use of the resource, and second, an increase of the bycatch of the intercept commercial fleet in the False Pass fishery area which is believed to be depleting the resource. Both threats were initiated by competing commercial interests for the resource. The first was initiated by a commercial interest which was in direct competition in the area of the fishery, at a time when there was very limited fishing allowed. Reconciliation of the parties has occurred, and they have united to address the outside threat against their combined interests. It appears the Alaska Board of Fisheries has shown a preference for the interests of commercial users of the resource outside of the area of origination of the fishery, and subsistence and commercial users in interior Alaska have had the burden of proof placed upon them.

The Alaska Constitution, ANILCA, and ADF regulations specify sustained yield management (ANILCA specifies "natural and healthy"), and then a preference for subsistence use. In regulating a resource, the state or federal agencies must regulate commercial use first, sport use second, and subsistence use last. The False Pass decision is viewed by rural interior interest groups as having violated the Alaska state and federal provisions by allocating the resource to commercial users over subsistence users--to intercept fleets over terminal stream users--as well as jeopardizing biological diversity (Naneng, 1992). The Alaska Constitutional provisions for management of fisheries and other natural resources,

the federal management provision in ANILCA for "natural and healthy populations" and those federal laws governing endangered and threatened species have the potential to be triggered by the actions of the Board of Fisheries in the case of False Pass.

While the Board of Fisheries did not pass the resolution banning the use of subsistence fish by commercial kennels, the intent by commercial fishers appeared to be to limit demand for the resource. Protection of interior Alaskan subsistence and commercial fishers interests by the Board of Fisheries is perceived by them to be inadequate. An adversarial relationship has been established between the Alaskan Board of Fisheries, and western interior Alaskan fishers, Native interest groups, and dog mushers. Future conflict resolution will be tainted by this relationship.

## 6. IMPLICATIONS FOR RESEARCH

The interior fisheries provide both monetary and non-monetary returns. Subsistence harvest, by definition, is non-commercial, and therefore not traded in formal markets. Thus, there is no market clearing price upon which to base estimates of benefits from subsistence activities. Additionally, while commercial harvest in the interior is sold in markets, these returns do not fully capture its benefits. Revenues from commercial harvest support the subsistence lifestyle of interior state residents. Decreases in commercial harvest may severely limit the ability of interior residents to maintain subsistence practices. Economic techniques for valuing non-market commodities, such as contingent evaluation, are inadequate in this case (Brown and Burch, 1989). Evaluation of activities on a regional basis, with relation to interfaces with the market economy, time and labor involved, inputs, and final consumption is needed to accurately describe the nonmarket, subsistence part of the economy, and the impact of changes to it.

In cases of regulation by a governing board, there are clear delineations of political and economic interests affected by resource use decisions. What is not clear is quantification of economic impact of the decisions. Immediate impact to affected parties can be easily estimated, but total effects to regional economies are not so simply calculated. The subsistence economy in interior Alaska has been studied by social scientists, including economic anthropologists and economists (Ellana and Wheeler, 1989 ; Langdon, 1984 ; Lonner, 1980). However, a comprehensive economic database has not been derived for regional analysis for impact studies on the interior subsistence and noncash economy. Because of this lack of data, accurate impact analysis is not possible.

We are currently initiating a study to gather data to construct a database for input-output regional economic analysis using IMPLAN software. The incorporation of the subsistence economy in the Yukon-Koyukuk Census region in interior Alaska is the immediate priority of the study. Past economic studies in Alaska have been limited in scope, or lacked sufficient detail to capture the unique structure of rural Alaskan economies. Research has focused primarily on single resource development issues, failing to incorporate interrelationships which exist between various sectors within regional economies, especially subsistence. These limitations are due primarily to the absence of an adequate database upon which to base more comprehensive economic analysis.

Subsistence activities include commodity production, processing and manufacturing activities, distribution, and consumption of regional products. Alaska's economy in general resembles that of a developing country. It's cash component is based on resource extraction and services. For the monetized economy, almost all manufactured goods are imported, and raw materials are exported. There is a distinct lack of entrepreneurial activity in Alaska. Interior commercial fish processing is one example, and subsistence use is a distinct economic activity involving economic resources for regional use by local residents. Thus, most currently measured economic activity in rural Alaska is expected to have a very low multiplier because of the loss of production revenue to Outside. Subsistence activities are very different from most monetized activities because their products are almost exclusively produced, processed, and consumed locally. Our future research on this topic is expected to show comparatively high multipliers for subsistence economic activity, and also those activities that are linked closely to local production, compared to competing extractive uses of resources for export.

Future regional economic research in Alaska will be necessary to accurately describe impacts that government policies, economic development, or competing economic activities will have upon local economies. The description of subsistence activities in an input-output framework will provide a firm foundation upon which to base future natural resource management decisions in Alaska. Resource conflicts will more accurately be reflected by being able to analyze total

economic activity and linkages in the interior Alaskan economy. Replacement of subsistence fish will be costly in terms of substitution of imported food and dog food. Commercial fisheries are also affected. The full economic effect on interior Alaskan economies due to economic linkages and multipliers will be substantial. Accurate economic data and input-output modeling will provide needed documentation of the importance of interior Alaskan fisheries to industries, communities, and individuals.

## REFERENCES

**Alaska Attorney General File** No : 366-416-85.

**Alaska Commercial Fisheries Entry Commission** (1992). Summary Data on Limited Fisheries (1977-1990), Basic Information Table #1A, Juneau.

**Alaska Dept. of Fish and Game, Div. of Commercial Fisheries. Memorandum 121291.MEM.** (1991). Review of False Pass Tagging FRB 91-01. Anchorage.

**Alaska National Interest Lands Conservation Act.** (Dec 2, 1980). Pub. L. No. 96-487, Title VIII, 94 Stat. 2371, 2422 (codified at 16 U.S.C. 3111-12).

**Alaska Native Claims Settlement Act.** (Dec. 18, 1971). Pub. L. No. 92-203, 85 Stat. 688 (codified at 16 U.S.C. 1601-29a).

**Alaska Statute AS16.05.940 (23).**

**Anderson D.B.** (1992). "The Use of Dog Teams and the Use of Subsistence-Caught Fish for Feeding Sled Dogs in the Yukon River Drainage, Alaska." AK Dept. of Fish and Game, Div. of Subsistence, Juneau. Tech. Paper No. 210.

**Brown T.C. and E.S. Burch JR.** (1989). Estimating the Economic Value of Subsistence Harvest of Wildlife in Alaska. Pres. to *Alaska Wildlife Valuation Workshop,* Anchorage.

**Eggers D.M., K. Rowell and B. Barrett** (1991). Stock Composition of Sockeye and Chum Salmon Catches in Southern Alaska Peninsula Fisheries in June. AK Dept. of Fish and Game, Div. of Commercial Fisheries, Juneau. Fishery Res. *Bull. No. 91-01.*

**Elim V. State.** Native Village of Elim ; Nome Eskimo Community ; Kawerak, Inc. ; and Arctic Regional Fish and Game Council v. State of Alaska and Carl Rosier (1992). Superior Court for the State of Alaska Second Judicial District at Nome.

**Ellana L.J. and P.C. Wheeler** (1989). Wetlands and Subsistence-Based Economies in Alaska, U.S.A. *Arctic and Alpine Research,* **21** (4) : 329-340.

**Feit H.** (1990). Hunting and the Quest for Power : The James Bay Cree and Whitemen in the 20th Century. In Bruce Morrison and C. Roderick Wilson, eds., *Native People : The Canadian Experience.*

**Hilsinger J.** (1991). 1987 Tag Study Questions Memorandum, Arctic-Yukon-Kuskokwim Region, AK Dept. of Fish and Game, Div. of Commercial Fisheries, Anchorage.

**Hulen D.** (1992). Fishing Pits AFN vs. State : Native Federation Prefers Federal Subsistence Control. Anchorage Daily News, Mar. 3.

**Jacobson J., D. Conner and R. Tozer** (1985). *Federal Fisheries Management : A Guidebook to the Magnuson Fishery Conservation and Management Act.* Rev. Ed. Ocean and Coastal Law Ctr., Univ. of OR Law Ctr., Univ. of OR Law School, Eugene.

**Katelnikoff V.** (1991). U.S. Boyd Didrickson and Marina Katelnikoff Beck v. the United States Department of the Interior, et al. U.S. District Court for the District of Alaska. No. A85-336 Civil.

**Langson S.J.** (1984). Contemporary Subsistence Economies of Alaska. Prepared for the U.S. Dept. of Fish and Game, AEIDC, Univ. of AK, Anchorage, *Tech. Paper No. 55.*

**Lonner T.D.** (1980). Subsistence as an Economic System in Alaska : Theoretical and Policy Implications. ADF Div. of Subsistence, *Tech. Paper No. 67.*

**Marine Mammal Protection Act.** (1972). 16 U.S.C. 1361-1407.

**McDowell v. State,** 785 P.2d (Alaska 1989).

**McCormuk J.A.** (1992). Interior Fish Processors, Fairbanks. Personal and telephone interviews.

**Naneng M.** (1992). Opinions Differ on False Pass Allocation Decision by Fish Board, Con. Anchorage Times, Mar. 8.

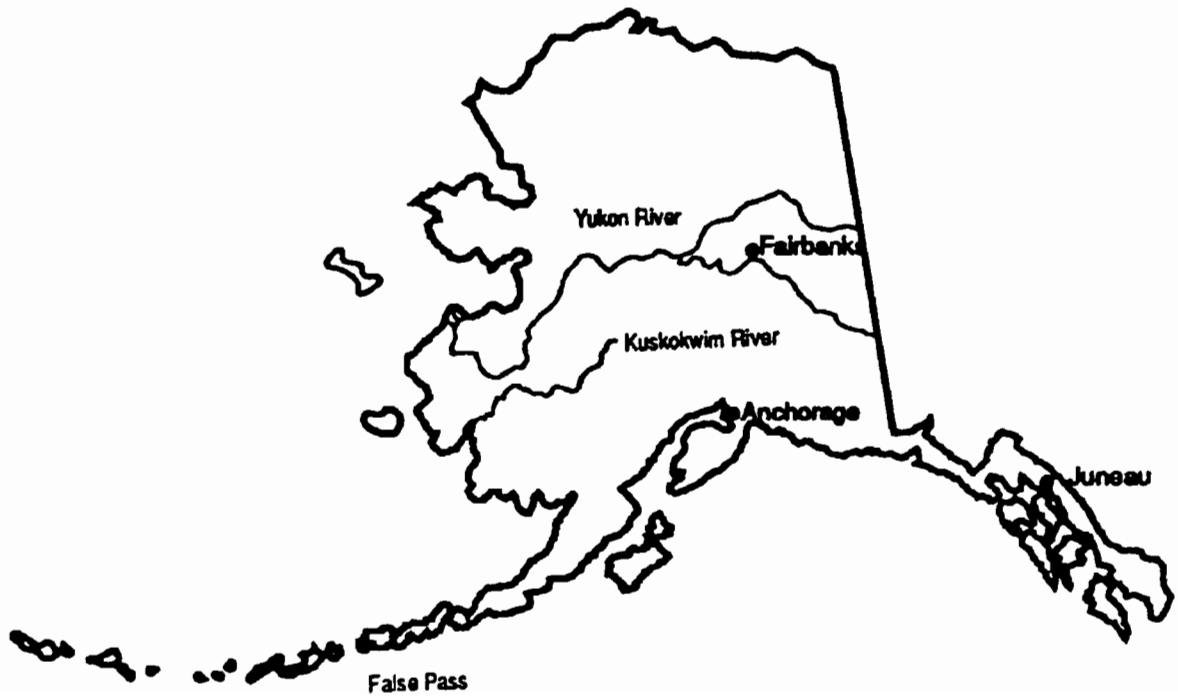
**Osterback P.** (1992). Opinions Differ on False Pass Allocation Decision by Fish Board, Pro. Anchorage Times, Mar. 8.

**Rextad E.** (1991). Comments concerning Fisheries Research Bulletin 91-01, Institute of Arctic Biology, University of AK, Fairbanks.

**Umphenour V.L.** (1992). Yukon River Drainage Fisheries Assn. Personal interview.

**Yaska G.** (1992). Director, Wildlife and Parks, Tanana Chiefs Conference, Fairbanks, AK. Personal Consultation.

**FIGURE 1.**
**MAP OF ALASKA SHOWING YUKON AND KUSKOKWIM RIVERS AND THE FALSE PASS FISHERY LOCATION.**



# Information Needs and the Management of Joint Commercial and Recreational Fisheries : the UK Fishery for Sea Bass (*Dicentrarchus Labrax*).

**Simon Potten[a], Michael Dunn[b] et David Whitmarsh[a]**

[a]Centre for the Economics and Management of Aquatic Resources, University of Portsmouth, Locksway Road, Milton, Southsea, Hampshire PO4 8JF, United Kingdom.

[b]Department of Economics, University of Portsmouth, Locksway Road, Milton, Southsea, Hampshire PO4 8JF, United Kingdom.

ABSTRACT

*In order to manage effectively those fisheries being exploited by both commercial and recreational interests, regulatory agencies require a wider range of information than that needed for solely commercial fisheries. Methodologies have been developed and applied in North America and elsewhere to provide information on such fisheries but until recently European regulatory agencies have not normally incorporated information on recreational sectors in making choices on regulatory frameworks and policies, except perhaps in the management of anadromous stocks such as salmon.*

*This paper analyzes developments in the UK in connection with the marine fishery for sea bass (Dicentrarchus labrax), a fishery which provides both significant income opportunities for commercial fishermen as well as being the basis for one of the most highly regarded recreational fisheries. The authors have undertaken work in conjunction with the UK regulatory agency (the Ministry for Agriculture, Fisheries and Food) in developing relevant quantitative and qualitative data concerning both sectors of the fishery. In particular, the paper outlines work undertaken to generate economic data concerning the recreational sector of the fishery, the first time that such information has been gathered as an input into marine fisheries management in the UK.*

*Partly in the light of the information generated, the regulatory agency has increased the scope of its management measures to apply to recreational as well as commercial fishing interests. This demonstrates an increasing awareness by*

*the UK regulatory agency both of the economic (and biological) significance of recreational fishing, and also of the need to consider a wider range of information when choosing management objectives and techniques for jointly exploited fisheries.*

## 1. INTRODUCTION

Throughout the world, marine fish stocks are being threatened by commercial fishing. In many areas, exploitation of these stocks is being increased by the growth of recreational fishing as a leisure activity. This growth is associated with factors such as increases in leisure time, personal disposable incomes, participant mobility and in the appreciation of environmental qualities. Yet only in relatively few countries is explicit attention being paid to these recreational fisheries, and even in countries with rather sophisticated fisheries management regimes, the significance of recreational activities may be unknown or disregarded.

Hence, whilst countries like the USA and Australia are conspicuous examples of where fisheries management authorities seek to pay particular regard to marine recreational fisheries within the broader framework, in the UK almost no attention is paid to the recreational sector, save in the important exception of salmonid fisheries. This has been the case, even where commercial and recreational fisheries have been in direct competition. Only in the last few years have such considerations begun to play a part, and this has rapidly uncovered the absence of almost any reliable information on these fisheries.

This absence is in some ways surprising : biologists are concerned with the joint management of the commercial and recreational sectors of a fishery since the fish mortality caused by recreational fishing needs to be taken into account before scientific advice can be provided to fisheries management authorities. At the most basic level, their calculations and advice will otherwise risk being erroneous ; at another level, increased restrictions on the commercial sector (e.g. by gear, area, etc.) may not prevent depletion of the resource if the recreational sector remains uncontrolled (and indeed, able to benefit from any controls over their commercial competitors). From an economist's viewpoint, if management is to pursue rational objectives, then the "value" of recreational fishing needs to be determined in a form that is comparable with the "value" of commercial fishing at any time when the economic impact of management measures is under debate. At another level, determination of the value of the components of a fishery may well soon become an influence in determining "who pays" for the costs of management.

However, recreational fisheries have traditionally been thought of as insignificant in scale, localised in impact, and economically unimportant. The largely diffused nature of the activity can conceal its size and significance, just as the fishing port emphasises that of the commercial sector. Indeed in some cases management authorities have regarded recreational fishing as being beyond their remit anyway (as being "leisure", or "sport").

Nevertheless, there is clear evidence that recreational fishing is indeed important, in both biological and economic terms. To take a few examples from many possible, Kearney (1991) reports that the tailor fishery in the Richmond River (New South Wales, Australia) shows recreational catches almost a hundred times greater than the commercial landings. In Tasmania, commercial bluefin tuna fishermen tie up their boats at weekends, because the influx of recreational fishermen has made it too difficult and costly to fish (Lal *et al.*, 1991). On the west coast of North America, over 1.2 million coho salmon are caught annually by recreational fishermen, and over 1.5 million kelp bass (NOAA 1990). In Great Britain, recreational landings of salmon are some 38 % of total reported landings in England, Scotland and Wales ; indeed our own recent work has estimated the capitalised total net economic value of these salmon fisheries to be some £340 million (1988 prices), of which the recreational sector contributed 96 % (Radford *et al.*, 1991). We shall later report that we have estimated the recreational catch of sea bass in the UK to be at least as large as the commercial catch.

There can be no doubting the biological and economic significance of marine recreational fishing in a wide range of circumstances internationally, and it is a significance that appears to be growing. This significance has been recognised in the USA, where the Fisheries Conservation and Management Act (1976) made express provision for the allocation of harvests between commercial and recreational interests, and already some Regional Fishery Management Councils are making these allocations. In Australia, some State governments have recently incorporated recreational fishing into their management plans. In Western Australia, for example, all recreational fisheries are now managed by bag limits and three are licensed. In contrast, in the UK and much of Europe, there is no precedent for managing marine recreational fishing, let alone allocating harvests between the sectors. Indeed, little appears to be known about marine recreational fishing at all.

Since 1987 CEMARE have been working with the UK fisheries management agency, the Ministry of Agriculture, Fisheries and Food (MAFF), investigating the joint recreational and commercial fishery for bass. This paper reports on some aspects of our work, and highlights in particular the difficulties of generating significant data which are required information in making informed management decisions, in an environment in which little or no previous work has been conducted.

## 2. ECONOMIC INFORMATION

With regard to the management of fisheries which have a restricted harvest, managers must allocate that harvest, explicitly or implicitly, between user groups. If they ignore any group, then that group can expand its activities to benefit from inhibitions on other groups. The criteria for determining an optimal yield or the optimal levels of effort from both sectors must be based on economic considerations (see for example, McConnell and Sutinen, 1979). Economic information is also needed to evaluate the impact and effectiveness of management measures. The following section considers briefly some economic information that is required by fishery managers, particularly with relevance to recreational fishing.

Edwards (1990) provides a useful brief summary of the relevant economic analysis. The key element lies in the estimation of what Edwards refers to as 'net national benefit', which is perhaps more usually called net economic value. In calculating this net economic value, estimations have to be made concerning both sectors. In each case, there are elements of both consumer and producer surplus to be considered, and estimates of total economic value must always be net of total resource costs. In the seafood sector, there is producer surplus being gained throughout the chain from the fishermen to the retail sector, together with the consumer surplus gained by the fish consumers. In the recreational sector, there is consumer surplus deriving to all the recreational fishermen, together with producer surplus accruing to those involved in the charter fishing element of the sector. In certain cases where private ownership exists, there may also be producer surplus for the resource owner, as for example in the case of UK salmonid fisheries.

When referring to the economic significance of a commercial fishery, it is common practice, however, to talk in terms of the first-hand value of landings (output). This over-estimates the net economic value associated with commercial fishing because resource costs are not subtracted. On the other hand, it disregards other aspects of consumer and producer surplus.

Since recreational fishermen are by definition not fishing for profit, the value of their retained catch (based on current market prices) cannot provide a relevant measure of the economic significance of recreational fishing, where the output is 'recreation', not 'fish caught'. This output is a multi-dimensional concept and involves a wide range of satisfactions : this has been the subject of considerable research, e.g., Stevens (1966), Moeller and Engelken (1972), Bryan (1974), Dawson and Wilkins (1980) and Hudgins (1984). However, as Cunningham *et al.* (1985) conclude, economists concerned with fisheries management are generally forced to make certain assumptions ; they will for example usually assume that the value of recreational fishing will increase with fish density over a relevant range.

How this recreational output is best valued is still the subject of widespread debate. Non-economists may consider the expenditures of recreational fishermen to be a relevant indicator of the "significance" of recreational fishing. Indeed, gross expenditure data are a popular measure, particularly with recreational pressure groups because they tend to produce impressively large figures. Whilst expenditures may have important **economic impact** effects (particularly at the local economy level) and are useful for such studies, they have sometimes been wrongly used as indicators of the **net economic value** of the activity itself in social welfare terms.

The central problem is that a great deal of recreational fishing is a non-market good, although there are some important exceptions. For example, in the UK most fishing rights in the salmon fishery are under private ownership, and most of the economic value is in fact rent (capitalised at £327 million in 1988 : Radford *et al.*,1991, *op. cit.*). Nevertheless for most recreational fishing, in order to make estimates of consumer surplus it is necessary to construct a hypothetical demand curve, employing data from either surrogate or created markets. This enables us in theory to make a first estimate of the net economic value of the recreational fishery, although there may well be other non-consumptive use values and non-use values which should theoretically be included (see for example Bishop, 1987).

Various techniques have been developed to derive monetary estimates for the value of non-priced recreational resources. Stabler (1980) and OECD (1989) provide useful summaries of methods that have been used in the evaluation of the benefits of recreation, and Rockland (1986) provides a comparison of social welfare and economic impact techniques.

The principal measures that have commanded widespread attention are the Travel Cost Method (TCM) and the Contingent Valuation Method (CVM). In the latter, first proposed by Davis (1964), a market is created by questions put to recreationists on their evaluation of the resources they use. Steinhoff *et al.* (1987) summarises by explaining that recreationists may be asked how much they would pay to have a given experience, object or privilege (willingness to pay, WTP), or how much they would have to be paid to give it up (willingness to sell, WTS). In contrast in the TC method, a surrogate market is employed, based primarily on the contention that consumers' responses to travel costs and time can be employed as a surrogate for their response to resource access prices (if they existed).

Both these methods have been severely criticised. Eberle and Hayden (1991) discuss the use of these techniques in valuing natural resources and ecosystems, and encapsulate such criticisms by saying, "the CV and TC approaches lack methodological, theoretical and empirical grounding. Their continued use will mislead valuation attempts and frustrate policy.....". Others take a more positive view : for example, "the travel cost demand model is a useful tool in understanding recreation behaviour and economic aspects of outdoor recreation" (Fletcher *et al.*, 1990 ; see also Smith, 1989). However, no-one would pretend that a wholly acceptable technique for such work yet exists.

Meanwhile, however, fisheries management must proceed : one recalls that admirable fisheries scientist John Gulland calling many years ago for more "quick and dirty biology" as we could not afford to wait for the perfect version. Likewise, economists have a responsibility to input information into conflict situations in fisheries management - albeit, making clear the limitations and reservations attached to the data and analyses.

## 3. THE UK BASS FISHERY

In the waters around the UK, the bass is towards the northern limit of its range, and annual distribution and abundance are determined largely by environmental factors (particularly sea temperatures). In 1972, official MAFF statistics recorded only 21 tonnes of bass landed at major ports. With the development of the market for bass in Europe and the high unit value of bass, the fishery expanded considerably and in 1987 MAFF statistics recorded 125 tonnes landed. The basic point of departure for this investigation was therefore that here was a (very) small fishery, but one highly regarded by inshore fishermen and recreational anglers alike. It seemed likely that it was in reality rather larger than the official data suggested. How big was it ? What were the relative sizes of the commercial and recreational sectors ? How valuable was it to each sector ? Management could not proceed with any confidence without having some answers to these questions.

In 1981, under pressure from recreational interests (for whom bass is the premier marine sport fish), MAFF's Directorate of Fisheries Research (DFR) initiated a research programme aimed at, "providing advice to the Government on the state of bass stocks and the management measures needed to safeguard their future and to maintain a fishery" (Pawson and Pickett, 1987).

This programme investigated the biology of bass and gradually developed a log-book recording scheme for a sample of volunteer bass fishermen to monitor fishing effort and landings - see Pickett (1990) for details. Initially these estimates were probably rather unreliable, due to sampling problems. However, as the quality of the data improved, it soon became apparent that official MAFF statistics significantly under-estimated landings (see Figure 1), mainly because most bass is landed at scattered minor ports which are not included in the MAFF statistics. The programme also estimated there to be significant numbers of recreational fishermen exploiting the fishery. By 1987, the log-book sampling system had become sufficiently robust to suggest with reasonable confidence that true landings were some 785 tonnes - very much higher than the officially recorded data, but including some estimate of recreational landings (though this was based only on charter and other boat angling activities).

In their work, MAFF scientists became increasingly aware of the need to identify some of the economic aspects of the fishery, both in terms of understanding the dynamics of the fishery and as an input into the analysis of management options, particularly concerning the recreational sector. In 1987 MAFF commissioned the Centre for Marine Resource Economics (CEMARE) to undertake an economic evaluation of the bass fishery (see Dunn *et al.*, 1989).

## 4. COMMERCIAL SECTOR

In investigating the commercial sector of the fishery, the first step was to examine and verify the log-book system for estimating commercial landings. This was undertaken, and commercial landings in the study year 1987 were estimated at 630 tonnes. Subsequent work was directed at identifying some of the economic parameters of the fishery by means of questionnaire and interview survey of just over 10 % of the 1,200 boats in the commercial fishery (DFR census data). This concluded, *inter alia*, that the first hand value of the commercial fishery was some £3.9 million, which reflects the high unit value of sales, estimated at £6.19/kg.

Although of interest, this figure is not of course net economic value. As an indicative approximation, it can be estimated that economic rent comprised about 42 % of the gross revenue generated by the commercial bass fishery, giving a figure of £1.6 million. In arriving at this figure it was assumed that for much of the labour employed in the fishery there were limited alternative job opportunities, and accordingly labour was shadow-priced at 50 % of its market value. It should also be noted that the figure of £1.6 million is likely to consist of intra-marginal rent (i.e., producer surplus) rather than resource rent, since the latter will have been largely dissipated on account of the open-access character of this particular fishery. Strictly, total producer surplus for the fishery should also include producer surplus at subsequent stages in the marketing chain, but it was not possible to generate data on this (graph 1).

In addition to producer surplus, we must also consider consumer surplus within the commercial sector. In the UK the bass is a very highly priced fish, much of which goes for export, from which market forces influence UK prices. Much of the remainder is used in restaurants, where it is usually amongst the most expensive fish on the menu. Econometric demand investigations suggested that the demand curve was very flattened, and this was suggestive that consumer surplus in the UK was very low. Again, however, it should be stressed that the estimates which were made of price flexibility with respect to domestic supplies were extremely tentative, owing to the unreliability of the available information on landings data.

Although this work in the commercial sector raised a number of problems of data and analysis, these were overshadowed by difficulties in the recreational sector. Here, the investigation began with no significant information at all, on the size or significance of the fishery.

## 5. RECREATIONAL SECTOR

### *5.1 Methodology*

Marine recreational fishermen in the UK are not required to purchase a licence. There is no register of anglers and only a small proportion belong to fishing clubs - 17 % in 1980 (NOP, 1980). Therefore a direct interview, on-site survey sampling technique provides the only realistic option for analyzing marine recreational fishing.

In addressing the recreational sector of the UK bass fishery, the CEMARE study initially undertook on-site interviews with 487 anglers at 76 representative sites around the coastline of England and Wales (from Norfolk to Cumbria). Personal interviews were conducted on selected sampling units (fishing days) throughout the bass fishing season. This very modest sample set illustrates the problem of undertaking an evaluation where almost no baseline data exists : with little or no other source of information (addresses, etc.) regarding anglers, there was no alternative, even though in the case of bass angling, this presented significant operational difficulties (e.g., isolated locations, night angling, interception of boat anglers, etc.). A stark contrast can be drawn with the Connelly and Brown (1991) study, where an available database permitted the use of 17,000 mailed questionnaires related to freshwater fisheries in New York.

A comprehensive questionnaire was developed for use in the on-site survey, containing questions relating, *inter alia* , to effort, catches and expenditures. To estimate the economic significance of the recreational fishery for bass in the UK, the CEMARE study adopted the CVM in the expectation that this would at least produce upper and lower estimates, using WTP and WTS, even if they were subject to potentially wide and unknown margins of error. The questionnaire therefore included two questions designed to elicit meaningful responses based on hypothetical scenarios which required the anglers to state how much they would have been willing to pay to gain access to bass fishing for one year and how much they would have required in compensation to forego bass fishing for one year. Responses were refined by means of an iterative bidding-game procedure.

Strictly, in addition to consumer surplus, the net economic value of the sector should also include any producer surplus accruing to those involved in it as charter boat operators. Unfortunately, again very little information exists on this sub-sector in the UK, and no reliable estimates were possible.

### *5.2 Results*

Survey results from the questionnaire work were grossed up to census data provided by the 1980 National Angling Survey (NOP, 1980). The CEMARE study estimated there to have been just under 500,000 recreational fishermen participating in the UK bass fishery in 1987. These included some who fished just once, through to "specialist" bass anglers, in some cases fishing for bass as often as 300 times annually. It was estimated that these anglers caught between 660 and 694 tonnes of bass, to be compared with the estimated commercial catch of 630 tonnes.

With regard to the economic significance of the recreational fishery, the study estimated the annual gross expenditure of bass anglers to have been at least £15.8 million. The estimate of the net value of the recreational fishery based on WTP for one year's bass fishing (as estimated employing CVM) was calculated to have been £8.7 million, whilst that based on WTS was some £111.6 million. Such a large divergence is notable, but not without precedent in CVM studies (see for example, Knetsch and Sinden, 1984), and various explanations are possible (see OECD, 1989). The usual reservations for CVM work must be added, particularly that whilst the investigators felt that respondents certainly understood the hypothesis being pursued, it was difficult to tell whether they responded with the same judgements as if faced with the phenomenon in a real situation, and other undetected biases may have been present. The study considered that the WTP estimate did represent a reasonable first approximation to the *minimum* amount of money that would have to be paid to bass anglers to compensate them satisfactorily for a one year closure of the recreational bass fishery.

## 6. SUMMARY

In considering the management of the bass fishery in the UK in the mid-1980s, the management agency faced a situation where it was analyzing a small but developing inshore fishery, highly regarded by both commercial and recreational fishermen. Conflict over the resource was apparent, and pressure groups were pressing for advantage. Commercial landings data were known to be erroneous by a wide (but unknown) margin, there was no information on recreational catches, and no information at all on economic aspects of either sector.

The study being reported here was not able to fill all the gaps, even for 1987 let alone on an on-going basis. However, it did reveal the existence of a recreational sector that was at least as large in terms of landings as the commercial sector. It also suggested that the agency was managing a fishery with a considerable net economic value in recreational use, whilst it was also significant to commercial fishermen because of the high unit value of the catch. The exact data produced were not perhaps in themselves vital, and certainly not totally reliable. However, the study did perhaps demonstrate that relevant and useful data can be generated.

This is a lesson that has already been absorbed and acted upon elsewhere. The UK, and possibly other parts of Europe, are lagging significantly behind countries such as the USA and Australia in recognising the significance of recreational fishing and incorporating it into fisheries management plans. Economic evaluations of joint commercial and recreational fisheries are likely to become increasingly important as fishery managers in the UK and in Europe begin to appreciate the need for economic information relating to both sectors in fisheries management.

In relation to the UK bass fishery, *ex post* evaluations of recreational fisheries in themselves may not provide the fisheries management agency with information that is of use in managing the fishery, but they can provide a basis for *ex ante* evaluations of the impacts of management measures. Having established base values for the UK recreational bass fishery in 1987, it is now possible to assess the impact of the package of management measures introduced in 1990 on both sectors of the fishery (see MAFF, 1990 for details).

In extending the management measures for the UK bass fishery to include recreational as well as commercial fishermen, MAFF have demonstrated an increasing awareness of the economic (and biological) significance of recreational fishing. Management of other marine fisheries would undoubtedly benefit from the input of information regarding recreational fishing.

## REFERENCES

**Bishop R.C.** (1987). Economic values defined. Chapter 3 in *Valuing Wildlife - Economic and Social Perspectives.* Decker, D.J. and Goff, G.R. (eds.). Westview Press / Boulder and London. Published in co-operation with The Wildlife Society (New York Chapter). pp. 12-23.

**Bryan R.C.** (1974). *The dimensions of a salt-water sport fishing trip or what do people look for in a fishing trip besides fish ?.* Fisheries and Marine Service, Southern Operations Branch, Pacific Region, Environment Canada. 33 pp.

**Connelly N.A. and T.L. Brown** (1991). Net economic value of the freshwater recreational fisheries of New York. *Transactions of the American Fisheries Society* , **120 :** 770-775.

**Cunningham S., M.R. Dunn and D.J. Whitmarsh** (1985). Fishing as Recreation. Chapter 9 in *Fisheries Economics - an Introduction.* Mansell. pp. 263-307.

**Davis R.K.** (1964). The value of big game hunting in a private forest. *Transactions of the North American Wildlife and Natural Resources Conference*, **29 :** 393-403.

**Dawson C.P. and B.T. Wilkins** (1980). Social considerations associated with marine recreational fishing under FCMA. *Marine Fisheries Review*, December : 12-16.

**Dunn M.R., S.D. Potten, A.F. Radford and D.J. Whitmarsh** (1989). *An Economic Appraisal of the Fishery for Bass in England and Wales.* Report to the Ministry of Agriculture, Fisheries and Food. Centre for Marine Resource Economics, University of Portsmouth. 217 pp.

**Eberle W.D. and F.G. Hayden** (1991). Critique of contingent valuation and travel cost methods for valuing natural resources and ecosystems. *Journal of Economic Issues*, **25** (3) : 649-687.

**Edwards S.F.** (1990). *An economics guide to allocation of fish stocks between commercial and recreational fisheries.* NOAA Technical Report NMFS 94. 29 pp.

**Fletcher J.J., W.L. Adamowicz and T. Graham-Tomasi** (1990). The travel cost model of recreation demand : theoretical and empirical issues. *Leisure Sciences*, **12 :** 119-147.

**Hudgins M.D.** (1984). Structure of the angling experience. *Transactions of the American Fisheries Society*, **113 :** 750-759.

**Kearney R.** (1991). Resource sharing. *Australian Fisheries*, **50** (1) : 18-23.

**Lal P., P. Holland and P. Power** (1991). Recreational fisheries management - who pays ? *ABARE Conference Paper 91.45*, 9 pp.

**McConnell K.E. and J.G. Sutinen** (1979). Bioeconomic models of marine recreational fishing. *Journal of Environmental Economics and Management*, **6 :** 127-139.

**MAFF** (1990). *Bass Nursery Areas and Other Conservation Measures.* Ministry of Agriculture, Fisheries and Food Advisory Booklet. MAFF Publications, London. 15 pp.

**Moeller G.H. and J.H. Engelken** (1972). What fishermen look for in a fishing experience. *Journal of Wildlife Management*, **36 :** 1253-1257.

**NOAA** (1990). *West Coast of North America Coastal and Ocean Zones Strategic Assessment : Data Atlas.* National Oceanographic and Atmospheric Administration. September 1990.

**NOP** (1980). *National Angling Survey 1980* . The Social Research Unit, National Opinion Polls Market Research Ltd. 62 pp.

**OECD** (1989). *Environmental Policy Benefits : Monetary Valuation.* Paris. 83 pp.

**Pawson M.G. and G.D. Pickett** (1987). *The Bass and Management of its Fishery in England and Wales* . Laboratory Leaflet Number 59. Ministry of Agriculture, Fisheries and Food. 38 pp.

**Pickett G.D.** (1990). *Assessment of the UK bass fishery using a log-book-based catch recording system* . Fisheries Research Technical Report No. 90. Ministry of Agriculture, Fisheries and Food. 33 pp.

**Radford A.F., A.C. Hatcher and D.J. Whitmarsh** (1991). *An economic evaluation of salmon fisheries in Great Britain.* Report to the Ministry of Agriculture, Fisheries and Food. Centre for Marine Resource Economics, University of Portsmouth. 292 pp.

**Rockland D.B.** (1986). A comparison of the social welfare and economic impact techniques. *International Conference on Fisheries - Proceedings.* Third Conference of the International Institute of Fisheries Economics and Trade. August 10-15. pp. 647-652.

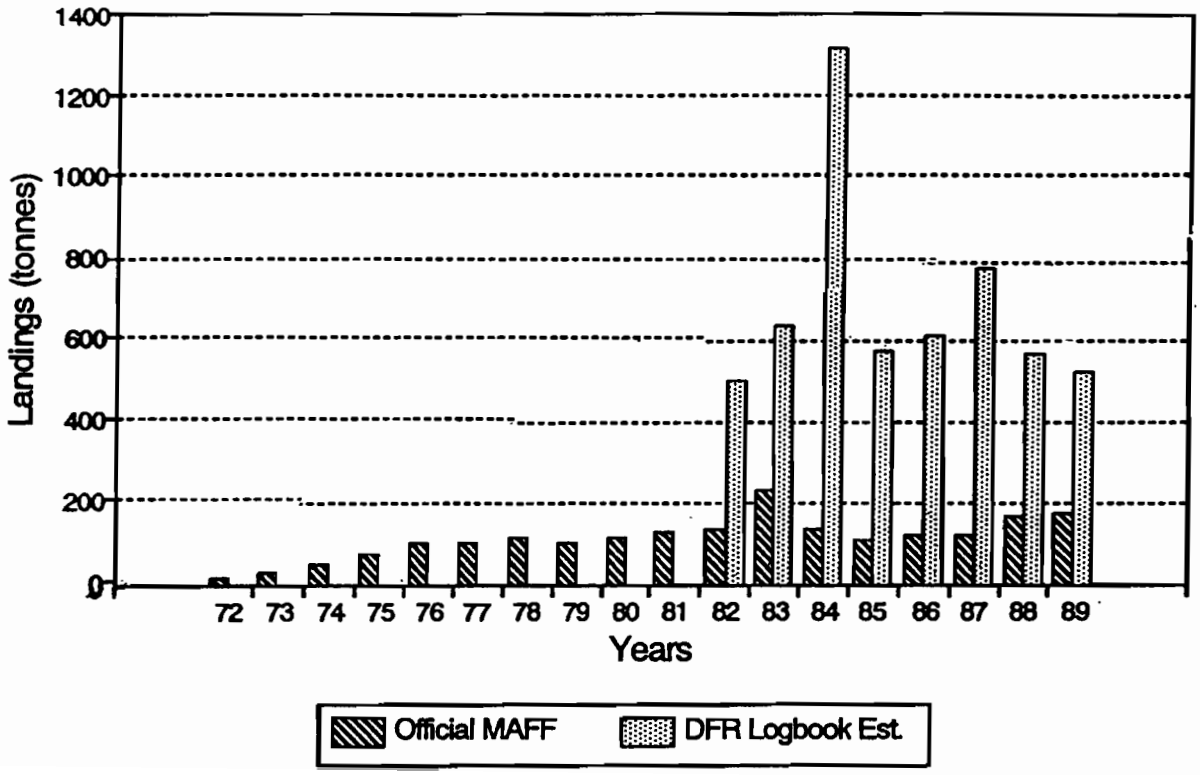
**Smith V.K.** (1989). Taking stock of progress with travel cost recreation demand methods : theory and implementation. *Marine Resource Economics* , **6** (4) : 279-310.

**Stabler M.J.** (1980). Estimation of the economic benefits of fishing : a review note. In *Allocation of Fishery Resources.* (J.H. Grover ed.). Proceedings of the Technical Consultation, Vichy, France. FAO/AFS. pp. 356-365.

**Steinhoff H.W., R.G. Walsh, T.J. Peterle and J.M. Petulla** (1987). Evolution of the Valuation of Wildlife. Chapter 4 in *Valuing Wildlife - Economic and Social Perspectives.* Decker, D.J. and Goff, G.R. (eds.). Westview Press / Boulder and London. Published in co-operation with The Wildlife Society (New York Chapter). pp. 34-48.

**Stevens J.B.** (1966). Angler success as a quality determinant of sport fishery recreational values. *Transactions of the American Fisheries Society* , **95 :** 357-362.

**FIGURE 1.**
**UK LANDINGS OF BASS (1972–1989)**



# The New Institutional Economics (NIE) Applied to the Fisheries : the Role of Information in the (Continuing) Solution of Resource Problems

**James R. Wilson [a] and Rebecca Lent [b*]**

[a]Département d'économie et de gestion, Université du Québec à Rimouski, 300 allée des Ursulines, Rimouski Canada G5L 7B5

Division of Highly Migratory Species, National Marine Fisheries Service, Silverspring Maryland, USA.

ABSTRACT

*New Institutional Economics (NIE) includes many theoretical developments in the social sciences which address shortcomings in the neoclassical rational choice paradigm. Certain limitations of economic theory, particularly assumptions pertaining to information and transactions costs (ITCs) and collective behaviour are addressed by this school of thought. NIE appears to be an excellent framework for analyzing problems in development, since economic stagnation may be due in part to high ITCs which preclude not only markets, but many other normally occuring non-market institutions as well. Finally, the NIE provides useful insights into policy design, implementation and enforcement, because it focuses analytical attention on ITC management.The main objectives of this paper are to : 1) Identify applications of NIE to problems in fisheries ; 2) Interpret the implications of NIE for fishery policy, and contrast these policies with those policies which might be suggested with a more orthodox neoclassical approach. Results of a modelling exercise of a fishery in open access underline the reason for and the significance of simple rules. It is argued that these rules can reinforce the endogenous tendencies of the open access system to disrupt itself, when the ITC environment is favourable.*

## 1. INTRODUCTION

"What I am saying, in effect, is that it is not possible to be of much help in policy formation unless analysis is combined with studies of how various kinds of institutions (firms, markets, regulations) actually work in

* Thanks to the students of Micro-économie des ressources maritimes (Fall 1991), to Eduardo Klein Salas for computer assistance and to Anthony Charles for his review. Comments are invited.

The views expressed in this paper are those of the author(s) and do not necessarily represent the official position of the National Marine Fisheries Service or any other Federal Agency

> practice...If this were done, it would become possible to begin to make more useful policy recommendations, and to say whether an institution should be extended, modified or curtailed in favour of some other. These studies of what Heaven is like are not without interest, but they are bound to have most interest for people who are sure of getting there." **R. H. Coase (1970)**[1].

New Institutional Economics (NIE) includes many theoretical developments in the social sciences which address shortcomings in the neo-classical rational choice paradigm. It is an out-growth of institutionalist writers, who tended to take subjectivist approaches to the analysis of economic behaviour, rather than seeking to derive refutable hypotheses from abstract propositions. These approaches, though rich in observation and historical value, uncovered few general mechanisms of individual or collective behaviour, in the opinion of some economic historians. It was not until the landmark works of the Property Rights and Collective Choice authors that there were many refutable hypotheses which could be related to the formation, change and disintegration of institutions. Certain limitations of conventional economic theory, particularly assumptions pertaining to information and collective behaviour were addressed by these authors. Now, there are many good examples of how institutional economics has been re-vitalized by a judicious marriage of the rational choice paradigm, with its power to elegantly produce refutable hypotheses, and the more "bio-sciences" approach of field observation.

However, within the fisheries economics profession, with some exceptions, the interpretation of events from the perspective of NIE, and the formation of policy positions from these perspectives seems limited. The reasons for this might be four-fold. First, so much has been focused upon the act of fishing and the resulting stock effects in a static and a dynamic context that comparatively little work (by economists) has gone into the study of the other institutions which evolved to function in this environment. Second, the static neoclassical model of the fisheries has seldom met any formal and frontal theoretical challenge by an NIE economist. Third, there appears to be an illusion that "creation" of property rights by the state, whatever that means, was the dominant policy recommendation of property rights theory, when in fact the recommendations were far more subtle than that. Fourth, a theory grounded in the Pigovian conception of the competent and benevolent state, developed and applied largely by public servants, can hardly escape arriving at the two policy conclusions of state-run privatization or state control [2].

This paper has two objectives. One objective is to discuss some of the recent applications of NIE to the fisheries. The other objective is to demonstrate how an NIE perspective can significantly change how one looks at data and interprets history taken from the fisheries, and what one considers to be relevant policy variables.

The next section begins with a brief description of NIE. The following section will expand upon the terms used in the first section. Next, applications of the NIE are discussed, in the context of fishery production and management. Finally, the paper offers an interpretive example of how an NIE perspective might change the way one views the issue of fisheries management.

## 2. WHAT IS NIE ?

NIE builds upon the work of classical institutionalists and extends the neoclassical rational choice paradigm of economic behaviour, by positing theories which explain the formation, change and demise of all *institutions*, including the market institution. It is an amalgamation of field observations and *a priori* hypothesis derivation and testing. Certain limitations of conventional economic theory, particularly assumptions pertaining to information and the ability of the individual rational choice model to forsee and explain collective behaviour, were addressed by these major branches of economics. The resulting theories are more susceptible to testing, yielding a rational choice model more applicable to a greater range of *in vivo* observations.

Since the field is "new", there is some divergence of opinion on basic theoretical issues. For example, Eggertsson (1991) advocates studying economic behaviour both of individuals and institutions from within the rational choice paradigm, but

1. It is interesting to note that the object of Coase's ridicule is a paper by Scott and Southey on the sole owner ; itself an important contribution to the neo-classical literature on the economic theory of the fisheries.
2. In the famous good road\bad road debate between Frank Knight and A. C. Pigou, for example, it almost seems as if they are arguing theoretical points from different institutional perspectives. One would think that to Pigou, the Crown ultimately owned the roads, was empowered to manage the roads, and therefore was obliged to do something about the problem of congestion. This reality of the British system makes it tricky even when Canadians swap economic theories of resource use with Americans.

using the theoretical extension of *transactions costs*. He differentiates institutional economic thought into New Institutionalist and Neo-institutionalist (which he calls NIE) factions. The difference between the two factions is that the New institutionalists, according to him, tend to reject the rational choice paradigm of the neo-classical tradition in favor of "bounded rationality" models. The Neo's retain the rational choice paradigm.

Explaining the mechanisms by which different institutions form and change is a strong focus of NIE literature. Ostrom (1990) takes a "field biologist" approach to deriving testable hypotheses, preferring to choose and analyse selected cases of commons management, principally from the fisheries, to demonstrate those attributes of small group (50 to 1500) dynamics which contribute to or detract from commons management. She also provides a history of the "Tragedy of the Commons" literature, and the two major policy solutions which have thus far fallen out of that literature : Privatization and state control. Ostrom casts these as various forms of the "Hardin Prisoner's Dilemma" game, and concludes that none necessarily guarantee Pareto superior moves from open access, essentially for the reasons described by the Public Choice and Property Rights theorists. Endogenously-derived rules are demonstrated to be potentially Pareto superior to either state control or privatization, under some well-defined conditions. Although there are examples of failures in commons management, there is significant empirical evidence to suggest that individuals and collectives are not *a priori* doomed to exploit their resources in a state of anarchy.

There are subtle theoretical disagreements within NIE concerning the costs of overcoming transactions barriers to get things done, and the role (and cost) of individual and collective innovations designed to dismantle the barriers. Ostrom still sees the rent dissipation of open access as a sign of inefficient allocation of resources. It is in fact inefficient, if there is an observable, endogenous mechanism which, if more artfully exploited, will render the open access condition undesirable to a rational human. Other authors arguing from Eggertsson's perspective seem to suggest that rent dissipation can certainly be a motivation to form contracts, but it cannot be a sign of inefficiency, without knowing more about the transactions cost environment, and the real opportunities to invent devices or rules that reduce those costs, or that slow the dissipation. Still, there are numerous points of agreement among NIE economists.

## 3. TERMS, CONCEPTS AND CONTEXTS

### *3.1 Institution*

An institution is an understanding between individuals concerning the way in which they interact in a specific activity. It is also characterized as a set of rules as well as a manner of enforcement. Both of these components can be defined and applied ranging from very informal agreements with no enforcement to highly rigorous and stylized rules. It seems that most researchers also concur that institutions are endogenously formed, arising out of the need by individuals as well as the collective to facilitate and coordinate social transactions given the cost environments which prevail. Thus institutions are rule structures which are created out of the desire to economically deal with *costs of transacting* [3]. Institutions evolve as the *transactions cost* environment changes, although lags in institutional adjustment are common, particularly in situations of rapid changes.

Since an institution is largely the result of efforts at dealing with *transactions costs*, the regime of open access (*res nullis ; constrained anarchy*) is an institution in which those involved might at least tacitly agree to no rules and no enforcement, because the costs of transacting are too high to consider other alternatives. In situations where conflict costs are low, this institution may be the source of significant amounts of surplus flow into an economy. The regime of *common property* management, under certain well-defined cost environments, has been demonstrated to be a highly effective institution for managing resource bases and is even the model used in modern corporate activity, as well as in subsistence economies (Bromley and Cernea, 1989 ; Acheson, 1975 ; Feeny et al 1990). It is also what is most often encountered in the fisheries, despite the language used by some economists. The *market* is an institution of high order, usually with high costs of creation and maintenance. Markets can exist even when transactions costs are positive. In the unlikely event that

3. It is important to reflect on a hind-sight analysis made by Coase on his most famous two papers, taken during an interview with Eggertson (1991) : "Transactions costs were used in one case to show that if they are not included in the analysis, the firm has no purpose, while in the other, I showed, as I thought, that if transactions costs were not introduced into the analysis, the law has no purpose."

*transactions costs* are zero, then markets exist for all things, and they will replace all other institutions motivated by economic interest, including the *firm* and *government*. However, firms and governments thrive, and non-market institutions abound. Therefore, to admit any institution besides a market into a theoretical analysis is tantamount to admitting existence of transactions costs, and by inference, imperfect information. The richness of economic theory becomes apparent not when we study the abstract firm embedded within perfectly defined markets (which, from an NIE perspective is a theoretical redundancy) but when one realizes that firms exist *because of* imperfect information. To an NIE economist, *government* and *law* are, at least *a priori*, economically motivated inventions which are an important first step toward reducing the cost environment sufficiently for other institutions to exist [4]. Aknowledging a transactions cost environment renders the neo-classical paradigm intellectually pertinent, but admitting the existence of this environment does away with the model's power to propose an *optimum optimorum* to guide toward, other than the general efficacy of enforceable contracts, where possible (Randall 1983). The NIE is particularly destructive to normative economics, which attempts the theoretical demonstration of the inherent inefficiency of certain institutions against the standard of perfect competition.

### *3.2 Information and Transactions Costs*

Given that imperfect information transmission exists in real economies, the economic problem of the extent and form of contracting becomes the primordial issue. High information and transactions costs (ITCs) can preclude the emergence of markets even among the most well-intentioned traders. In these cases, non-market institutions may take the place of markets, with their own specific "rules" of operation. These institutions take many forms, but generally reflect the circumstances in which they evolve. As pointed out in the literature, the institutions which do emerge are those which minimize transactions costs under a given state of nature, and as this state is modified, so are the institutions on which they are based. For example, the firm might be viewed as a command economy in miniature organized by a nexus of long-term contracts. It is characterized by the suspension of continuous pricing of outputs, and where inputs are managed by the entrepreneur (Eggertsson, 1991). Coase (1937) seems to view the size of the firm as a function of entrepreneurial capacity, but also the ITC environment in which the firm finds itself. We can imagine that ITCs can be so high that it is economically efficient for individuals and for society to opt for open access. These are the cases where individuals and collectives are not competent or willing, because of cost considerations, to solve the technical problem of innovating institutions which reduce ITCs. Fortunately, both individuals and governments appear to innovate constantly to reduce those barriers which make for high ITCs. These innovations extend corporeal vision, hearing, and memory by remarkable means. Thus, institutional formation, change and destruction is endogenous, evolving continuously with the changing cost environment.

A theme associated with transactions costs is incomplete and/or asymmetric information on how contracts are formed. Certain institutions of high precision in contracting such as markets for hours of labour cannot emerge because conditions of imperfect or asymmetric information prevail, and moral hazard as well as adverse selection problems must be dealt with. For example, the difficulty in monitoring workers may lead to a preference for a non-wage contract, such as the share system present in some fisheries (Nabli and Nugent, 1989). The absence of markets for insurance explains the emergence of non-wage contracts, as is also evidenced in share cropping arrangements in agriculture.

### *3.3 Property and Rights*

The reason why there is a desire to surmount barriers to transactions is to negotiate with others for the exchange of rights. Formally speaking, a right is a social sanction which allows the person to benefit by behaving in specified ways, even if it means damaging someone else. Property is not an object such as land but is rather a right or a group of rights to a benefit stream that is only as secure as the duty of all others to respect the conditions that protect that stream (Bromley and Cernea, 1989). Many rights, as well as the negotiations for them, occur in non-market contexts, again because of transactions costs. The absence of such rights might provoke negotiations to establish an institution which more clearly defines rights, while the presence of non-attenuated property rights can allow negotiation of the exchange of goods and services. For example, the lack of clearly defined rights to fishing grounds prohibits the exchange of fishing rights

4. Nozick (1973) concludes that individuals in a state of anarchy as defined by Locke will opt for an entity to hold the rights to the legitimate use of violence. Furthermore, such an entity would be viewed by all as a Pareto efficient move.

through a market. While in many cases this has led to overfishing, there are also numerous cases of the emergence of information networks which virtually prohibit outsiders from participating in the fishery (Wilson, 1990). Finally, non-attenuated rights act very much like those environmental barriers which provoke transactions costs. Environmental stress on the economic system can force institutional change, but so can a moral imperative. For example, public management might hold non-attenuated rights to preserve bio-diversity, based upon inter-generational equity or on moral grounds.

### *3.4 Collective action*

NIE bridges individual economic behaviour with collective behaviour by providing an explanation of economic motivations for the formation of collective institutions. This is done essentially by borrowing heavily from the Public Choice and Public Finance literature. There are many important areas in the study of collective action, but the most germane to fisheries seem to be Rent Seeking and Commons Managment.

The fisheries are examples of Common Pool Resources (CPRs), based upon a *resource system* providing a flow of *resource units* (Ostrom, 1990). The CPR is a resource system large enough to make contracting for exclusive individual rights costly, although not impossible. A CPR cannot be jointly used, and is *subtractible* in nature. An interesting example of the production and distribution of CPRs in the fishery is the participation of fishers in the restocking of marine resources. The historical existence of private transferrable property rights granted by the Crown to individuals (usually nobility) for the river sportfishery in Scotland is cited as a primary reason for the survival of Atlantic salmon in Scotland while the species is virtually extinct elsewhere (Johnston and Lent, 1981). However, in Québec, where government is more populist, the policies of putting in place local collectively-managed Zones d'exploitation controllées (ZECs) for salmon rivers in the 1980's has encountered resistance, mainly from rural populations with lower incomes (Wilson, et al 1991). Oregon and Alaska, on the other hand, have been experimenting with the private provision of salmon in a CPR context (Wilson, 1991). Each institutional organisation for the provision of salmon is clearly framed by governmental institutions with different underlying philosophies about how "public" a resource such as salmon should be, and thus who reaps the benefits.

Rent Seeking (RS) according to Buchanan (1980) occurs when entrepreneurs target on rents or opportunities for rents which have already been discovered and concentrated, usually by government, instead of innovating ways to deal with transactions costs for a profit. Surplus which is burnt up in competition for these rents is a pure loss to the economic system. D'nes (1985) has explored the implications of RS for the static open access theory of the fishery. Another potential application of RS theory to the fishery could be to study the behaviour of both foreign and domestic fishermen under the special provisions for public input within the Magnuson Fisheries Conservation and Management Act (MFCMA) of the U.S. Some fishery managers in the U.S. feel that the MFCMA was a tool created mainly for displacing foreign fishermen. However, it is less able to successfully manage domestic fisheries. This loss of management control is because factions of the domestic harvest sector, who had strong RS motivations for supporting the MFCMA, are now directing their RS energies at the Regional Fisheries Management Councils (FMCs), as well as through other political channels. However, others maintain that the FMCs are good institutional platforms for regional-based commons management, in part because of the RS motivation. These opposing hypotheses either point to a dysfunctional institution which should be abolished in favor of more precise contracting, or to a fundamentally healthy institution for the management of the commons.

## 4. ACTUAL AND POTENTIAL APPLICATIONS OF NIE TO FISHERIES

There have been a few persistent "NIE" authors who have written on the fisheries, and who have challenged some of the presumptions of the neo-classical model of the fisheries, practically from its inception. This is a list of some who have used NIE arguments. Finally, one potential application of great pertinence is presented ; the efficient management of fisheries.

### *4.1 Actual Applications*

Cheung (1970) clearly explains why rent dissipation in the standard theory of the fishery is an asserted and not a derived result, and then offers a derived result using an n-person oligopoly model. He also advances the idea that certain types

of contracts carrying enforceable exclusion clauses have a low chance of forming in the face of the environmental realities of the ocean fishery. This discussion breaks open the questions of the internal validity of the static fisheries model as an explanatory and as a policy device.

Bromley and Bishop, both jointly and severally ( Bromley, 1969 ; Arnold and Bromley, 1970 ; Bishop, 1973 ; Bromley and Bishop, 1976) challenge the conventional wisdom and the policy prescriptions deriving from the fisheries model, by rigorously examining the broader welfare-theoretic implications of policies made to render the fishery more "efficient" (limited licencing, in their case). They make a convincing case that the position taken by most fisheries economists of the time was not put into the MFCMA for good reason ; because the profession never addressed the pivotal public policy question "efficiency for whom ?" in a coherent manner. They conclude that Congress was perhaps wise in ignoring economists' recommendations for obligatory limited entry.

Acheson (1975) argues that the tragedy of the commons did not necessarily hold in the Maine lobster industry, because unofficial inshore fishing rights are enforced through community pressure as well as outright violence. Fishers have even gone so far as to apply self-imposed trap limits and closed seasons, which resulted in a higher catch per unit effort, larger lobster size and higher incomes for the fleet. This implicit privatization of the lobster resources has led to fewer problems of overexploitation in contrast with the other marine resources of New England. Acheson thus challenged the "tragedy of the commons" but called on fisheries managers to seriously consider existing social institutions in the fishery when designing management plans.
Wilson (1975) demonstrated that there was no "tragedy" in the commons, at least in a comparative analysis of earnings of lobstermen within perimeter defended areas having well-developed communications networks compared to fishermen not having these institutions in place. Another example of information networks established in the harvesting sector is the California harpoon swordfishery (Lent, 1978). This fishery is characterized by relatively high search costs, and information networks have emerged as cost-minimizing (and competition excluding) institutions. Similar environmental and cultural realities of multi-species fisheries leads Wilson (1983) to suggest the return to simple, endogenously derived rules of use.

Lent and Drouin (1989) investigate non-market institutions in the provision of inputs to the Québec cod fishery. The seasonality which characterizes this fishery, brought about in part by the lack of limited entry, has resulted in considerable excess capacity in the processing sector. As a result, each buyer faces substantial risks of not obtaining sufficient raw material to process at an economically efficient level. Given the lack of insurance markets for this sort of risk, processors provide services such as credit, bait, ice, moorage and employment of family members of the fishing fleet in order to secure their loyalty and their landings. While the lack of a market for insurance (due to moral hazard) may explain the presence of this implicit vertical integration, some explanation may also be found in information and transactions costs. Wilson (1990) explains the dissemination of information among fishing vessels based on the theory of collective action. Individuals are not able to collect sufficient information for successful fishing, and thus some forms of contractual arrangements must be made among fleet members. This brings up issues of exclusion, free-riders and problems in cooperative behaviour. Wilson suggests that a better understanding of the functioning of information networks in the fishery would improve the quality of public management.

### *4.2 Potential applications ; Efficient Regulation of a Fishery Re-considered*

Perhaps one of the more important applications of NIE to the fisheries is to re-examine what efficient regulation actually means. Ostrom provides some empirical studies of small group dynamics in an effort to examine why some succeeded in commons management, and why some failed. However, a skeptic might respond by saying that it is no surprise that she can produce success stories when the groups are small. The problem is to find the same behaviour with big groups; Are large groups doomed to perpetual anarchy? Answering this question is the subject of this section.

There have been researchers who, instead of using the fisheries model to derive policy statements, have described the condition of open access in a dynamic context. These efforts have been very interesting and worthwhile, since the result has been a greatly improved understanding of the dynamic behaviour of the open access environment. One can build upon this work by demonstrating how a NIE perspective can change the way one looks at management problems, the data, and the relevant policy variables for public management. Several studies are discussed in light of the potential applications of the NIE.

From an NIE perspective, the first noteworthy thing about these analyses is that they are ex-post explanatory presentations of existing economic[5]. The fact that data were already being collected in quantities sufficient for a researcher to subsequently model the fishery suggests that there was already substantial economic interest in the fishery, or at least there was enough interest to warrant the expense of generating information.

The second interesting thing about these studies is that they analyse fisheries, just before or between major structural changes, away from what might be called pure open access. For example, there was a global moratorium on the taking of Blue Whales in 1965. Although some might criticize the timing and effectiveness of this action, it is nevertheless true that political action was taken at the international level to avoid wiping out the Blue Whale. It is also interesting that the political act of moratorium seems like one of those "bangs" in a "bang-bang" control model, which has been defended elsewhere as an optimal control in the face of extinction (Spence, 1974). Now, after nearly 30 years of consciousness-raising, estimates of Blue Whales are now around 10,000, up from fewer than 5000 individuals in 1965 (Ozincki, 1992). One possible explanation is that political institutions, even very large ones, eventually tend to disrupt open access cycles. If this is so, what keeps them from being more "rational" more quickly, and what is the role of the economist in this context?

Wilen's (1976) dynamic analysis of the open access condition on the Pacific Fur Seal fishery ends in 1900, after which the fishery came under the control of a single firm. The approach to a dynamic equilibrium in open access was again disrupted. In this instance, it may well have been because the fleet became so small and centrally located that they were able to communicate with one another sufficiently well to form the Victoria Sealing Company in 1896. It appears that the disruption of this dynamic process in open access has an NIE explanation related to transactions costs. When enough fishermen left the fishery, it became organizationally feasible to consider other institutions besides open access. The chronology of the Pacific Halibut fleet (Orth et al 1980) suggests that in the late 1930's, similar attempts were made to organize that fleet during a time when stocks were down. To take another example, the first limited licencing program in the U.S. was enacted into law in Alaska in 1973. The enabling legislation came in the wake of some of the worst stock levels of salmon in recorded history. Conrad (1986) suggests that the MFCMA dealt with some but not all dimensions of open access. The legal framework of MFCMA "boxed up" the open access solution, but after a period of adjustment, domestic fishermen could be seen drifting towards a new dynamic equilibrium in open access. So the idea of simple and incremental solutions to problems brought on by a persistent open access phenomenon is visible within several well-known studies.

Two other NIE interpretations might fall from these observations. Technological change in public management tools follows the same laws as does technological change in the private sector. Change is motivated by need as well as the stock of knowledge necessary for application. Inventions contribute to the stock of knowledge, but may not be directly applicable as innovations. This stock is independent of the discoveries of any one person. As need coincides with stocks of knowledge, innovations or practical applications of inventions occur. Part of the frustration that economists may feel as public managers could be related to the timing problems associated with introducing innovations, as well as the act of innovating itself. Suggestions about how institutions could be cost effectively changed build a store of inventions which at the appropriate time can be applied as innovations. However, the innovation or application of an invention is related to the competence of the public inventors and innovators, as well as the timing and institutional context in which they find themselves. Many inventions are clearly too costly to effect, because other necessary infrastructure is not yet in place to accomodate the innovation. The other NIE-type observation is that open access conditions are nested and chronic. They are "boxed up" by the evolution of institutions, but they never go away. Talk of "solving" the open access problem in general is pointless.

Conrad and Bjorndal (1987) provide a base from which one might make further interpretations with an NIE perspective. Their analysis demonstrates the open access condition with data taken from the North Sea herring fishery, with the well-known spiral tendancy towards a dynamic open access equilibrium. However, as with the Blue Whale, the structural interruption of the dynamic cycling is a moratorium on fishing. They suggest that patching behaviour of herring schools makes for a non-increasing industry cost structure, which makes it easy for that industry to wipe out the stock. Because they publish their raw data, it is possible to exploit and perhaps take other interpretations away from their work. These interpretations suggest other possibilities which might be useful to managers willing to forgo attempts at "solving" the open access problem.

5. Some might argue that there is nothing "striking" about the fact that ex-post explanatory presentations of existing economic conditions can or had been done. We would agree, were it not for the fact that information is costly, and the hows and whys of its acquisition and disappearance figure heavily into management decisions. The question of what to record and maintain as history (and therefore what information will survive to be re-analysed) as well as who will have access to this information is far from a trivial topic.

The work of Bjorndal and Conrad (1985 and 1987) (B&C) was re-analysed using Quattro Pro version 4.0. The objective was to look at the sensitivity of their parameters on the dynamics of the fishery, as well as to demonstrate how an NIE orientation might change how one model the dynamics of endogenously derived institutional change. The first step was to verify the dynamics of the model. There are no surprises, except that the model was extremely sensitive to changes in certain parameters.

Part of the verification included positing what we believe to be reasonable relations describing ex-vessel price and average per boat cost. Lagged relations for these two important variables were estimated. The results of these estimates performed on Statgraphics 2.6 are presented in Table 1. It is noteworthy that we may have uncovered some evidence of a negative relationship between average costs and stock levels, although there have been some cogent arguments in the literature why we would not expect this result in the North Sea Herring fishery (Bjorndal and Salvenes, 1993). Perhaps more robust is the negative relation between ex-vessel prices for herring and landings.

14 observations fitted, forecast(s) computed for 0 missing val. of dep. var.

B&C's estimate of the maximum price per ton of herring (2000NoK) is used. Another change which might bear upon the comparative interpretation is that there is always at least one vessel in the fishery in this formulation. This does not seem to be an unreasonable assumption, given that the stocks of many fisheries are still monitored by direct sampling. Estimated instead of observed values of Pt and Ct were used, which filters out the stochastic problem (which can be important) and makes the trajectories look smooth. Finally, this simulation does not correct for measurement errors in discrete time. This might explain the divergence between the observed and simulated dynamic paths. The simulation is to the year 2003. However, our objective is not to make predictions but to observe the sensitivity of the open access model. One surprising feature of our simulations is that the stock does not become extinct over the range observed, neither when using a mix of real and simulated data nor when using simulated data, and using the parameters of B&C (Figure 1a).

It is often argued that simple rules such as global quotas or gear restrictions, and tactics like maintaining barriers to information transfer are suboptimal, compared to more refined management methods. To some NIE economists at least, sub-optimality is a moot point, compared to the problem of extinction and the tractability of centralized plans from an ITC standpoint. Within the dynamics of large groups, simple rules may be all that can be assimilated and agreed upon, and without a clear notion of ITCs, one simply does not know how "sub-optimal" these rules are. However, because of the positivist approaches of many dynamic analyses, it may be possible to see why fisheries managers and fishermen in large groups have tended to focus on simplicity and incrementalism, instead of more fundamental solutions invented by economists. First, an attempt is made to show why this happens. Simple rules tend to focus directly or indirectly on the productivity of factors used in fishing. In real situations, these controls are diverse, but are generally divided into Time, Area, and Gear restrictions. Gear restrictions are the most obvious example of "regulated inefficiency". In the paper by B&C, they estimated a parameter b, which is the elasticity of production for capital (Kt). It is this parameter which might be affected by such simple rules.

In a world of perfect and symmetrical information, markets are the dominant institution, and inframarginal profits are dissipated immediately for all factors of production, including (homogeneous) entrepreneurial capacity. In such a world, it is obviously irrelevant how much faster rents might be dissipated after the discovery of an unowned resource. But in the real world open access fishery, proprietary knowledge of information may well be the only effective barrier to rent dissipation. This may explain why fishermen try to affect entry and exit by maintaining information asymmetries; because it is an important rent preserving strategy in a commons management framework. The parameter n (the responsiveness of Kt for a dollar of profit), also estimated by B&C, would be affected by these individual or public policies.

Finally, the notion of the endogenous nature of institutional evolution in the face of persistent open access is a new concept which owes its existence to the NIE. Adoption of that theoretical point of view might suggest that the existence of open access is of limited importance, but the control of its effects during institutional evolution is crucial. The role of the manager changes from one of innovator and implementer of rules to one of ITC manager, where the objective is to encourage the disruption of the open access cycling, and to constrain it to a less damaging form. We will demonstrate the importance of ITC management with the help of some model extensions.

### *4.3 Changes in b*

Changing b, the elasticity of production for capital is the modelling analogue of gear and other technical restrictions on the fishing industry. Although regarded as relatively primitive and inefficient, the effects on the fishery of relatively minor

changes in its value can be very pronounced. The original trajectory using B&C's estimates is depicted in Figure 1a. If the value of b is increased up to one standard deviation from the mean value estimated by B&C (from 1.3556 to 1.4383), the trajectory "unrolls" to a point where extinction is assured (Figure 1b). When b is reduced by one standard deviation below the mean value (1.2729 from 1.3556), the spiral tightens toward a dynamic equilibrium with a stable positive capital and fish stock (Figure 1c). This is an example of so-called "regulated inefficiency" in an industry, but it is readily understandable why managers might resort to it. Relatively simple and low cost to put into place and to control, the effects are striking. Such a measure can avoid the large erratic spirals which eventually bump into either the capital stock or the fish stock axis. If one cannot induce a workable sea-tenure system tied to the resource base on the down-side of the first or second cycle, (like what happened "by mistake" in the Alaska salmon fishery) the least that should be done is to dampen the oscillations by negotiating rights to impose gear restrictions. If the objective is to encourage the emergence of new institutions, one might ask if gear restrictions encourage change. If alternative attainable institutions exist in a given ITC environment, we may see change motivated by comparing rents in open access versus other regimes. However, with stable capital and stock levels, ITCs have to fall in order to provoke an endogenous change. The reason for wanting the fishery to experience "biologically safe" open access is to entice the system to disrupt itself. If public management systems are geared to trying to reduce the ITCs of collective rule formation, hard simple rules can provoke more refined institutions.

### *4.4 Changes in n*

B&C(1985) estimate an adjustment function related to the profitability of the fleet interpreted as "boat dollars"; the amount of capital attracted into (out of) the fishery for an increase (decrease) of one dollar in profits.

Learning curves and start-up costs in fisheries like high-seas herring can be steep. On the other hand, B&C estimate that alternative fisheries and opportunity costs also affect capital dynamics. Some of their best estimates of capital dynamics (1985, Table 5, LIII.3) include parameter estimates for the opportunity cost of capital. In these cases, assuming positive effects on capital growth, n1 = 0.2390. When the point estimates contributing to the outflow of capital are added, then n2 = -0.1644. There is no reason to suppose that rates of inflow incited by an additional dollar of profit will equal rates of outflow for one dollar of loss, and in fact B&C note this as a possibility. This reasoning is used in order to modify the capital ajustment equation such that n1 = a*n2, a 0. In Figure 1a, the trajectory corresponds to the situation where a =1, and the parameters are set to those used in B&C's 1987 paper. Diminishing a by only 13 % (to .87) suggests that capital flows more easily into the fishery than it flows out, and thus leads to the extinction of the stock (Figure 1d). Increasing a by 13

would suggest that the flow of capital is relatively slower to respond to profits than it is to respond to losses. This tightens the trajectory spiral rapidly to a positive fish and capital stock level (Figure 1e). Information asymmetries as well as other incentives aimed at changing the cost of entry andør exit can have a profound effect upon the fisheries. For example, public efforts at improving profitability of open access fisheries can lead to management nightmares in one case, while in another case it would be considered useful. The public knowledge that opportunity costs are high in a certain fishery can affect the rate of exit. Informational barriers imposed by fishermen on profitability and location of fish may play an important role in slowing the rate of entry. Information, in effect, is the ultimate control variable in the NIE framework. Innovations in information management which affect entry and exit can ultimately lead to stable resource use institutions.

### *4.5 Triggering institution formation*

Although much work has been done on examining those parts of our economy which are related purely to the management of transactions costs, quantitative descriptions of the ITC environment of the fishery seem to be absent. However, we suggest that both timing and management innovations appropriate to the transactions cost environment play a large role in institutional evolution. To show this, we take a very simple world in which there is open access, as described by B&C(1987). Another regime was posited in which it was assumed that fishermen could contract with a management agency to impose a global quota at a (hypothetical) ITC cost of 20*(#vessels)1.2 per vessel, based upon the assumption that it costs more per participant to agree to strike a deal with greater numbers of individuals. We wish to stress that these are hypothetical ITC functions, because no real ones exist at present. However, it would seem that the measurement of ITCs and their effect upon the behaviour of fishermen would be an important line of applied research.

It is assumed that the management agency can and will enforce a global quota of MSY. In fact, any time the stock falls below K/2, where K is carrying capacity, the fishery closes except for one vessel which monitors the stock (this is done for computational convenience, but it can also reflect some practical realities of management; information is needed on the stocks). Note also that no one is excluded from the fishery, but the global quota is respected rigorously. Further, the decision to have a global quota and when it is to be put into place was made by the fishermen themselves, and is a function of the comparative net benefits of each regime for the representative boat owner, assuming a homogeneous fleet. The actual modelling exercise simply says that when the average fisherman, with a knowledge of the aggregate harvest and stock effects on his future individual earnings, encountered multiple periods where individual net benefits with global quotas exceed those in open access, he or she would be willing to form a contract with the agency to put the new regime in place, even with positive transactions costs. Homogeneity of the fleet assures a relatively clean collective decision, again for purposes of exposition. Another feature of this analysis is that once an institutional change is made, the management agency will not let the fishermen abrogate the contract. This is realistic because public rule formation tends to be somewhat "sticky". Once a system goes through the trouble to form a collective contract, its abrogation is usually difficult to accomplish. The results are in Figure 2. The industry rounds the first corner and the number of fishermen begin to decline. The declining stock has taken its toll on the profitability of each boat. The institutional "innovation" is present and the (hypothetical) ITC environment is favourable, so a change is made in "1971". Notice also that the result appears to be a stable limit cycle similar to pulse fishing, but this is only if public and private managers do nothing to encourage further institutional innovations. One can easily imagine continued refinements which further change the trajectory, perhaps even provoking a dynamic equilibrium. The point of this discussion is that such behaviour, which exists in reality, is a very encouraging sign. Despite the continued existence of open access, rational economic choices can be and are still being made. The job of an economist, from the NIE perspective, is to help make sure that the transactions cost and informational environments are such that rational choices can continue to be made.

## 5. CONCLUSIONS

NIE is a cogent extension of the rational choice model of economic behaviour which offers much in terms of how to model and test observations on economic behaviour. The emphasis in NIE fisheries management is oriented towards managing ITCs so that the industry will contribute substantively to the evolution of collective institutions. Economists can help by being ready to work on the practicalities of making it easy to form contracts. This work can include proposing institutional changes, but these proposals need to be geared to an ITC environment. Timing is also important.

The decreasing costs of information accumulation and management might change public management by allowing agencies the option of looking at efficient rule formation or institution building which is tied to catching the industry at the right time with the right innovation. As such institution-building continues to cut away at the never-ending open access "problem", we may see more rapid convergence to "rational" resource use, but the process will essentially be the same. The incremental formation of rules will be subject to informational constraints. Agencies have a role in this process, but it might be more to minimize ecological disasters having inter-generational economic impacts while the economic system grapples with the shorter term resource problem. Government also can innovate ways to reduce transactions costs. Simple rules work ; moratoriums, seasons, gear restrictions, and global quotas. Providing a forum for the measured exchange of management related information seems to be important. In this sense, the "Regional Management Councils" of the United States are potentially very potent institutions. This economic point of view is summed up by Coase :

> "....there can be found in fisheries errors so gross that we can have little doubt that a certain kind of change would be beneficial. Perhaps therefore what we should do is to concentrate on these cases (so far as our policy recommendations are concerned) and leave other problems alone. And, perhaps, if we reiterate these recommendations over a long enough period, one day the political forces will be such that, probably for reasons which would not commend themselves to us, our proposals will be adopted because they are there."(Coase, 1970)

In a well-functionnary society, those "political forces" are motivated by individuals ready for a change. This willingness to change will make certain proposals *feasible*, where before they were not. While economists should not always expect to have an audience, there is still some use for them as inventors of possible rules and managers of ITCs. However, their usefulness is in direct proportion to how well economic recommendations resonate with the transactions cost and institutional environments of the real world.

## REFERENCES

**Acheson J.M.** (1975). The Lobster Fiefs : Economic and Ecological Effects of Territoriality in the Maine Lobster Industry. *Human Ecology*, **3** (3) : 183-207.

**Arnold V. L. and D. W. Bromley** (1970). "Social Goals, Problem Perception, and Public Intervention : The Fishery" *San Diego Law Review* : July : 469-487.

**Bishop R. C.** (1973). "Limitation of entry in the United States Fishing Industry : An Economic Appraisal of a Proposed Policy". *Land Economics* : **XLIX** (4) : 381-390.

**Bjorndal T. and J.M. Conrad** (1985). Capital Dynamics in the North Sea Herring Fishery. Institute of Fisheries Economics, Norwegian School of Economics and Business Administration. Discussion Paper 01\85.

**Bjorndal T. and J.M. Conrad** (1987). "The Dynamics of an Open Access Fishery", *Canadian Journal of Economics* : 74-85.

**Bromley D. W.** (1969). "Economic efficiency in Common Property Resource Use : A Case Study of the Ocean Fishery". Bureau of Commercial Fisheries, Economic research Division, Washington, D.C. Working Paper 28.

**Bromley D.W. and R. C. Bishop** (1977). "From Economic Theory to Fisheries Policy : Conceptual Problems and Economic Prescriptions" Chapter 15 from Impacts of of Extended Fisheries Jurisdiction : 281-301

**Bromley D. and D. Cernea** (1989). *The Management of Common Property Resources : Some Conceptual and Operational Fallacies* ; World Bank Discussion Papers.

**Buchanan James M.** (1980). "Rent Seeking and Profit Seeking" ; in James M. Buchanan (ed.) *Toward a Theory of the Rent-Seeking Society* : Texas A&M University Economics Series **4 :** 367p.

**Cheung S.N.S.** (1970). "Contractural Arrangements and Resource Allocation in Marine Fisheries" in *Economics of Fisheries Management, A Symposium.* H. R. MacMillan Lectures in Fisheries ; The Institute of Animal Resource Ecology, University of British Columbia : 97-108.

**Clark C.W.** (1976). *Mathematical Bioeconomics* . Wiley Inter-science, New York : 352 p.

**Coase R. H.** (1937). "The Nature of the Firm". *Economica* ; **4** (November) : 386-405.

**Coase R. H.** (1970). "Comment" in *Economics of Fisheries Management, A Symposium.* H. R. MacMillan Lectures in Fisheries ; The Institute of Animal Resource Ecology, University of British Columbia : 97-108.

**Conrad J.M.** (1986). Economic Benefits of the Magnuson Fishery Conservation and Management Act (MFCMA) on the U. S. East Coast". Paper presented at the 1986 Meetings of the American Fisheries Society, Providence, Rhode Island, September 1986.

**Dines A.W.** (1985). "Rent-Seeking Behavior and Open Access Fishing" ; *Scottish Journal of Political Economy* **32** (2) : 159-170.

**Eggertsson T.** (1991). *Economic Behavior and Institutions.* Cambridge Surveys of Economic Literature. Cambridge University Press : 385p.

**Feeny D., F. Berkes, B.J. McCay and J.A. Acheson** (1990). "The Tragedy of the Commons : Twenty-two Years Later". *Human Ecology* , **18** (1) : 1-19.

**Hardin G.** (1968). "The Tragedy of the Commons". *Science* 162 :1243-1248.

**Johnston R.S. and R. Lent** (1981). *The Salmon Fishery in Scotland.* Oregon State University unpublished manuscript.

**Lent R.** (1978). *Socioeconomics in the Expansion of the California Swordfishery.* Unpublished MS Thesis, San Diego State University.

**Lent R. and S. Drouin** (1989). "Implicit Vertical Integration in the Quebec Cod Fishery." Selected Paper, AAEA Meetings, Michigan State University.

**Nabli M.K. and J.B. Nugent (ed)** (1989). *The New Institutional Economics and Development : Theory and Applications to Tunisia.* North Holland, Elsevier Science Publishers, Amsterdam.

**Nozick Robert. 1974.** *Anarchy, State, and Utopia.* Basic Books, New York, 367p.

**Orth F., J. Wilson, J. Richardson and S. Pidde** (1980). *Market Structure of the Alaska Seafood Processing Industry, Volume II, Finfish* ; University of Alaska Sea Grant Report 78-14.

**Ostrom E.** (1990). *Governing the Commons : The Evolution of Institutions for Collective Action.*Cambridge University Press, Cambridge : 250p.

**Ozincki V.** (1992). Marine Mammal Specialist, Fisheries and Oceans Canada, Institute Maurice Lamontagne, Mont Joli, Québec ; Personal communication.

**Randall A.** (1983). "The Problem of Market Failure". *Natural Resources Journal* ; **23** (January) : 131-148.

**Spence M.** (1973). *Blue Whales and Applied Control Theory* . Technical Report 108, Stanford University, Institute for Mathematical Studies in the Social Sciences,

**Wilen J.E.** (1976). *Common Property resources and the Dynamics of Over-exploitation : The Case of the North Pacific Fur Seal* . Paper No. 3. Program in Resource Economics, Department of Economics, University of British Columbia, Vancouver.

**Wilson J.A.** (1975). "The Tragedy of the Commons : A Test". In Batin and Hardin (ed.) *Managing the Commons*, Freeman, San Francisco.

**Wilson J.A.** (1983). "The Economical Management of Multi-species Fisheries". *Land Economics*, **58** (4) : 417-434.

**Wilson J.A.** (1990). "Fishing for Knowledge". *Land Economics* , **66** (1) : 12-29.

**Wilson J. R., J. C. Michaud, R. Bouchard and R. Boily** (1991). Analyse de la Demande pour la Pêche récréative au saumon : Invesitgation des aspects Légaux et Illégaux de la pêche au saumon au Québec. Rapport soumis au Ministère du Loisir de la Chasse et de la Pêche, Québec. 159 p.

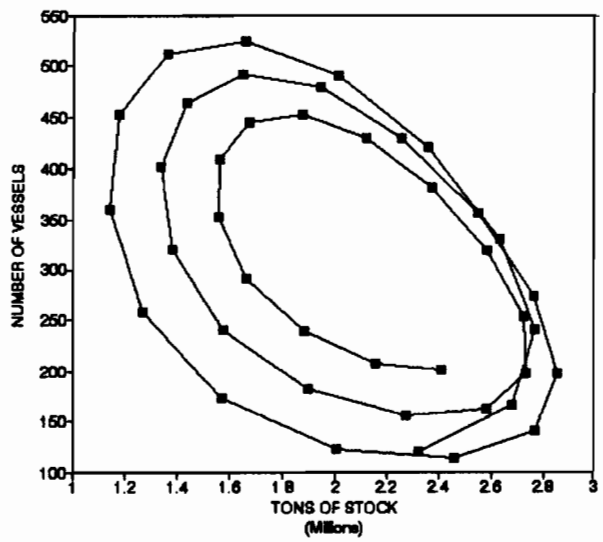
**Wilson J.R.** (1991). The Public Finance of Salmon Enhancement : Two Other Perspectives. Colloque sur l'ensemencement, Ministère du Loisir de la Chasse et de la Pêche et Conseil de l'aquiculture et de la pêche au Québec, Ville de Québec, 1-3 Mars 1991.

**FIGURE 1. OPEN ACCESS TRAJECTORIES FOR THE NORTH SEA HERRING FISHERY, BASED UPON DATA FURNISHED BY B&C (1985 AND 1987).**

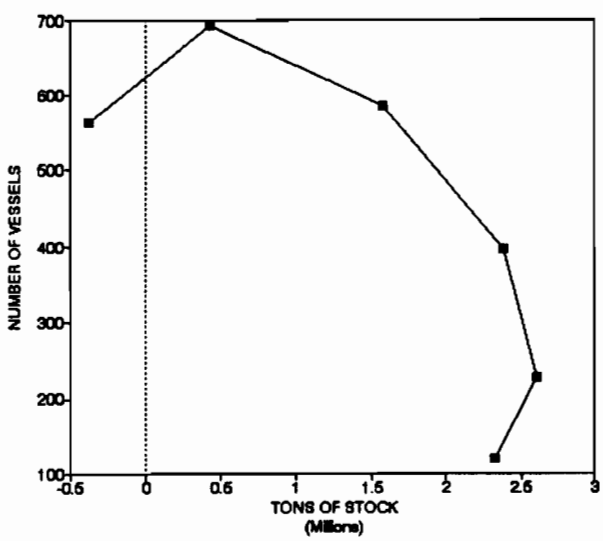
The relevant parameters with their base values are : $b$ = 1.3556, elasticity of production for capital : $n$ = 0.1, sensitivity of capital entry and exit to profits : a =1, the degree of difference between entry ($n_1$) and exit( $n_2$) sensitivity ; $n_1$ = a*$n_2$.All other parameters are as reported in B&C, 1987.

Figure 1. Open access trajectories for the North Sea Herring fishery, based upon data furnished by B&C (1985 and 1987). The relevant parameters with their base values are : $b$ = 1.3556, elasticity of production for capital : $n$ = 0.1, sensitivity of capital entry and exit to profits : a =1, the degree of difference between entry ($n_1$) and exit( $n_2$) sensitivity ; $n_1$ = a*$n_2$.All other parameters are as reported in B&C, 1987.

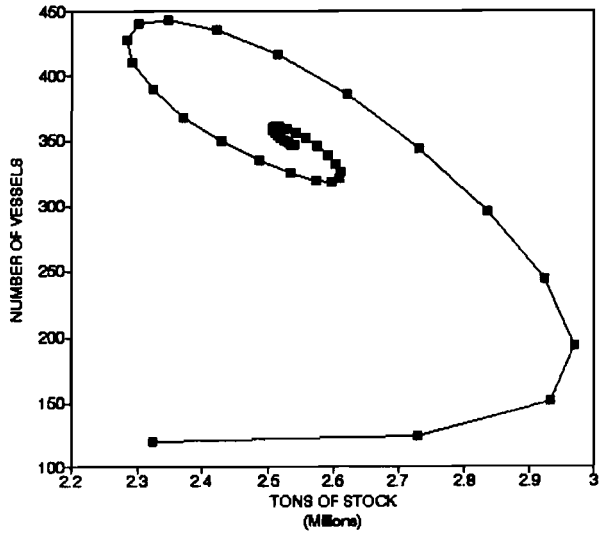
1a



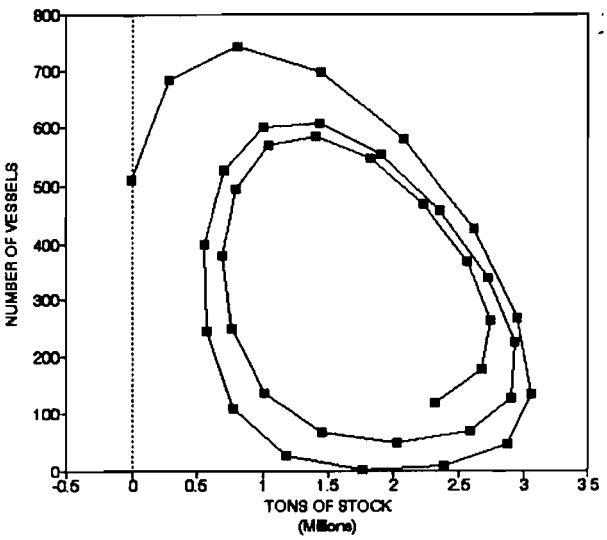

1b



1c


NUMBER OF VESSELS
450
400
350
300
250
200
150
100
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
TONS OF STOCK
(Millions)

1d


NUMBER OF VESSELS
800
700
600
500
400
300
200
100
0
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
TONS OF STOCK
(Millions)

1e

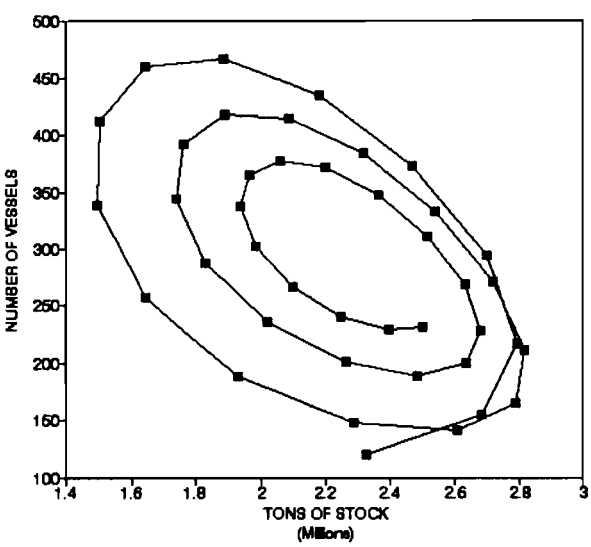
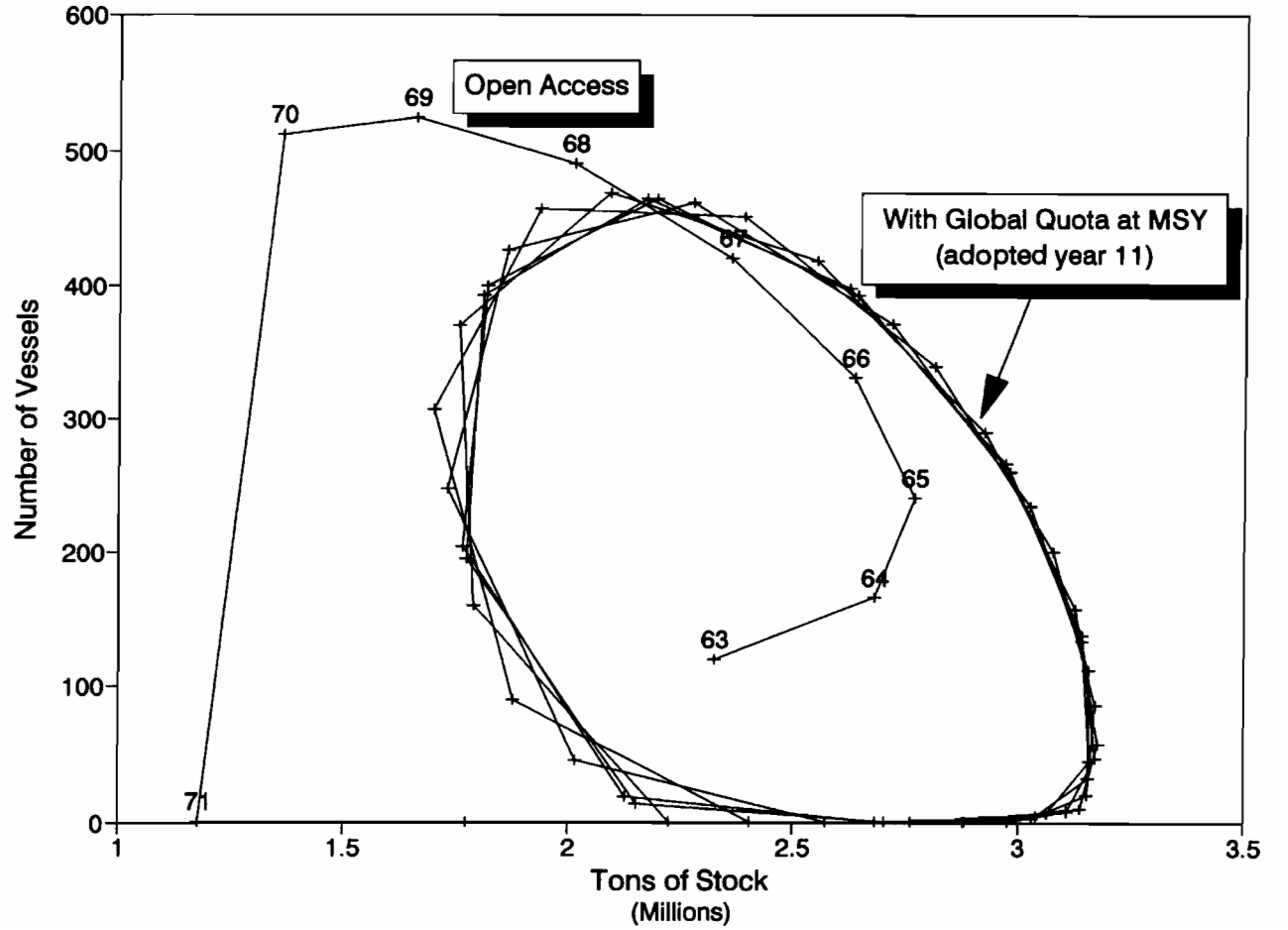

NUMBER OF VESSELS
600
450
400
350
300
250
200
150
100
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
TONS OF STOCK
(Millions)

**FIG. 2**
**WITH SELF-IMPOSED GLOBAL QUOTA**



# Cooperative Fishing Arrangements between Coastal Countries and Distant Water Fleets

**Lewis E. Queirolo [a] and Richard S. Johnston[b] ***

[a]NOAA NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Bin C15700 Seattle, Washington 98115, USA

[b]Department of Agricultural and Resource Economics, Oregon State University, Ballard Extension Hall 213, Corvallis, Oregon 97331-3601, USA

ABSTRACT

*While extended jurisdiction has characterized most fisheries for the past 15 years, nations continue to look for their comparative advantage positions in that sector. In so doing, they sample from a variety of production and trade arrangements. Consequently, numerous arrangements may co-exist, perhaps for extended periods. An important dimension of such arrangements is their duration.*

*Consider, for example, a coastal state that seeks to uncover a latent comparative advantage in fishing and, thus, forms a cooperative fishing arrangement with a foreign partner through which virtually all fishing decisions are made by that partner under a long term contractual arrangement. The planned life of that arrangement will influence the extent to which the potential yield of the resource is husbanded by the foreign partner. This, in turn, will determine the long term success with which the coastal country develops its comparative advantage in fishing.*

*In analyzing the nature and consequences of such cooperative arrangements, it is important to distinguish between the effects on resource use and the way in which the benefits are divided between the partners. An important dimension of the latter is the role of information on biological and market conditions. Such information is often asymmetrically held by partners. As a consequence, the terms of cooperative fishing contracts may be designed to address equity issues. These are different from, but not necessarily independent of, efficiency issues. This is particularly true when partners discount the future at different rates. It is important for the analyst to be aware of these efficiency and equity issues and how they relate to each other.*

* The authors are grateful to Grant G. Thompson and Russell F. Kappenman for both helpful insights and technical assistance in preparation of this paper. Discussions with James D. Hastie, David A. Colpo, and Gilbert Sylvia have also been valuable.

Partial support for the research reported here has been provided by the Cooperative State Research Service, U.S. Department of Agriculture (Agreement No. 92-34276-7140) and by the Alaska Fisheries Science Center, Alaska Region, National Marine Fisheries Service.

The findings in this paper are solely those of the authors and do not necessarily reflect the opinions of the National Marine Fisheries Service, NOAA, or the U.S. Department of Commerce.

*On the other hand, it is also important to distinguish between the terms of agreements between partners operating in isolation and those that result when there are many potential partners. Competitive conditions on both sides of the market for access to resources may generate incentives to signal resource values by competing bidders and, in the process, reduce the magnitude of the asymmetric information problem. Competition, then, may address the efficiency issue. Equity considerations may remain, however, and could be large enough to overwhelm efficiency concerns. Indeed, this may explain why actual contractual arrangements in the world's fisheries diverge from those predicted by the competitive model.*

## 1. INTRODUCTION

The world's oceans have been regarded through time as the common heritage of all mankind, held in trust for the collective good. When demands upon the oceans were relatively few, this noble philosophy was probably not unreasonable [1]. But the burgeoning of human populations and the accelerated growth of technology have conspired, in the latter decades of the twentieth century, to make the concept of a "common property interest in the oceans" functionally obsolete. High speed vessels and aircraft, satellite communication and observation, radar and radio, among others, have extended our political and economic reach beyond the coastal horizon.

Technology has made possible, for the first time, exercise of effective "private property rights" over the, heretofore, remote and often fugitive resources of the extended continental shelf and high seas. Population pressure, leading to increasing consumptive demands, has in many cases made these changes imperative.

In response, many coastal nations have unilaterally extended economic jurisdiction over adjacent waters, traditionally regarded as "open ocean." While petroleum exploration, minerals mining, etc., have been a consideration in extended jurisdiction, living marine resources, and particularly economically valuable fish stocks, have been the principal focus.

One consequence of the nearly universal extension of fisheries jurisdiction (EFJ), which has taken place over roughly the last fifteen years, has been the acquisition by coastal nations of virtually exclusive control of the fishery resources off their shores. In most circumstances, this has resulted in an enormous, and relatively abrupt, international redistribution of wealth.

## 2. COOPERATIVE FISHING ARRANGEMENTS AND GAINS FROM TRADE

Where the fleets of "traditional" distant water fishing nations once operated with complete autonomy, exploiting the fishery resources of the world's continental shelves, they have now, in large part, been displaced. Only when distant water operators have been able to demonstrate to newly endowed coastal states that joint benefits would accrue by their presence have cooperative fishing arrangements emerged. Munro (1985) has demonstrated the potential gains from trade that accompany such arrangements.

In examining the development and evolution of these cooperative fishing arrangements, research has been directed primarily at the economics of bilateral and multilateral agreements, or on the short run behavior of the respective cooperating partners (see, for example, Clarke and Munro ; Kaczynski ; Kerr and Sharp ; Johnston and Wilson ; Anderson and Sutinen). Little attention has been paid to the reaction of other, potentially competing, coastal and distant water nations. That is, the bulk of the economic literature on this topic centers on the potential short term benefits to the newly endowed coastal state, which may accrue from entering into a cooperative fishing agreement with a foreign distant water operator. These benefits may include technology transference, access to new markets, realization of gains in domestic consumer and producer surpluses, and extraction of resource rents from the contracting distant water nation.

But this approach stops short of examining the intermediate and long run implication of joint-venture arrangements for the coastal nation, its distant water partner(s), and the fishery resource itself. As each party acquires experience and

1. In point of fact, because of the limitations of knowledge and technology, this perspective was likely as much a reflection of pragmatic reality as of altruistic ethos.

information from the cooperative arrangement [2], short run adjustments are made, both by the parties themselves and by the broader community of coastal nations and distant water fleets. These latter groups represent potential competitors, whether supplying "access" or "expertise", and may influence the form and stability of future cooperative arrangements. What emerges, we have argued (Queirolo and Johnston, 1988), is a market for access, created precisely because of the widespread movement away from "common property" rules of exploitation of the resource, towards "private property" rights.

In the present paper we extend our earlier analysis, in part, to embrace arguments advanced by Clarke and Munro (1980) under which the coastal nation and the distant water fleet are assumed to have different discount rates. They argue that, under this circumstance, the coastal nation will be unable to design an incentive scheme that induces the distant water fleet to harvest the resource as if the coastal nation's discount rate prevailed. Theirs is an imaginative use of principal-agent theory to demonstrate the existence of an "incentive gap" and the resulting inappropriate (from one partner's perspective) exploitation of the resource.

We propose an alternative perspective : namely, that the presence of competing buyers and sellers of access eliminates Pareto relevant externalities and, in so doing, removes the need to design complex contractual, monitoring, and policing arrangements. We do not suggest that the market for access is perfectly competitive. Rather, by considering what the "access market" would look like if it were, analysts can better understand actual arrangements by focusing on the nature of and the reasons for deviation from the competitive model. The arguments presented here are preliminary in nature. Nonetheless, we hope they stimulate discussion of an important issue in global fishery management.

## 3. COOPERATIVE FISHING ARRANGEMENTS AND THE PRINCIPAL-AGENT FRAMEWORK

Perfect competition is characterized not only by large numbers of buyers and sellers, but also by relatively accessible information. In the case of cooperative fishing arrangements (cfa), however, it is significant that the "accessible information" condition may be violated. Indeed, it is highly likely that, when assessing the relative positions of two participants in a cfa, information will be asymmetrically held. For example, most distant water fleets come from countries with relatively long histories of involvement in industrialized fishing and, in many cases, with established markets for fisheries products. Thus, decision-makers within these fleets will hold more information on the fishing process (especially large scale fishing), on processing and product technology, and on market conditions. They may, in fact, know more about the condition of the resource and its population dynamics, than the host country. In addition, since their fishing activity takes place away from the view of the coastal state, information on catch rates, discards, and other variables crucial to economic decisions will be held disproportionately (if not exclusively) by one side - the distant water fleet.

It is this feature of many two-party arrangements that has led Clarke and Munro to view the issue within the context of the "principal-agent" framework (1987, 1990). In their work, the coastal nation - the owner of the fishery resource - is the "principal" who grant the "agent" - the distant water fleet operator - permission to participate in the exploitation of the resource. The authors demonstrate that a mix of fees and taxes may cause the agent to act in a fashion that is consistent with the principal's best interests, although the situation is muddied when the two parties discount the future differently. It may be helpful to review some of the key findings of their work, before proceeding further with the presentation of our own.

First the Clarke-Munro (hereafter,CM) analysis, in which fee fishing is the specific cooperative fishing arrangement analyzed [3], is motivated by the inability of the coastal nation to dictate effort - and, therefore, harvest - levels to the distant water fleet. CM assume, however, that all cost, production, and market relationships are known with certainty by both partners. The work, then, abstracts from some features of "real world" cfas. Even under these conditions, the authors demonstrate that, when the coastal nation and the distant water fleet value the future differently, there will be a difference between them regarding the optimal level of resource exploitation and they are unable to devise a tax-fee scheme that closes the incentive gap. This appears to imply that, contrary to one of the basic premises of both this paper and our

2. Information may not accrue to the two parties symmetrically, however. Because information may be employed to the advantage of one party and at the expense of the other, in such a situation, the asymmetry of information is an issue we consider in further detail in this paper.
3. Although they argue that their approach is appropriate for other cfas.

earlier work, the effort level that maximizes social benefits is not independent of how benefits are distributed between the partners. We suggest, however, that this is the case only in the absence of competition, i.e., the finding follows from examining the issue as one between a single coastal country and a single distant water fleet.

Second, the principal-agent analysis reveals that, when both parties discount the future at the same rate, imposition by the coastal state of either a profit tax or a lump sum tax on the distant water partner could lead to the same result as would direct control of effort and, therefore, harvest. That is, there exist policies that would induce the distant water fleet to use the resource in a "socially optimum" fashion, from either country's perspective, irrespective of which nation owned it. All that is necessary is for the distant water partner to receive a return over the course of the harvest program that is just enough to induce it to participate in the fishery. This minimum return, "... may be determined by market forces or by negotiation" (p.6). CM reject these options, however, as being politically infeasible. For our purposes, it is sufficient that such policies exist.

Third, when future income is discounted more heavily by the distant water fleet than by the coastal country, the above finding does not hold. While there does exist a payment that would induce the fleet to participate in the fishery, that payment would have to occur entirely, "... at the first instant of the exploitation program. The reason is transparent : any return received by the agent after that first instant will be worth more to the principal than to the agent" (p. 7) [4]. The difficulty, however, is that "... if the agent receives its entire share of the benefits from the fishery in the first instant, it has no reason to continue on in the fishery, unless compelled to do so,... an obvious moral hazard problem" (p. 7). It is this result that leads CM to consider a mix of fees and taxes as the way to address the problem. As indicated above, however, they are unable to find a mix that closes the incentive gap between the coastal country and the distant water fleet. It is our position, outlined below, that "competition" also addresses the issue.

Finally, CM points to the possibility that a coastal nation may value future income less than does its distant water partner. This could be the situation if, "... the principal is a developing country and... the agent is a capital rich developed country" (p. 29). As CM point out, the coastal country would "... make the greatest economic gain by simply selling out the resource at the commencement of the program" (ibid). This is unlikely to be politically feasible, however, and thus the authors conclude that the income-maximizing solution for the coastal country is to devise a taxation policy that, it turns out, is more conservationist, i.e., maintains a higher sustainable stock level, than would be the case if the coastal country controlled the fishing effort. CM confine their discussion of this point to a footnote. Yet it may be among their most valuable insights. Indeed, it is this phenomenon that leads Kaczynski to advocate use of joint-ventures by developing coastal nations. In a recent paper, for example, Kaczynski (1991) argues that the fishing activity of a developing country's fleet would, "... without timely government intervention and proper conservation measures,... lead to the depletion of the coastal fishery resource and destruction of artisanal fisheries" (p. 12). He sees joint-ventures with developed countries as one way to avoid this consequence.

The CM analysis offers important insights into the problems the coastal resource owner confronts in dealing with a distant water fishing partner, and helps to place certain conflicts in perspective. For example, Chile's early dissatisfaction with some joint-ventures it had with Japan may reflect differences in information about market conditions between the two partners. Peru recently rescinded fishing licenses it had issued under a three year contract to twenty factory trawlers from the former Soviet Union because "...Peru says that the Soviets have not met the terms of the contract" (Fishing News International, June, 1991).

The world is, however, witnessing a movement towards increased opportunities for cooperative fishing arrangements. Thus, we propose expanding the CM analysis to examine the likely consequences of active competition among buyers and sellers of resource access. We extend the four findings summarized above to the case of access competition.

## 4. MANY PRINCIPALS AND MANY AGENTS

We begin by considering the first, third, and fourth of the CM points summarized above : (1) different assessments of future earnings lead to an incentive gap ; (2) only lump sum payments will work ; and (3) some coastal countries may have higher rates of time preference than do their distant water partners.

4. In other words, it is only at the initial time period when the present value of the payment is the same for both principal and agent. Any one payment in a stream of payments consistent with that present value will, by itself, be discounted differently by the two partners.

The CM analysis is motivated by the assumption that coastal fleets are unable to dictate the behavior of distant water partners. In their model, the coastal nation is assumed to know what would be the optimum effort levels from the perspective of both partners. Under these circumstances, the coastal nation will be motivated to provide the opportunity to competing distant water fleets to become long-term cfa partners. If a particular coastal nation is the only one offering fishing opportunities to distant water fleets, and if there are many such fleets, a solution would be to auction fishing rights - with indefinite tenure - to the highest bidder. If all competing fleets are identical except for their social rate of time preference, and if those rates are higher than that of the coastal country, the successful bidder would be that fleet with the lowest rate ; i.e., the one closest to that of the coastal nation [5]. Where the coastal nation values future earnings at a lower rate than do the distant water competitors, accepting the highest bid means the Kaczynski result emerges, yielding more resource conservation than would otherwise occur.

Next, extend the model to include many competing coastal countries. Now each distant water fishing nation will seek to select fishing arrangements that maximize the present value of the payments it receives from the cfa, over time. In the bidding process of the above paragraph, this amounts to offering low bids. Suppose the social rates of time preference range from the very high to the very low, on both sides of the market. As a consequence of this bidding competition for resource use and access, competitive equilibrium will bring together those partners at the margin with equal valuations of future earnings. In the limit, of course, the competitive process may bring together distant water operators who share the same high rate of social time preference as the developing coastal country. In this situation, the "calming" influence provided by the presence of a developed nation's distant water fleet on the rate of fishery exploitation, anticipated by Kaczynski, will not emerge. In fact, prospects for overfishing of its newly acquired resource, by the developing coastal country, will actually be enhanced through such a joint-venture arrangement. This is, nonetheless, entirely consistent with our expectations concerning the influence of the duration of access.

Next, consider the political feasibility question. While lump sum payments may be politically unacceptable as between two isolated partners, competitive conditions may force their acceptance. Thus, we take issue with the CM observation that the case in which there are many prospective partners is "... much less interesting" than the case where "... fleets do not compete with one another" (Clarke and Munro, 1985, p.8 and fn.1). Their conclusion follows from their implicit assumption that the competition is only for access during the current period, meaning that, "(T)he foreign exploiters... have no 'stake' in the resource as individuals" (ibid. fn.9).

But we see no reason to suppose that the competition will not be for long term contractual arrangements of the kind CM explore in their principal-agent analysis and that we use here. There exist numerous examples of foreign ownership of resource access, even in the fishery. In many cases, it is to the economic advantage of the foreign owner to hire domestic labor, capital, processing and marketing services, etc. For example, U.S. maritime law permits up to 49 % foreign ownership of fishing vessels operating in its EEZ. In 1991, of the total U.S. catcher/processor capacity operating in the North Pacific and Bering Sea groundfish fisheries, foreign ownership was estimated to be on the order of 30 %. Similarly, in the same year, an estimated 80 % of the total Alaska shore based groundfish processing capacity, operating in the U.S. Bering Sea pollock and Pacific cod fisheries, was owned and operated by Japanese fishing companies. Furthermore, contracts that guarantee long-term access to international markets (those of the distant water nation) could be highly popular features of a contract in a coastal country that depends heavily on trade.

We recognize that this extension of the model takes us out of the principal-agent framework. Once the distant water fleet acquires fishing rights over an indefinite [6] tenure, the coastal nation would no longer have a monitoring problem and the asymmetric information feature disappears. Note that fishing rights, granted with indefinite tenure, are not the same as resource ownership, since only the fishing activity is at stake. It is more appropriate to think of such rights as having many of the attributes of transferable fishing quotas that are made available to non-citizens.

CM point out that, when the two partners discount future earnings at the same rate, the question of how payment is made is not an issue. We have addressed this topic above in the context of the competitive model. But our response really begs the question : why do the partners differ in how they value future earnings ? There are many explanations. We suspect that one reason it is commonly believed that distant water fleets discount future earnings heavily is that they have been

5. Following the CM argument, this fee would have to be a lump sum payment, because future payments would be valued differently by the two partners. However, if the successful bidder and the coastal country had identical rates of time preference, the method of payment would be irrelevant.

6. "Indefinite" is intended to pertain to provision of an extended duration of access and not to the issue of risk and uncertainty. These latter considerations are beyond the scope of the present paper, but will be treated in a subsequent paper.

observed harvesting at what appears to be highly exploitive, non-sustainable rates. We suggest that another possible explanation for this behavior may lie more in the tenure of the contract under which they fish than in their rates of time preference.

## 5. LONG RUN EQUILIBRIUM : RESOURCE USE VS INCOME ALLOCATION

Would one expect the market for access to generate a long run equilibrium solution analogous to that of the perfectly competitive model of economic theory ? Probably not, but that is not the salient issue. Rather, we suggest that, in the presence of EFJ conditions, one would expect the forces behind the neoclassical model of perfect competition to prevail. If, 1) access rights were negotiable over time, perhaps, for example, auctioned off to the highest bidder ; 2) transactions costs were minimal ; and 3) there were numerous buyers (distant water fleets and some fleets from adjacent coastal countries) and sellers (coastal nations), competitive efficiency should emerge and sustain, even in the face of changing economic conditions. That is, we would expect to see the rents dissipating "race-for-fish" on the fishing grounds, associated with open access conditions, replaced by competition at the negotiating table, or in the EFJ access marketplace ; a clear step towards economic "rationalization" of the fishery. If our argument is correct, this means discussion can focus on the characteristics of that process and on the conditions that might limit its applicability.

First, however, we wish to reiterate a point we made in our 1988 paper. It is important to distinguish between "resource use" and the "distribution of income" generated by that use. There is debate within the fishery management community, as well as the economics profession, over the need for and extent of enforcement and monitoring under EFJ cooperative arrangements to ensure that the fishery resources of the coastal country are efficiently managed by the contracted distant water operator. Consider the following hypothetical case. Assume, for the sake of argument, that the contracting distant water fleet was given sole access, for an indefinite period, to the coastal nation's fishery resource. In essence, this is equivalent to transference of "quasi-property interest" in the resource from the coastal nation to the distant water fleet. Assume further that the two partners discount the future at the same rate. The distant water fleet would, in this situation and under competition, have an economic incentive to harvest at the *same* rate as would the coastal nation, assuming the latter was "hiring" the physical capacity to fish.

This congruence of exploitation rates will emerge under a variety of contractual arrangements, e.g., a division of rents, lump sum payments (Cheung ; Clarke and Munro). Therefore in this situation, the only enforcement required would be by the distant water fleet, monitoring the performance of its own fishermen (i.e., self-policing). Of course, both parties would have an incentive to guard against potential third-party interlopers, to precluding a return to pre-EFJ "open access" exploitation patterns.

Under these idealized conditions, the distant water operator would, nonetheless, have an incentive to "cheat". But the incentive would not extend to "mismanagement" of the resource. Rather, they would seek to retain as much of the earnings (including resource rents) as possible. That is, the cheating would involve revenue distribution, not resource management (overfishing) considerations.

Among the most important characteristics of the arrangement which produces this equilibrium result is the assumption of "indefinite access" to the resource. Because of the temporary conference of access (essentially transference of quasi-property interest in the resource), consideration of the implications of "contract duration" becomes relevant to an understanding of the nature and stability of the cooperative joint-venture arrangement under EFJ.

Only when the contractual arrangement is of sufficient duration to impart an effective "property interest" in the resource, will the distant water fleet find its optimal rate of exploitation to be equal to that of the coastal nation. Absent such assurance of access, the "property interest" of the contracting fleet is so reduced that it will always seek to accelerate the harvest to the point of biological overfishing.

In practice, even with intensive monitoring and restrictive enforcement, the nearer the potential termination of the assured access, the greater the incentive to abandon cost minimizing and conservation maximizing practices, in favor of accelerate extraction of the target species. The combined costs of the necessary monitoring and enforcement programs, the inefficient use of productive inputs, and waste of fishery resources under these circumstances, results in the dissipation the potential rents (both short and long term) which could have been realized from a stable, equilibrium solution.

In effect, provision of short term access, with the probability of imminent exclusion, results in behavior, on the part of the contracted fleet, which approximates that of open access. That is, because there is no long term "property interest" in stewarding the resource on the part of the distant water harvester, conservation of the biological resource base is economically irrational.

## 6. SOME EMPIRICAL EVIDENCE

Such outcomes can be cited from the U.S. experience with joint-venture (JV) fisheries in the North Pacific and Bering Sea, which began in 1978 and extended through 1990. In 1990, for example, the JV trawl fishery for flatfish in the Bering Sea was governed by a quota which specified the "allowable catch" of the target species (yellowfin sole and "other" flatfish). In addition, strict "bycatch" limits (or caps) were imposed on the JV operations for red king crab, Tanner crab, and Pacific halibut (collectively identified as "prohibited species catch" or PSC).

The halibut PSC cap was ultimately exceeded and the JV fishery was closed prior to completion of the harvest of the available flatfish quota. The interesting thing to note, with respect to the present discussion, is the daily rate of halibut bycatch that was recorded over the course of the JV flatfish season.

JV fisheries were monitored by on-board observers and catch data (both target and bycatch) were tracked, for in-season management purposes, on a fleet-wide basis. As the PSC quota for halibut was consumed, information concerning the remaining balance was made available to the fleet. As the PSC quota neared exhaustion, a management decision was made by the Alaska Region of NMFS concerning the closure of the fishery, and a projected closing date was announced to the fleet. As the data indicate, (see figure) the bycatch performance of the monitored fleet was relatively stable through the first weeks of the season, (with perhaps a slight upward trend owing, in part, to increasing competitive effort on the grounds and, perhaps, greater numbers of halibut moving into shallower waters as the season progressed). However, once exhaustion of the PSC cap was inevitable (and thus loss of access was imminent), concerns about "conservation" of the halibut resource were discounted in fishing decisions of the JV operators, as members of the fleet "raced" to maximize their individual catches of the target flatfish species. The result was an explosive rise in the halibut bycatch rate immediately preceding the announced closure date.

This pattern of behavior is evident throughout the data on U.S. JV fisheries. Often, the rapid acceleration of bycatch, in the face of an announced closure, resulted in the quota or cap being exceeded. On occasion, the overage proved to be quite substantial.

## 7. DIFFERING VIEWS OF THE FUTURE

While the contractual arrangements associated with U.S. JVs were certainly a far cry from the idealized cooperative arrangement described in the hypothetical example presented earlier, these empirical results suggest that the absence of "property interest" in the resource may effectively subvert a coastal nation's efforts to optimize (rationalize) the exploitation of its fish resources. That is, to the extent that conveyance of property interests is incomplete, due, for example, to insufficient duration of the access guarantee, imposition of EFJ regimes will not resolve the tendency to move to the open access solution. When the cooperating parties jointly share property interest in the resource, a long run biological and economic equilibrium solution becomes possible.

## 8. EXTENSIONS AND CONCLUSIONS

As Clarke and Munro have shown, when coastal and distant water partners have different rates of time preference (discount rates) it will be difficult, if not impossible, to design a contractual arrangement that has no incentive gap. Consequently, the resource will be exploited at a level that is not optimal from the coastal country's perspective.

If there are many potential partners bidding for access rights, however, it is possible that partners with identical discount rates will pair up, at least "at the margin". Inframarginal rents and surpluses would be no different in nature from those in any competitive market involving traders with a variety of taste and cost structures. The asymmetric information problem would be solved through lump sum payments.

Suppose, however, that no such equilibrium exists because the discount rates for all distant water fleets exceed the discount rates for all coastal countries. In this case, while there would be a divergence between access buyers and sellers regarding resource management desires, competitive bargaining should lead to trades that eliminate all Pareto-relevant externalities. Any tax/subsidy scheme imposed on the solution would lead to one party gaining at the expense of the other. Thus, even if the coastal country "hired" the services of distant water partners, if this were done on a competitive basis (competition among buyers and among sellers) the result would be the same.

It has been argued in this paper that a distant water fleet will harvest the resources of a coastal nation at the same rate whether it is hired by that nation or, instead, is a partner in a cooperative fishing arrangement (cfa). As discussed above, the validity of this argument depends upon two fundamental assumptions.

First, that the cfa involves the effective conveyance of "quasi-property interest" in the resource to the distant water operator. Through a contractual arrangement of sufficient duration the coastal country and the distant water fleet may be induced to jointly conserve and steward the resource base.

Second, it relies upon the presence of competitive market structures. That is, it depends on the condition that, if the distant water fleet did not offer an arrangement that was attractive to the coastal country, the latter could turn to competing fleets to obtain more attractive offers. Similarly, the fleets themselves are assumed to have numerous coastal water nations among which to negotiate a cfa partnership.

With respect to the second, is there in fact such a market ? Evidence suggests that one is emerging. As a consequence of EFJ, excess harvesting and processing capacity has led countries such as Norway, the USSR, and most recently the United States to seek partners in distant waters. Even fleets within countries are competing among themselves for access. Sullivan reports that fleets from the former Soviet Union vie with each other for Canadian partnerships in Atlantic Canada. With the ascendancy of the new republics, this competition may become even more intense. Countries are now advertising in international trade and fishing magazines for partners in joint-ventures. While data are scarce, a competitive market for access appears to be emerging [7].

In effect, as we see it, the three key elements which underlay the foregoing discussion include :

(i) the duration of access [which conveys an effective property interest in the resource to the distant water partner]
(ii) consideration of the respective rates of social time preference among the cfa partners ; and
(iii) the influence of asymmetric information on cfa arrangements. We contend that all three are inextricably linked. Specifically, contract duration and rate of social time preference are inversely related to one another.

In one sense, with respect to distant water operators, the higher the rate of social time preference the less important will be the duration of assured access under the terms of the cfa. For the coastal nation, the higher the rate, the less concerned they will be about granting long term access. In the limit, cfa partners with sufficiently high rates of discount may cooperatively engage in pulse fishing, extracting the maximum harvest in the shortest amount of time, without regard for future harvests. This result is contrary to the joint-venture outcome suggested by Kaczynski.

Furthermore, it is through a reasonably competitive market for access that (at least at the margin) partners with compatible expectations about contract duration, and thus similar rates of time preference, may be brought together.

The asymmetric information problem, cited above, is overcome in the presence of competitive conditions. That is, in the presence of many potential "buyers" and "suppliers" of access, unfair practices by one cfa partner, based on asymmetrically held information, need not be tolerated (endured) by the other partner. Furthermore, as suggested, once the distant water fleet has fishing rights of indefinite tenure, the coastal nation no longer has a monitoring problem and the asymmetric information feature disappears.

7. This development has been recognized in other quarters. The OECD has very recently acknowledged an emerging world market for access to fisheries resources and harvesting expertise. It has just undertaken an empirical study of the "joint-venture" market phenomenon, with the U.S. National Marine Fisheries Service as one of the principal participants.

Since the access market will tend to bring together suppliers and demanders who share expectations concerning contract duration (and, implicitly, rates of social time preference), relatively stable, mutually beneficial relationships will emerge through cfas, reflecting the "optimal" rate of resource use of the coastal (and coincidently of the distant water) nation.

This paper is in no way intended as a critique of the Clarke-Munro analysis. Rather, it should be regarded as an extension of that work, integrating their insights with those of our 1988 paper.

The reader is reminded that the arguments presented in this paper are in a preliminary state. While world events seem to suggest we are on the right track, the authors would welcome comments.

## REFERENCES

**Anderson P. and J.G. Sutinen** (1983). Fisheries Law Enforcement and International Trade in Seafood. In Melteff B.R. (ed). Proceedings of the International Seafood Trade Conference. 509-517. Fairbanks, Alaska. University of Alaska Sea Grant Report No. 83-2.

**Cheung S.N.S.** (1968). Private Property Rights and Sharecropping. *Journal of Political Economy.* **76** (6) : 1107 -1122.

**Clarke F.H. and G.R. Munro** (1987). Coastal States, Distant Water Fishing Nations and Extended Jurisdiction : A Principal-Agent Analysis. *Natural Resource Modeling.* **2 :** 81-107.

**Clarke F.H. and G.R. Munro** (1990). Coastal States and Distant Water Fishing Nations : Conflicting Views of the Future. University of British Columbia. Department of Economics. Discussion Paper No. : 90-24. Vancouver, Canada.

**Munro G.R.** (1985). Coastal States, Distant Water Fleets and Extended Fisheries Jurisdiction : Some Long-Run Considerations. *Marine Policy.* **9 :** 2-15.

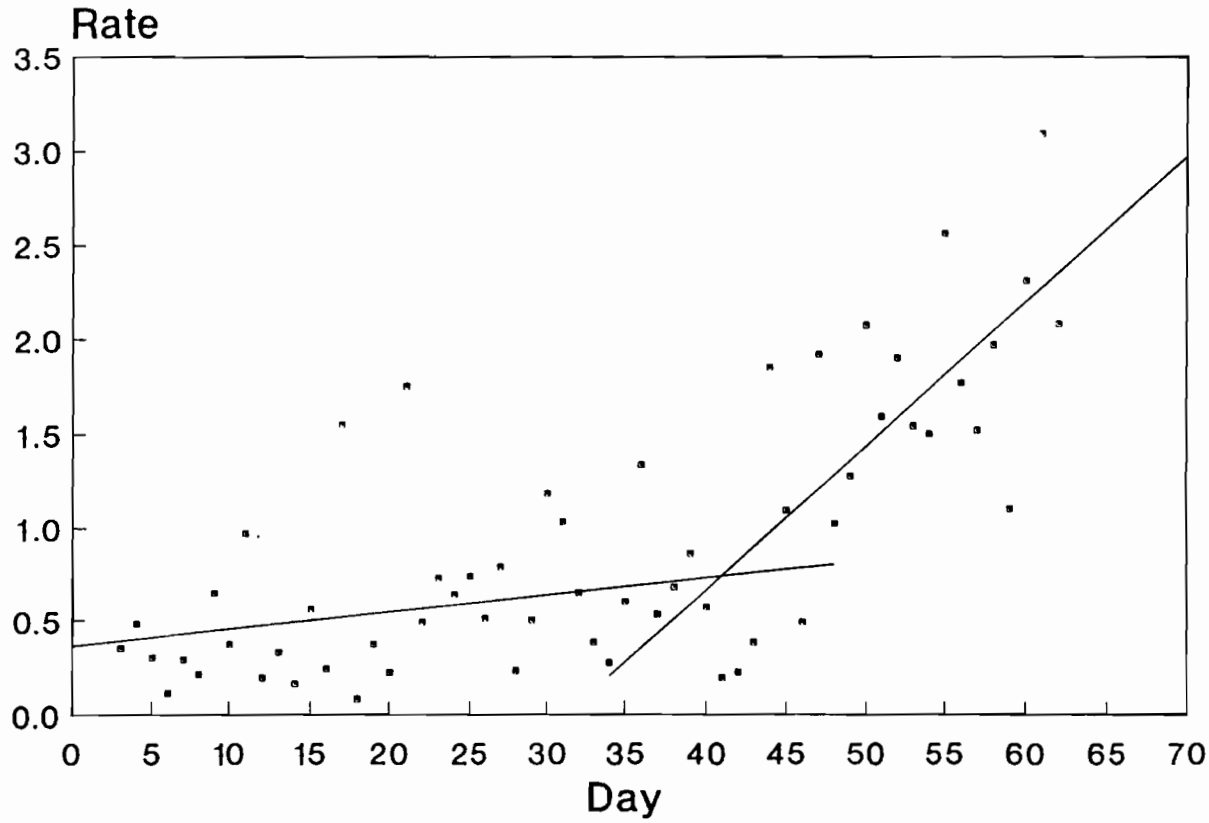
**Kaczynski V.M.** (1991). International Fishery Ventures as an Instrument of Aid and Cooperation Between Developed and Developing Countries. Unpublished manuscript prepared for International Conference on Coastal Fisheries, May 23-25 1991, University of Tromsø, Norway. School of Marine Affairs, University of Washington, Seattle, Washington.

**Kerr G.H. and B.M.H. Sharp** (1985). Multinational Arrangements and the Role of Bargaining in Fisheries Development. In *Proceedings of the Conference of the International Institute of Fisheries Economics and Trade.* Volume 1, Economic Recovery, Fisheries Economics, and Seafood Trade. 263-269. Corvallis, Oregon : International Institute of Fisheries Economics and Trade, Oregon State University.

**Johnston R.S. and J.R. Wilson** (1987). Interdependencies Among Fisheries Management, Fisheries Trade, and Fisheries Development : Experiences with Extended Jurisdiction. *Marine Fisheries Review.* **49** (3) : 45-55.

**Queirolo L.E. and R.S. Johnston** (1990). Some Economic Consequences of Extended Jurisdiction for Cooperative Fishing Arrangements. In *Proceedings of the Fourth Biennial Conference of the International Institute of Fisheries Economics and Trade.* Esbjerg, Denmark, August, 1988. **1**, pp. 763-777.

**FIGURE**
**HALIBUT BYCATCH AS A PERCENT OF TOTAL FLATFISH CATCH (MT)**



# La comptabilité des ressources naturelles: une application aux ressources salmonicoles

**Alain Webster**

Université du Québec à Montréal, Institut des Sciences de l'Environnement,
C.P. 8888, Succ. A, Montréal, Québec H3C 3P8, Canada

RÉSUMÉ

*La présence d'un certain consensus social sur l'importance de l'interaction environnement-économie relance à nouveau la question de l'intégration de l'environnement au système de comptabilité nationale. Plusieurs organismes multilatéraux et différents pays ont donc entrepris des travaux visant à réaliser une nouvelle comptabilité environnementale.*

*Peu de travaux ont cependant été réalisés pour les ressources halieutiques. Pourtant, l'intérêt d'une telle comptabilité de l'environnement ne se limite pas à la "correction" des comptes nationaux. Il s'agit aussi d'un système d'information pouvant constituer un outil de gestion important au niveau sectoriel. Cette intégration des informations économiques et biologiques devrait faciliter la gestion pluridisciplinaire, permettre de décrire le rôle des différents agents (qui paie et qui bénéfice) et constituer un outil de gestion rationnel pour la prise de décision.*

*La présentation communication vise à présenter cette problématique en s'intéressant en particulier au cas des ressources non-marchandes comme le saumon de l'atlantique.*

ABSTRACT

*The necessity to integrate the state of the environment in the indicator of economic development, is now recognized. Much research is being done on this topic by multilateral organisations and some countries. The methodology used and the framework developed differ with the different experiments but the objective is the same: to describe the variation of stock and flux of natural resources, and to present the interaction between this resource and the economic system.*

*The usefulness of this natural resource account is not only to "correct" the national account system, it is also an important tool for the management of this resource. The integration of economic and biological informations can facilitate the multidisciplinary management, gives better information about the role of different economic agents (who pays and who benefits) and provides a rational economic tool to help make a decision between the preservation of the environment and the development of economic activities.*

*The present paper wants to contribute to the development of this research for fisheries resource, especially for the resource with no price market. We present two of the most important research done on natural resource account, the few experiements done on the commercial fisheries and some aspects of the application of this approach for sport fishing, especially salmon fisheries.*

## 1. INTRODUCTION

La problématique de la prise en compte de l'environnement et des ressources naturelles dans la comptabilité nationale n'est pas nouvelle. On reconnaît depuis longtemps que cette comptabilité, basée essentiellement sur les flux financiers, ne tient pas compte de la dégradation de l'environnement et de l'épuisement des ressources naturelles. Parce qu'elle ignore certaines "fonctions" du milieu naturel, permettant notamment de fournir des ressources naturelles essentielles au système de production et d'assimiler une partie des résidus de ce système, la comptabilité nationale ne permet pas de porter un jugement sur le caractère soutenable des activités économiques.

Si cette problématique n'est pas récente, elle suscite aujourd'hui un nouvel intérêt pouvant s'expliquer entre autres par l'émergence d'un consensus social sur le rôle essentiel de l'interaction environnement-économie. En effet, si l'on considère que la dégradation de cet environnement peut avoir un effet sur la richesse des sociétés, on doit alors chercher à prendre en compte l'état de l'environnement dans la comptabilité nationale puisque ce système d'information doit décrire l'évolution de la richesse et permettre de répondre aux questions de la collectivité relative à cette richesse. De plus, la présente révision de l'ensemble du système de comptabilité nationale par le Bureau des statistiques des Nations-Unies a contribué également à relancer au niveau international la discussion sur cette perspective d'intégration environnement-économie.

Dans ce contexte, on peut maintenant affirmer qu'il "est assez bien établi que la comptabilité nationale devrait refléter cette dégradation environnementale. Mais il reste plusieurs controverses sur comment faire ces ajustements" (El Serafy, 1991).

La présente communication vise à présenter cette problématique et à explorer la pertinence d'une telle comptabilité pour les ressources halieutiques en général et de façon plus spécifique pour les ressources non-marchandes telles que le saumon de l'Atlantique au Québec.

La première partie de notre exposé présentera donc la problématique générale de la comptabilité environnementale en décrivant deux cadres conceptuels visant à réaliser cette comptabilité: le premier étant le système français de "Comptabilité du patrimoine naturel", le second étant le "Système intégré de comptabilité économique et environnementale" développé par le Bureau des statistiques des Nations-Unies. Nous présenterons ensuite brièvement deux cas concrets d'application pour les ressources halieutiques, le premier développé en Norvège et le second au Costa-Rica. Nous aborderons finalement le cas spécifique des ressources non-marchandes. Notons toutefois que nos travaux visant à élaborer un compte pour le saumon de l'Atlantique ne sont pas encore complétés. La présente communication se limitera donc à présenter la problématique générale d'une telle comptabilité sans présenter de compte chiffré.

## 2. LA COMPTABILITE DU PATRIMOINE NATUREL

L'objectif de tous les travaux de comptabilité de l'environnement est de refléter les interactions environnement-économie pour permettre d'orienter les décisions politico-économiques dans une perspective de développement soutenable. Si l'objectif est le même, la démarche employée varie beaucoup d'une expérience à l'autre.

Une des principales différences entre les approches proposées est l'importance accordée à l'évaluation monétaire de l'environnement et, par le fait même, à la possibilité d'élaborer des agrégats globaux. Pour certains, l'évaluation monétaire est l'élément central de cette comptabilité, permettant d'élaborer des agrégats économiques qui tiennent compte de la dégradation de l'environnement. Pour d'autres, l'évaluation monétaire n'occupe pas une place privilégiée dans le système, elle ne permet que de déterminer à quel point on s'est éloigné d'une situation jugée soutenable.

Le système de "comptabilité du patrimoine naturel", développé en France par la "Commission interministérielle des comptes du patrimoine naturel", représente un exemple de cette dernière tendance. Ce système de comptabilité environnementale, développé en parallèle à la comptabilité nationale, permet de colliger et de mettre en cohérence les diverses informations relatives aux éléments de ce patrimoine naturel tout en permettant d'établir un lien entre ces informations et celles de la comptabilité nationale traditionnelle. Ce système est considéré comme l'un des plus complet et des plus ambitieux dans ce domaine puisqu'il vise à décrire les dimensions écologique, économique et socio-culturelle de l'ensemble du patrimoine naturel pouvant être affecté par l'activité humaine.

Pour permettre une telle représentation des éléments du patrimoine naturel, le SCPN fut développé selon une approche modulaire comprenant trois pôles (figure 1). Le compte d'élément, élaboré pour un élément donné du patrimoine naturel, permet de décrire le passage entre le stock initial et le stock final à l'aide d'une description des différents flux physiques d'origine naturelle ou humaine (croissance et mortalité naturelle, prélèvement humain, ensemencement, etc). Le compte d'écozone décrit l'état de santé des écosystèmes où évolue cet élément ainsi que l'évolution de la répartition spatiale de cet élément. Finalement le compte d'agents devrait décrire l'interaction entre les êtres humains (et leurs institutions) et cette ressource. Les informations présentées dans ce compte sont de nature économique et physique et décrivent les dépenses de gestion et d'exploitation, l'évaluation de la valeur monétaire de cette ressource et des informations de nature socio-culturelle. La première étape dans l'élaboration de ce compte d'agents étant l'identification et le rôle de l'ensemble des intervenants permettant d'identifier les flux de l'ensemble de cette filière et de déterminer combien on dépense, qui finance, qui en bénéficie (INSEE, 1986).

Bien que cela ne soit pas considéré comme prioritaire dans le cadre des travaux français, on peut chercher à attribuer une valeur économique à cette ressource naturelle, ou plutôt une valeur à la variation de cette ressource. Se pose alors tout le problème de l'évaluation monétaire d'un bien environnemental, problématique bien différente s'il s'agit d'un bien marchand ou d'un bien non-marchand. Dans le premier cas on dispose, bien qu'il soit imparfait, du mécanisme des prix pour refléter la valeur de cette ressource. Dans le second cas, et c'est celui du saumon de l'Atlantique au Québec, ont doit "révéler des prix non-payés" (Pillet, 1992), ce qui pose des problèmes méthodologiques relativement complexes.

On peut pousser le raisonnement un peu plus loin et dire que ces informations économiques doivent non seulement être mises en relation avec les indicateurs économiques mais également servir à les corriger.

Un exemple de cette démarche est celle développée au niveau du Bureau des Statistiques des Nations-Unies en collaboration avec la Banque Mondiale et visant à élaborer un "Système intégré de comptabilité économique et environnementale" (SCEE) (Bartelmus et al., 1991). Dans la mesure où il n'existe pas de consensus international sur la façon d'évaluer et d'incorporer les coûts environnementaux, on ne propose pas modifier le cadre actuel de la comptabilité nationale mais plutôt de développer en parallèle à ce système un "compte satellite de l'environnement" pour intégrer cette nouvelle comptabilité économique et environnementale.

Ce Système intégré de comptabilité économique et environnementale propose d'étendre le concept de capital pour couvrir non seulement le capital d'origine humaine mais également le "capital naturel" (Bartelmus, 1992). On y définit également le revenu comme étant "le maximum qu'on peut consommer dans une période donnée tout en maintenant le capital initial..." (Potvin, 1991). Partant de ces deux principes, on peut considérer l'évaluation économique des dommages environnementaux comme une diminution de la valeur du capital naturel, comparable à la dépréciation du capital d'origine humaine. On peut ensuite corriger les agrégats macro-économiques, tel le Produit intérieur brut, pour tenir compte de la dépréciation du capital d'origine humaine ainsi que du capital naturel. On obtient ainsi de nouveaux indicateurs économiques tenant compte des coûts environnementaux engendrés par l'ensemble du système de production et de consommation. Ce nouvel indicateur, le "produit intérieur net ajusté de l'environnement", correspond donc au Produit intérieur net moins la valeur de l'épuisement des ressources naturelles et les coûts de la dégradation de l'environnement (Lutz et Munasinghe, 1991).

L'ensemble du système intégré de comptabilité économique et environnementale ne se limite pas à cette correction des agrégats. Il devrait permettre également:

- d'identifier et de séparer les activités de protection et de restauration de l'environnement permettant ainsi d'identifier la part du PIB nécessaire pour compenser les impacts négatifs de la croissance économique;

- et de décrire les liens entre la comptabilité physique des ressources naturelles et les évaluations économiques de la comptabilité nationale (Bartelmus, 1992).

Tout comme dans le cas du système français, la comptabilité physique constitue donc un élément de base de ce système. Toutefois, l'approche développée par le BSNU privilégie l'élaboration d'agrégats globaux permettant de refléter, en terme monétaire, la prise en compte de l'environnement dans la comptabilité nationale.

## 3. LA COMPTABILITE DES RESSOURCES HALIEUTIQUES

La plupart des informations biologiques ou économiques composant ces comptes sont familiers aux gestionnaires des pêches. Ainsi, les informations biologiques présentées dans le compte d'élément constituent des éléments traditionnels de la gestion des pêches permettant de décrire l'état du stock et ses principales sources de variation. Au niveau économique, on retrouve pour plusieurs pêcheries une évaluation des coûts et revenus associés à cette activité alors que l'évaluation de cette richesse peut être associée à la notion de rente ou surplus économique. Si certaines données sont courantes, on ne dispose pas cependant de cadre permettant de synthétiser l'ensemble de ces informations. La comptabilité de l'environnement fournie un tel cadre.

Peu de travaux de comptabilité ont donc été réalisés pour les ressources halieutiques. Parmi les rares travaux traitant de ces ressources, notons ceux réalisés en Norvège et au Costa Rica. L'approche retenue dans le premier cas est essentiellement biologique alors que dans le second elle est essentiellement monétaire. Elle permettent toutes deux de bien situer cette problématique pour les ressources marchandes.

L'expérience norvégienne constitue en fait l'expérience la plus ancienne de comptabilité des ressources naturelles (les premiers comptes ont été présentés en 1974) et la seule qui soit actuellement opérationnelle.

La structure théorique des comptes comprend trois éléments soit les comptes de stock, de commerce et d'utilisation. Le premier décrit l'évolution de la ressource entre la période T0 et T1, le second décrit les échanges commerciaux reliés à cette ressource et le troisième constitue un bilan matière pour les différents secteurs de l'économie norvégienne. En pratique toutefois, "une ressource biologique comme le poisson requiert un compte de stock relativement bien détaillé avec des spécifications sur la structure de l'âge et la localisation des différentes classes et types de poissons. La partie III du compte - le compte d'utilisation- est toutefois relativement simple puisque quelques secteurs utilisent le poisson comme intrant dans leur production... De façon similaire, l'importance du commerce extérieur des ressources détermine l'accent mis sur la partie commerce du compte" (Alfsen et al., 1986).

Les informations que l'on retrouve dans cette comptabilité des ressources halieutiques constituent donc essentiellement des informations de nature biologique: biomasse, nombre de géniteurs, indice de recrutement, quotas et prises. On y retrouve également des informations illustrant le partage des stocks entre la Norvège et ses principaux partenaires ainsi que des informations économiques sur l'importance de ce secteur dans le commerce extérieur norvégien (CBS, 1989 et 1992).

Cette approche essentiellement biologique, peu intégrée aux informations économiques, n'apporte pas d'informations supplémentaires par rapport à la gestion traditionnelles de cette ressource. Il n'est donc pas surprenant de constater que ces données soient peu utilisées et que leur mise à jour ne soit pas régulière (Asbjorn. et al., 1991). Une comptabilité environnementale essentiellement physique n'apporte donc aucun élément nouveau pour ces ressources qui sont déjà gérées sur la base d'un rendement soutenu.

L'approche adoptée au Costa Rica est différente puisqu'il s'agit d'une approche essentiellement monétaire; différence toutefois plus faible qu'il n'y parait à première vue puisque l'évaluation physique est un prérequis à l'évaluation monétaire et cette dernière n'est que la multiplication d'une quantité physique par un prix ou un pseudo-prix (Weber, 1991). Cette étude s'inscrit dans le cadre des travaux de World Resources Institute de Washington visant à évaluer la dépréciation du capital naturel, au même titre que l'on évalue la dépréciation du capital d'origine humaine. Une telle évaluation permettant de corriger directement les agrégats nationaux, tel le PNB, pour mieux refléter l'aspect soutenable

de la croissance économique (Repetto, 1989). Moins ambitieuse que les cadres théoriques présentés précédemment, cette comptabilité ne vise qu'à prendre en compte la dépréciation de certaines ressources naturelles exploitées commercialement.

L'approche retenue pour l'évaluation de la dépréciation des ressources halieutiques au Costa-Rica est classique (Repetto, 1991). L'évaluation de l'effort de pêche et de la biomasse permet de déterminer le rendement soutenu de la pêcherie pour ce niveau donné d'effort de pêche. On est alors à même de déterminer la rente annuelle que peut générer cette pêcherie; rente définit comme les revenus annuels provenant de ce rendement soutenu moins les coûts totaux, incluant le retour sur le capital et le coût d'opportunité du travail. Cette rente annuelle est ensuite actualisée pour obtenir la valeur économique de la pêcherie. La figure 2 illustre le déclin de la valeur de ce capital suite à l'augmentation de l'effort de pêche et la diminution du rendement soutenu. Notons toutefois que ces évaluations ne sont obtenues qu'au prix de nombreuses estimations pour pallier aux lacunes du suivi statistique.

La mesure de la dépréciation, ou de la perte en capital provenant de la surexploitation de la ressource, est obtenue en ne considérant que la variation annuelle de la valeur de la pêcherie résultant de la diminution du rendement soutenu; les variations résultant d'un changement de prix ou de coûts de production n'étant pas considérées comme une dépréciation. L'effet de cette dépréciation peut être illustrée en comparant l'évolution de la valeur brute et de la valeur "nette" de cette production (figure 3).

Précisons toutefois qu'il ne s'agit pas de déterminer un sentier optimal d'exploitation mais bien de déterminer l'effet d'une modification du niveau d'exploitation sur la richesse que peut générer à long terme cette ressource. Une telle comptabilité ne permet donc de juger que du caractère soutenable du revenu engendré par cette activité.

## 4. LA COMPTABILITE D'UNE RESSOURCE NON-MARCHANDE

Les deux exemples que l'on vient de présenter ne décrivent chacun qu'un aspect de la gestion de ces ressources exploitées sur une base commerciale; dans le premier cas on décrit le bilan physique et dans le second on évalue le revenu soutenable. La comptabilité que nous cherchons à réaliser pour les ressources non-marchandes ne cherche pas uniquement à décrire un indicateur agrégé, physique ou monétaire, mais vise à élaborer un système d'information plus complet permettant une meilleure gestion de la ressource. Dans ce contexte, les travaux français de comptabilité du patrimoine naturel nous semble pertinent puisque cette approche permet de décrire l'ensemble des caractéristiques de cette ressource tant d'un point de vue écologique qu'économique.

Le bilan physique constitue l'élément de base d'une telle comptabilité et devrait permettre de décrire les changements dans l'état de la ressource survenus durant la période d'étude.

Toutefois, une telle approche ne permet pas de décrire toute la problématique et doit être complétée par un ensemble d'évaluation économique.

La première démarche au niveau de cette évaluation monétaire vise à décrire l'ensemble des flux financiers et des sources de financement reliés à cette ressource. Dans le cas spécifique qui nous intéresse, on pourra élaborer une "dépense saumon totale" comprenant les dépenses des pêcheurs ainsi que les dépenses de gestion, de restauration du milieu naturel et d'exploitation permettant d'offrir des services de pêches récréatives. On pourra ensuite identifier les différentes sources de revenus associées à ces dépenses. Mis à part la difficulté d'identifier ces flux pour une espèce spécifique, telle le saumon, une telle évaluation ne pose pas de problème méthodologique particulier.

L'évaluation monétaire du capital naturel est plus délicate. En l'absence de prix de marché (on peut considérer que c'est le cas pour le saumon de l'Atlantique au Québec puisque moins de 50 % des prises sont effectuées par des pêcheurs commerciaux (Caron et Shields, 1991), on doit estimer le bénéfice associé à cette espèce à l'aide de l'évaluation du consentement à payer. Idéalement, on devrait évaluer non seulement la valeur d'usage mais également la valeur d'existence reliée à cette ressource, soit la "valeur économique que les individus accordent au fait qu'ils savent que la ressource existe dans la nature" (Bergstrom et al. 1990). On obtient ainsi ce que David Pearce qualifie de "Valeur économique totale" (1990), ou le bénéfice total associé à cette ressource pour l'ensemble de la société. Cette valeur économique totale correspond donc aux dépenses effectivement réalisées plus le consentement à payer une somme excédentaire pour l'usage ou la préservation de cette ressource.

Différentes techniques d'évaluation sont disponibles pour évaluer cette valeur. La méthode d'évaluation contingente est généralement la méthode recommandée pour évaluer ce consentement à payer puisqu'elle est la seule qui permette d'évaluer la valeur d'existence (Mitchell et Carson, 1989). On retrouve d'ailleurs dans la littérature plusieurs exemples d'évaluation contingente pour évaluer le bénéfice associé à cette espèce (Hager et al;, 1989; Bonnieux et al., 1992). Cette évaluation contingente peut toutefois être difficile à appliquer dans le cas du saumon au Québec puisqu'on y retrouve plusieurs modes d'exploitation: pêche sportive, pêche de subsistance pratiquée par les amérindiens, pêche commerciale et, en plus, une pêche d'interception en mer le long des côtes du Groenland.

Une autre alternative serait d'évaluer les coûts associés à la restauration, ou au rétablissement de la capacité écologique du milieu, principe retenu par le BSNU dans le cadre du système intégré de comptabilité. Pour obtenir une telle évaluation, il faut estimer les coûts éventuels de restauration nécessaires, soit pour rétablir la qualité de l'environnement à son niveau initial au début de la période comptable, soit pour ramener à un niveau établi selon les normes environnementales officielles (Potvin, 1991). Reste toutefois à déterminer ce qu'est le niveau initial et à distinguer parmi les causes de cette variation celles qui sont d'origine naturelle.

Notons toutefois que les résultats que l'on pourrait obtenir par ces deux techniques sont forcément différents. La méthode contingente évalue le coût de maintenir constant le bénéfice associé à cette ressource. La méthode des coûts de restauration évalue le coût de maintenir constant le stock physique de cette ressource. Le choix de la méthode d'évaluation n'est donc pas neutre et peut être considéré comme une certaine vision du concept de développement durable.

Finalement pour que le portrait de l'ensemble de la filière soit complet il faudrait y inclure, dans l'optique de la comptabilité du patrimoine naturel, des informations de nature écologiques et culturelles. Dans le premier cas, il n'est pas nécessaire de chercher à décrire l'ensemble du fonctionnement de cet écosystème. On peut se limiter à utiliser des indicateurs de qualité du milieu ainsi que des informations décrivant la superficie du territoire accessible. Une telle évaluation permettant de situer cette espèce dans un contexte plus large, le poisson n'étant que le produit d'une ressource plus globale qu'est l'écosystème marin (Reveret, 1991). Cette approche plus systémique soulève cependant une question délicate, soit la différence que l'on fait entre la gestion de la ressource et la gestion du milieu où évolue cette ressource. En ce qui concerne le volet socio-culturel, on pourrait présenter un ensemble d'informations permettant de décrire des composantes culturelles qui ne sont pas pris en compte par l'évaluation des coûts. Ce dernier volet fait toutefois l'objet de très peu de travaux pratiques.

## 5. CONCLUSION

L'intérêt de cette comptabilité environnementale se situe au moins à deux niveaux. Au niveau national, elle permet de mieux suivre l'évolution du capital naturel et de mieux intégrer l'environnement dans les décisions politico-économiques. Mais il nous semble que c'est surtout au niveau sectoriel qu'une telle démarche est la plus utile. En regroupant dans un même cadre d'analyse toutes les informations physiques et monétaires relatives à une espèce ainsi que les informations décrivant l'état de l'écosystème où évolue cette espèce, on se dote d'un outil de gestion facilitant l'intégration des considérations économiques et écologiques dans une perspective de gestion pluridisciplinaire des ressources naturelles.

Dans cette optique, les données physiques sont nécessaires pour décrire l'interaction environnement économie mais elles ne sont pas suffisantes. L'identification des flux monétaires, soit l'ensemble des dépenses et de leurs sources de financement, constitue un élément de gestion important permettant d'identifier le rôle de l'ensemble des intervenants. Quant àl'évaluation monétaire, elle permet de déterminer les coûts nécessaires pour retrouver une situation considérée comme soutenable. Il ne faut pas cependant pas perdre de vue que cette démarche reste encore dans une phase exploratoire, en particulier pour l'ensemble des ressources environnementales ne possédant pas de prix de marché. L'évaluation monétaire constitue donc un aspect très controversé dans la comptabilité environnementale "requérant des travaux exploratoires pour arriver à une méthodologie standardisée acceptable" (BSNU, 1991). La ressource halieutique constitue selon nous un objet d'étude pertinent pour faire avancer cette problématique.

## REFERENCES

**Alfsen K.H. et al.** (1986) *Natural resource accounting and analysis. The Norwegian experience 1978-1986.* central Bureau of Statistics, Oslo, 71p.

**Asbjorn A., O. Lone et K. Nyborg** (1991). *Natural resource accounting: the Norwegian experience.* Présenté à la Conférence spéciale de l'IARIW sur la comptabilité de l'environnement. Baden (Autriche), 27-29 mai 1991

**Bartelmus P.** (1992). Environmental accounting and statistics, *Natural resources forum: a United Nations Journal,* vol. **16**(1) : 77-84.

**Bartelmus P., C. Stahmer et J. van Togeren** (1991). Integrated environmental and economic accounting: framework for a SNA satellite system, *Review of Income and Wealth,* Series 37(2) : 111-148.

**Bergstrom J.C., J.R. Stoll, J.P. Titre et V.L. Wright** (1990). Economic value of wetlands-based recreation, *Ecological Economics,* vol 2, pp. 129-147.

**Bonnieux F., B. Desaigues et D. Vermersch** (1992). French experiments in contingent valuation: two cases studies, *Valuing the environment. The European experience. Oxford University Press (in press).*

**Bureau des statistiques des Nations-Unies** (1990). *SNA Handbook of integrated environmental and economic accounting-Preliminary draft.* New York.

**Bureau des statistiques des Nations Unies** (1991). *Integrated environmental - economic accounting.* Work session on specific methodological issues in environmental statistics, Working Paper no. **10**. Ottawa, 14-17 mai 1991.

**Caron F. et M. Shields** (1991). *Bilan de l'exploitation du saumon au Québec.* Ministère du Loisir, de la Chasse et de la Pêche, Québec.

**Central Bureau of Statistics** (1989). *Naturressurser og miljo* 1988, Oslo, 116p.

**Central Bureau of Statistics** (1992). *Natural resources and the environment,* Oslo, 159p.

**CICPN** (1986). *Les comptes du patrimoine naturel,* INSEE, C137-138, 552p.

**El Serafy S.** (1991). Sustainability, income measurement and growth, *Environmentally sustainable economic development: building on Brundtland,* eds. R. Goodland, H. Daly, S. El Serafy and B. von Droste. UNESCO, Paris : 59-69.

**Hager T., T.H. Stevens et C.E. Willis** (1989). *Economic benefits of salmon restoration in Massachusetts.* Machachussets Agricultural Experiment Station, Research bulletin number 726.

**INSEE** (1986). Les comptes satellites de l'environnement. Méthodes et résultats, INSEE, Paris, 146p.

**Lutz E. and M. Munasinghe** (1991). La comptabilisation de l'environnement. *Finances et développement* mars : 19-21.

**Mitchell R.C. et R.T. Carson** (1989). *Using survey to value public goods: the contingent valuation method.* Resources for the future, Washington D.C., 463p.

**Pearce D.W. et D.W. Turner** (1990). *Economics of natural resources and the environment*, John Hopkins Press, 378p.

**Potvin J.R.** (1991). Colloque sur les indicateurs d'un développement écologiquement durable: synthèse. Conseil consultatif canadien de l'environnement, Ottawa, 49 p.

**Pillet G.** (1992). Mettre un prix sur ce qui n'a pas de prix, dans *Ecodecision,* no. **5** : 40-43.

**Repetto R. et al** (1989). *Wasting assets: natural resources in the national income accounts,* World resources Institute, Washington D.C., 68p.

**Repetto R. et al.** (1991). *Accounts overdue: Natural resource depreciation in Costa Rica,* World Resources Institute, Washington D.C., (110p.

**Revéret J.P.** (1991). *La pratique des pêches.* L'Harmattan, 198p.

**Weber J.L.** (1991). Comptabilité du patrimoine naturel et integration des statistiques de l'environnement Présenté à la Conférence spéciale de l'IARIW sur la comptabilité de l'environnement. Baden (Autriche), 27-29 mai 1991

**FIGURE 1.**
**STRUCTURE DU SYSTEME DE COMPTES DU PATRIMOINE NATUREL.**

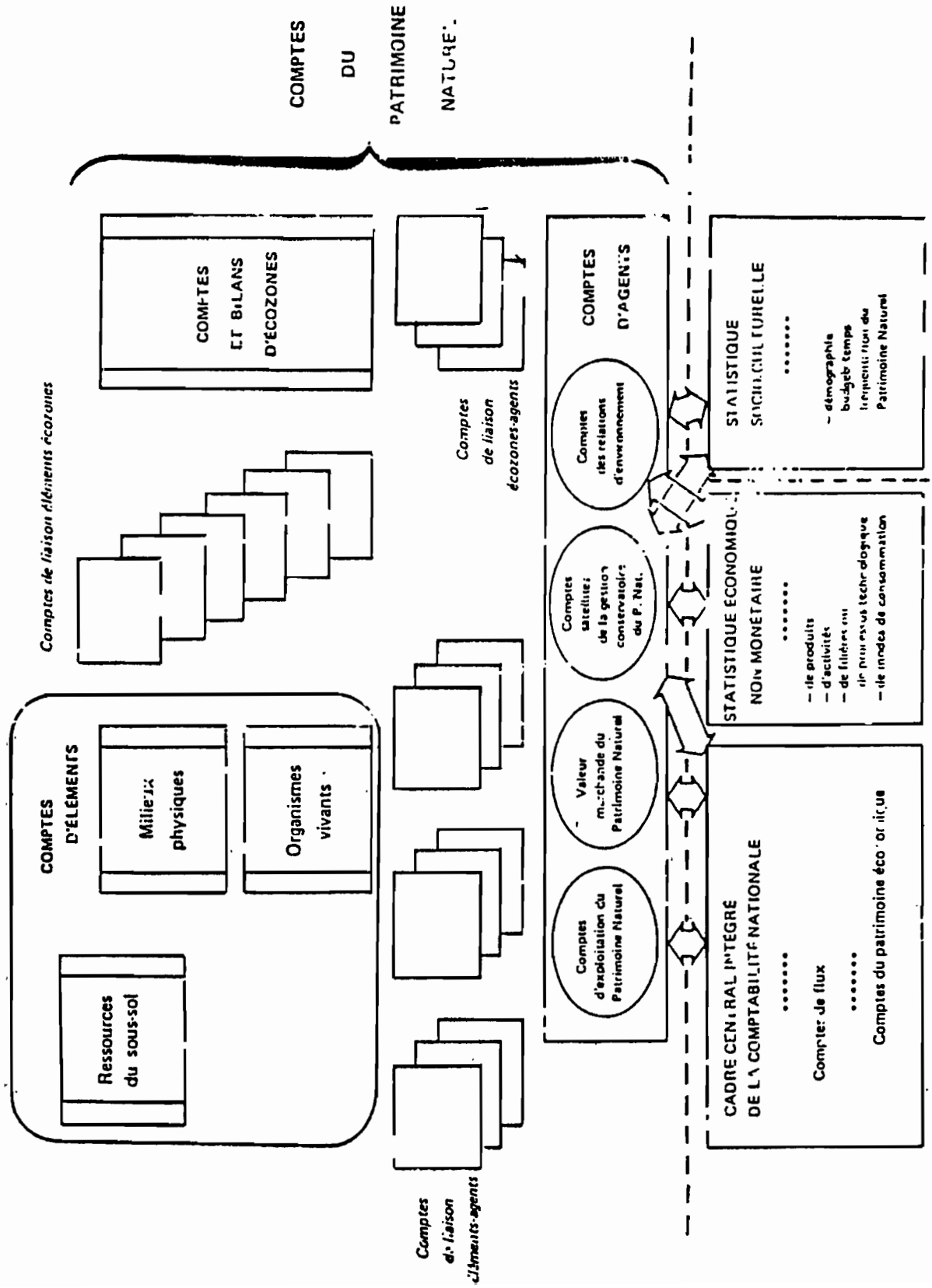
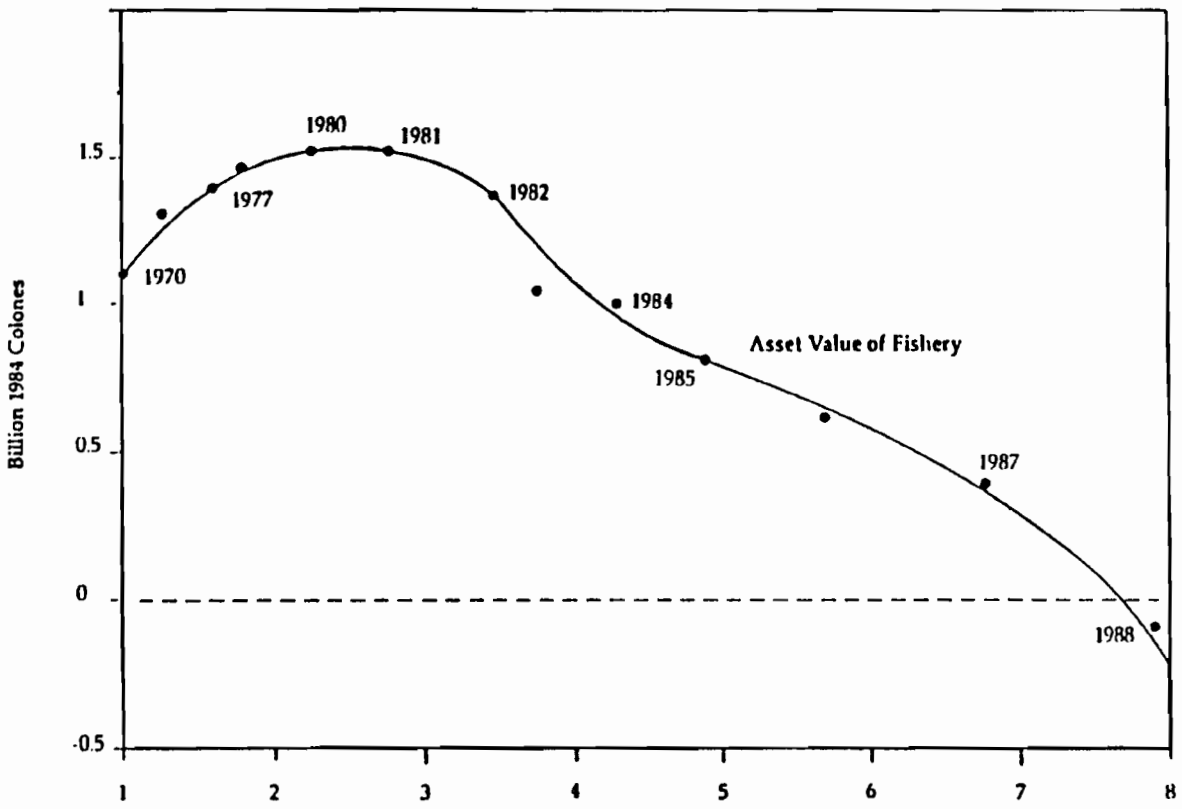
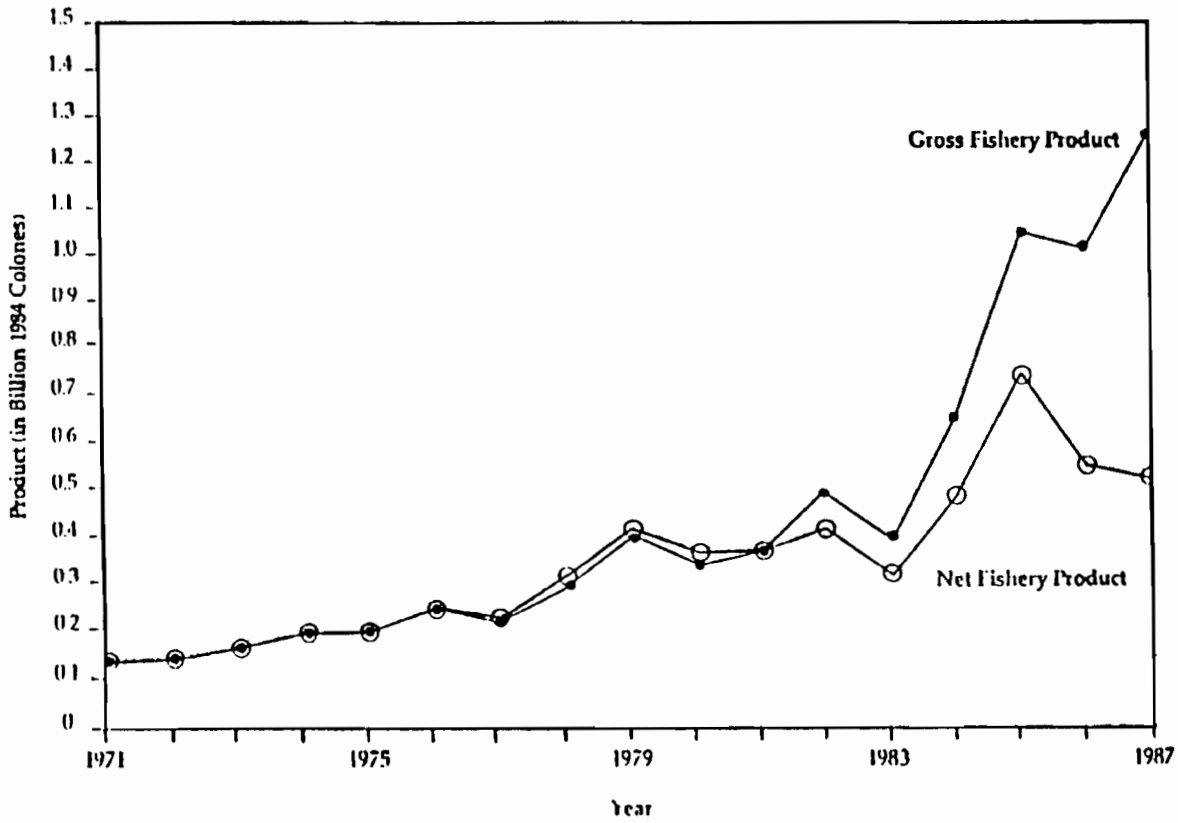


**FIGURE 2.**
**DECLINE IN FISHERY ASSET VALUE WITH INCREASING EFFORT, GULF OF NICOYA, COSTA RICA, 1970-88.**




Source : Repetto et al., 1991.

**FIGURE 3.**
**GROSS AND NET FISHERY PRODUCT, COSTA RICA.**




Source : Repetto et al., 1991.

# Fishing and Development
# by
# J. Catanzano

Traitée dans cette session selon différentes acceptions et différents points de vue, la question du développement reste à l'heure actuelle, tant sur le plan des économies nationales des pays côtiers les plus défavorisés que sur le plan des secteurs de production halieutique, l'une des questions fondamentales adressée à l'ensemble des sciences sociales intéressées aux ressources, espaces et sociétés littoraux. En effet, force est de constater que dans le monde actuel, les ressources halieutiques tendent à devenir pour quelques-uns des pays en développement les principales richesses porteuses des plus grandes potentialités sociales et économiques. Trois éléments suffisent à illustrer ce constat. Tout d'abord le poids qu'elles représentent dans les échanges internationaux, devenant souvent les premières sources de devises pour les pays en voie de développement au détriment d'autres secteurs de production agricole ou minier bien souvent en repli (cas de la Mauritanie, de Madagascar, du Sénégal...). Ensuite le rôle que joue dans les pays côtiers les activités économiques de production, de transformation ou de commercialisation des produits de la mer, tant du point de vue des richesses créées que de celui des emplois. Les économies littorales s'en trouvent ainsi revitalisées. Les activités de pêche permettent la fixation des hommes sur la bande côtière dans des pays souvent enclins par le passé à de fortes migrations humaines vers des zones économiquement viables (sites urbains ou industriels) de pays voisins ou pays développés. Enfin de part la nature même des produits halieutiques, la pêche joue un rôle croissant dans la satisfaction des besoins alimentaires des populations locales devenant en bien des cas la source essentielle de protéines animales.

La nouvelle répartition des richesses halieutiques née du nouveau droit de la mer confère aux pays en développement de nouvelles responsabilités d'exploitation et de gestion de leurs ressources dans un monde où les systèmes de production se sont internationalisés, où se sont transformées tout récemment encore les capacités

In this session the problem of development is dealt with in all its meanings and from various points of view. It remains one of the most fundamental questions for all the social sciences interested in coastal resources, spaces and communities, whether one is looking at the poorest coastal countries national economy or the fisheries production sector. Indeed, we cannot but notice that in today's world, fisheries resources have tended to become the main source of wealth for some developing countries, bringing with them great economic and social possibilities. Three points suffice to illustrate this statement. First, the importance that they have in international exchange, often becoming the major source of hard currency for developing countries and this at the expense of other sectors of production such as agriculture and mining which are often in decline (as the case in Mauritania, Madagascar, Senegal...). Second is the role that the whole range of economic activities, involving, production, processing and marketing of sea products, play in the creation of wealth and jobs in coastal countries. In this way coastal economies have been revitalised. Fishing has helped to fix populations in the coastal zones in countries which, in the past, have often witnessed large scale human migration towards economically viable areas (such as urban or industrial sites) in neighbouring or developed countries. And finally, the very nature of fisheries products gives fishing and increasing role in achieving food security for local populations, becoming in many cases the main source of animal protein.

The distribution of fisheries resources, resulting from the new Law of the Sea gives developing countries new responsibilities for the development and management of resources in a world with new international production systems, which has very recently seen the transformation of potential productive capacities of big industrial blocks (such as Eastern Europe, Asia, European Union), and where the trend is increasingly towards the globalisation of markets. All this contributes to the growing instability

productives mobilisables par les grands blocs industriels (pays de l'Est, Asie, Union européenne...), où se sont accélérées aussi les tendances à l'internationalisation des marchés. Tout cela exacerbe à la fois l'instabilité et l'incertitude des facteurs à prendre en compte dans les stratégies nationales. De fait, ce sont autant de difficultés supplémentaires qui en découlent face à des pays encore dépendants en grande partie des capacités productives extérieures. La question du développement abordée selon les différentes facettes précédemment évoquées renvoie l'observateur ou scientifique devant l'obligation de prendre en compte différentes échelles socio-politico-économiques depuis les économies et stratégies internationales jusqu'aux économies locales.

A côté de cela, la question du développement tend à contenir l'une des interrogations majeures du monde actuel, non spécifique à la pêche, même si celle-ci en fournit une illustration intéressante, consistant à chercher les bases d'un nouveau paradigme pour l'exploitation des ressources naturelles renouvelables selon le concept d'un développement durable. On verra que certaines propositions sont discutées dans cette session qui ouvrent sur une révision des paradigmes anciens attachés aux dynamiques de l'exploitation des ressources halieutiques.

Mais l'accession au développement, tant sectoriel que global pour des économies nationales, ne va pas sans poser elle aussi un certain nombre de questions. Ainsi on peut se demander quelles sont les modalités les plus efficientes d'appui au développement ? Quelles sont les politiques globales et initiatives locales les plus appropriées ? Que peut-on tirer des leçons des tentatives passées plaquées sur l'ensemble des secteurs de production primaire avec des schémas de spécialisation productive et commerciale souvent fondés selon des modes de production très artificialisés (cultures d'exportation à côté des cultures vivrières par exemple) ? Que dire des projets de développement ?

N. Sinkam et J. Weber, dans leur communication respective, abordent ces différentes questions adressant au passage quelques critiques aux schémas artificiels plaqués trop souvent sur les sociétés traditionnelles en guise d'accession au développement. Fondés essentiellement sur l'Afrique, leurs propos gardent du point de vue des questionnements et souvent même des constats, une applicabilité quasi universelle tant sont communs souvent les modèles promus par des acteurs extérieurs au PED.

Les autres auteurs qui s'expriment dans cette session illustrent assez largement aussi quelques-unes de ces questions utilisant pour cela des références *a priori* différentes dans leur contexte géographique, social, his-

and uncertainty concerning the factors which have to be taken into account in national strategies. In fact, these are just so many more difficulties for countries which, for the most part, still depend on external productive capacity. Such a multifaceted approach to the problem of development requires the observer or the scientist to take account of various socio-politico-economic scales ranging from international economies and strategies to local economies.

In addition, the problem of development tends to include one of the major questions facing today's world, not really specific to fishing even though fishing represents and interesting example, a question concerned with the search for the bases of a new paradigm involving the exploitation of renewable natural resources within the concept of a sustainable development. We will see that some proposals are discussed in this session as a first step towards revision of the old fisheries paradigm which is concerned with the dynamics of fisheries exploitation.

But the development process, whether from a sectoral or global point of view in the national economy, also raises a number of questions. For instance, what are the most efficient ways and means of supporting development ? What are the most appropriate global policies and local initiatives ? What lessons can be drawn from previous attempts grafted onto the whole of the primary production sector with plans for productive and commercial specialisation often founded on very articificial modes of production (export crops next to food crops for example) ? What can be said about development projects ?

In their respective papers, N. Sinkam and J. Weber deal with these different questions while expressing some criticisms of the artificial plans grafted onto traditional societies in the hope of achieving development. Although founded mainly on African experience, the questions that they ask and even their answers remain practically universally valid as the models promoted by those outside the LDCs are so similar.

Other authors in this session also discuss some of these questions using references which seem to be a priori different in their geographical, social and historical context but which, in many respects allow us to understand the duality of development, considering some fisheries in developed countries in some cases. It is in particular the case of the snow-crab fishery in the gulf of St Lawrence used by J.C. Brêthes to try to understand and explain the dynamics of this productive sector by deciphering the role of each economic and social agent placed in a social an economic frame within different systems. Beyond the example's own conclusions, it is a perfect illustration of the way that the question of development can be applied to countries considered already beyond that issue.

torique, mais qui à bien des égards nous donnent l'occasion de comprendre la dualité d'un développement, perçu en quelques cas à propos de pêcheries en pays développés. C'est le cas notamment de la pêcherie du Crabe des Neiges dans le Golfe du Saint-Laurent à laquelle fait référence J.C. Brêthes pour tenter de comprendre et expliciter la dynamique de ce secteur de production en décryptant le rôle de chacun des acteurs économiques et sociaux placé dans un cadre de représentation sociale et économique construite en différents systèmes. Au-delà des conclusions propres à l'exemple traité, il s'agit là d'une illustration parfaite de l'applicabilité de ce questionnement du développement à des pays pourtant considérés comme déjà dégagés de cette question.

M. Kebe s'intéresse quant à lui aux modalités et exigences qui s'imposent dans les relations entre partenaires du nord et du sud, dans le nouveau contexte mondial d'obligations nées du nouveau droit de la mer. On y retrouve mêlés les objectifs sociaux des uns et les objectifs économiques des autres. On prend conscience également sur la base d'un cas concret des difficultés encore fortes qui viennent freiner les substitutions voulues dans les systèmes productifs. Le développement doit ainsi se conduire encore en bien des cas en coopération au travers de conventions ou contrats d'exploitation particuliers. L'auteur s'appuie dans ces propos sur les relations qu'entretiennent les Etats africains et l'Union Européenne, s'interrogeant notamment sur les avantages et risques de différentes solutions de partenariat.

Revenant à un niveau d'interrogation plus global, A.T. Charles et A. Herrera développent leur analyse des formes sociales coopératives de pêcheries du Costa Rica en se référant à quelques aspects fondamentaux de l'idée de développement que l'on retrouve aujourd'hui exprimés de plus en plus dans le concept de développement durable. Les auteurs mettent en avant une sorte de triptyque ou triangle susceptible de rassembler les conditions de durabilité que l'on doit rechercher dans les pêcheries. Au travers de cette vision se regroupent plusieurs conditions nécessaires. Ce sont différents domaines qui participent du système pêche et donc différents points de vue qui se retrouvent sur chacun des sommets. Assurer la durabilité du système et de son développement nécessite alors, selon les auteurs, une durabilité combinée des éléments écologiques, des éléments sociaux et économiques ainsi que des éléments institutionnels. Fédératrice, cette vision schématique permet également d'insister sur la pleine participation au système pêche d'éléments a priori plus extérieurs qui tendent à jouer un rôle essentiel dans la dynamique des pêcheries. Le développement durable, défini ainsi et appliqué à ce secteur, correspond à un développement

M. Kebe is interested in modalities and requirements essential to the relationships between North and South partners, in the new world background of duties resulting from the New Law of the Sea. The social objectives of some tend to be mixed with economic objectives of others. And a case study shows that very real difficulties emerge which act as a check upon the desired substitutions in the production systems. In many cases development must then still be organised on a cooperation basis through conventions of particular exploitation contracts. The author's remarks are based on relationships between African countries and the European Union and query in particular the advantages and risks linked to different parternship solutions.

Returning to a more general level of enquiry, A.T. Charles and A. Herrera develop an analysis of cooperative social forms of fisheries in Costa Rica by referring to some fundamental aspects of the idea of development that we find increasingly expressed today in the concept of sustainable development. The authors put forward a kind of three-phase plan or triangle supposed to bring together the conditions for sustainability that we must look for in fisheries. This way of looking at things clarifies the necessary conditions. These are different areas involved in the fishery system and hence different points of view are found at each apex. According to the authors, ensuring a sustainable system and its development depends on a combination of ecological, social and economic as well as institutional factors. Favouring a collective approach, this schematic vision insists that all elements participate fully in the fishing system, even those which are a priori more external but tend to play an essential part in the dynamic of the fishery. Sustainable development, as defined and applied to this sector, is a development which tends not to compromise the renewal of resources, social cohesion and the means of social regulation and also to keep institutions on their appropriate evolutionary path. Such a schematic representation as a "beneficial" triangle allows the identification of the conditions necessary to the success of development projects.

qui tend à ne pas compromettre le renouvellement des ressources, la cohésion sociale et modes de régulation sociaux, et garder aux institutions une trajectoire d'évolution qui leur est propre. La représentation schématique sous forme d'un triangle « bénéfique » permet de poser clairement certaines des conditions requises pour l'aboutissement de projets devant servir le développement.

# Quelle Place pour les Pêches Africaines dans le Cadre de la Nouvelle Donne Mondiale ?

**Samuel C. Nana Sinkam**

Commission des Nations Unies pour l'Afrique, Directeur de la Division Conjointe CEA/FAO de l'Agriculture (JEFAD), PO Box 3001 Addis Abeba, Ethiopie

ABSTRACT

*The objective of this document is to analyse and discuss on the development of the fisheries sector in Africa and on its role in the world exchanges of fishery products. In the framework of the new world deal of the 90's and facing the external constraints of the fisheries sector, many questions are raised. They concern both the future relations between Africa and its economic partners, and also the choices that Africa has to formulate to go ahead with the development of its fisheries.*

*Illustrated by precise and concrete examples, the following points are reviewed :*

- *Importance of the fisheries sector in Africa versus its disorganization.*
- *Specific problems of the fisheries sector and the african economy in general.*
- *New world context and the consequences for Africa.*
- *Main strategies for a sustainable development of fisheries activities in Africa.*

*Lastly, concrete recommendations are proposed, which should be implemented by african countries, and also accepted and assumed by their partners from the North within the framework of a genuine co-operation and real partnership.*

RÉSUMÉ

*L'objectif de cette intervention est de discuter du développement du secteur halieutique en Afrique et de sa place au sein des échanges halieutiques mondiaux. Dans le cadre de la nouvelle donne mondiale des années 90 et face aux externalités du secteur des pêches, des questions décisives se posent. Elles concernent aussi bien les relations à venir de l'Afrique avec ses partenaires économiques, que les choix qu'elle doit formuler pour poursuivre le développement du secteur.*

*Illustrés par des exemples précis et concrets, les points suivants sont abordés :*

- *L'importance du secteur des pêches en Afrique, malgré sa désorganisation ;*
- *Les problèmes spécifiques au secteur des pêches africain, et à l'économie africaine en général ;*
- *Le nouveau contexte mondial et ses conséquences pour l'Afrique ;*
- *Les stratégies possibles pour un développement soutenu des pêches en Afrique.*

*Enfin des recommandations concrètes sont proposées, qui devraient être mises en oeuvre par les pays africains, mais aussi acceptées et assumées par leurs partenaires du Nord, dans le cadre d'un partenariat véritable.*

## 1. INTRODUCTION

La production halieutique africaine, après avoir augmenté de 25 % de 1985 à 1988, connaît depuis une légère régression, due à la pleine exploitation des stocks. Parallèlement, près de la moitié des ressources marines sont encore exploitées par des flottes étrangères, sur un potentiel estimé à 9 millions de tonnes. De plus, la production africaine est relativement concentrée, 10 pays représentant 70 % de cette production. Pour le continent et pour ces pays en particulier, le secteur est vital, tant sur le plan de l'emploi (9 % des emplois agricoles) que sur celui de l'apport protéique (près de 50 % des apports de protéines animales).

De plus depuis vingt ans, on assiste à une chute des parts de marché de l'Afrique dans le commerce mondial. De 3,8 % en 1970, la valeur des échanges africains dans les échanges mondiaux est passée à 1 % en 1990. Ce ralentissement des échanges s'observe tant sur la valeur globale des produits exportés que sur celle des produits d'importation.

Or si, depuis dix ans, les valeurs en dollars constants de l'ensemble des exportations africaines, y compris celles du secteur agricole sont en baisse, la valeur en dollars constants des exportations de produits halieutiques africains n'a cessé d'augmenter et a été multipliée par trois sur la période 1980 à 1989 (cf. **encadré 1**).

Si l'on considère l'Afrique dans son ensemble, le secteur agricole est un importateur net en valeur en 1989 ; a contrario, le secteur des pêches dégage un excédent commercial et contribue à l'entrée de devises fortes dans les économies africaines (cf. **encadré 1**).

C'est dire combien les activités primaires halieutique et aquacole constituent pour certains pays africains des facteurs et des sources de croissance, dans un contexte de besoins nutritionnels importants :

- apport alimentaire,
- apports en devises fortes,
- investissement des plus values dégagées par la pêche dans les secteurs industriels,
- emploi...

Ce secteur important de l'économie africaine risque cependant d'être très touché dans les années à venir par les modifications de son environnement extérieur. La mondialisation actuelle des échanges, le développement des marchés des produits aquatiques dans les pays du Nord et les récents bouleversements politiques et économiques dans les pays de l'Est doivent et devront être pris en compte dans les nouvelles politiques et stratégies de développement, les anciennes orientations étant bien souvent obsolètes face à cette "nouvelle donne mondiale".

Le secteur des pêches devra s'adapter à ces nouveaux paramètres, en tenant compte des besoins importants (nutritionnels, devises) à satisfaire, des spécificités existantes (complémentarité ou compétition entre les pêcheries artisanales et industrielles) et des grandes tendances économiques, sociales et politiques africaines (croissance démographique, exode rural).

## 2. LE SECTEUR DES PECHES EN AFRIQUE, DESORGANISE MAIS D'UNE IMPORTANCE CAPITALE

Deux types d'exploitation fondamentalement différents coexistent à l'heure actuelle en Afrique : les pêches artisanales (barques, pirogues) et les pêches industrielles (flottes africaines - flottes étrangères). Tenant compte de ces différents types

d'exploitation, la production halieutique africaine en 90 se décompose comme suit : sur un total de 7,8 MioT, 1,3 MioT proviennent des eaux continentales, le reste, soit 6,5 MioT provenant des eaux marines. La production continentale est largement dominée par les pêches artisanales, les seules pêcheries industrielles ou semi-industrielles se trouvant dans les grands lacs du Rift. La production marine, quant à elle, comprend 3,3 MioT pêchées par les flottes industrielles étrangères et 3,2 MioT par les flottes africaines, desquelles environ la moitié sont produites par les pêcheries artisanales.

Au total, les pêches artisanales comptent pour environ les deux tiers de la production nationale africaine.

Du fait de la surexploitation de certaines ressources, on observe actuellement une concurrence accrue entre l'artisanal et l'industriel. A cette compétition pour l'espace et la ressource se surajoute une compétition pour les aides publiques et la commercialisation, où la pêche industrielle est généralement favorisée. A côté de ces problèmes intra-africains, se pose celui de l'exploitation des stocks hauturiers par les flottes étrangères : mauvaise négociation des accords de pêche, pêches illicites mais aussi vide laissé par le retrait des flottilles de l'Est.

Cette situation difficile est favorisée et compliquée par la faiblesse des structures administratives, des moyens humains et financiers disponibles pour organiser le secteur, au niveau national comme au niveau régional.

A ce titre, la création des ZEE par le nouveau Droit de la Mer en 1982, si elle est une chance pour l'Afrique, en lui octroyant la gestion de son espace maritime, représente également une difficulté de taille par l'augmentation des besoins organisationnels qui en découle, la tâche étant compliquée par une profonde méconnaissance du secteur (absence de statistiques fiables sur les ressources, l'exploitation, l'emploi, la rente économique,...). De fait, la plupart des pays africains ont encore d'importantes difficultés à gérer cette ressource qui leur a été confiée.

Quant au secteur aquacole, il compte environ pour 110 000 tonnes dont les deux tiers produits par un seul pays, l'Egypte. L'aquaculture "de subsistance" du tilapia, que l'on a cherché à développer en Afrique sub-saharienne depuis de nombreuses années, a toujours ou presque été un échec, dans lequel nombreux sont ceux qui continuent à persévérer. Il serai là aussi temps de regarder vers de nouvelles orientations (crocodiles, crevettes, acadjas,...) pour que l'Afrique participe enfin à l'expansion mondiale de l'aquaculture.

Malgré sa désorganisation, le secteur halieutique reste d'une importance cruciale en Afrique, tant sur le plan de l'emploi (2 millions de pêcheurs, 8 millions d'emplois induits) que sur celui des échanges (excédent commercial de 600 millions de $ en 89) et, enfin et surtout, sur le plan de l'apport protéique : malgré la relative faiblesse des approvisionnements (7,9 kg/hab/an contre un niveau mondial de 12,3 kg/hab/an), le poisson est une source majeure de protéines animales pour l'Africain, et une source qui vaut par la stabilité de ses apports (moins sensible que le bétail aux variations climatiques et à la compétition pour l'espace, dans un contexte de croissance démographique). Cependant, pour maintenir sa place dans l'avenir, compte tenu d'une croissance démographique de 3 % par an, l'approvisionnement en poisson de l'Afrique devra augmenter chaque année de 50 000 tonnes dans les années à venir.

Pour relever ces défis africains, il faudra prendre en compte les spécificités des ressources halieutiques africaines, leurs modes d'exploitation et le cadre socio-économico-politique africain, mais aussi l'évolution du contexte mondial dont l'impact sur l'Afrique ne fera qu'augmenter avec la mondialisation des échanges.

## 3. QUELS PARAMETRES ESSENTIELS POUR LE DEVELOPPEMENT DES PECHES AFRICAINES ?

### *3.1 Le contexte particulier des pêches africaines*

#### 3.1.1 Une demande en augmentation, une production à son maximum

Face à la croissance démographique, les besoins alimentaires africains ne cessent d'augmenter, et particulièrement les besoins en protéines, satisfaits pour une large partie par le poisson dans nombre de pays africains.

Les gros consommateurs africains (Nigéria, Zaïre, Côte d'Ivoire,...) doivent avoir recours aux importations pour satisfaire la demande de leurs populations. Or les importations intra-africaines sont largement entravées par les difficultés

d'acheminement des produits (manque d'infrastructures et de voies de communication), et les importations extérieures à l'Afrique sont quant à elles limitées par le manque de devises chronique de la plupart des pays africains. Ainsi, malgré une demande croissante, les importations ne peuvent augmenter.

Pour ce qui est des ressources halieutiques africaines, elles sont, comme partout dans le monde, pleinement exploitées, mise à part une fraction des ressources continentales. Une augmentation substantielle de la production ne pourra donc être obtenue sans un effondrement rapide des stocks, sauf à s'approprier l'exploitation de stocks exploités jusqu'à présent par des flottes étrangères.

#### 3.1.2 Un fait majeur : la prééminence politique des villes sur les campagnes, de l'industriel sur l'artisanal

La concurrence que nous avons mentionnée entre pêches artisanales et industrielles se rattache à un phénomène plus large de domination des villes sur les campagnes.

Cette domination est au départ politique, le pouvoir et les richesses étant concentrés dans les villes, la population urbaine étant la seule à représenter un danger potentiel pour les gouvernements. Cela se manifeste par des politiques d'alimentation faciles (importations, aide alimentaire) et une ponction sur le secteur rural, seul productif, des ressources nécessaires aux gouvernements et au maintien du niveau de vie dans les villes, par une politique de prix "artificiels".

En ce qui concerne les pêches, on observe de même des politiques favorisant la pêche industrielle, du fait d'un apport direct en devises (accords de pêche, licences négociés par l'Etat), mais aussi d'un contrôle plus facile des débarquements, centralisés dans les agglomérations portuaires, voire même simplement pour une raison de prestige. La pêche artisanale, au contraire, est disséminée le long des côtes et des fleuves, et les tentatives de des Etats pour la contrôler (coopératives, centres de commercialisation) ont toujours été des échecs. De plus, sur les mêmes ressources, elle est plus compétitive que la pêche industrielle et parvient parfois à l'évincer ( cas du lac Tanganyika dans sa partie burundaise, où les captures de pirogues ne cessent d'augmenter, les captures industrielles étant en diminution). Enfin la pêche artisanale est non seulement plus productive, plus génératrice d'emploi mais nécessite aussi un investissement en capital, et partant en devises, bien moindre. Par contre, l'accès aux stocks est dans son cas bien moins contrôlable que pour la pêche industrielle et, afin d'éviter la surexploitation, il sera nécessaire si l'on veut développer la pêche artisanale de mettre en place de nouveaux moyens de régulation de l'accès.

Alors que la tendance générale est à une croissance des villes aux dépens des campagnes, à une concentration croissante des activités, le secteur des pêches peut être l'un des premiers à renverser cette tendance ou du moins à la freiner, l'indépendance de l'activité artisanale par rapport à l'Etat étant relativement forte, et sa rentabilité étant élevée. Il peut donc jouer le rôle d'un exemple au sein du secteur agricole, et montrer qu'il est essentiel de promouvoir le secteur rural, seul générateur de richesses indispensables à l'investissement productif.

### *3.2 Des enjeux mondiaux et globaux, aux répercussions certaines*

#### 3.2.1 La mondialisation des échanges : quel rôle pour l'Afrique ?

L'augmentation de la consommation mondiale de produits aquatiques et la mise en place des grands marchés de consommation (Grand Marché européen de 1993, ouverture du marché des pays de l'Est), représentent pour les pays africains une chance à saisir dès maintenant (**cf. encadré 2**) ?

En effet, dans un environnement mondial où la compétition pour la commercialisation des produits halieutiques est de plus en plus vive, la concurrence des pêcheries du Sud-Est asiatique et de l'Amérique du Sud constitue un risque majeur pour les pêcheries africaines d'exportation, si celles-ci ne réagissent pas à temps pour se positionner sur les marchés extérieurs des pays du Nord. De plus, face à l'émergence des produits aquacoles et au réajustement de fait des cours des produits de la pêche, quel va être l'avenir de certaines pêcheries traditionnelles en compétition avec les produits d'élevage (cf. **encadré 3**) ?

La baisse de rentabilité des activités de pêche industrielle pour les pays les plus développés et la pleine exploitation des stocks halieutiques de leurs ZEE, ont conduit soit à leur désengagement vis-à-vis de leur flotte de pêche industrielle (modèle américain : vente de la flotte thonière à Taïwan) soit à une délocalisation de leur flotte dans des pays où les coûts

d'exploitation sont plus faibles (modèle européen : soutien au secteur des pêches européen à travers les subventions par achats de licences, mise en place de joint-ventures avec des pays tiers). L'aide de fait accordée à l'Afrique par la CEE dans l'exploitation de ses ressources hauturières s'inscrit dans une logique d'intérêt mutuel entre les deux parties (zones de pêche et main d'oeuvre des pays Africains, capital et immobilisations des pays européens). De plus, les liens historiques de coopération établis avec les pays européens, et en particulier la France, sont autant de facteurs qui devraient favoriser les échanges entre les deux continents. Face au danger que représentent les pays du Sud-Est asiatique, l'Afrique se doit de traiter avec l'Europe dans le cadre de l'aide au développement et ce d'autant plus que les accords ACP augmentent la compétitivité des produits halieutiques africains sur la marché européen (pas de prélèvements douaniers).

De plus l'apparition des biotechnologies, l'évolution rapide des nouveaux process et *in fine* des marchés (**encadré 4**) entraîneront des changements structurels considérables, auxquels les industries de la pêche ne devraient pas échapper. La sophistication des marchés dans les pays du Nord conduira à des difficultés croissantes pour l'accès des produits africains à ces marchés : apparition des labels de qualité, mise en place ou changement des normes, législations nationales restrictives (cf. **encadré 5**)... Dans cet environnement mondial évolutif, l'Afrique doit s'allier à des partenaires bien choisis pour éviter l'isolement économique.

### 3.2.2 La pression des écologistes occidentaux : une contrainte de plus en plus préoccupante

La montée des mouvements et pressions écologistes autrefois marginaux, prend de plus en plus de poids politique sur le plan national et international (cf. **encadré 6**). Cette nouvelle tendance doit être prise en compte sous ses différentes formes d'expression :

Tout d'abord, le discours écologique trop souvent passionnel et de surcroît porté par les opinions publiques occidentales, pèse lourd auprès des décideurs politiques qui sont contraints d'intégrer cette dimension dans leur choix. Cependant, les données écologiques sont parfois difficiles à prendre en considération de façon rationnelle et globale, d'une part parce qu'elles s'inscrivent dans un cadre dynamique et complexe où il est difficile d'avoir une démarche prospective, d'autre part parce que les problèmes et les priorités en matière d'écologie et de protection de l'environnement peuvent être très différentes d'un pays à l'autre, en fonction notamment du niveau de développement (cf. **encadré 7**).

Aujourd'hui, l'écologie devient également une "arme stratégique" utilisée par les industriels pour influencer et favoriser le développement de certains marchés (cf. **encadré 8**), et utilisée par les gouvernements comme mesure protectionniste (cf. **encadré 9**), souvent accompagnée de mesures discriminatoires à l'encontre de pays peu respectueux envers la Nature. Le danger, consiste surtout ici en des prises de positions "écologiques" irrationnelles et non scientifiquement fondées.

### 3.2.3 La déstructuration restructuration des pays de l'Est : quels risques pour l'Afrique ?

Les bouleversements survenus récemment dans les pays de l'Est ont entraîné une nouvelle donne sur la scène internationale des négociations : aujourd'hui, se posent un certain nombre de questions sur lesquelles nous devons engager une réflexion commune. En premier lieu, quel rôle vont jouer les partenaires traditionnels de l'Afrique et en particulier la CEE dans les années à venir : vont-ils privilégier des axes de coopération Nord-Sud ou Est-Ouest (cf. **encadré 10**) ? En particulier, dans le secteur des pêches, il est certain que les flottilles de l'Est ont des besoins d'aides importants, pour faire face à la mise en place de l'économie de marché (vérité des coûts, impératifs de rentabilité). Un arbitrage sera nécessaire entre les besoins d'aides réels des pays de l'Est et l'aide traditionnelle aux pays d'Afrique, dont les besoins ne cessent de croître. Pour le secteur des pêches, l'impact à terme de ces bouleversements est particulièrement difficile à évaluer, tant la mondialisation du secteur a développé des réseaux complexes d'accords et d'échanges (**encadré 11**).

Dans ce nouveau contexte, le redéploiement éventuel de la flotte de pêche hauturière russe ne pourrait s'opérer qu'en tenant compte des contraintes d'exploitation des stocks halieutiques mondiaux (sur quelles zones et sur quelles espèces), et des contraintes socio-économiques dans les pays de l'Est (coût de restructuration de la flotte, chute du niveau de vie et de la production globale, problème de solvabilité à terme...). En particulier, les pays de l'Est pourront-ils continuer à exploiter les stocks hauturiers des ZEE africaines, et garder leurs liens traditionnels avec leurs partenaires africains ?

Ce brutal bouleversement des données d'exploitation par les flottilles des pays de l'Est aura des répercussions à la fois économiques chez leurs partenaires traditionnels et écologiques sur les stocks précédemment exploités. Aujourd'hui, sur

quelles bases et à qui accorder de nouveaux droits de pêche en remplacement de l'exploitation soviétique ? Faut-il, en définitive, accorder de nouveaux droits sur les anciens stocks exploités par les pays de l'Est, ou l'Afrique doit-elle les exploiter par elle-même ?

En plus de ces données mondiales qui ne vont pas manquer d'influencer notablement le secteur des pêches en Afrique, il faut également prendre en compte les caractéristiques propres du continent africain, concernant bien sûr le secteur des pêches mais aussi son environnement social, économique et politique.

## 4. LES STRATEGIES DE DEVELOPPEMENT PROPOSEES

La question est simple : quel doit être la destination des pêches africaines (apport nutritionnel, devises) et par qui les ressources doivent-elles être exploitées (flottes étrangères, flottes nationales, industrielles ou artisanales) ?

Pour ce qui est du premier point, une constatation s'impose : mis à part les stocks "libérés" par les flottille de l'Est, la production halieutique africaine n'a guère de chances d'augmenter. On pourrait envisager différentes solutions pour satisfaire les besoins nutritionnels de l'Afrique :

i) *Développer l'aquaculture.* Cette solution, telle qu'appliquée actuellement, ne semble pas capable de fournir une quantité de poisson suffisante, n'ayant jamais montré de développement satisfaisant. Par contre, l'aquaculture "extensive" d'aménagement à grande échelle des plans d'eau (acadjas du Bénin) serait à même de fournir des quantités bien plus importantes. Il faut donc réorienter les politiques de développement aquacole.

ii) *S'approprier les ressources exploitées actuellement par les flottes étrangères.* Cette solution ne peut être sérieusement envisagée dans le court terme car la majorité des pays africains ne peuvent se permettre d'investir dans une flotte industrielle extrêmement coûteuse, et de rentabilité marginale. Part contre, dans le cadre d'accords de pêche, de joint ventures... il est tout à fait envisageable et normal que les pays africains s'approprient une part de cette ressource, que se soit en nature ou en devises.

iii) *Exploiter les stocks de pélagiques côtiers auparavant pêchés par les flottille de l'Est.* Il existe là une possibilité, ces stocks de faible valeur monétaire pouvant facilement trouver des débouchés en Afrique et n'intéressant pas les pays développés. Pour les mêmes raisons que précédemment cette exploitation ne pourrait être raisonnablement être faite de façon industrielle et devra donc faire l'objet du développement d'un nouveau créneau de pêche artisanale, là où cela est techniquement possible. Compte tenu des coûts d'exploitation (en particulier vérité des coûts pour les flottilles de l'Est) et de la valeur marchande de ces poissons, il est extrêmement peu probable qu'ils soient exploitables à court terme par des flottes industrielles, africaines ou étrangères.

iv) *Augmenter les importations.* Cette solution qui ne se heurte pas directement à un problème de ressource (disponibilité sur le marché mondial de grandes quantités de poisson congelé de faible valeur monétaire) est actuellement limitée par la pénurie en devises et les politiques d'ajustement structurel.

Ceci nous amène au deuxième niveau où le secteur des pêches peut avoir un intérêt : celui de l'apport en devises. En effet, compte tenu de la limitation en volume des captures, la solution qui s'impose est de rechercher une valorisation maximale pour retirer le meilleur parti de la production halieutique. Là encore, plusieurs solution sont possibles :

i) *Tirer le meilleur parti des accords de pêche et lutter contre les pêches illicites.* Ceci nécessite une coopération entre Etats africains, un renforcement du cadre administratif, pour négocier les accords sur des bases solides et avoir les moyens de contrôler les pêches illégales, qu'aucun Etat n'a les moyens de se procurer seul.

ii) *Valoriser au mieux les différents types de poissons pêchés en Afrique.* Il faut pour cela tenir compte des marchés existants, de leur solvabilité et de leurs demandes. Par exemple, la pêche artisanale africaine produits une part importante d'espèces dont la valeur sur les marchés occidentaux est élevée. Leur exportation pourrait être une source notable de devises, mais ne pourrait se faire efficacement que part des accords de type joint venture avec des partenaires privés connaissant ces marchés, leurs contraintes (normes...) et disposant des infrastructures nécessaires à la commercialisation du poisson dans les meilleurs conditions. Des espèces de moindre valeur

pourraient être commercialisées sur les marchés intra-africains, mais encore faudrait-il une connaissance réciproque des besoins et des disponibilités ainsi qu'une amélioration des infrastructures de communication. Enfin, les espèces de faibles valeurs pourraient être commercialisées directement sur les marchés locaux, par des circuits courts (sans chaîne du froid) permettant de maintenir des prix bas sur ces marchés à faible pouvoir d'achat.

iii) *Développer l'exportation de produits aquacoles de luxe.* L'Afrique dispose de nombreux sites aquacoles potentiels et d'une main d'oeuvre bon marché. Elle a déjà développée (Zimbabwe) un élevage de crocodiles fournissant des peaux de haute valeur marchande sur le marché mondial. Par contre, l'aquaculture de crevettes, en explosion en Amérique du Sud et dans les pays du Sud Est asiatique n'a pas encore décollé en Afrique, malgré quelques tentatives prometteuses (Madagascar). Les pêcheries étant menacées à terme par ce développement mondial de l'aquaculture, il faudra étudier les possibilités pour l'Afrique de se placer sur ce créneau, sans doute par le biais de joint ventures avec des partenaires étrangers détenant savoir-faire et circuit de commercialisation. A plus long terme, la limitation du volume des captures au niveau mondial induira également une recherche de valorisation maximale de toutes les espèces, déjà commencée avec des produits comme le surimi. Cette tendance qui devrait s'accentuer, pourra conduire à terme à la hausse des prix des espèces pélagiques et donner un avantage certain aux régions qui en disposent en grande quantité, telle l'Afrique.

Il y a de nombreuses voies possible pour développer les pêches et l'aquaculture africaines, soit dans le sens d'un meilleur apport nutritionnel, soit dans le sens de rentrées accrues de devises. Ces deux alternatives ne s'excluent pas l'une de l'autre, mais peuvent et doivent être complémentaires et effectuées conjointement sur des segments de production et de marché différents. Compte tenu des caractéristiques particulières de chaque pays il n'existe pas une solution idéale, mais pour chacun un équilibre à trouver et des pistes à explorer.

Cependant, des conditions indispensables à terme au développement du secteur sont d'abord l'adoption de politiques claires et réfléchies, la création d'un cadre propice à l'initiative, la mise en place de structures d'encadrement et de formation efficaces...

Ceci ne pourra se faire que dans le cadre d'une coopération accrue entre pays africains, mais aussi avec les pays non africains, cette coopération pouvant prendre un grand nombre de formes différentes mais devant toujours partir d'un intérêt mutuel ressenti par les différentes parties.

## 5. CONCLUSION ET RECOMMANDATIONS

Oui, il existe une place pour le secteur halieutique africain dans le cadre de la nouvelle donne mondiale.

Pour cela il faut :

**- maintenir et accroître les efforts de coopération à tous les niveaux :**

i) *favoriser le rapprochement entre Etats africains* présentant des caractéristiques communes (données géographiques communes/données politiques et économiques semblables...) pour établir des programmes et des actions conjointes dans le secteur des pêches et de l'aquaculture. Ceci devrait permettre de définir et d'expliciter clairement les objectifs nationaux pour le secteur des pêches, de renforcer ou mettre en place des capacités administratives, l'application des réglementations (harmonisation des législations pour l'exploitation des stocks partagés), la collecte et les échanges d'informations : bases de données sous régionales d'informations maritimes (ex : projet des 22 Etats africains riverains de l'Océan Atlantique), commission sous régionale (ex : COI), colloques, séminaires, programmes universitaires communs, programmes scientifiques conjoints... (cf. **encadré 12**). Ceci devrait aboutir à terme à une intégration sous-régionale entre pays ayant des besoins comparables ou complémentaires. Ceci devrait permettre des économies d'échelle et des réalisations communes dans le cadre de structures de négociation, de recherche, d'enseignement, voire même à terme de production (flottes communes sous forme de joint-ventures permettant une exploitation des stocks non pêchables artisanalement).

ii) *coopération avec les pays tiers traditionnellement partenaires de l'Afrique,* en particulier l'Europe. Etablissement de joint-ventures, accord de droits et de licences de pêche avec les pays possédant des flottes de

pêche industrielle pour permettre l'exploitation des stocks hauturiers (cf. **encadré 13**). Eviter tout développement inutile de flottes de pêche industrielle nationales dans des pays où les coûts d'opportunité sont souvent élevés et le capital rare. Ce partenariat avec les pays du Nord est également indispensable pour la commercialisation des produits et pour assurer une veille à l'évolution des marchés.

**-Favoriser le développement du monde rural et avec lui, celui du secteur artisanal :**

Promouvoir la mise en route de nouveaux projets en mettant l'accent sur les opérateurs réels, surtout ceux du monde rural qui sont à terme les seuls garants d'un développement économique durable en Afrique. Ceci doit correspondre à un choix politique délibéré accordant une large place à la composante sociale. Dans le domaine des pêches, si, sur les mêmes ressources, la pêche artisanale est plus compétitive que la pêche industrielle, il reste que cette dernière est la seule à pouvoir exploiter certains stocks (ex : stocks hauturiers) et ne doit en conséquence ne pas être abandonnée. Il faudra donc favoriser, *lorsque ceci est possible*, le développement de la pêche artisanale à travers trois volets :

i) Face aux contraintes de niveau d'exploitation, la seule voie possible pour accroître la richesse potentielle extraite des ressources halieutiques consiste *en une maximisation de la valorisation des espèces pêchées.* La commercialisation des produits de la pêche artisanale sur les marchés extérieurs du Nord est pour les espèces nobles le meilleur moyen de maximiser cette valorisation. Cette action procède d'une double constatation. D'une part, elle répond à l'intérêt grandissant envers ces produits, de la part des divers intervenants du secteur pêche des pays du Nord, préoccupés par l'augmentation et par la diversification de leurs sources d'approvisionnement face à un marché européen dont la demande en produits de la mer est croissante et la production stationnaire. D'autre part, elle répond également à l'intérêt des pays africains qui peuvent valoriser une part de leurs ressources halieutiques de très bonne qualité par le biais d'exportations payables en devises fortes sur des marchés demandeurs et riches (cf. **encadré 14** ). Dans ce cadre et tenant compte de la sensibilité "écologique", l'image d'un produit "artisanal" et exotique pourra être pleinement valorisée, pour peu qu'il rentre dans les normes de qualité.

C'est à travers des structures conjointes (joint venture), de partenariat (investissement d'entreprises privées en Afrique et opérateurs africains) que cette commercialisation doit se concrétiser, car de telles structures favorisent, d'une part, la rencontre entre l'offre des producteurs africains et la demande des marchés du Nord, et d'autre part elles permettent les financements notamment en infrastructures indispensables à la commercialisation de produits de qualité (packaging, logistique de transport...). Elles permettent enfin d'assurer la création d'emplois dans le pays hôte, un transfert de savoir-faire et une veille à l'évolution de la demande des grands marchés du Nord (évolution des contextes normatifs, et législatifs, évolution des grandes tendances de consommation) (cf. **encadré 15).** ). Le pays hôte, quant à lui, à travers ses opérateurs, garantit l'accès aux circuits de production et de vente par sa connaissance du terrain, des acteurs de la filière et des spécificités culturelles liées au pays.

Cette commercialisation ne peut néanmoins se concevoir sans des études de marchés précises et des efforts de promotion pour positionner les produits de la pêche artisanale africaine sur un ou des segments de marchés adaptés au pays du Nord. Il faut privilégier le développement des productions artisanales, pratiquement seules à fournir un tel niveau de qualité, de diversité des produits et génératrice d'un nombre d'emplois potentiels en Afrique bien supérieure à ce que l'on peut espérer de la pêche industrielle. Ceci implique également la mise en place de conditions nécessaires au montage de sociétés mixtes et à l'investissement de capitaux étrangers en Afrique : mesures fiscales favorables à l'investissement étranger et aux opérateurs africains (cf. **encadré 16**), accès au crédit pour ces derniers, un niveau de développement minimum assurant un environnement favorable à l'initiative privée et favorisant la concurrence.

ii) *le deuxième volet de développement de la production artisanale se situe sur le plan des marchés intra-africains* dont certains sont fortement demandeurs (Nigéria, Côte d'Ivoire, Zaïre, Angola et Cameroun, ces cinq pays concentrant à eux seuls 59 % des quantités de poissons importées en Afrique). La plus grande part de la demande africaine est satisfaite par des importations de poissons de faible valeur comme les petits pélagiques. Certaines pêcheries artisanales pourraient trouver un créneau en remplacement de l'exploitation soviétique sur des stocks de petits pélagiques côtiers. Ceci permettrait en outre de restituer en partie l'équilibre des apports alimentaires de petits pélagiques dont les débarquements en Afrique par la flotte Russe ont été interrompus. De plus, l'exploitation de tels stocks par des unités de pêche artisanale pourrait être valorisée à travers un pool de transformation, à condition toutefois que les apports de la flotte soient suffisamment réguliers et importants. A l'heure actuelle, la technique de conservation par appertisation, sur ce type de ressources, semble la plus rentable et la mieux adaptée aux contraintes de commercialisation sur le territoire africain. Dans le cadre d'échanges intra-africains une coopération entre les pays est nécessaire afin de mettre en place des règles douanières concertées, d'effectuer des études de marchés, des études de complémentarités...

iii) *le troisième volet enfin, concerne les productions artisanales peu ou pas exportables vers les pays du Nord et vers les pays africains.* Ces productions doivent trouver quant à elles des débouchés sur les marchés locaux. Dans tous les cas les circuits de distribution doivent être courts et sans surcoûts qui grèvent les marges et ne peuvent être de toute façon supportés par le consommateur final (en particulier éviter les chaînes de froid et les entrepôts frigorifiques qui sont des investissements trop coûteux). Là encore le développement des échanges ne peut se faire que dans le cadre d'un système qui soit en compétition réelle, en évitant la mise en place de tous monopoles, en particulier ceux induits par les coopératives sous contrôle de l'Etat, et en réduisant enfin l'intervention étatique à sa stricte nécessité.

Concernant l'amont du secteur, il convient de rappeler que l'aménagement de la pêche artisanale doit s'effectuer par le contrôle de l'accès à la ressource afin de ne pas accroître la pression d'exploitation sur les stocks. Il faut pouvoir réguler l'effort de pêche afin d'accroître le revenu des pêcheurs, leur pouvoir d'achat et non leurs effectifs. Pour ce faire, il est nécessaire de porter une attention particulière aux systèmes coutumiers de droits territoriaux qui représentent une bonne base d'aménagement des pêcheries artisanales dispersées et éloignées (gestion déléguée aux communautés de pêcheurs) et réduisent également le coût de la surveillance. Enfin, il est nécessaire de réguler l'entrée dans certaines pêcheries, mais ceci ne pourra se faire que dans un contexte de croissance démographique maîtrisée et de développement de l'emploi dans d'autres secteurs.

**- Réorienter les politiques de développement aquacole.**

Face à l'échec enregistré depuis trente ans dans le développement de la pisciculture "rurale" de tilapias, et vu les défis posés à l'Afrique en terme de besoins nutritionnels, de concurrence mondiale sur certains produits (crevettes) et de besoins en devises, il faut réorienter le développement aquacole en Afrique selon deux voies principales :

i) *une voie à dominante "nutritionnelle"* par aménagement extensif sur des zones étendues (types acadjas au Bénin, qui devrait permettre la production d'une grande quantité de poisson à faible coût, et en même temps créer des emplois et une élévation du niveau de vie.

ii) *une voie à dominante "exportation"* portant sur des produits de hautes valeur telle que la crevette ou le crocodile. La production de peaux de crocodiles, déjà effective dans certains pays (Zimbabwe) semble particulièrement prometteuse. La production de crevette semble également intéressante dans certains pays (Madagascar), et, à terme, nombre de sites aquacoles potentiels représentera certainement un avantage pour l'Afrique, face aux grandes concentrations et aux risques, en particulier pathologiques, qui en découlent en Amérique du Sud ou en Asie du Sud Est.

Toutes ces recommandations doivent être assumées et soutenues, non seulement par les pays africains, mais aussi par leurs partenaires du Nord, dont l'intérêt ultime reste un développement équilibré de l'Afrique, sous peine de supporter le coût exorbitant d'un "mal développement" de ce continent (immigration massive, augmentation des aides alimentaires et de diverses formes à fonds perdus). C'est à travers cette philosophie, à un stade de réflexion amont et globale que la CEA, quant à elle, entend exercer ses compétences.

**Encadré 1** : sources FAO

| | 1980 | 1989 |
|---|---|---|
| Exportations africaines (US$ constants) : | 122 000 millions | 81 500 millions |
| Exportations agricoles (US$ constants) : | 14 200 millions | 12 200 millions |
| Exportations halieutiques (US$ constants) : | 500 millions | 1 500 millions |

Solde commercial du secteur halieutique en 1989 : + 600 millions US$

**Encadré 2** : source INFOFISH INTERNATIONAL jan-fev/90 et sept-oct/90

Mise en place des grands marchés de consommation

En 1992, avec l'abolition des particularités réglementaires nationales grâce à la mise en place du **Marché Unique de la CEE**, les exportateurs de produits aquatiques auront un marché de **320 millions de consommateurs** à leur portée. La volonté de créer un **"Espace Economique Européen" (CEE + AELE Association Européenne de Libre Echange)** porterait le marché à **355 millions d'habitants**. Les changements politiques récents en Europe de l'Est avec l'ouverture vers l'économie de marché vont faciliter les échanges commerciaux avec 137 millions d'habitants. Si on ajoute **283 millions de soviétiques**, ce serait un marché de **770 millions de personnes dans une Europe entièrement unifiée. Ce marché est évalué à 21 millions de tonnes de produits aquatiques.**

**Encadré 3** :

Nous citons ici des exemples illustrants la substitution ou la compétition entre certains produits de la pêche et les produits d'élevage :

Le Saumon d'élevage a entraîné la disparition de certaines pêcheries des Iles Féroé et du Groënland spécialisées dans ce poisson. D'une manière générale, comme pour le Saumon, l'aquaculture des crevettes Pénéïdes risque de mettre en péril bien des pêcheries de pays en développement, notamment celles de petite envergure sur le plan des tonnages, même si leur rôle économique est primordial : première source de devises pour Madagascar, que représentent 6000 tonnes de crevettes face aux centaines de milliers de tonnes produites maintenant par l'aquaculture ?

Quel impact auront l'élevage du Coryphène mahimahi (Coryphanae hippurus) et des Thonidés sur les pêcheries tropicales lorsque leur technique d'élevage seront au point ?

**Encadré 4** :

En 1984, une société malgache, la S.M.E.F., lance une étude de marché pour la chair du Crabe des mangroves (Scylla serrata) en France. L'existence d'un créneau pour plusieurs milliers de tonnes de produits est ainsi mis en évidence (800 à 900 Tonnes). Lorsqu'en 1988 la société lance son produit sur le marché, celui-ci a été réduit à quelques centaines de tonnes (300 Tonnes). Pourquoi ? Parce qu'entre temps, les japonais se sont lancés dans l'exportation du surimi au goût de crabe produit à partir du lieu des îles Aléoutiennes (Alaska pollack).

**Encadré 5** : source INFOPECHE 07/03/92

CEE : les importations de produits de la mer doivent se conformer aux normes européennes

La CEE a approuvé deux Directives pour l'adoption par les pays membres. **La Directive fixant les règles sanitaires régissant les produits de la pêche et une autre s'appliquant aux mollusques bivalves vivants** veulent que les pays exportateurs s'assurent que **les normes sanitaires des produits de la pêche exportés vers la CEE soient "au moins équivalentes" à celles des produits en Europe**... Des exigences générales sont prévues pour les navires usines, la manutention et la transformation, l'inspection des produits, l'emballage, le marquage et l'entreposage, le stockage et le transport... Les pays exportateurs peuvent se concerter avec la CEE en vue de l'établissement des conditions spécifiques d'importation et des inspections sur place par la CEE. **Les Etats membres de la CEE devraient faire appliquer les Directives avant janvier 1993.**

**Encadré 6** : source INFOPECHE 22/01/92

Nations Unies : résolution pour mettre fin à la pêche aux filets dérivants.

Le deuxième comité (affaires économiques) de l'Assemblée des Nations Unies a adopté le 6 décembre 1991 une résolution interdisant la pêche aux grands filets dérivants en haute mer par consensus de tous les pays participants. La résolution comprend deux parties :

i) les captures par les grands filets dérivants seront réduites par moitié, d'ici juin 1992,

ii) d'ici fin décembre 1992, il y aura un moratoire global sur la pêche aux filets dérivants. Le 20 décembre, l'Assemblée générale de l'ONU a adopté à l'unanimité la résolution qui a été conjointement proposée par 31 pays, sans vote.

**Encadré 7 :** Source RESUME ANALYTIQUE DES QUESTIONS DONT A ETE SAISIE LA DIX-HUITIEME CONFERENCE DES MINISTRES AFRICAINS 20/04/92

Dans le domaine de l'environnement, la Conférence des Nations Unies sur l'environnement et le développement s'est tenue à Rio de Janeiro (Brésil) en juin 1993. La position africaine a été élaborée lors de la réunion ministérielle tenue au Caire du 11 au 16 juillet 1991 et de la réunion complémentaire tenue à Abidjan du 11 au 14 novembre 1991. Il existe une différence entre la Conférence de Stockholm (1972) et celle de Rio. En 1972, on pouvait constater une intention affirmée d'élaborer des solutions écologiques aux problèmes causés par le développement. Les "méchants" étaient clairement identifiés : industries polluantes, moteurs à essence inefficaces, agriculteurs et bûcherons à la négligence criminelle. Les "bons" seraient les organismes à vocation écologique qui, nantis de pouvoir juridiques appropriés, mettraient hors d'état de nuire les ennemis d'un environnement sain. Le problème était perçu sous l'angle des pays développés : la dégradation de l'environnement était un moyen de réduire les coûts de production et de fonctionnement. Vingt ans après, **les pays en développement perçoivent les problèmes d'environnement sous un angle beaucoup moins simple. La dégradation de l'environnement résulte en effet de la pauvreté et seul le développement durable peut apporter des solutions. En Afrique, la pollution industrielle représente un faible pourcentage de la dégradation de l'environnement : les principaux problèmes sont la désertification, le déboisement et la pollution des eaux dans les zones pauvres et surpeuplées. Les acteurs les mieux placés pour résoudre ces problèmes ne sont plus les organismes écologiques traditionnellement orientés vers la lutte contre la pollution, mais plutôt les organismes de développement eux-mêmes. Cette manière de voir est aujourd'hui largement partagée.**

**Encadré 8** : source SEAFOOD INTERNATIONAL 06/90

A la suite des pressions écologiques américaines **pour la protection des dauphins** qui sont capturés dans les sennes coulissantes avec les thons dans l'Océan Pacifique (dans cette zone les deux espèces occupent les mêmes niveaux trophiques), **des industriels de la conserverie de thonidés (Starkist) de la côte Ouest ont délocalisé leur industrie vers le Sud Est asiatique** où les captures de thons se font sans prise de dauphin. L'utilisation des lobbies américaines a permis de cautionner ce redéploiement **sous couvert de protection de l'environnement** "nous n'achèterons plus que des thons capturés sans dauphin". **La réalité : les coûts de main d'oeuvre nettement plus faibles pour l'industrie de la conserve en Asie du Sud Est, le chômage pour les ouvriers de la conserverie sur la côte Ouest américaine...**

**Encadré 9** : source INFOPECHE 22/02/92

Etats-Unis : interdiction d'importation de tout thon albacore

**Une cour fédérale a ordonné au gouvernement américain d'interdire toute importation de thon albacore des pays qui importent et ré-exportent vers les E-U**. Selon Reuter, le Département Américain des Douanes a imposé cette **ordonnance de la Cour de justice à 20 nations qui traitent le thon capturé à la senne coulissante, une technique préjudiciable aux dauphins**. Les vingt nations visées seraient la Grande Bretagne, le Canada, la Colombie, le Costa Rica, l'Equateur, la France, l'Indonésie, l'Italie, le Japon, la Corée du Sud, la Malaisie, les Iles Marshall, les Antilles Néerlandaises, le Panama, Singapour, l'Espagne, Taïwan, Thaïlande, Trinidad et Tobago et le Vénézuéla. Le Earth Island Institute de Californie responsable de cette injonction a rapporté que l'institut est convaincu que la Thaïlande se conforme aux normes "Dolphin safe" des autorités américaines et que la pénaliser elle et d'autres nations se déclarant "Dolphin safe" ne ferait que leur créer des difficultés.

**Encadré 10** : source INFOPECHE 22/05/92

Norvège : participation à des investissements en Russie

La province du Finmark dans l'extrême Nord de la Norvège a reçu du gouvernement norvégien 5 millions de couronnes en vue de sa participation à des investissements dans la province russe d'Arkangelsic, sur la mer blanche. **L'éclatement de l'Union Soviétique offre aux Norvégiens du Nord de grandes opportunités, notamment dans la mer de Barents.**

**Encadré 11** : source INFOPECHE 22/02/92

Ecosse/Afrique : les Klondykers veulent diversifier vers l'Afrique

Depuis que les grands congélateurs soviétiques et l'Allemagne de l'Est n'écoulent plus la production de maquereaux, ce produit n'est plus rentable pour les Klondykers écossais. Les armements tentent dorénavant de diversifier leurs contacts avec d'autres pays importateurs : l'Egypte, les pays du golfe de Guinée et les pays de l'Est. D'autre part, ils ont demandé que leur production soit prise en charge par le Gouvernement britannique et incluse dans les aides alimentaires en direction de la Russie.

**Encadré 12** : source INFOPECHE 07/03/92

Ghana/Namibie : coopération en matière de pêche

Le Ghana et la Namibie ont signé le 5 février 1992 un **accord visant à la création d'une Commission permanente mixte de coopération. L'objectif est de promouvoir la coopération entre les deux pays dans les domaines de la pêche, de la formation, du commerce et des mines.**

**Encadré 13** : source INFOPECHE 07/05/92

Namibie/Norvège : développement de la coopération halieutique

Suite un **accord bilatéral** signé en septembre 1991 entre la Norvège et la Namibie, les deux pays développent leur coopération en matière de pêche. **La coopération en 1991-1992 porte, entre autres, sur une assistance pour la surveillance de la pêche, la recherche sur l'environnement et les ressources halieutiques, le développement institutionnel et l'assistance technique. Pour 1992-93, la coopération concerne l'achat de navires de patrouille, une formation de haut niveau pour la recherche marine et la création d'un centre de recherche**. Un don de 1,2 millions de rands est également prévu pour 1992-93.

**Encadré 14** : source INFOPECHE 07/04/92

Kenya : percée de la perche du Nil sur le marché français

**Des perspectives prometteuses pour la perche du Nil en France**. Il y a trois ans, ce poisson était pratiquement inconnu en France. Mais actuellement **les filets congelés de perche du Nil sont activement commercialisés en France et sont très appréciés par les consommateurs**. Le Kenya fournit 90 % des importations françaises et l'Ouganda les 10 % restants. La demande émane principalement des collectivités mais aussi des magasins spécialisés dans la vente des produits surgelés. **Malgré les exigences strictes et les normes élevées du marché, la perche du Nil se taille graduellement mais sûrement un créneau sur les marchés européens. Cependant, pour assurer une expansion de sa part de marché, les campagnes promotionnelles ciblant les consommateurs, acheteurs institutionnels et restaurateurs doivent être entreprises, l'hygiène assurée au maximum dans les ateliers de filetage, la congélation et le stockage effectués selon les normes les plus élevées**.

**Encadré 15** : source INFOPECHE 22/03/92

Guinée : du poisson par avion de Conakry à Paris.

Depuis la fin de 1989, à raison de deux ou trois opérations par semaine, Soguipêche, la filiale de **la société française Jégo-Quéré, met du poisson de pirogue, en général 8 tonnes en caissettes avec de la glace sur le vol régulier de Conakry à Paris**. Là, les colis sont pris en charge par le transporteur Tradimar et expédiés à Lorient, où Europêche, autre filiale de Jégo-Quéré, les met à la disposition des acheteurs. **Sont ainsi proposés dorade, barracuda, carpe rouge, sole et thiof**. Les Dorades intéressent beaucoup les mareyeurs, cette espèce s'étant raréfiée en Europe. En 1991, le poisson de Conakry a représenté 162 tonnes à la criée de Kéroman, pour une valeur de 5,5 millions de francs. **Le développement du pôle guinéen devrait permettre de réaliser des expéditions de 20 à 23 tonnes par voyage**.

**Encadré 16** : source INFOPECHE 07/06/92

Sénégal : exonération douanière pour produits de la pêche

**L'exonération du timbre douanier** est désormais exclusivement réservée aux produits importés par les opérateurs économiques du secteur de la pêche, et utilisés comme intrants dans la production effectivement exportée, rapporte les "Marchés tropicaux". D'après le Conseil National du Patronat du Sénégal (CNP), **cette mesure s'insère dans le cadre du plan de relance de la pêche, secteur essentiellement tourné vers l'exportation**.

TABLEAU 1.
CHIFFRES CLES DU SECTEUR HALIEUTIQUE AFRICAIN (SOURCE FAO 1988-1989).

## I PRODUCTION

**Production halieutique (tonnes)** : 7 800 000

. Eaux continentales : 1 300 000
. Eaux marines production africaine : 3 200 000
. Eaux marines production étrangère : 3 300 000

**Production aquacole (tonnes)** : 110 000
**2/3 produites par l'Egypte**

**Principaux pays producteurs** : 70 % de la production totale

. Afrique du Sud
. Maroc
. Ghana
. Tanzanie
. Nigéria
. Sénégal
. Egypte
. Ouganda
. Zaïre

**Nombre de navires** : 7 600
**Nombre de pirogues** : 355 000

## II EMPLOI

**Nombre de pêcheurs** : 2 millions
**Nombre d'emplois induits** : 8 millions

**Total** : 10 millions

10 millions qui représentent 9 % de la population active totale du secteur agricole.

## III COMMERCE EXTERIEUR

Exportations (millions US $) : 1 500
Importations (millions US $) : 900

Solde (millions US $) : + 600

**Principaux pays exportateurs :** 83 % des exportations en valeur

| | |
|---|---|
| . Maroc | . Côte d'ivoire |
| . Sénégal | . Afrique du Sud |
| . Mauritanie | . Tunisie |

**Principaux pays importateurs :** 77 % des importations en valeur

| | |
|---|---|
| . Egypte | . Zaïre |
| . Côte d'Ivoire | . Afrique du Sud |
| . Nigéria | . Cameroun |
| . Angola | . Algérie |

## IV CONSOMMATION

**Offre moyenne en poisson :** 7,9 kg/hab/an en 1989

Pour maintenir ce niveau d'offre les approvisionnements (production + importations) devront croître de 50 000 tonnes par ans.

**FIGURE 1.**
**PRODUCTION DE PRODUITS AQUATIQUES EN AFRIQUE**

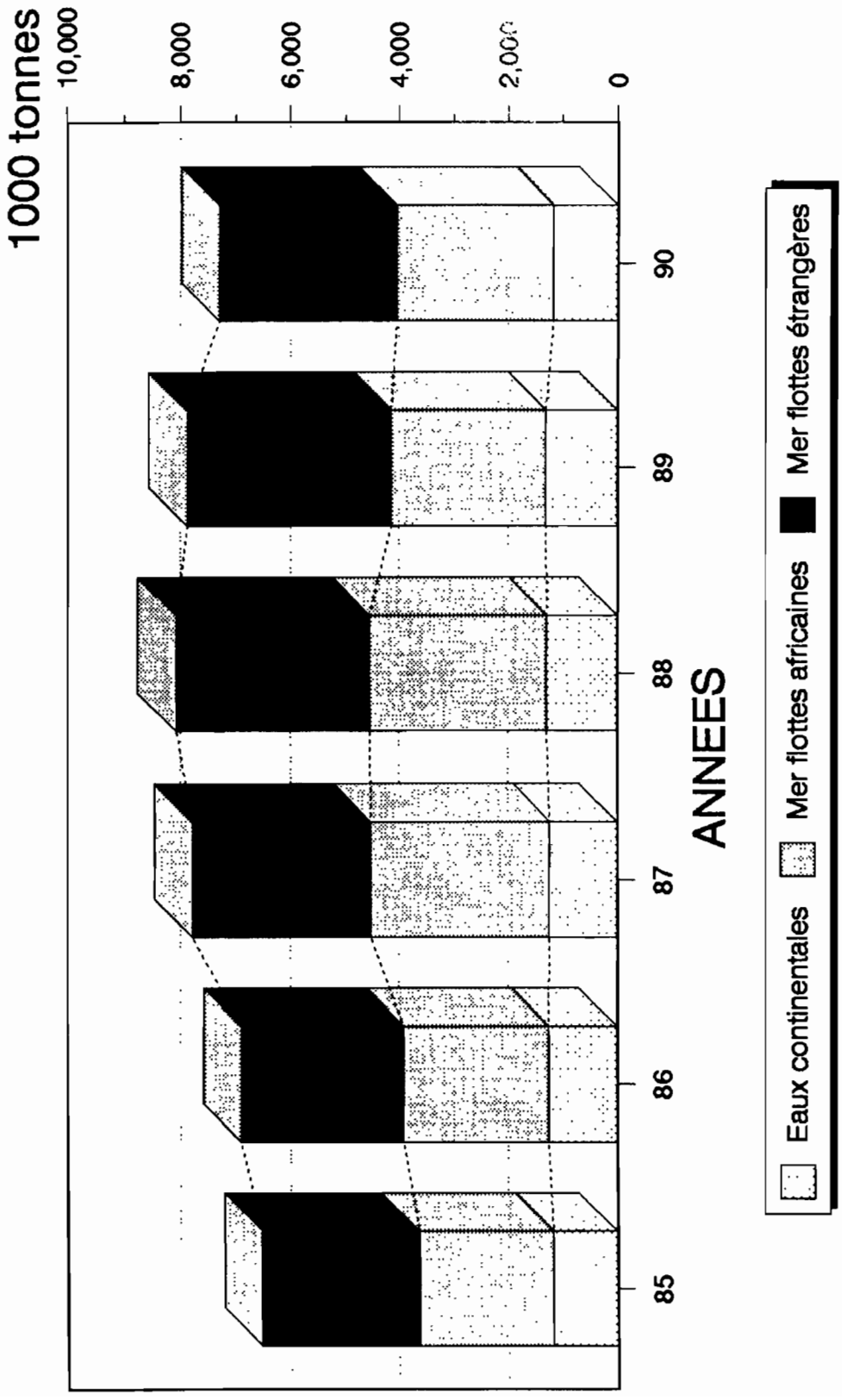


FIGURE 2.
IMPORTS-EXPORTS DE PRODUITS AQUATIQUES EN AFRIQUE 1979-89 (FAO, 1991)

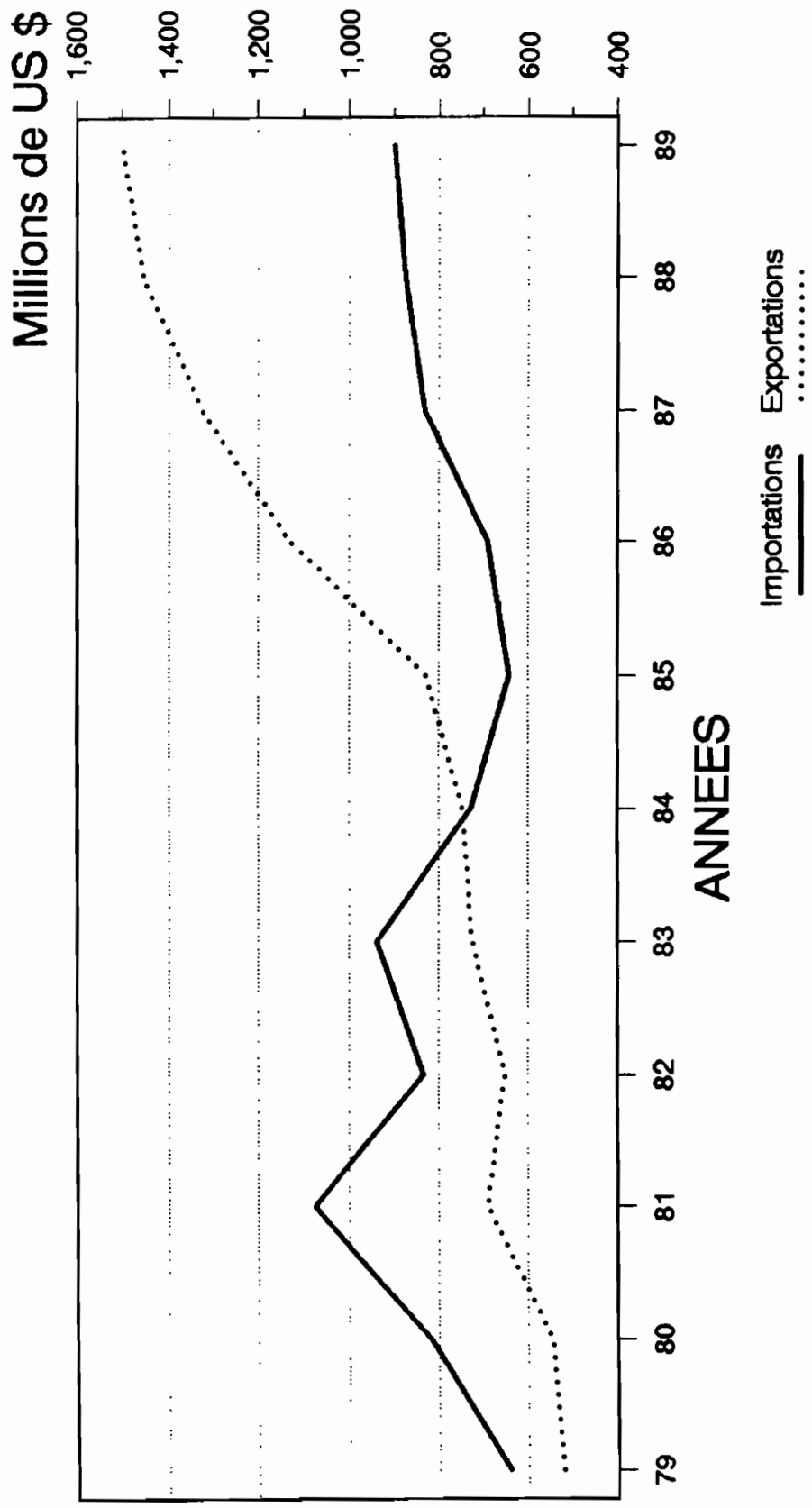
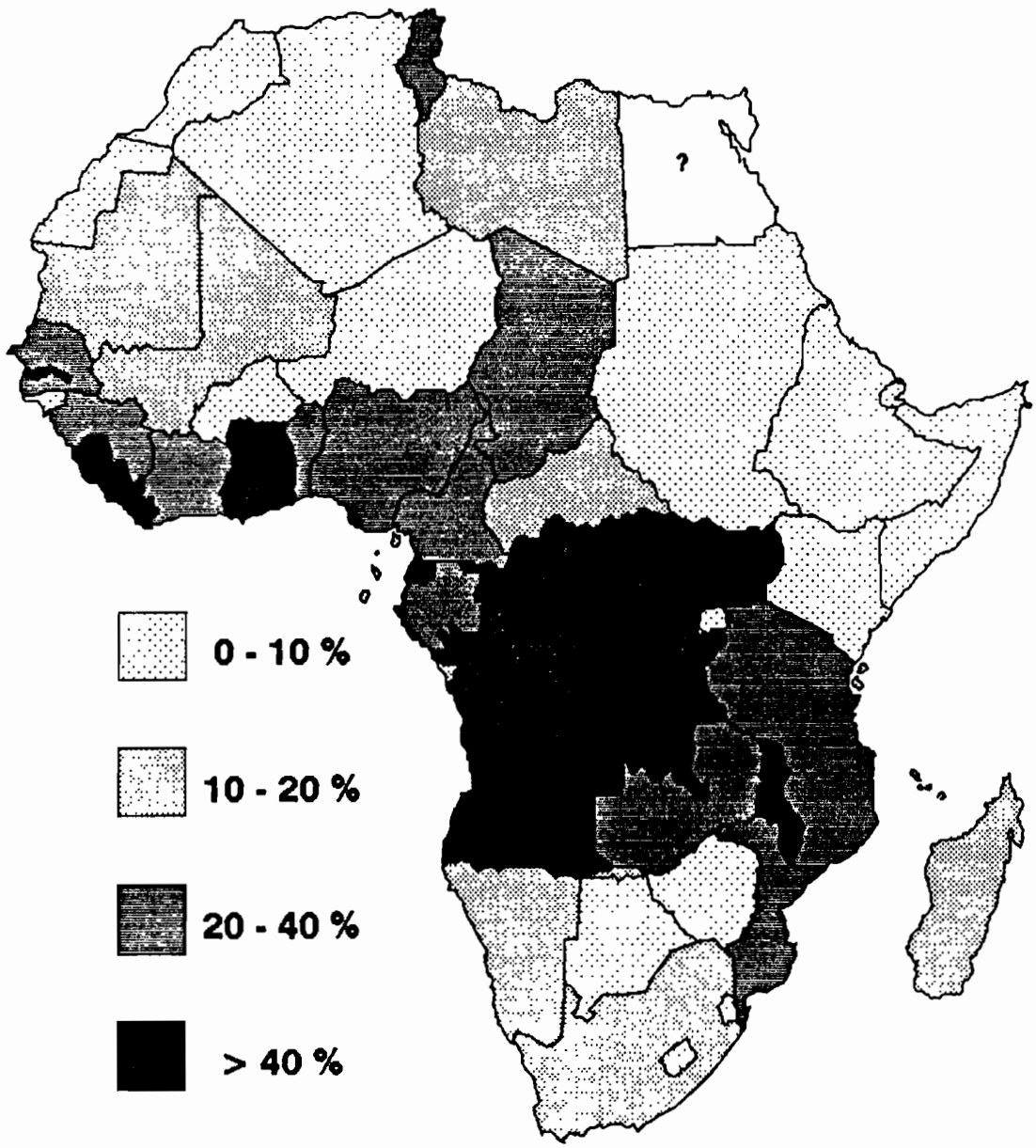
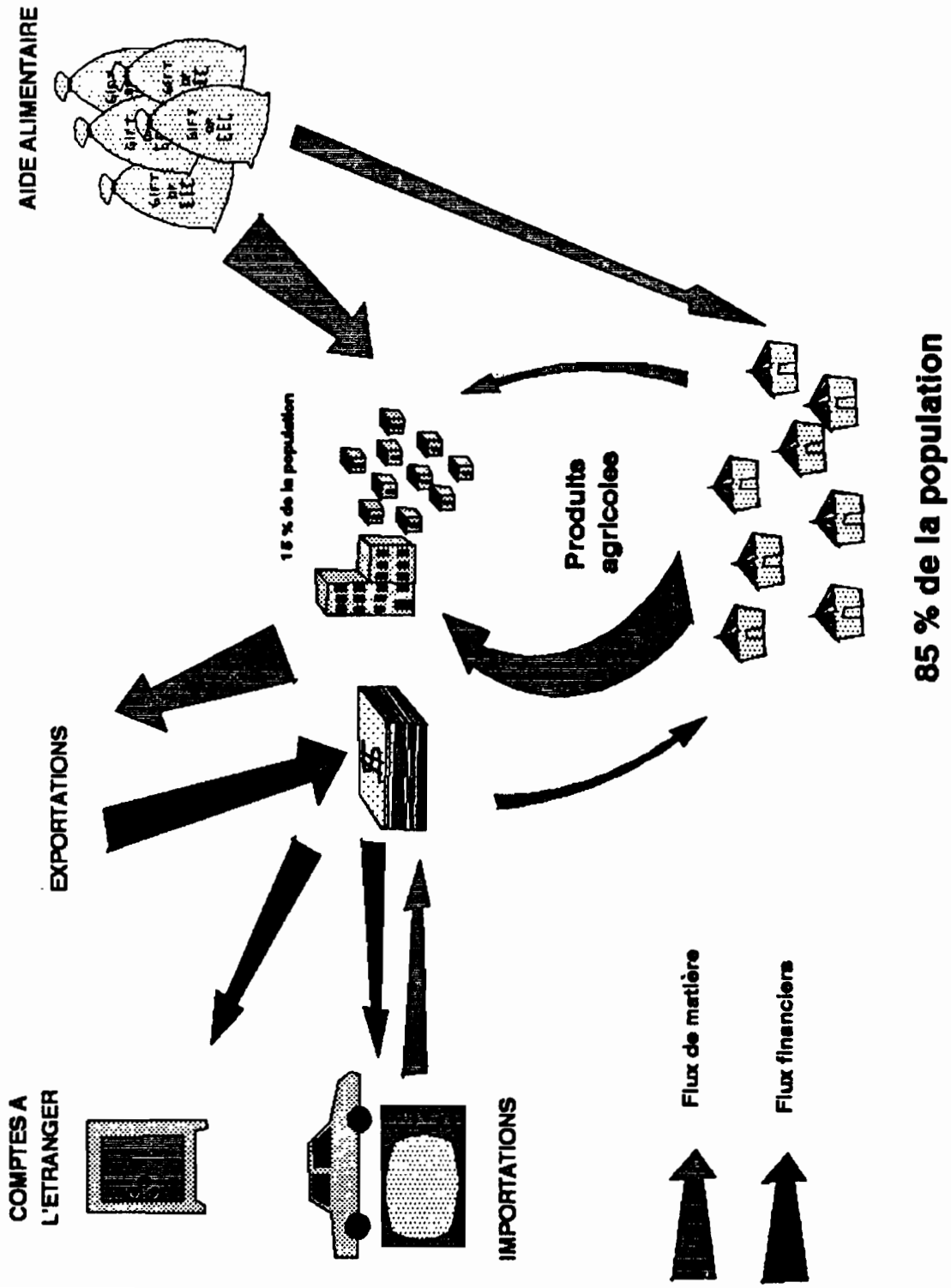


FIGURE 3.
PART DU POISSON DANS LA RATION DE PROTEINES ANIMALES (1988)




*Approvisionnement moyen en poisson : 7.8 kg/hab/an*

FIGURE 4.
DEUX MONDES EN AFFRONTEMENT EN AFRIQUE : MONDE URBAIN ET MONDE RURAL



# Problématiques du Développement des Pêches

**Jacques Weber**

IFREMER/DRV, Technopolis 40, 155 rue J.J. Rousseau, 92238 Issy Les Moulineaux, FRANCE

RÉSUMÉ

*Depuis trente deux ans, le "développement", dans les pêches comme en agriculture, est fondé sur des "projets" dont le taux de réussite est très faible en dépit de la qualité de leur conception et des experts qui en ont eu la charge. Pendant la même période et dans les mêmes secteurs, de multiples réussites techniques, économiques et sociales sont observables, qui ont en commun, sauf exception, de n'avoir aucun lien avec les projets de développement. Et si la longue litanie des échecs trouvait son origine dans la notion même de "projet de développement" ? L'opinion personnelle avancée ici est que la solution ne réside pas dans l'amélioration des projets, mais peut-être bien dans leur suppression, comme condition nécessaire du développement halieutique et agricole dans les PVD. La mise en oeuvre d'une innovation est un processus d'appropriation sociale, qui ne peut être initié de l'extérieur ; il est par contre possible de repérer des évolutions déjà entamées et de contribuer à leur accélération. Ceci ne nécessite ni structure de projet, ni bureaucratie, mais implique une révision profonde des doctrines des organisations internationales et bancaires.*

ABSTRACT

*For 32 years, "development" in fisheries or agriculture has been based upon "projects" the effectiveness of which has been very low, despite the quality of their conception and of the experts in charge of these projects. Meanwhile and at the same place, a lot of technical, economic and social successes can be observed, which have usually in common the fact of having no relationship at all with development projects. Why would not all these failures be rooted in the very notion of "development project" ? The personal opinion presented here is that the solution is not in improving the projects but perhaps in their suppression, a necessary condition for development of fisheries and agriculture in developing countries. The implementation of an innovation is a process of social appropriation which can not be initiated from outside ; on the contrary, it is possible to point out starting evolutions and to contribute to their speeding up. That requires neither project structure, nor bureaucracy but implies a deep revision in the way of thinking among international and financial organizations.*

## 1. INTRODUCTION

Il existe pas une mais des pêches artisanales, des problématiques, des développements. L'approche la plus répandue consiste à décrire des situations en recherchant ce qu'elles ont en *commun* , leur plus petit commun dénominateur, puis à baser une analyse générale sur ce denominateur commun. Il est proposé de chercher explicitement ce que les situations ont de *différent,* et ce que ces différences nous disent à la fois sur les pêches artisanales et sur le développement. Il ne s'agit pas d'une invitation à sombrer dans le relativisme et l'idée que tout étant spécifique, il n'y aurait aucune perspective générale à dégager !

Lorsqu'on parle de "développement", ce sont les *projets* qui nous viennent en tête. Il convient donc de rappeler qu'on entend par *développement* "un processus cumulatif de croissance auto-entretenu", non un projet ou son absence. En assimilant plus ou moins consciemment le développement et les projets de développement, il est aisé de conclure à une répétition d'échecs. la difficulté de trouver des *success stories...* Pourtant, il existe bien des exemples de dynamiques de développement ayant nécessité ou entraîné des modifications profondes du système pêche, ceci sans la présence de projets de développement.

Il n'y a pas une mais *des* pêches artisanales et/ou industrielles, avec des développements forts différents d'un pays à un autre ; qu'il y a donc *des* problématiques de développement des pêches.

## 2. DES DÉVELOPPEMENTS RÉUSSIS

### *2.1. Le développement d'une pêcherie de céphalopodes au Sénégal*

A la fin des années soixante-dix, les industries japonaises diffusent du matériel de pêche adapté à la seiche parmi les pêcheurs artisans du Sénégal et organisent un circuit de collecte des débarquements de cette espèce. La technique se répand rapidement (turlutte, casiers) sur la Petite Côte du Sénégal, permettant l'avènement d'une pêcherie saisonnière spécialisée débarquant jusqu'à dix mille tonnes de céphalopodes par an, dans les années quatre-vingt.

Aucun "projet de développement" ne se trouve derrière ce développement mais une industrie qui génère ses approvisionnements en fournissant matériels de pêche et prix rémunérateurs ; une recherche qui *accompagne* ce développement par la localisation et le suivi des ressources comme par l'amélioration des techniques de pêche (Bakayoko, 1989). Pour finir, si les bateaux industriels permettent dans un premier temps la localisation des lieux de pêche par les artisans, c'est l'inverse qui est observable après quelques années, lorsque les pêcheurs piroguiers ont appris à connaître leur espèce-cible.

### *2.2. L'association crevettiers-piroguiers*

Chacun sait que la pêche crevettière rejette une part très importante de ses captures, y compris les espèces nobles. Au Sénégal, au début des années quatre-vingt, des pêchers piroguiers associés avec les crevettiers, récupéraient une partie de ces rejets pour les commercialiser dans les points de débarquement de la pêche artisanale. Cette association s'observait également avec certains chalutiers.

L'intérêt de ce genre d'association est multiple : outre qu'elle transforme les habituels conflits entre industriels et artisans en copération, elle valorise les rejets et allège d'autant l'effort de pêche des piroguiers tout en assurant un revenu avec faible coût de production.

Ce genre d'association n'est, à ma connaissance, suivi ni par la recherche, ni par les administrations, au-delà d'éventuelles déclarations. Or si ces associations sont "bonnes" dans leur principe, elles peuvent donner lieu à toutes sortes d'effets pervers, en l'absence de contrôle.

Enfin, il n'y a pas de "projet de développement " derrière ces associations.

On retrouve ce type d'asociation entre piroguiers et navires hauturiers, qui emmènent pirogues et pêcheurs sur des hauts fonds qui leur seraient inaccessibles, et achètent leurs captures.

*2.3. La diffusion des sennes tournantes au Sénégal*

En 1967, la recherche contribue, avec l'assistance de technologistes FAO, à la diffusion du Filet Maillant Encerclant (FME) sur la Petite Côte du Sénégal. Cet engin se diffuse sans gros changement dans l'outil de production, la pirogue de 14 mètres, et contribue à un accroissement de l'équipage : 7 marins contre 3 à 5 antérieurement.

Devant le succès de cet engin, il est envisagé de tenter la diffusion des Sennes tournantes et Coulissantes. Sur proposition de la recherche, la FAO met un technologiste *à la disposition* des pêcheurs, munis de nappes de filets et accessoires. C'est un dialogue quotidien entre ce technicien et les pêcheurs qui aboutit au modèle actuel de senne, de 300 m. de longueur et 30 mètres de chûte. Nous sommes en 1972-73 ; en 1980, 200 unités de senne tournante sont recensées ; elles seront 250 en 1983 et 391 en 1987 (SOCECO-PECHART, 1983 et 1988). Le succès de cet engin est total.

Une innovation *technique* est en fait un *processus social complexe.* Il ne s'agit pas que l'innovation soit *acceptée* ou *adaptée* , mais bel et bien qu'elle soit *appropriée par* les pêcheurs, qu'elle devienne leur propriété. Et cela implique une modification en profondeur de tout le système pêche concerné.

*Au niveau de la production* : l'outil passe de une pirogue à deux. L'une, de 14 mètres, porte la senne et opère la poursuite et l'encerclement du banc ; la seconde, de 18 à 25 mètres et d'une capacité pouvant aler jusqu'à 25 tonnes, transportera la capture. Dans un premier temps, cette grande pirogue provient du transport de coquillages et d'arachides sur le Saloum et la Gambie ; progressivement, elle sera construite spécifiquement pour la senne tournante. L'unité de pêche comprend en outre trois moteurs, deux de 25 ch., un de 40 ch. pour l'encerclement du banc. Entre le FME et la Senne Tournante, l'investissement initial est passé de 1,5 Millions CFA à 5 Millions CFA (données de 1983).

*Au niveau de l'emploi* : on passe de 7 à 14-16 marins embarqués. Ce qui suppose un effectif total de l'ordre de 24 à 25 personnes, pour tenir compte des repos, maladies et absences. Des paysans viennent s'embaucher sur ces unités de pêche qui, hormis le patron et son adjoint, ne nécessitent pas de connaissances particulières.

*L'innovation de la senne tournante conduit en fait à une unité de production entièrement nouvelle, tant par sa dimension que par sa structure en capital et en emploi.*

*La commercialisation.* Le mareyage ne pouvait pas absorber facilement un afflux important de poisson débarqué par les sennnes tournantes (80.000 tonnes par an environ). Si la commercialisation en frais avait été le seul débouché, les cours se seraient effondrés, des quantités importantes auraient été rejetées à la mer et, très vraissemblablement, les pêcheurs se seraient repliés sur les anciennes techniques de pêche. Certaines entreprises de mareyage se sont construites sur le développement de la senne tournante, puis ont acquis des unités de pêche : certains mareyeurs possèdent jusqu'à 12 unités de pêche, soit un personnel de l'ordre de 300 personnes...

*La transformation artisanale.* Au fur et à mesure du développement des sennes tournantes, les femmes ont développé à grande échelle le braisage des poissons pélagiques. La technique est ancienne, mais portait avant cela sur des quantités peu importantes de matière première. Ce développement sans précédent de la transformation artisanale aura des conséquences multiples :

- les femmes se posent en concurrentes des mareyeurs et assurent un prix plancher au débarquement
- par la transformation qui permet une conservation du produit, elles permettent une relative régularisation du marché
- l'importance des débarquements permet à des femmes de l'intérieur du pays de venir s'adonner à cette activité en morte-saison agricole

*Au total, c'est un nouveau système pêche qui se met en place, pour donner plein effet à une innovation technique particulière.*

Il convient de remarquer que dans ce processus endogène de développement n'intervient aucun projet de développement spécifique. Mais que l'innovation bénéficie d'une conjonction de facteurs favorables qui *l'accompagnent* :

- la motorisation des pirogues était indispensable : le projet motorisation des pirogues y avait pourvu
- la recherche a accompagné le processus en permanence et dès le début
- la possibilité d'acheter moteurs et filets à crédit à été déterminante.

Ainsi, il existe bien des *"success stories"* . Elles ont en commun d'être le fait des pêcheurs eux-mêmes, qui s'approprient une innovation et, à partir de là, modifient s'il le faut l'ensemble du système-pêche. C'est, me semble-t-il, la grande leçon qu'il nous faut retenir : aussi longtemps que les pêcheurs ne s'approprient pas une innovation, à partir de critères qui sont essentiellement sociaux, cette innovation ne peut être imposée de l'extérieur du système. Par contre, une innovation n'est pas acceptée en raison de sa simplicité ou de sa complexité, mais bien de son appropriabilité, laquelle n'est pas affaire de complexité technique, mais de compatibilité sociale. Le caractère social de l'innovation conduit à prendre conscience également que l'innovation ne peut pas être le fait d'un individu isolé.

## 3. QUELQUES PROJETS DE DEVELOPPEMENT

### *3.1. Les coopératives*

Un peu partout en Afrique, les projets de développement ont cherché à susciter la création de coopératives sur lesquelles ils pourraient s'appuyer. La première fonction de ces coopératives étant de fournir une caution solidaire pour la seconde fonction qui est l'accès au crédit et la troisième fonction qui consiste en la distribution de matériels de pêche. A ces trois fonctions vient souvent s'ajouter une quatrième, la commercialisation.

Ainsi les coopératives devraient être à la fois organisme relais pour les prêts ; organisme de cautionnement bancaire ; commerçant de matériels ; commerçant de produits de la mer. C'est beaucoup pour une structure unique ! Aussi, dès qu'une des fonctions est mal assumée, les autres tendent à servir d'instrument de contrainte : un remboursement en retard (fonction 2) entraîne la saisie du moteur (fonction 3) ou des retenues sur la vente du produit (fonction 4), ou le retrait de la caution (fonction 1). Imagine-t-on que mon garagiste refuse de réparer ma voiture sous prétexte que je dois de l'argent à la banque ou que mon banquier puisse directement saisir cette voiture sans passer par la justice ?

Fatalement, le mélange de fonctions contradictoires au sein de coopératives conduit à leur échec, par désaffection assez rapide de la part des coopérateurs. Pourtant, il existe des coopératives qui marchent : elles ont une seule fonction et bien une seule. Ainsi, dans la pêche artisanale française, en Bretagne : il existe des coopératives d'avitaillement, d'autres de transformation des produits, d'autres de commercialisation (les Organisations de Producteurs), et la banque est elle-même coopérative (le Crédit Maritime Mutuel). Chacune des ces organisations coopératives a une fonction bien définie et exclusive.

On remarquera que la plupart des coopératives en Afrique, sinon toutes, sont des créations de l'extérieur du milieu. Souvent, leur création fut posée comme condition d'accès au crédit...

L'échec des coopératives n'a donc rien de bien mystérieux ni d'inéluctable ; il n'est pas imputable, comme on le lit trop souvent, à "l'individualisme" des pêcheurs.

### *3.2. Le remplacement des pirogues.*

Dès avant les indépendances, les projets de remplacement des pirogues par d'autres embarcations n'ont jamais cessé de se succéder les unes les autres, aussi bien en Mauritanie qu'au Sénégal ou en Côte d'Ivoire et au Bénin. Avec l' insuccès que l'on sait. Les arguments avancés en faveur d'un remplacement des pirogues vont du simplisme à des faits précis mais qui relèvent d'interprétations très différentes entre l'expert et les pêcheurs. Nous l'illustrerons dans le cas du Sénégal

- argument 1 : la pirogue est "traditionnelle", il faut la remplacer par une embarcation "moderne". Ce genre d'argument a, hélas, encore cours... En fait, la pirogue "traditionnelle" n'a cessé d'évoluer depuis le début du siècle comme l'a montré

J.P. Chauveau (1986). Pour finir, les pirogues de remplacement n'ont le plus souvent de "moderne" que le matériau, puisqu'elles reprennent des moulages de pirogues existantes. Entre "traditionnel" et "moderne", c'est en fait la rentabilité et la tenue en mer qui font la différence, jusqu'ici en faveur du "traditionnel".

- argument 2 : l'instabilité des pirogues. Cet argument est fondé, mais reçoit des pêcheurs une justification précise. L'instabilité, délibérément préservée, et compensée par du lest lorsque la pirogue est à vide, permet de faire l'économie de moyens de levage pour les grandes pirogues : il suffit que l'équipage se porte du même côté pour que le plat-bord vienne au niveau de l'eau, facilitant ainsi le chargement de la capture.

- argument 3 : les pirogues ont une faible rigidité. Argument fondé, mais là encore invoqué par les pêcheurs en leur faveur : la souplesse de la pirogue la rendrait plus confortable qu'une embarcation rigide sur une mer à clapot comme celle du Sénégal.

- argument 4 : les pirogues ont une faible étanchéité. Cet argument est admis par les pêcheurs, qui disent que l'amélioration de l'étanchéité doit être possible avec les pirogues actuelles.

- argument 5 : une supposée courte durée de vie. Les pirogues sont refaites à peu près tous les 7 ans et leurs éléments sont repris le plus souvent pour la construction d'une pirogue de taille inférieure à celle d'origine. Le madrier ou tronc de base est utilisé pendant plus de vingt ans. En termes de coût, le remplacement s'avère difficilement concurrentiel.

Les faits sont là, les remplacements n'ont pas eu de succès, et la pirogue continue son évolution endogène, en s'adaptant à la motorisation, puis à de nouveaux engins, à la conservation à bord...

### *3.3. Le projet CAPAS (Centre d'Assistance à la Pêche Artisanale Sénégalaise)*

Dans ce projet, il s'agissait initialement d'aider les coopératives *de pêcheurs* à s'assurer la maîtrise *de la commercialisation* de leur production, au motif qu'ils auraient subi une exploitation par les mareyeurs. Le projet visait donc sinon l'élimination, du moins une diminution du rôle des mareyeurs.

Les mareyeurs sont des commerçants et comme tels doivent avoir une activité rentable. Ce ne sont pas des philanthropes. Mais cela implique, dans le contexte sénégalais, qu'ils entretiennent avec les pêcheurs des relations non exclusivement marchandes, comme l'ont montré C. Chaboud et M.Kebe (1983). Les pêcheurs font l'avance du poisson ; en revanche, le mareyeur "fait les courses" du pêcheur en ville, lui fournit des avances de campagne, ou pour des fêtes familiales ou religieuses etc. Le rapport marchand est inséré dans des relations interpersonnelles complexes.

Le projet CAPAS reposait sur "l'encadrement" des coopératives et la formation des coopérateurs à la gestion des centres de mareyages comprenant véhicules, chambres froides et machines à glace. Le CAPAS n'a jamais commercialisé plus de 5 % des débarquements des lieux où étaient implantés les centres de mareyage. Au bout de six années, le projet a "baissé les bras" et les mareyeurs ont en partie pris le contrôle des centres de mareyage...

Il ne s'agit pas ici de faire l'analyse fine du projet CAPAS, ni de le considérer comme un échec total : il a eu des effets positifs directement et indirectement. Il s'agit par contre d'en examiner la genèse institutionnelle. A l'origine du projet se trouve une demande du gouvernement sénégalais au Canada. Puis des missions d'experts qui aboutissent à un projet lourd, techniquement et bureaucratiquement : importante infrastructure et importante administration. Le projet doit être expliqué aux pêcheurs auxquels il faut faire *"prendre conscience"* du besoin qu'ils sont censés avoir de ce projet. Il faut ensuite *encadrer* les coopératives. Enfin, la recherche n'est aucunement partie prenante à la genèse de ce projet.

Que ce projet soit canadien ne doit pas prêter à confusion : tous les pays et toutes les agences de développement ont connu des échecs répétés de leurs projets de développement.

### *3.4. Les projets "intermédiaires"*

Jusqu'à la Conférence Mondiale des Pêches à Rome, en 1984, la tendance la plus répandue en matière de développement des pêches considérait que l'évolution logique devait conduire les pêches piroguières de l'Afrique vers des formes

modernisées, voire industrielles. Dans le domaine des pêches comme dans d'autres, il s'agissait donc de mettre en place des "formes intermédiaires" de production (ou encore des "formes de transition") : il est attendu de ces formes de production qu'elles permettent l'apprentissage de l'industrie par les pêcheurs dits "traditionnels".

Au Sénégal, cette tendance a revêtu la forme des "cordiers", unités de douze mètres disposant d'une cale à glace et pouvant effectuer des marées d'une semaine. M.Kebe (1982) a publié une évaluation de la pêche cordière sénégalaise en plein déclin, et montré que :

- ces unités, qui nécessitent des structures portuaires, étaient utilisées et gérées comme des pirogues, avec entre autres, des arrêts durables du navire à l'occasion d'événements familiaux ou sociaux ;

- ces unités se retrouvaient en concurrence avec les pirogues sur les mêmes marchés, en situation défavorable.

Cette idée que l'évolution des formes de production soit liée à une question de difficulté technique est centrale dans ce que j'appellerai le "prêt à penser" du développement.

## 4. LE PARADIGME DES PROJETS DE DEVELOPPEMENT

### *4.1. L'économiste et le développeur*

En tant qu'économistes, nous avons développé des méthodes d'évaluation des projets qui, en principe valent pour tous les types de projets, une fois connus leurs objectifs et les moyens mis en oeuvre pour les atteindre. On peut avancer que les méthodes d'évaluation des projets sont "neutres" par rapport au type de projet analysé. Elles permettent de juger la cohérence interne et la faisabilité théorique du projet, mais ne disent rien sur sa pertinence (Squire et Van der Tak, 1975 ; Price Gittinger, 1985). Cette neutralité est à l'honneur de notre discipline ; mais à l'issue de plus de trois décennies d'échecs des projets, aussi bien évalués soient-ils (Banque Mondiale, 1986), nous sommes légitimement fondés à nous demander "si le roi est nu".

Tous les projets ont en commun :

- d'être issus d'un regard extérieur projeté sur une réalité sociale

- d'être initiés hors discussions préalable ni association avec les pêcheurs

- de pratiquer l'amalgame et le mélange des genres en préjugeant des objectifs qu'une communauté de producteurs assigne à son activité.

- d'être conçus sur un principe *d'encadrement* des populations visées.

Tout projet de développement initié de l'extérieur sur des objectifs et critères étrangers au groupe concerné se présente comme un ensemble d'a priori

- sur les intérêts individuels et collectifs

- sur les structures sociales ("réduire les inégalités")

- sur les comportements individuels et collectifs face au marché, au profit, au crédit.

### *4.2. Projet de développement ou projet d'accompagnement ?*

Tout projet de développement est basé sur une vision particulière de la réalité sociale dans laquelle il doit être implanté, que cette vision soit explicite ou, le plus souvent, implicite [1].

1. Il serait possible de classer les projets selon les théories de la croissance auxquels ils renvoient : théorie de la croissance harmonisée, "industries industrialisantes", "take off", import-substitution etc., mais ceci sort du cadre de cet exposé (cf. Weber 1978).

Les exemples présentés dans cet exposé amènent à considérer que les échecs répétés des projets de développement proviennent essentiellement de la notion même de *projet de développement.* Etranger à la société concernée, il conduit à *encadrer* les producteurs et, pour reprendre les termes en usage, à *les "conscientiser" :* il est fréquemment avancé qu'il faudrait *"changer les mentalités"* etc. Bref, faute d'avoir un projet appropriable par les producteurs, ce sera le projet qui tendra à s'approprier les producteurs...

Les *"success stories"* évoquées précédemment montrent que l'action des chercheurs, des administrations, des bailleurs de fonds, est *très* efficace lorsqu'elle *accompagne* des dynamiques *endogènes* de développement, leur donnant ainsi plein effet. Il est remarquable que cet accompagnement a lieu le plus souvent sans que l'administration ou les bailleurs de fonds n'en prennent réellement conscience. Il convient donc de les "conscientiser", et d'espérer que la notion de projet d'accompagnement se substitue un jour à celle de projet de développement.

Il ne s'agit pas d'un jeu de mots, mais bien d'une approche radicalement différente des problèmes de développement.

## REFERENCES

**Bakayoko M. et M. Kebe** (1991). Problématique des relations entre la pêche artisanale et la pêche industrielle : le cas des ressources démersales. *In "La recherche face à la pêche artisanale"*, Durand, Lemoalle et Weber (Eds), Paris, ORSTOM : 933-942.

**Banque Mondiale** (1986). *Compte-rendu de la conférence des Bailleurs de Fonds dans le domaine du développement des pêches et de l'Aquaculture*, Paris, Octobre 1986.

**Chaboud C.** (1983). *Le mareyage au Sénégal.* Doc. Sci. et Tech. n° 87, Dakar, ISRA-CRODT, 112 p.

**Deme M.** (1991). Les effets du soutien financier de l'Etat à la pêche artisanale. *in "La recherche face à la pêche artisanale".* Durand, Lemoalle et Weber (eds), Paris, ORSTOM : 845-850.

**Chaboud C. et E. Charles-Dominique** (1991). Synthèse Afrique de l'Ouest sur l'évolution des recherches sur la pêche artisanale. *in "La recherche face à la pêche artisanale,* Durand, Lemoalle et Weber (eds), Paris, ORSTOM : 99-142.

**Durand J.R., J. Lemoalle et J.Weber** (eds) (1991). *La recherche face à la pêche artisanale.* Actes du Symposium International ORSTOM-IFREMER, Montpellier, 3-7 Juillet 1989 ; Paris, ORSTOM, 2 vol., 1070 p.

**Price Gittinger J.** (1985). *"Analyse économique des projets agricoles"* . Paris, Economica.

**Soceco-Pechart.** *Recensements semestriels de la pêche artisanale sénégalaise.* Dakar, ISRA-CRODT.

**Squire L. et H.G. Van Der Tak** (1975). *" Economic Analysis of Projects"* . Baltimore, Univ. of John Hopkins Press.

**Weber J.** (1978). "Le développement : concept, doctrine ou idéologie ?" Séminaire ORSTOM Sciences Sociales, Paris, ORSTOM, Travaux et Documents.

# La Pêcherie de Crabe des Neiges au Canada en tant que Système : Variables, Interactions et Incertitudes

**Jean-Claude Brêthes[a] et Réjean Dufour[b]**

[a]Département d'océanographie, Université du Québec à Rimouski, 300, Allée des Ursulines, Rimouski (Québec), G5L 3A1 Canada

[b]Ministère des pêches et des océans du Canada, Institut Maurice-Lamontagne, 850, Route de la Mer, C.P. 1000, Mont-Joli (Québec), G5H324 Canada

ABSTRACT

*The Canadian Atlantic Snow Crab Fishery as a system : variables, interactions and uncertainty.*

*The Canadian snow crab fishery began in 1966. Its evolution is the result of the conjunction of several factors. The systemic approach is used in this paper to analyze this fishery. The present work defines the major variables, the centres of decision and interactions. The four identified factors (resource, politics, economics and sociological factors) have different levels of importance in the evolution of any fishery but are particularily stressed out in this particular case. The social factor was at the origin of the fishery. The resource was not known precisely, but neither was it a constraint nor a factor of uncertainty, due to the accumulated virgin biomass. The explosive development (5000 mt captured in 1968, 48000 mt in 1982), was encouraged by a favourable economic situation (0.6 $ CAD/kg in 1980, 3.4 $ CAD/kg in 1988) and the political decision to give more licences to solve local social problems. In a following phase (1982-1988), the major source of uncertainty became the resource. Catches were decreasing almost everywhere with an unpredictable behaviour. Sociological problems appeared locally, especially in the processing sector, while the market stayed strong enough to maintain a reasonable income for the fishermen. In the later phase, both resource and economic factors became the main sources of uncertainty and risk (decreasing price and high variability in catch for certain areas). The market is essentially oriented towards USA and Japan and appear to be very sensitive to fluctuations in supply within these countries. The risks are presently supported by fishermen and the processing sector, acting in close interaction. Political factors played a dual role during those phases. Consider the development phase : on one hand it was spreading the risks and reducing uncertainty, through grants and support, but on the other hand it was increasing uncertainty through constant modification of the fishing regulations. Presently, political factor is a major factor of risk to the*

*fishermen, because the declared politics are to reduce the number of fishermen and processing plants. The sociological and economical factors may take on a greater importance in the near future because of this fact and because of the low possibilities of alternative employment for fishermen and plant workers.*

## 1. INTRODUCTION

Classiquement, on décrit le développement d'une pêcherie en trois périodes : (a) en développement ; (b) développée ; (c) en décroissance (souvent) ; (d) en effondrement, parfois (Garcia, 1984). Bakun *et al.* (1982) ont proposé une description de l'évolution d'une pêcherie et en parallèle la progression des connaissances scientifiques requises pour le suivi de cette pêcherie. Au début de l'exploitation (phase 1), la connaissance de l'extension et du potentiel de la ressource est nécessaire ; lors de l'expansion (phase 2), on cherche à définir les caractéristiques biologiques et écologiques de la population ; dans une phase de pleine exploitation (phases 3 et 4), on s'intéresse aux facteurs de croissance et de mortalité, à la prédiction des captures et aux estimations précoces de la force des classes d'âge. Un tel schéma ne tient compte, toutefois, que des connaissances strictement biologiques de la pêcherie. On sait que la ressource n'est pas seule en cause. Pour qu'une exploitation débute, une série de facteurs préalables doivent exister, parmi lesquels les conditions économiques (prix, marché) jouent un rôle important (Garcia, 1984). Il faut aussi que les technologies de capture et de transformation existent et à un coût « acceptable ». Enfin, il faut que des pêcheurs soient prêts à assumer le risque du développement. La ressource est ainsi une « variable » parmi les autres à l'intérieur du système (Brêthes et Fontana, 1992). Pour leur part, Chaboud et Fontana (1992) considèrent que la ressource fait partie d'un déterminant plus vaste du système (« le potentiel de production »), puisque si elle est « une condition nécessaire à l'activité de pêche, elle n'en est pas pour autant une condition suffisante ». Ressource et marché exercent des contraintes évidentes et représentent des incertitudes, à divers degrés, sur le développement et le maintien de la pêcherie. Le processus de gestion de l'exploitation, lui-même, devient une autre source d'incertitude (Hannesson, 1984), bien qu'il soit à la fois imposé à l'industrie et réclamé par elle (Anderson, 1984).

L'étude de la plupart des pêcheries mondiales a débuté alors que l'exploitation était déjà ancienne. La réglementation et les connaissances scientifiques se sont, dans la plupart des cas, mises en place bien après la phase de développement, parfois pour faire face à un effondrement, potentiel ou observé. La pêcherie du crabe des neiges de l'Atlantique canadien est récente. Elle s'est développée au début des années 1960 sur une ressource vierge dans un contexte global où existaient depuis longtemps une structure de recherche et un cadre juridique de gestion (« Fisheries Act », de 1867, amendé en 1961, et le « Territorial Sea and Fishing Zones Act », de 1964). Elle a connu une expansion particulièrement rapide (captures totales : 7 000 t, 1975, 15 000 t, 1980, 48 000 t, 1982) et concerne maintenant de nombreuses régions du golfe du Saint-Laurent (Fig. 1) et également, à un degré moindre, de la côte de Terre-Neuve. Son évolution récente (baisse des captures totales : 26 000 t en 1990, dont 10 000 t pour le Sud-Ouest) ; oscillation des prix) indique qu'elle est soumise à divers facteurs, internes et externes, dont l'importance s'est modifiée au cours de son évolution.

Le présent travail tente d'analyser le développement de la pêcherie de crabe des neiges du golfe du Saint-Laurent (côte est du Canada) sous un angle systémique. A partir de la structure de cette pêcherie, on va chercher à définir les variables du système, leur interaction et le rôle qu'elles ont pu jouer dans ce développement.

## 2. DONNÉES GÉNÉRALES

Le crabe des neiges, espèce d'eau froide et profonde, est pêché sur les vasières du golfe du Saint-Laurent, à des profondeurs généralement supérieures à 60 m (Fig. 1). Seuls les mâles de largeur de carapace égale ou supérieure à 95 mm sont exploités. Cette réglementation a été établie pour répondre d'abord aux exigences de l'industrie. Selon les hypothèses alors en vigueur, le potentiel reproducteur du stock devait être préservé : les femelles atteignent exceptionnellement la taille commerciale et les mâles deviennent physiologiquement matures vers 50-75 mm de largeur de carapace soit au moins un an avant d'entrer dans la pêche (Elner, 1982). Les crabes à carapace molle, venant de muer (« crabes blancs ») sont également exclus des débarquements en raison de la mauvaise qualité et du faible rendement en chair qu'ils procurent.

Le secteur de la transformation produit essentiellement de la section congelée (78 % des produits au Québec en 1990) et de la chair congelée (21 %). La vente de crabe entier est devenue une activité marginale mais elle représentait encore 9 % des ventes québécoises en 1989 (Boucher *et al.*, 1991). Le type de produit transformé répond à la demande des marchés d'exportation, où s'écoulent entre 90 et 95 % de la production. Selon les statistiques du Ministère des Pêches et des Océans, les deux principaux marchés sont les USA (30 à 45 %) et le Japon (30 à 60 %, en augmentation). La Communauté européenne (surtout Royaume-Uni, Belgique et France) est la troisième région d'exportation. Le marché européen a connu une baisse importante en raison de la montée de la valeur du Dollar à la fin des années quatre-vingt et de la concurrence des produits de substitution en provenance de l'Asie du Sud-Est.

L'intervention du Gouvernement est apparue assez tôt dans cette pêcherie, les permis spécifiques ayant été instaurés en 1972. Le cadre réglementaire a connu par la suite de nombreux ajustements pour répondre à la fois à l'expansion de la pêcherie, à la progression des connaissances, aux demandes de l'industrie et à des questions sociales. La gestion des pêches s'insère dans les principes généraux du Gouvernement du Canada :

(i) maintien de la ressource à un niveau optimal tout en protégeant le stock reproducteur ;

(ii) industrie de la pêche économiquement viable ;

(iii) maximisation de l'emploi.

D'une façon très générale, et pour l'ensemble des pêcheries canadiennes, on s'oriente vers une stratégie d'« effort constant » en se fondant sur le principe du « $F_{0.1}$ ». La réglementation agit soit sur les intrants (accès limité, limitation de la taille des navires, du nombre et du type d'engins, saison de pêche) soit sur les extrants (tailles minimales légales, quotas de capture). Dans le cas particulier du crabe, les données actuelles ne permettent pas d'utiliser les modèles classiques d'évaluation de stock, comme l'analyse séquentielle de population employée pour les poissons (Bailey et Elner, 1989), et on vise plutôt à ce que le taux de d'exploitation (capture/biomasse exploitable) soit compris entre 50 et 60 %. La biomasse est calculée soit à partir des statistiques de pêche (méthode « de Leslie ») soit par mesure directe (prospections par chalutage, marquages, etc.). La répartition des ressources halieutiques entre les différents acteurs cherche, par ailleurs, à optimiser les avantages socio-économiques. La pêcherie de crabe est ainsi divisée administrativement entre pêche semi-hauturière et pêche côtière. Cette répartition doit répondre aux critères suivants : proximité des côtes ; dépendance des communautés par rapport à ces ressources ; la spécialisation ou diversification potentielle des flottilles. Les 130 crabiers semi-hauturiers appartiennent essentiellement au Nouveau-Brunswick et au Québec et ils exploitent le stock du sud-ouest du Golfe, entre la baie des Chaleurs et les îles de la Madeleine (Fig. 1). Cette pêcherie correspond à l'exploitation « historique », dans la mesure où ce sont ces pêcheurs qui ont été les premiers à obtenir des permis de pêche au crabe. Pêche semi-hauturière et pêche côtière se différencient par le nombre de casiers autorisés (150 dans le premier cas, de 50 à 75 dans le deuxième, sauf droits historiques) et la taille des bateaux utilisés.

Dans l'optique du maintien de la ressource à un niveau optimal, la réglementation actuelle de la pêche au crabe a adopté un éventail de moyens portant à la fois sur des aspects biologiques (protection des femelles et des crabes blancs, taille minimale de capture, dès 1976) ; sur la capacité de capture (nombre de casiers/permis) ; sur la saison de pêche (durée fixe, 10 semaines pour les semi-hauturiers en 1986 ; ou variable selon les quotas ou l'apparition du crabe blanc) ; et sur le cadre législatif : accès limité (1975), zones de pêche côtière (Moyenne Côte-Nord : 1978 ; Basse Côte-Nord : 1980 ; île du Prince-Édouard : 1984), quotas (semi-hauturiers : quota global en 1986, quota individuels en 1991 ; côtiers : quota individuels, en 1983 pour la Basse Côte-Nord, 1991 pour la Moyenne Côte-Nord et 1992 pour la Haute Côte-Nord).

L'accroissement de l'exploitation correspond principalement à l'octroi de nouveaux permis pour la pêche côtière (Fig. 2), qui a débuté en 1978 au Cap-Breton et dont le nombre atteint actuellement 250 répartis sur neuf zones dans le Golfe. A cette augmentation du nombre de permis s'est ajoutée une expansion de l'aire exploitée (dans tous les secteurs) et une progression du nombre autorisé de casiers pour la pêche côtière, passant de 25 ou 30/permis en phase dite « exploratoire », à 50 par la suite. Durant cette période, on a également assisté à une modernisation des techniques : accroissement de la taille des navires, généralisation du radar, des systèmes de positionnement électroniques et de l'éclairage pour travailler de nuit, modification des casiers (Chiasson *et al.*, 1992). La capacité globale de capture est stabilisée depuis 1986. La diversification des flottilles est nette puisque la plupart des pêcheurs ont conservé les autres permis qu'ils détenaient et plus de la moitié en possèdent trois, surtout pour le poisson de fond (Fig. 2). L'usage effectif de ces autres permis est variable. Peu fréquent dans la pêche semi-hauturière, il est général pour la pêche côtière, pour laquelle la capture du crabe est considérée comme une activité économique complémentaire (Bailey et Elner, 1989). La diminution des captures a toutefois augmenté l'utilisation des permis additionnels : au Nouveau-Brunswick, le

pourcentage de pêcheurs qui ont utilisé une combinaison de permis est passé de moins de 20 % en 1974-1976 à plus de 40 % en 1989 (Chiasson *et al.*, 1992). Le secteur de la récolte emploie environ 1 300 personnes pour l'ensemble du Golfe (550 pour la pêche semi-hauturière).

## 3. LE SYSTÈME DE LA PÊCHE : RÔLE DES ACTEURS

Les données générales de la pêche permettent de réaliser un schéma conceptuel du système qu'elle constitue (Fig. 3), faisant ressortir les diverses variables impliquées : sociale (comportement des pêcheurs, effets en retour), économique (influence des marchés internationaux sur les prix et la rentabilité des flottilles), politique (stratégie générale de l'État, réglementation) et biologique (situation et évolution de la ressource). En reprenant, par ailleurs, les phases de développement définies par Bakun *et al.* (1982), on peut retracer les grandes étapes de l'évolution de cette pêcherie de crabe des neiges et le rôle respectif que ces variables ont pu y jouer. On regardera principalement le cas de la pêche semi-hauturière, la plus ancienne et la plus importante. Le cas des pêcheries côtières ne sera considéré qu'à travers les questions spécifiques qu'elles posent.

La ressource constitue classiquement un pivot du système. On constate toutefois que son « rôle » principal, en début de développement a été seulement d'exister. En effet, l'exploitation a débuté sur la constatation de sa présence avec un potentiel qui paraissait suffisant aux pêcheurs. Les quelques données biologiques préalables semblaient indiquer une abondance limitée et ne laissaient pas prévoir de grandes possibilités économiques (Brunel, 1962). L'initiative est donc venue du milieu de la pêche, qui a poussé les biologistes du Gouvernement a réaliser des prospections plus exhaustives. Le stock du sud-ouest du Golfe a été jugé pleinement exploité successivement en 1971 (Watson et Wells, 1972) puis en 1977 (Lamoureux et Lafleur, 1982). L'effort de pêche exercé dans cette région a augmenté jusqu'en 1980 et les captures ont suivi cette augmentation (Fig. 4), ce qui semblait confirmer les intuitions de la profession. Lors de cette « phase 1 » (début), on doit admettre que c'est la dynamique sociale qui a joué le rôle principal, par l'action de pêcheurs opportunistes (les pêcheurs « stochastiques », au sens de Allen et Mcglade, 1986, à la recherche du meilleur rendement « possible »). La contrainte principale s'est révélée être, toujours dans cette phase, la variable économique. En effet, les premiers efforts, venant des pêcheurs de l'île du Prince-Édouard, se sont soldés par un échec en raison de l'absence de marché. Il a fallu la chute importante de la pêcherie de crabes d'Alaska, fondée sur l'exploitation de plusieurs espèces, pour accroître la demande et permettre au crabe des neiges canadien de s'implanter.

L'expansion (« phase 2 ») n'a donc pu avoir lieu que dans la mesure où l'exploitation s'est avérée rentable financièrement, avec une bonne rémunération du risque (rapport interne de Pêches et océans, 1985). Les captures provenant du stock du Sud-Ouest ont alors crû régulièrement jusqu'en 1982, passant de 4 000 - 7 000 t durant la période 1968-1975 à 26 000 t en 1982. Face à ce développement explosif, le rôle du pouvoir politique est devenu particulièrement important, avec la mise en place progressive de politiques de gestion de plus en plus contraignantes (instauration d'un système de permis, accès limité, fixation des niveaux d'effort, instauration de saisons de pêche et enfin de quotas). Cette phase a été relativement brève. Il y a eu un apprentissage rapide des techniques de capture et du comportement de l'espèce du côté des pêcheurs. Ainsi, l'effort de pêche du Sud-Ouest s'étant théoriquement stabilisé (dans la mesure où les règlements ont pu ne pas être strictement respectés) dès 1980, l'augmentation des débarquements est sans doute reliée à l'extension des zones prospectées, à une meilleure performance des unités de capture, en raison des améliorations technologiques (Chiasson *et al.*, 1992) et, peut-être, à une augmentation du recrutement au sein de la ressource. Le développement général de la pêcherie correspond ensuite à la mise en place des zones de pêche côtière.

Le démarrage de la pêche côtière a été différente de celle du Sud-Ouest. Exception faite de la zone de l'île du Prince-Édouard, qui a été instaurée à la suite de pressions locales, ces pêcheries ont été créées à l'initiative du Gouvernement du Canada dans le but de favoriser l'émergence d'industries régionales avec accès exclusif pour un petit nombre de pêcheurs (Bailey et Elner, 1989). La variable politique a donc été déterminante dans ce développement. Les permis ont alors été octroyés sur une base volontaire, dans un premier temps à titre expérimental, puis de façon permanente. L'évolution de la pêcherie a varié selon les zones : captures relativement stables sur les Moyenne et Haute Côte-Nord (autour de 2 000 t et 1 000 t, respectivement) ; décroissance rapide et brutale sur la Basse Côte-Nord où les débarquements sont passés de 2 200 t en 1986 à 168 t en 1989, avec une légère reprise à 740 t en 1991.

La phase de pleine exploitation (« phase 3 ») a fait apparaître deux niveaux d'incertitude. Le problème est d'abord venu de la ressource. Les captures ont commencé à décroître dès 1983 (Fig. 4) et, en 1990 dans le Sud-Ouest, elles n'étaient

plus que de l'ordre de 50 % de celles de 1982. Cette incertitude s'est accrue par la suite avec l'acquisition de nouvelles données biologiques. Alors que l'on pensait que les mâles connaissaient une croissance continue, il apparaît que cette croissance peut être interrompue avant l'atteinte de la taille légale (« mue terminale »). Seuls les individus ayant atteint ce stade seraient capables de s'accoupler efficacement (Conan et Comeau, 1986). Ainsi, la taille légale actuelle ne garantirait plus la protection du potentiel reproducteur du stock, ce qui pourrait hypothéquer le maintien à long terme de la population. De plus, un contexte de rationalisation de la flotte a fait en sorte que les mesures de protection se sont accrues avec la mise en place de quotas par entreprise. Les aspects économiques, ensuite, ont révélé la grande dépendance de la pêcherie vis à vis des marchés extérieurs. L'expansion s'était déroulée dans un contexte favorable de diminution des captures japonaises et américaines et d'un accroissement de la demande sur le marché japonais (Fig. 4). L'offre canadienne s'est avérée essentiellement « preneuse de prix », n'ayant aucune influence sur leur formation (Michaud et Abgrall, 1985). Ces prix apparaissent fortement reliés, par exemple, à la situation des inventaires des industries américaines (Fig. 4). Cette situation devient particulièrement cruciale dans la mesure où les captures de *Chionoecetes* ont augmenté de façon dramatique depuis 1985 dans le Pacifique Nord-Est (Fig. 4). Cette dernière période a également vu le développement de productions concurrentes d'Asie et d'Amérique latine (selon la FAO, les captures mondiales, toutes espèces confondues, sont passées de l'ordre de 800 000 tonnes en 1982 à 1 100 000 tonnes en 1989) et du simili-crabe (« surimi »), dont la consommation américaine a progressé de 20 000 t en 1984 à 68 000 t en 1989 (source : Pêches et océans). De fait les prix au débarquement dans l'Est canadien sont à la baisse depuis 1989, étant passé de 4 $[1]/kg en 1988 à 2,6 $/kg en 1991. Cette tendance semble se poursuivre en 1992. Associée à la chute des captures, la baisse des prix a fait passer la valeur des débarquements de 98 millions de dollars en 1988 à 49 millions en 1990.

## 4. PÊCHERIE ET ÉCONOMIE LOCALE

Les tendances observées ont des effets en retour sur la dynamique sociale et économique et affectent en premier lieu les revenus des pêcheurs. Une étude complète a été réalisée pour le Québec (Boucher *et al.*, 1991). En considérant le revenu de trésorerie [2], on constate, pour la pêche semi-hauturière, que ce revenu moyen est passé de 51 000 $ en 1984 à 207 000 $ en 1988. La progression des prix sur le marché international a ainsi réussi à compenser l'effondrement des débarquements, ce qui n'a plus été le cas par la suite : le revenu moyen a chuté à 21 000 $ en 1990, en raison de la baisse conjointe des prix et des captures. En 1991, une légère reprise est observée (51 000 $). Les revenus de la pêche côtière sont plus faibles et varient d'une région à l'autre, avec des tendances sensiblement identiques à celles de la pêche semi-hauturière.

La pêche a un impact important sur les communautés maritimes de l'est du Canada, où plus de 30 % des emplois dépendent de cette activité (46 % aux îles de la Madeleine ; 80 % sur la Basse Côte-Nord). La plupart des communautés de pêche est implantée dans des villages et la majorité des emplois offerts par la pêche se trouvent dans ces villages côtiers (Kirby, 1982). Par ailleurs, il est fréquent que plus d'une personne par ménage aillent à la pêche, tandis que les employés d'usine sont constitués à plus de 10 % par des personnes appartenant à des ménages de pêcheurs. On conçoit donc que le crabe des neiges, en progression tant en quantité qu'en valeur, ait été perçu comme pouvant jouer un rôle moteur dans les économies locales. C'est d'ailleurs ce qui motivé la création des pêcheries côtières. De fait, l'incidence sur le niveau de l'emploi a été notable. En 1988, 21 % des emplois directs issus de la pêche québécoise étaient reliés au crabe. Les activités de transformation ont subi de plein fouet la baisse de la production. De 1986 à 1989 au Québec, le nombre d'emplois dans les usines traitant le crabe a diminué de 50 %, passant de 2000 à 1000. Il a légèrement réaugmenté en 1990 et 1991 (1300) en raison de la reprise des débarquements et de la production de chair (Boucher *et al.*, 1991).

L'action des pouvoirs politiques, ne concernant pas seulement la réglementation, a également favorisé l'expansion et le maintien de l'activité halieutique. La pêche a bénéficié d'aides financières de divers ordres. Les programmes ont été orientés essentiellement vers la modernisation des entreprises. On espérait ainsi concurrencer les autres États pêcheurs. Dans le secteur de la collecte, l'aide s'est manifestée sous la forme du Programme d'aide aux bateaux de pêche, instauré

1. L'unité monétaire est le Dollar Canadien (1 $ CAD ≈ 0,8 $ US).
2. Le revenu de trésorerie correspond au revenu brut diminué des dépenses (salaire de l'équipage et intérêt) et du remboursement en capital : il correspond donc au salaire du capitaine plus la rémunération pour le risque (avant impôt). Il ne tient donc pas compte de dépenses «comptables» qui n'entraînent aucun déboursé d'argent (amortissement et rémunération en capital).

pour fournir aux exploitants des capitaux quand il n'y avait que peu de ressources disponibles (Crowley *et al.*, 1990). L'aide globale, incluant des subventions directes et des garanties de prêts à taux préférentiel, pouvait atteindre 85 % des frais occasionnés par l'achat de bateaux neufs semi-hauturiers, incluant les aides des gouvernements provinciaux. Pour la pêche côtière, l'investissement personnel était plus élevé (25 % ; source : Pêches et océans). En 1984, les aides gouvernementales ont permis d'accroître les revenus nets des bateaux de 12 % au Québec (source : Pêches et océans). Les programmes d'aide directe ont été arrêtés en 1986, d'une part en raison de la surcapacité de capture des flottilles canadiennes et d'un changement de philosophie, les principes de l'économie libérale prenant le pas sur les principes d'assistance. On constate, selon les informations de Chiasson *et al.* (1992), que la modernisation de la flotte a été pratiquement arrêtée à cette date.

Une aide importante provient de l'assurance chômage. Ce programme assure un revenu additionnel aux pêcheurs (propriétaires ou marins) entre deux saisons. La durée des prestations vont de 15 à 25 semaines (Crowley *et al.*, 1990). Leur importance dans le revenu total des pêcheurs est variable selon les années mais elles peuvent en représenter 10 % pour un capitaine et 16 % pour les marins, ce qui en fait un apport non négligeable. Depuis 1990, l'assurance chômage doit s'auto-financer. Considérant que les primes versées sont supérieures au montant des cotisations perçues, une partie de cette aide est maintenant prise en charge par l'ensemble des travailleurs canadiens.

## 5. DISCUSSION

La pêcherie de crabe des neiges du golfe du Saint-Laurent a connu toutes les phases d'un développement classique mais dans un laps de temps très court. A un début rapide et une expansion quasi explosive a fait suite, non moins rapidement une phase de décroissance à la fois dans les captures et dans les prix. Lors de chaque phase du développement, il a existé des niveaux de risques liés aux incertitudes sur plusieurs variables externes au secteur de la récolte : ressource, réglementation et marché.

Les incertitudes sur la ressource été accentuées par le fait que la pêcherie a exploité la biomasse vierge d'une espèce peu et mal connue. Elles correspondent aux interrogations que se posent les biologistes sur son taux réel de production, sur l'incidence de la pêche sur son maintien à long terme et sur l'effet éventuel de l'environnement écologique sur le recrutement à la pêche. On peut supposer que l'avancement des recherches en cours permettra de diminuer le niveau d'imprécision pour cette variable.

Les instances gouvernementales ont eu un rôle contradictoire. D'une part, elles ont octroyé des aides pour augmenter la performance des flottilles (particulièrement au Québec, qui visait à rattraper le retard sur les autres Provinces de l'Est canadien) ; ces aides, organisées selon des plans à moyen terme pour l'ensemble des pêcheries, se sont poursuivies alors même que la ressource était en déclin. D'autre part, comme le souligne Hannesson (1984), le processus de gestion est devenu, assez vite, une nouvelle source d'incertitude. D'une attitude plutôt neutre, ou sceptique, au début de l'exploitation, le Gestionnaire a progressivement assuré un contrôle de plus en plus étroit sur la pêcherie. Selon les processus de décision actuels du Ministère des pêches et des océans, le plan de gestion des espèces exploitées commercialement est établi pour une année. Ce système ne pose pas de problème important dans un contexte stable. Dans le cas du crabe, les modifications ont été fréquentes, particulièrement en fin de la phase d'expansion et dans la phase de plein développement où l'état de la ressource est devenue préoccupante. Ainsi, pour la pêche semi-hauturière, en 1984, le quota de 24 000 t a été haussé à 26 000 t en cours de saison, puis organisé sous la forme de quotas hebdomadaires par bateau (pour étendre la saison de débarquement sous la pression des travailleurs d'usines) ; en 1985, le quota était de 26 000 t et il y a eu extension de la saison après atteinte de ce quota ; la diminution des quotas a été régulière chaque année jusqu'en 1990. En 1991, un effort est réalisé en établissant un plan de deux ans avec un quota annuel de 10 000 t réparti individuellement (80 % partage égal, 20 % calculés sur les prises historiques), mais révisable en fonction des évaluations faites de la ressource (il a été ainsi augmenté à 12 000 t en 1992). Dans un tel contexte en perpétuelle évolution, l'établissement de plan d'investissement, la négociation avec les acheteurs, etc., deviennent particulièrement problématiques. Les tendances récentes de la gestion, toutefois, cherchent à amoindrir ces incertitudes en associant la profession au processus de décision. Ainsi en 1990, les pêcheurs semi-hauturiers ont accepté de ne pas augmenter les quotas pour laisser dans la mer un peu du « capital biologique » de l'année, en espérant ainsi faciliter la récupération du stock.

Les aspects économiques sont de plus en plus importants à l'heure actuelle. La pêche a pu se développer dans un contexte international favorable. Mais la pêcherie est liée à une évolution des prix est sous le contrôle des grossistes étrangers (américains et japonais).

Dans ce contexte « incertain », le développement de l'exploitation a représenté des risques. Ce risque est assumé à plusieurs niveaux, mais sous des formes différentes et variables selon le stade de développement de la pêcherie (tableau 1). Pour le pêcheur, toute sortie en mer est un « pari » dans un jeu de hasard (Gates, 1984). Les individus qui se sont engagés dans ce nouveau type d'exploitation ont dû assumer un risque élevé, n'ayant aucune certitude d'obtenir de bénéfice sur leur investissement, financier et humain. L'incertitude sur la ressource et sur les marchés est sans doute la plus élevée au début de l'exploitation. Pour la communauté, les impacts potentiels sont encore faibles, la nouvelle activité ne modifiant pas profondément les habitudes et pratiques locales. L'industrie est liée à la fois à la garantie d'approvisionnement (la ressource) et à la garantie de vente (le marché). Le risque est alors élevé, puisqu'elle doit investir dans des technologies adaptées. Pour les instances de gestion, les problèmes sont d'une autre nature, surtout dans la mesure où il n'existe aucune donnée préalable. Freiner l'activité à son début peut nuire au développement, par contre, refuser tout contrôle peut amener à la destruction d'une ressource. Aussi, un moyen terme est-il adopté, avec un minimum de règlements. A cette étape, la réglementation n'a donc pas représenté d'incertitude. Le Gouvernement prend, par contre, des risques plus concrets en s'impliquant directement, et financièrement, dans la pêche au crabe des neiges, par le biais des aides à l'investissement, mais aussi en encourageant, ou favorisant, l'ouverture de nouvelles pêcheries côtières dont on ne pouvait prévoir le devenir. A ce début d'exploitation, on doit admettre qu'il y a un certain partage des risques entre les intervenants, même s'il existe une disymétrie du côté des industries de capture et de transformation.

En phase d'expansion, les niveaux d'incertitude changent. Les captures suivant l'augmentation de l'effort, les marchés répondant bien à l'augmentation de l'offre, ces éléments n'apparaissent plus comme facteurs de risque importants, bien que le spectre des fluctuations d'abondance et de prix soit toujours présent. Ce risque est, par contre, toujours bien rémunéré par les revenus que cette pêche génère. Pour le Gouvernement, la ressource commence à devenir un élément de crainte, puisque l'on ne sait pas quel niveau d'exploitation elle pourra supporter à long terme, et les contrôles deviennent de plus en plus serrés. L'accroissement, et la multiplication, des mesures restrictives de gestion deviennent, dans cette situation, de nouveaux facteurs d'incertitude pour le pêcheur. Le risque s'élève pour les communautés, puisque la nouvelle pêcherie génère des activités économiques spécifiques, donc éventuellement vulnérable. Par ailleurs, l'accès limité à une ressource profitable crée localement des clivages sociaux avec des modifications de la structure même de la communauté, comme cela a été observé sur la Basse Côte-Nord : aggravation des disparités sociales, diminution de l'esprit de solidarité (Breton, *in* Brêthes et Breton, 1992).

Dans la pêcherie développée, puis en décroissance, l'évolution des captures et des marchés met les activités de récolte et de transformation dans une situation périlleuse. Le risque s'accroît à tous les niveaux, la réglementation devenant extrêmement contraignante et ayant des répercussions en aval sur les usines de transformation. Pour limiter les problèmes socio-économique, le Gouvernement accepte de prendre un minimum de risques sur la ressource et, par conséquent, sur la réglementation, qui est un peu moins draconienne que ce qui est suggéré par les données biologiques. On note ici l'importance des délais de réaction du processus de gestion et de l'inertie propre au système, notamment le déphasage entre les aides (maintenues dans un contexte biologique douteux) et les contraintes à l'exploitation. Au niveau social, le contre-coup de la décroissance peut être sévère avec la diminution des activités rémunératrices. Les pertes d'emploi, l'endettement des ménages, contracté pendant la phase favorable, deviennent problématiques, surtout si le tissu social a pu se distendre à l'intérieur des collectivités.

Il est intéressant de constater qu'au cours du développement de cette pêcherie, les préoccupations gouvernementales ne se sont portées ni sur les marchés ni sur les aspects sociaux (mise à part l'assurance chômage) et que son action, notamment par l'octroi de subventions et de permis sur une base volontaire, a pu avoir un effet pernicieux et imprévu au niveau des communautés.

Dans le cas de la pêche au crabe, on constate que le niveau de partage des risques s'est modifié au cours du développement, avec le retrait progressif des pouvoirs politiques dans le soutien à l'industrie. Assumé au départ par les pêcheurs, la transformation et le Gouvernement, le risque apparaît maintenant devoir être pris en charge par l'ensemble du secteur social et économique. Dans une certaine mesure, les pêcheurs ont « prévu » les problèmes potentiels. Ils ont investi dans les moyens de capture (nouveaux bateaux, nouveaux équipements) afin de s'assurer une plus grande efficacité et ce d'autant plus que la pêcherie a longtemps été gérée sous un régime de quota global. Beaucoup ont également conservé leurs autres permis de pêche. La revitalisation de ces permis, particulièrement dans la pêche côtière, apparaît comme une solution aux problèmes du crabe. Ainsi, sur la Basse Côte-Nord, alors que les captures de crabe baissaient de 2000 à 160 t entre 1987 et 1989, les captures de morue passaient de 490 à 1500 t au cours de la même période pour les crabiers (Lalande et Dubé, 1990). Ce remède n'est toutefois que partiel dans un contexte de crise généralisée (les valeurs globales des débarquements des crabiers ont baissé de 5 millions $ entre 1987 et 1989 sur la Basse Côte-Nord).

Dans l'environnement politique actuel, tant national qu'international, il semble douteux que le Gouvernement en revienne à un véritable partage des risques. L'industrie doit trouver elle-même les moyens de résoudre ses problèmes. Dans la mesure où l'on ne prévoit pas de véritable reprise à long terme de la ressource aux niveaux connus antérieuremment et où la gestion paraît de plus en plus efficace pour éviter une récolte abusive et amortir les grandes fluctuations des débarquements, les incertitudes principales paraissent être d'ordre social et économique. On cherche déjà à sortir de la dépendance des grossistes étrangers en misant sur la qualité de produits négociés directement avec des acheteurs. On étudie des possibilités de stabulation pour approvisionner les marchés intérieurs en dehors de la saison officielle. D'autres approches innovatrices sont à rechercher. Quel en sera le coût pour les collectivités, dans un contexte de « rationalisation » ? Cela reste à déterminer.

## REFERENCES

**Allen P.M. et J.M. McGlade** (1986). Dynamics of discovery and exploitation : the case of the Scotian shelf groundfish fishery. *Can. J. Fish. Aquat. Sci.* **43 :** 1187-1200.

**Anderson L.G.** (1984). Uncertainty in the fisheries management process. *Marine Resource Economics* **1** (1) : 77-87.

**Bailey R.F.J. et R.W. Elner** (1989). Northwest Atlantic Snow Crab Fisheries : Research and Management. *In* : J.F. Caddy (éd.), *Marine Invertebrate Fisheries, Their Assessment and Management*, John Wiley and Sons, New-York : 261-280.

**Bakun A., J.B. Beyer, D. Pauly, J.G. Pope et G.D. Sharp** (1982). Ocean Sciences in relation to living resources. *Can. J. Fish. Aquat. Sci.* **39** (7) : 1059-1070.

**Boucher J., C. Cantin et D. Pelletier** (1991). Analyse économique et commerciale de l'industrie du crabe des neiges au Québec. Ministère des pêches et des océans (Canada), Rapport de l'analyse économique et commerciale **107 :** 21 p.

**Brêthes J.-C. et Y. Breton** (1992). Étude de cas : l'introduction de la pêche au crabe des neiges sur la Basse Côte-Nord du golfe du Saint-Laurent. In : J.-C. Brêthes et A. Fontana (éd), *Recherches interdisciplinaires et gestion des pêcheries*. Projet CIEO-890276, Centre international d'exploitation des océans, Halifax (Canada) : 157-177.

**Brêthes J.-C. et A. Fontana (éd.)** (1992). *Recherches interdisciplinaires et gestion des pêcheries*. Projet CIEO-890276, Centre international d'exploitation des océans, Halifax (Canada), 228 p.

**Brunel P.** (1962). Troisième série d'observations sur la biologie et la biométrie du crabe araignée *Chionoecetes opilio* (O. Fabr.). Rapp. Ann. 1962, Station de biologie marine de Grande-Rivière (Québec) : 91-100.

**Chaboud C. et A. Fontana** (1992). L'approche système dans les pêches. In : J.-C. Brêthes et A. Fontana (éd), *Recherches interdisciplinaires et gestion des pêcheries*. Projet CIEO-890276, Centre international d'exploitation des océans, Halifax (Canada) : 111-146.

**Chiasson Y.J., M. Hébert, M. Moryasu, A. Bourgoin et D. Noël** (1992). Une analyse rétrospective du développement et expansion de la pêcherie du crabe des neiges *Chionoecetes opilio*, dans le sud-ouest du golfe du Saint-Laurent. *Rapp. tech. Can. Sci. halieut. aquat.* 1847F : iv+24p.

**Conan G.Y. et M. Comeau** (1986). Functional maturity and terminal molt of male snow-crab *Chionoecetes opilio* . *Can. J. Fish. Aquat. Sci.* **43** (9) : 1710-1719.

**Crowley R.W., B. Mc Eachern et R. Jasperse** (1990). Aperçu de l'aide fédérale à l'industrie depuis 1945. Ministère des pêches et des océans (Canada), Rapport de l'analyse économique et commerciale 71 : 50p.

**Elner R.W.** (1982). An overview of the snow crab, *Chionoecetes opilio*, fishery in the Atlantic Canada. *Alaska Sea-Grant Rep.* 82-10 : 5-19.

**Garcia S.** (1984). Les problèmes posés par l'aménagement des ressources instables. Programme F.A.O. pour le développement des pêches dans l'Atlantique Centre-Est *COPACE/PACE Series* 84/28 (Fr.) : 38 p.

**Gates J.M.** (1984). Principal types of uncertainty in fishing operations. *Marine resource Economics* **1** (1) : 31-49.

**Hannesson R.** (1984). Fisheries management and uncertainty. *Marine Resource Economics* **1** (1) : 89-96.

**Kirby J.L.** (1982). *Naviguer dans la tourmente : une nouvelle politique pour les pêches de l'Atlantique. Points saillants et recommandations*. Rapport du Groupe d'étude des pêches de l'Atlantique, Ministère des pêches et des océans du Canada, Ottawa (Canada), décembre 1982, 168p.

**Lalande G. et N. Dubé** (1990). Analyse économique et financière de la pêche côtière au Québec. Ministère des pêches et des océans, Ottawa, Rapport de l'analyse économique et commerciale 68.

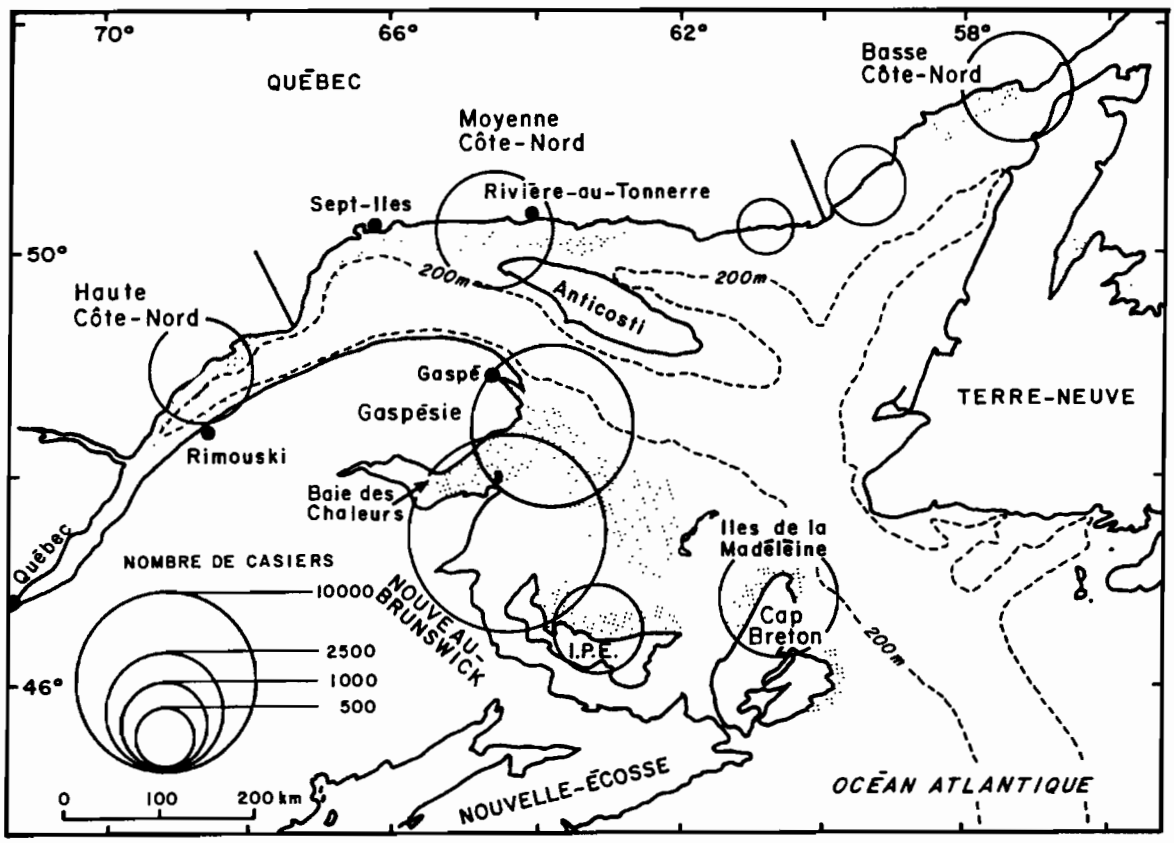
**Michaud J.-C. et J.-F. Abgrall** (1985). Forecasting the price of crab on the Boston wholesale market. *Alaska Sea-Grant Rep.* 85-12 : 401-418.

**TABLEAU 1.**
**ESTIMATION DE L'IMPORTANCE DES RISQUES ENCOURUS PAR LES ACTEURS FACE AUX SOURCES D'INCERTITUDE DANS LE DÉVELOPPEMENT DE LA PÊCHE AU CRABE DES NEIGES.**

| Phase de développement | Source d'incertitude | Preneurs de risque | | | |
|---|---|---|---|---|---|
| | | Pêcheur | Communauté | Industrie | Gouvernement |
| Début | Ressource | +++ | - | +++ | +++ |
| | Marché | ++ | - | +++ | - |
| | Réglementation | - | - | - | + |
| Expansion | Ressource | + | + | + | + |
| | Marché | - | + | - | - |
| | Réglementation | ++ | ++ | + | - |
| Développée | Ressource | +++ | +++ | +++ | + |
| | Marché | +++ | +++ | +++ | - |
| | Réglementation | +++ | +++ | +++ | + |

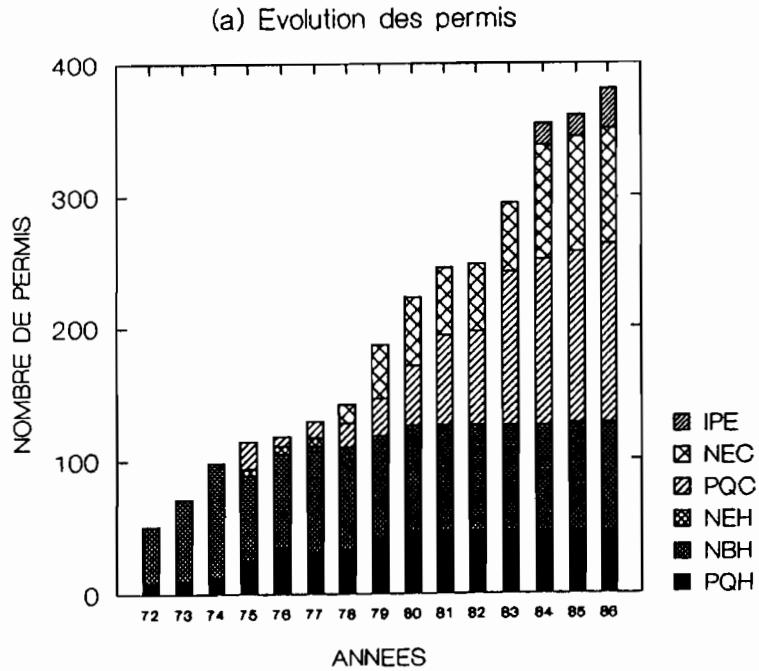
(-) risque faible ou nul ; (+) risque modéré ; (++) risque élevé ; (+++) risque très élevé ; « Commu nauté » représente les effets possibles sur la dynamique sociale ; « Industrie » signifie l'industrie de la transformation et de la commercialisation ; « Gouvernement » représente l'ensemble des décisions concernant l'aménagement et la gestion.

**FIGURE 1.**
**RÉPARTITION GÉOGRAPHIQUE DE LA PÊCHERIE DE CRABE DES NEIGES DANS LE Ggolfe ET L'ESTUAIRE DU SAINT-LAURENT (HACHURÉ).**




La taille des cercles est relative à la capacité autorisée de capture (nombre total de casiers/zone). Les capacités de la Gaspésie et du Nouveau-Brunswick correspondent aux pêches semi-hauturières.

**FIGURE 2. (a)**
**ÉVOLUTION DU NOMBRE DE PERMIS ACCORDÉS POUR LA PÊCHE AU CRABE DES NEIGES. (b) RÉPARTITION DES PÊCHEURS DE CRABE POSSÉDANT D'AUTRES PERMIS DE PÊCHE POUR LE GOLFE DU SAINT-LAURENT. SOURCE : MINISTÈRE DES PÊCHES ET DES OCÉANS DU CANADA.**




PQH = Québec, semi-hauturiers ; NBH = Nouveau-Brunswick, semi-hauturiers ; NEH = Nouvelle-Écosse, semi-hauturiers ; PQC = Québec, côtiers ; NEC = Nouvelle-Écosse, côtiers ; IPE = île du Prince-Édouard, côtiers.

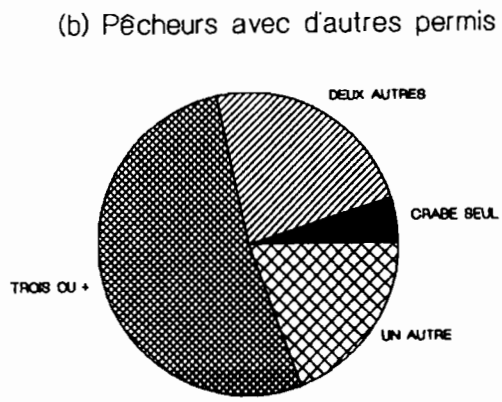


**FIGURE 3.**
**REPRÉSENTATION SCHÉMATIQUE DU SYSTÈME DE LA PÊCHE AU CRABE DES NEIGES AU CANADA : VARIABLES ET INTERACTIONS (MODIFIÉ DE BRÊTHES ET BRETON, 1992).**

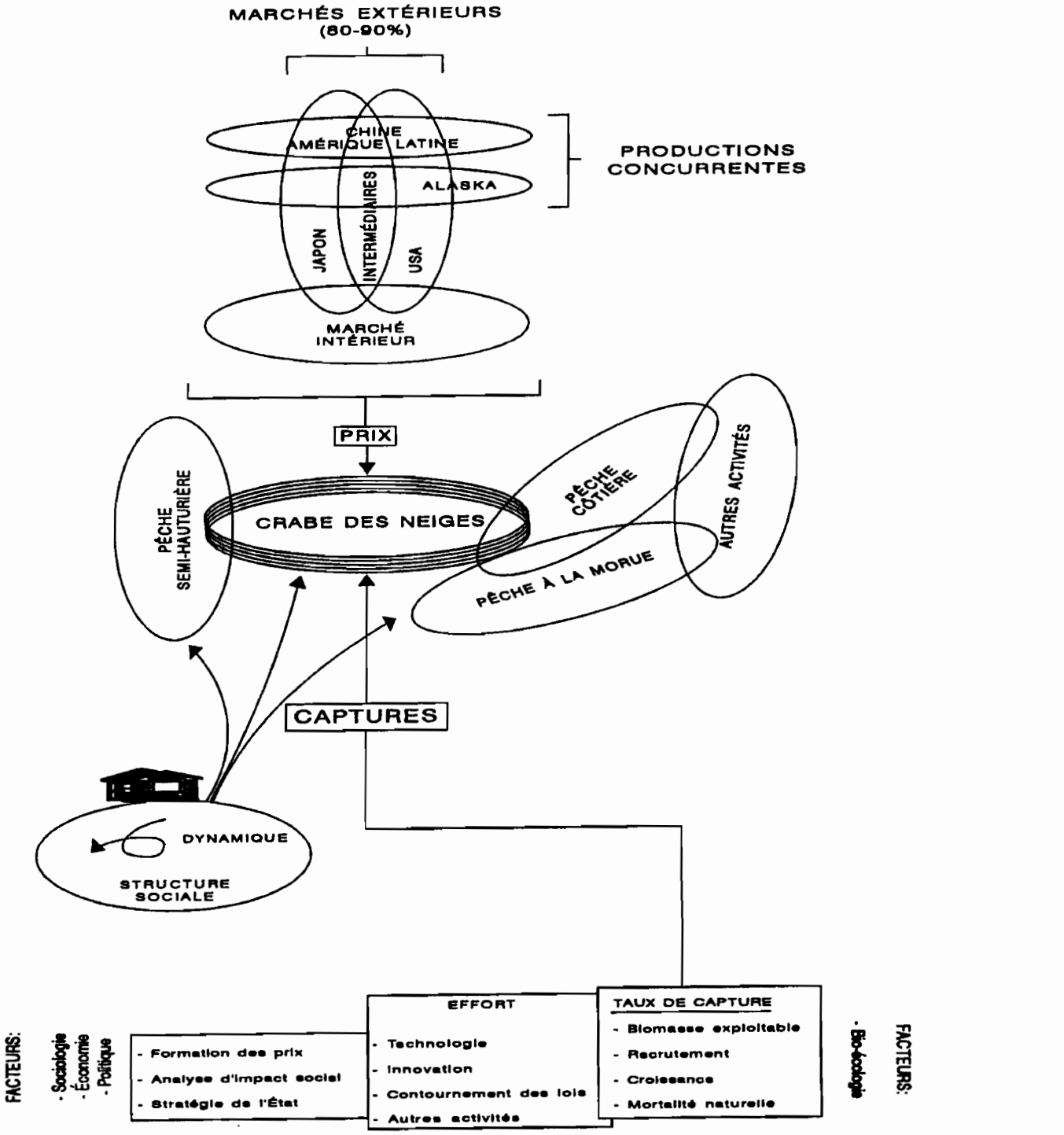
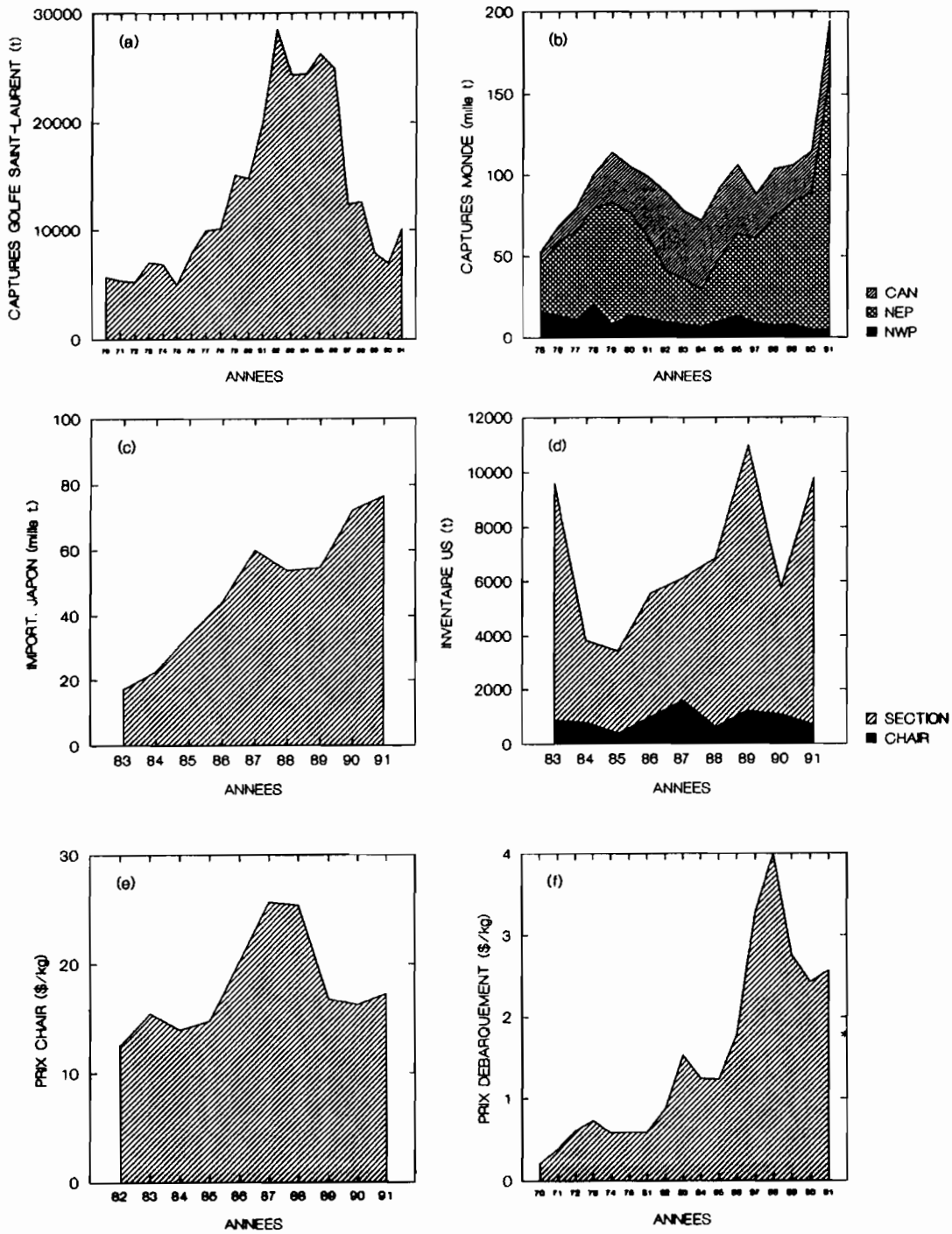


**FIGURE 4.**
**DONNÉES GÉNÉRALES SUR LE CONTEXTE DE LA PÊCHERIE DE CRABE DES NEIGES.(A) DÉBARQUEMENTS DANS LE SUD-OUEST DU GOLFE DU SAINT-LAURENT. (B) CAPTURES MONDIALES DE L'ESPÈCE *CHINOECETES***




(NWP = nord-ouest Pacifique ; NEP = nord-est Pacifique ; CAN = Canada). (b) Importations japonaises. (c) Inventaires des usines des États-Unis en section congelées (*section*) et en chair congelée (*chair*) au mois de juillet de chaque année. (c) Prix de vente de la chair congelée, paquets de 5 livres sur le marché de Boston. (d) Prix de vente moyen au débarquement pour la pêche semi-hauturière au Canada. Source : Ministère des pêches et des océans et Boucher *et al.* (1991).

# Development and Diversification : Sustainability Strategies for a Costa Rican Fishing Cooperative

**Anthony T. Charles[a] and Angel Herrera[b] ***

[a]Department of Finance and Management Science, Saint Mary's University, Halifax, Nova Scotia B3H3C3 CANADA

[b]School of Biological Sciences, Universidad Nacional, Heredia, COSTA RICA

ABSTRACT

*"Successful" fishery development can be defined as the simultaneous achievement of ecological, socioeconomic, community and institutional sustainability. This paper incorporates these sustainability elements within an integrated framework, which is applied in a case study of Puerto Thiel, a fishing community in the Gulf of Nicoya on Costa Rica's Pacific coast. The economic performance of the local fishing cooperative is analysed, and experiences with economic diversification are reviewed. We highlight the importance, especially in heavily exploited fisheries, of policies that simultaneously pursue development (to increase local socioeconomic and community fishery benefits within resource limitations) and economic diversification (to lessen the impact of fishery management restrictions by creating non-fishery employment alternatives).*

## 1. INTRODUCTION

Why have fishery development efforts experienced at best a mixed record of success ? Contrary to the perceptions of some development agencies, failures in fishery development can be traced not to the intractability of fishery problems themselves, but rather to overly-narrow approaches that have been used in tackling these problems. This paper attempts to formulate and to apply an integrated view of fishery development, situated within a modern context of sustainability.

* We are grateful to the Fishery Resources Management Section of the Universidad Nacional's School of Biological Sciences, and to the Economic Sciences Research Institute of the University of Costa Rica, for use of their facilities. Financial assistance from the Science Subvention Program of Canada's Department of Fisheries and Oceans, and from the Natural Sciences and Engineering Research Council of Canada, grant #A6745, is gratefully acknowledged.

In the following section, a conceptual framework of sustainable fishery development is developed. This is applied in sections 3, 4 and 5 to an examination of development, diversification and sustainability options for Puerto Thiel, in Costa Rica's Gulf of Nicoya. In section 3, the relevant fishery environment, fishing approaches, and recent economic history are described. Section 4 analyses the performance of the community's fishing cooperative, while in section 5, we examine experiences in non-fishery economic diversification. Finally, a number of conclusions are presented in section 6.

## 2. SUSTAINABLE FISHERY DEVELOPMENT

Thanks to the Brundtland Commission (WCED 1987), it has become increasingly clear that, whatever other objectives are pursued in the economy, the goal of "sustainable development" must be paramount. In the fishery context, this implies that policy proposals must be judged primarily on their contribution to fishery sustainability. But what exactly constitutes a "sustainable fishery" ? This section presents an integrated bio-socio-economic perspective, addressing in particular the key links between diversification and sustainability.

### *2.1 The Idea of Sustainability*

In broad terms, sustainable development involves the simultaneous pursuit of : (a) ecological, (b) socioeconomic, (c) community and (d) institutional sustainability. These criteria can be portrayed within a "Sustainability Triangle" framework (Charles 1994) :

> i) Ecological Sustainability...ensuring that the capacity and quality of the relevant ecosystem, and of each species therein, are maintained or enhanced over time.
>
> ii) Socioeconomic Sustainability... ensuring that (a) net benefits are as great as possible and as well distributed as possible amongst participants, and (b) viability is maintained within both the local and the global economy.
>
> iii) Community Sustainability... to maintain or enhance the social, cultural and economic welfare of communities -- both those dependent on the fishery and those affected indirectly by the fishery.
>
> iv) Institutional Sustainability...ensuring that institutional structures (including financing and administrative capabilities) are sufficient to maintain fishery management and development measures in the long term.

Fishery development policy can be viewed as sustainable ONLY IF it enhances, or at least maintains, each of the above components over time. This requires an integrated process of "sustainability assessment", in place of narrow uni-disciplinary measures of success such as economic efficiency.

### *2.2 Economic Diversification and Sustainability*

The fisheries of developing regions typically face a trio of key problems ; over-exploited stocks, an over-extended fleet, and a lack of alternative employment outside the fishery. In addressing these, the late economist Ian Smith (1981) expressed well a fundamental but oft-neglected reality : to be just, feasible and effective, policies cannot be restricted to resolving one or two of these problems alone. This key point, an insightful forerunner to multi-faceted concepts of "sustainable development", extends the conclusion of modern fishery economics that "bio-economic" management is needed to tackle even apparently biological problems. In other words, simple attempts to promote biological sustainability may reduce economic sustainability.

This realization, and the subsequent emphasis on "bio-economic" management, led to frequent promotion of policies to reduce the number of fishers through so-called "rationalization". However, one of Smith's key contributions was to point out that such a "release of labour" from the fishery may well be a social bad, except in rare cases where a high-employment economy is waiting to absorb labour for productive uses. He noted that in the absence of non-fishery economic alternatives, rationalization may (a) impose inhumane and hence nonsustainable impacts on those dependent

on the fishery, or (b) fail to be feasible politically, due to negative community-level effects or (c) fail from a practical perspective, since fishers without other options will do anything, legally or illegally, to maintain their livelihood. Hence, "bio-socio-economic" policies are required, to enhance ecological and economic sustainability while also incorporating community sustainability. These considerations will be examined further in the following case study.

## 3. THE GULF OF NICOYA AND PUERTO THIEL

The Gulf of Nicoya, on Costa Rica's Pacific coast, is the country's principal artisanal fishing area (Fig. 1). For physical, biological and management reasons, its area of 1500 $Km^2$ is divided into two parts, the "outer zone" and "inner zone" (Carranza 1985) ; it is the latter, dominated by coastal mangroves and small-scale fishing, that is the focus here. Shallow throughout and protected from the open sea, the inner Gulf provides a favorable environment for mangroves, which represent a crucial coastal habitat in many tropical regions. In the Gulf, mangroves cover 112 km (42.6 %) of the coastline and 15,174 ha of coastal area (Solórzano et al., 1991).

### *3.1 The Gulf of Nicoya Fishery*

Historically, the principal economic activity in the internal part of the Gulf was a traditional artisanal fishery, using longlines and gillnets to harvest a variety of fish stocks. This open access fishery experienced relatively low profitability, and required little in the way of government management efforts.

The situation changed dramatically in the early 1980s, with the introduction of a modified gillnet technology for catching white shrimp (genus *Penaeus*). These shrimp stocks rapidly became the most desired catches for fishers, although there remains commercial interest in a variety of finfishes, such as corvina (croaker), red snapper and snook, as well as the bivalve "pianguas" (genus *Anadara*), which grows on the roots of certain mangroves (genus *Rhizophora*).

Without changing the small-scale nature of the fishery, the shrimp harvest led to increased profitability, and (as would be expected in a relatively open access fishery) an increased migration of people from other areas to fish in the Gulf. In fact the number of *licensed* fishers grew from approximately 2000 in the early 1980s to reach almost 3000 today, while approximately 3000 more fish illegally without licenses. The capital stock of boats fishing in the Gulf has also increased dramatically (Figure 2). The number of small "botes" increased steadily since the mid 1970s, while the number of larger "pangas" grew rapidly between 1984 and 1988, reflecting a process of technological change in the fishery. In the late 1980s, this expansion began to slow, and was largely halted in 1989-90 by a ban on new boats in the area.

The rapid transformation in the fishery took place in the absence of adequate planning, so that by 1985 a substantial decline in the catches of shrimp was being felt. This led to what is still the major conservation management tool in the inner Gulf region, a 3-month closed season on shrimp harvesting between May and July each year. As well, other regulations have been implemented in the Gulf, including a limitation on gillnet mesh size (Herrera and Valerín, 1992).

### *3.2 Puerto Thiel*

Puerto Thiel is a small fishing community located on the northwest side of the Gulf. From the final years of the 19th century to the mid-1950s, it was a port for coastal trade, but has gradually transformed into a fishing community as water travel gave way to road transportation. Today the roughly 160 permanent residents depend largely on the fishery for their livelihood. Surrounded by coastal mangroves and two large cattle ranches, there are few nearby agricultural opportunities. However, despite a widespread lack of agricultural experience, current economic difficulties have led to seasonal migrations of Thiel residents to work in coffee and sugarcane harvesting in interior zones of the country.

### *3.3 The CoopeThiel Fishing Cooperative*

"CoopeThiel" was formed in 1984, began operating fully in 1986, and currently has a membership of 23. The cooperative's principal operation is a fish handling and storage centre, with offices, fish receiving space, cold storage and an ice machine. This facility provides important social benefits both to members and to other local fishers, being the community's sole year-round fish buying site.

CoopeThiel also maintains a fishing fleet of 10 wooden outboard-motor boats, averaging 6m in length. This fleet comprises a third of the community's vessels, but just one-sixth of those fishing from Thiel during the main shrimp harvesting months, when seasonal fishers and their roughly 30 vessels arrive from other locations. Shrimp gillnets are the principal fishing technology used by Thiel fishers, except in the closed season for shrimp, when rudimentary long-lines and large-mesh gillnets transform the fishery into a more selective activity targeting exclusively on fishes.

CoopeThiel's economic performance has been generally acceptable to its members. Although dividends have never been paid, it is recognized that members of the cooperative obtain sufficient to provide a minimal standard of living for their families. However, faced with increased concern over the state of Gulf of Nicoya fish stocks, future cooperative finances, and the general socioeconomic welfare of the membership, the cooperative has expressed an interest in (a) better understanding its recent economic record in the fishery, and (b) pursuing innovative ideas to diversify its economic activity. Results to date in each of these areas will be described in the following sections.

## 4. COOPETHIEL : AN ECONOMIC ANALYSIS

CoopeThiel maintains full records of its fish buying and selling activities, records which were made available for analysis to the Fishing Community Extension Program of Costa Rica's Universidad Nacional. The results reported here are based on almost 3000 landings receipts representing payments to fishers for harvests obtained through approximately 6000 days of fishing over the 3-year period from April 1988 to March 1991. Using this primary data, which also includes information on fishing costs (for gasoline, ice, cooperative service fees, etc.) it has been possible to obtain a rare detailed view of fisher activities in the Gulf.

It should be noted here that, unless stated otherwise, all catches, costs and incomes are on a "per day" basis, and all monetary figures are given in real terms, in January 1988 colones (US$1 = 85 colones approximately). Inflation of 200 % occurred over the period 1988-1991, so that 1 colón in March 1991 was equivalent to 0.54 colones in January 1988.

### *4.1 Fishing Income and Costs.*

Together, Figures 3 and 4 give a year-by-year view of average daily costs and earnings. Fig. 3 summarizes the key sources of fisher income by species groups (known as "First", "Second", "Cola" and "Bolillo", with the highest price being paid for large "First" class). Fig. 4 shows the proportions of total gross income allocated amongst the various fishing costs and to the fisher's net income.

Fig. 3 indicates that landed values were highest in 1988-89, with 1989-90 being particularly poor and 1990-91 slightly better. However, to fully understand these results, we must note that from historical data, pre-1988 catches appear to have been at least as high as that for year 1 of our study. Hence in reality the 3-year period shown in Fig. 3 depicts a major change in the state of the fishery from what appears to have been shrimp "resource mining" pre-1988 to the present lower level of combined shrimp and fish harvesting.

Two further points should be noted in Figure 3. First, while shrimp catches clearly provide the dominant source of income overall, finfish catches have come to represent nearly 50 % of total income. This reflects an increasing difficulty in locating sufficient shrimp stocks, together with a general increase in fish prices. Second, a notable concern from the conservation perspective is the apparent trend within the "1st class" category toward the harvest of smaller fish.

We turn next to Fig. 4, which indicates the breakdown of average daily gross income into net income and the various cost components -- gasoline, ice, cooperative fees, and other costs. It should be noted that any given sales receipt issued by the cooperative may or may not include any of these costs, depending on whether the fisher in question chose to buy supplies from the cooperative, and whether he or she rented one of the cooperative's boats. The cooperative fee, set at 25 % of landed value, is levied only in the latter case ; this fee can be viewed as a proxy for maintenance and capital costs. To provide as accurate a picture as possible of actual costs and earnings, Fig. 4 is based only on those landings receipts in which a rental fee as well as costs for gasoline and ice were paid.

Fig. 4 shows that costs on average form approximately 40 % of a fisher's gross income. Of these costs, gasoline and cooperative fees dominate. It can also be seen that gasoline constitutes an increasing fraction of total costs, while the reverse is true for cooperative rental fees. (This appears to be due to the fact that in 1990-91, in contrast to earlier years, the cooperative did not consistently collect its fee of 25 % of landed value.)

Trends in gross income for this set of fishers differ somewhat from the combined average shown in Fig. 3, being slightly lower in the first year and significantly higher in the third. Since those fishers included in this set tend to be most closely associated with the cooperative, this result may be due to an increase in the relative quality of those attracted to the cooperative over time.

The daily net income (in January 1988 values) ranges between approximately 500 and 1000 colones. If we assume an average of 15 fishing days per month (allowing for lost time due to heavy rains, high and low tides, and repairs, as well as the "satisficing" effect described below), this amounts to a monthly net income of between 7,500 and 15,000 colones (US$88-176). This range can be compared with official poverty levels (in January 1988 colones) of 22,200 (US$261), 11,500 (severe poverty : US$135) and 7,500 (extreme poverty : US$88).

### *4.2 Variability in Catches and Incomes*

Figure 5 shows the average daily catches of shrimp and finfish, month-by-month between February 1988 and March 1991. It is clear that artisanal fishing in the Gulf of Nicoya is highly cyclical in nature. Shrimp harvesting occurs for nine months of the year, being particularly successful between December and February. During the closed season for shrimp in May-July, fish catches tend to reach their peaks, due to the change in gear to longlines and larger mesh sizes (although fish by-catches have also been significant during the shrimp season, especially in 1990-1991).

Fig. 6 displays the variability in average net income per fishing day across all fishers involved with the cooperative, for the year 1990-1991. While some fishers show a zero net income (indicating that they did not fish, or did not sell to the cooperative, in that particular year), most average between 100 and 1000 colones per trip, and a few obtained very high average returns. This skewed distribution (around an average of 800 colones or US$9.40 per day) is typical of many fisheries. However, it is somewhat lessened here by an important behavioral factor : fishers in Puerto Thiel tend to make their operational decisions on a satisficing basis, in which fishing activity is oriented toward catching "sufficient". This behaviour has significant implications for the pursuit of sustainability, tending as it does to level out the fisher income distribution, thereby easing pressure on the resource and reducing conflict within the community.

## 5. ECONOMIC DIVERSIFICATION

Costa Rica's coastal zone provides an excellent example of the need to combine fishery management and regulation with efforts at economic diversification. Coastal inhabitants are in general among Costa Rica's poorest, receiving relatively little government aid and having relatively few employment alternatives. Pressure on the fishery as "employer of last resort" is enormous.

In an effort to deal with some of the problems facing Pacific fishing communities, the Fishing Community Extension Program of Costa Rica's Universidad Nacional has worked in cooperation with the Canadian nongovernmental organization "Desjardins Society for International Development", in a series of economic diversification projects :

i) The fishing community of Tárcoles is located in the outer part of the Gulf of Nicoya. Its fishery cooperative, which obtains most of its income from selling fresh seafood for export, obtained assistance in forming a small supermarket in the community. One of the fundamental goals of the supermarket has been to provide an employment option for local women. Indeed, the original idea was formulated by female cooperative members, who now administer the store.

ii) In Chacarita, a heavily-populated neighbourhood on the edge of Puntarenas city, the local cooperative is involved in deep-sea fishing, but wishes to diversify its economic base. The cooperative worked with the university and the Desjardins Society to develop a supermarket for the community, which is currently run by the directors of the cooperative.

iii) Nosara is located on the Pacific coast of Costa Rica's Guanacaste province. As in Tárcoles, emphasis in the diversification work was placed on working with the local fishing cooperative to provide employment for women, in this case in a bakery to be run by female members of the cooperative. However, this was never completed due to a variety of problems, ranging from discouragement following the cooperative's failure to develop a deepsea fishing operation, to an earthquake that partially destroyed the bakery during its construction.

iv) As noted earlier, the fourth economic diversification project is located in Puerto Thiel, and reflects the cooperative's desire to develop alternative economic activity which would not affect the fishers' principal activity of fishing and which would provide paid work to those women who wish to diversify from traditional domestic work and child-care.

The diversification project chosen -- one which clearly involved a major departure from the traditional fishing activity of CoopeThiel -- was the development of a tree nursery. This project appeared promising given government encouragement for reforestation in the region, the project's forecast profitability, and its potential to provide formal employment to women in the community. Accordingly, 2.5 ha of land near Puerto Thiel were purchased, on which a small covered workspace with suitable infrastructure was constructed, providing a potential annual production of 185,000 young trees, comprised of commercially viable species such as teak and pochote (genus *Bombacopsis*).

Production levels in the first year of operation were below expectations, due to low survival rates of the trees, and a lack of sufficient training in managing silvicultural activity. Nevertheless, the project is proceeding for a second year of operation, with increasing levels of training and some success in securing wider markets. Hence, the tree nursery continues to provide an alternative source of employment, while demonstrating to Thiel residents the possibility of developing further economic alternatives. The project may also assist in relieving pressure on the fishers to increase their harvesting effort in an attempt to maintain incomes as stock levels decline.

## 6. DISCUSSION

We have suggested that the key objective of fisheries development and management must be the achievement of broad-based sustainability within the fishery system. This idea of fishery "sustainability" has been explored from two perspectives : (1) a conceptual bio-socio-economic framework based on a "Sustainability Triangle" paradigm, and (2) a specific case study relating the ongoing search for sustainability in a Costa Rican fishing community, Puerto Thiel. We have highlighted a view of sustainable development as a multi-faceted process involving the simultaneous pursuit of ecological, socioeconomic, community and institutional sustainability.

What fishery development policy measures are most compatible with the need for fishery sustainability ? In the most common but most difficult context of heavily exploited fisheries -- where the challenge is to improve ecological sustainability through resource rehabilitation, while simultaneously maintaining or improving socioeconomic and community welfare, a dual focus on development and diversification may be optimal, emphasizing :

i) development approaches within the fishery which seek to maximize the benefits flowing directly to fishers, including encouragement of fishing behaviour (such as "satisficing") that tends to have a lower resource impact, a focus on fish sales to local cooperatives rather than to outside buyers, and measures to increase the value added from the harvest -- by improved handling as well as the development of ancillary fishery-related services in the communities affected,

ii) economic diversification outside the fishery sector, to maintain socioeconomic and community sustainability in the face of conservation-oriented management restrictions being implemented within the sector.

Supplementing this "development and diversification" strategy, the Puerto Thiel experience suggests that sustainable fishery development may well be enhanced by an emphasis on integrated policy designed and implemented at the "micro" (community) as well as the "macro" (industry) level. Such approaches are relatively unstudied -- the interdisciplinary research required for their full implementation presents many interesting challenges to practitioners of fishery economics.

## REFERENCES

**Carranza F.** (1985). Distribución y abundancia del recurso camarón blanco y alternativas de aprovechamiento mediante un método de pesca artisanal en el Golfo de Nicoya. Thesis, Universidad Nacional Autónoma de México, 60 p.

**Charles A.T.** (1994). Towards Sustainability : The fishery experience. *Ecological Economics* (forthcoming) .

**Herrera A. and N. Valerín**, (1992). Legislación pesquera de principal interés para los pescadores artesanales del Golfo de Nicoya. Publicaciones UNA. 40 p.

**Smith I.R.** (1981). Improving fishing incomes when resources are overfished. *Marine Policy* **5** : 17-22.

**Solórzano R., R. De Camino, R. Woodward, J. Tosi, V. Watson, A. Vásquez, C. Villalobos, J. Jiménez, R. Repetto and W. Cruz** (1991). Accounts Overdue : Natural Resource Depreciation in Costa Rica. Tropical Science Center and World Resources Institute, Washington D.C. 110 p.

**World Commission on Environment and Development** (1987). *Our Common Future*, Oxford University Press, Oxford.

FIG. 1.
COSTA RICA AND THE GULF OF NICOYA.

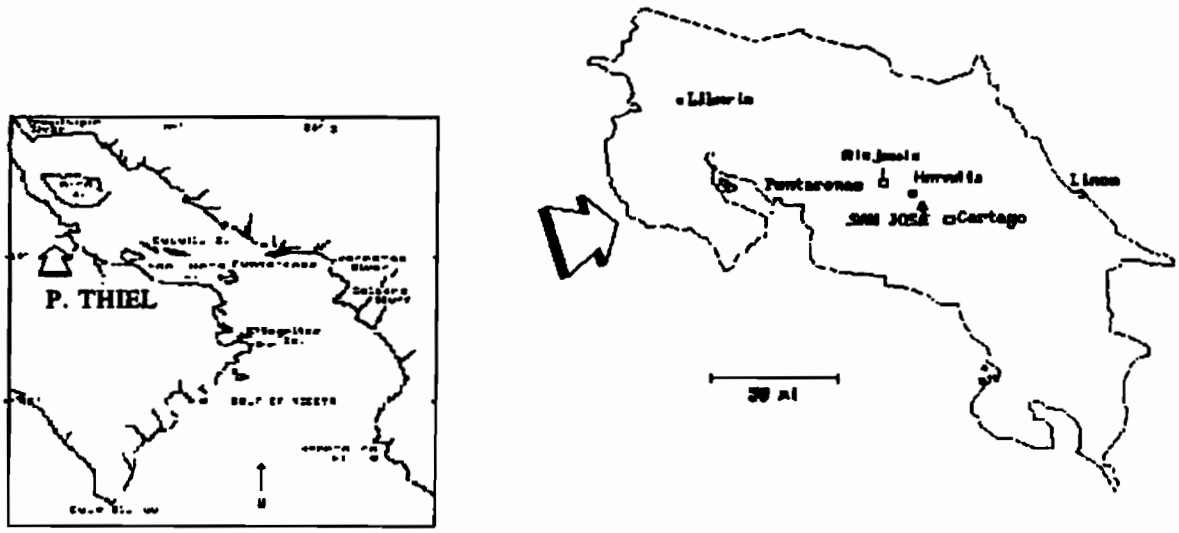



FIG. 2.
THE GULF OF NICOYA FISHING FLEET, 1970–1989.

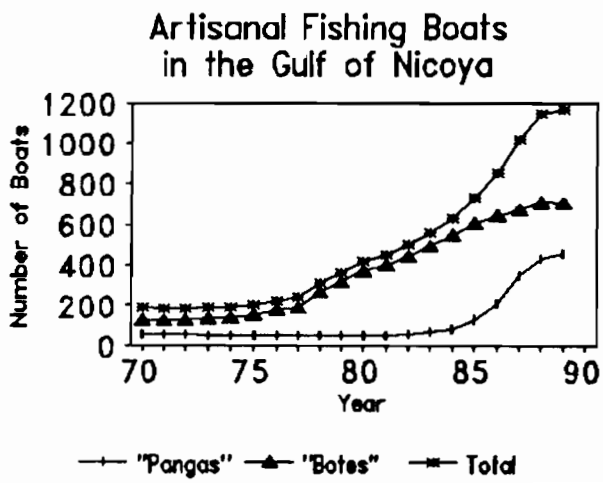


FIG. 3.
AVERAGE DAILY INCOME, BY SPECIES GROUP AND YEAR, FOR ALL FISHERS SELLING TO THE COOPETHIEL COOPERATIVE.

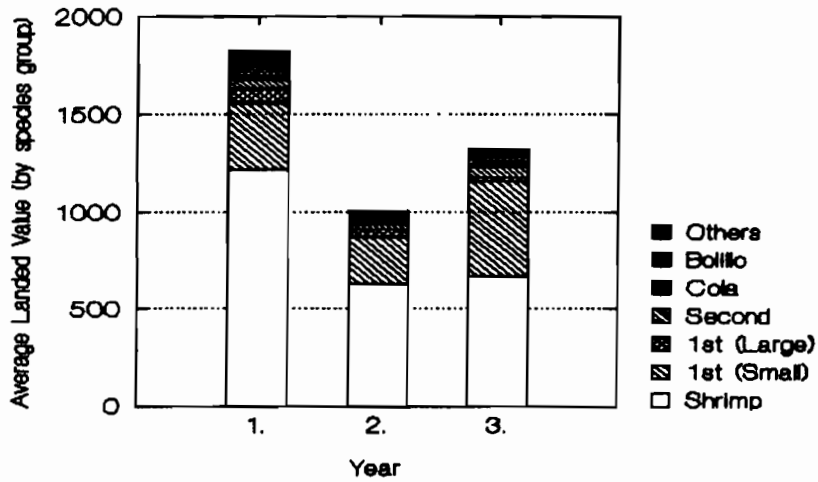



FIG. 4.
AVERAGE DAILY FISHING COSTS AND NET INCOME BY YEAR, FOR FISHERS RENTING BOATS FROM COOPETHIEL AND PAYING OPERATING EXPENSES TO THE COOPERATIVE.

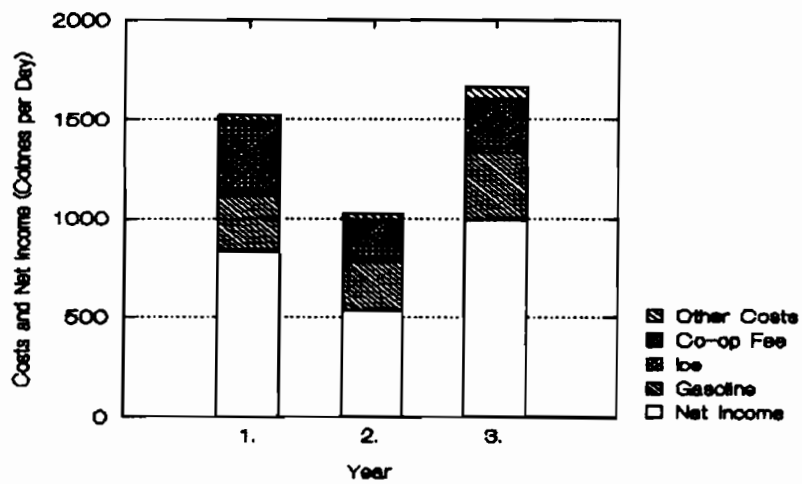


FIG. 5.
CYCLIC NATURE OF AVERAGE DAILY SHRIMP AND FISH HARVESTS, SHOWN MONTH-BY-MONTH OVER THE PERIOD 1988–1991.

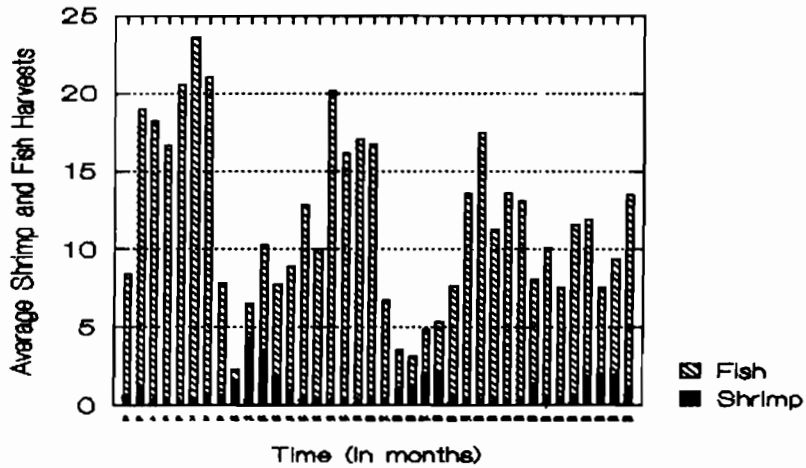
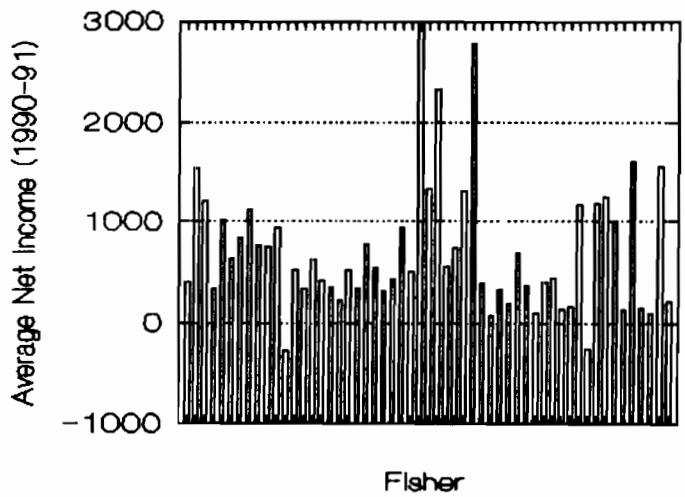



FIG. 6.
VARIABILITY IN AVERAGE DAILY NET INCOME AMONGST FISHERS SELLING TO COOPETHIEL, FOR THE YEAR 1990–1991.



# Structure, Constraints and Development Options of Fish Processing and Marketing in Namibia

**Rolf Lasch**

Institute of Agricultural Market Research, Bundesallee 50, 38116 Braunschweig, Germany

ABSTRACT

*1. Potential size of catches*

*The long-term sustainable yield in Namibian waters may be estimated at least around 1.2 million t per year involving 350 000 t of hake, 450 000 t of horse mackerel, 250 000 t of pilchard, and 150 000 t of anchovy, which will place Namibia among the more important fishery nations of the world.*

*2. Production capacities and product mix*

*The fishing industry is concentrated in Walvis Bay, still South African territory. The main items are canned pilchard, fish meal and oil, frozen rock lobster, and only small quantities of white fish. The current canning capacity of 400 000 t of pilchard during a half-year season is much higher than the current level of actual landings.*

*3. Market volume (local, regional and international)*

*As the internal consumption of fish in Namibia will be marginal compared to potential catch, almost the whole catch will have to be exported. The industry will be almost completely dependent on foreign markets and will have to produce according to the specifications of these markets.*

*Namibia may wish to continue its exports to South Africa as it is the dominant neighbouring market, with a relatively developed economy and a population of approximately 30 million. But it is necessary to develop alternative markets in Africa. The major African countries today are Nigeria and the Ivory Coast, but also Egypt, Zaire, Angola and Cameroon import substantial amounts. To what extent other countries in neighbouring southern Africa and in the rest of Africa will become markets for Namibian fish products does, however, depend also on their ability to pay for these imports or whether they can supply Namibia on barter terms with products needed by Namibia.*

*On the world market, there are well established markets for fish meal and oil and Namibia should have no problem in selling its products, which, when fully developed, will represent only a very small part of present total world exports. Namibia will also be able to find export markets for hake and other white fish, primarily as whole fish (headed and gutted) and frozen fillets. It may be more difficult to develop new markets for horse mackerel for human consumption.*

*Likewise, difficult to sell in much larger quantities will probably be canned pilchard. If the pilchard stock is allowed to recover, future catches may reach 250 000 t yearly. If the larger part (60 %) of these catches were canned, production may theoretically reach 10 million cartons a year, which is equal to one fifth of total world production today. It is uncertain that there would be a demand for this additional amount, even if new markets were developed. Even this amount will be substantial by world standards and Namibia will have to adhere to strict quality standards in order to develop and maintain such a share of international markets.*

## 1. INTRODUCTION

The maritime territory off Namibia's coast extends from the border of Angola in the North to the border of South Africa (RSA) in the South, with a coastline of 1 400 km which mainly runs in a north-south direction. This Benguela Current area, an upwelling zone in oceanographic terms, is roughly 150-200 nautical miles wide, overlies the coastal shelf area and represents a sensitive ecosystem. The south-west coast of Africa is one of the maritime areas with the highest worldwide primary production.

Although there are only a small number of fish species in the relatively limited fishing grounds they are present in very large quantities.

The high potential yield of fish resources in Namibia's coastal waters has been known for a long time. Up to independence in 1990, Namibia's unclarified situation in terms of international law has prevented the introduction and international acceptance of the generally acknowledged coastal fishing zone of 200 nautical miles. For many years, therefore, the waters off the Namibian coast have been the only productive and generally accessible fishing grounds for international long-distance trawler fleets. Since 1971 the International Commission for the Southeast Atlantic Fisheries (ICSEAF) has been responsible for the management of fishing in this area.

After the declaration of a 200 m Exclusive Economic Zone (EEZ) and extension of the jurisdiction over the fisheries in the Namibian waters in June 1990, the Government of the Republic of Namibia had to prepare immediately a full scientific resource management for permanent research, stock monitoring and stock assessment just as to establish an effective fisheries administration enabling the control and surveillance of the fishing activities within the 200 mile zone.

## 2. VOLUME OF CATCHES AND STOCK POTENTIAL

Off the coast of Namibia there are in general three major fishing areas, the first two of which have so far been almost exclusively available to the foreign long-distance trawler fleets outside of a coastal zone 13.5 nautical miles wide :

- Hake fishing, primarily carried out by using trawl nets.
- Trawl fishing for pelagic species, primarily carried out using pelagic trawls.
- Inshore fishing for pelagic species, primarily carried out from Walvis Bay using purse-seines inside the 13.5 nautical miles coastal zone.

The **total volume of catch** - sometimes more than 2 million t p.a. during the 1960's - declined markedly during the 1970's and dropped to an average of about 300 000 t in the post-independence period.

The stock biomass of the **hake** has declined steadily. The results of resource surveys on hake confirmed the diagnosis of overexploited resources and estimated total stock biomass for the whole area of 500 000 t, but the main part of fish was small sized and the fishable stock biomass was only 200 000-250 000 t.

In 1990, the Namibian authorities allocated only 55 000 t increasing to 90 000 t in the current year.

The population situation of the biomass of **horse mackerel** is currently characterized by an equilibrium between stock size and exploitation, and the population is not damaged by fishing. The previous biomass estimate made in 1990 showed an imprecise estimate of total biomass in excess of 2 million t. The findings must be interpreted as a confirmation of the good state of this resource.

From the allocated TAC of about 250 000 t one third is reserved for the inshore pelagic fishery.

The preferred target species, which was only fished moderately when fishing in this category began, then excessively and at the same time exclusively, was the **pilchard**. Today, its population is overfished. In the mid-1960's the entire pilchard biomass was still estimated at over 10 million t ; by 1970 this figure had dropped to roughly 1 million t, and since 1977 the level of the adult biomass has only amounted to somewhere between 100 000 and 200 000 t.

Resource surveys on inshore pelagic fish in 1990 gave estimates of pilchard biomass of 240 000 and 750 000 t respectively, which are significantly higher than those obtained in recent prior surveys and might indicate some recovery of the stock. Namibia pursued a policy of regulations of the pilchard fishery largely following the scientific advice. In order to maintain a viable canning industry a seasonal fishing has, however, been allowed, but at a low level with annual landings between 40 000 and 60 000 t in recent years. The allocated TAC's have in cases been exceeded due to the unfortunate by-catch of juvenile pilchard in the anchovy fishery.

The **anchovy** fishery started in 1968 when the pilchard within the catch of pelagic fish began to disappear on a larger scale. This short lived fish had shown large year to year natural fluctuations of yield and stock abundance from the start of the fishery, and annual catches varied between 80 000 t and 350 000 t.

Resource surveys in 1990 gave estimates of biomass of anchovy of around 200 000 t, which represents a very low level for the anchovy.

The **total long-term sustainable yield** may be estimated at least **around 1.2 million t** per year involving 350 000 t of hake, 450 000 t of horse mackerel, 250 000 t of pilchard, and 150 000 t of anchovy, which will, if fully utilized, place Namibia among the more important fishery nations of the world. In the long run the future of the Namibian fishery industry will perhaps lie more in the quantity than the quality of the resources. There are only few high value species (lobster, sole, kingclip etc.) in negligible quantities which may be used for high priced products. The hake is a medium priced fish, while pilchard, horse mackerel and anchovy represent low value species.

## 3. FISHING FLEET, FISH PROCESSING AND MARKETING

### *3.1 Namibian fleet*

The Namibian fleet in 1989 included 164 registered vessels with a tonnage of just under 48 000 BRT. This fleet comprised 39 purse seiners, 53 coastal and deep-sea trawlers, 35 rock lobster boats and 20 line-fisheries vessels. All vessels operating on quotas are now registered in Lüderitz and not as before in Walvis Bay.

### *3.2 Processing industry*

The fish processing industry is concentrated at Walvis Bay which is a fully integrated fishing centre, with modern fish processing and servicing facilities, and rail, road and air connections. The main items produced by the fish processing industry based in Namibia are canned pilchard, fish meal and oil, frozen rock lobster and only small quantities of processed white fish. Until 1977, Namibia was the world's leading supplier of canned pilchard. The entire fishing sector in Namibia was dominated by a small number of South African dominated companies. At present there are 4-5 factories processing pelagic fish, and 3 or 4 processing white fish.

All processing companies for pelagic fish - employing roughly 2 700 workers - are located in Walvis Bay ; together with the production of canned pilchard, fish meal and fish oil they represent the most important subsector of the Namibian fish industry. In 1990 approx. 60 000 t of pilchard were processed into canned fish (4 million boxes) and 190 000 t of pelagic fish processed into fish meal (50 000 t) and fish oil (6 000 t). The current canned fish production capacity of 400 000 t of pilchards during a half-year season is much higher than the current level of actual landings.

At present two factories in Lüderitz, employing a total of 450 workers, carry out lobster processing (primarily whole, deep-frozen lobsters).

*3.3 Products and markets*

The main products of the fishing industry in Namibia are canned pilchard, fish meal, fish oil, rock lobster, and various processed white fish (frozen, smoked, dried).

During the pre-independence period, the South African Government was only allowing exports of **fish meal** outside of the South African Union Agreement (SACUA) after its own demand has been satisfied. Price controls in South Africa did often keep prices lower than the world market, but in recent years Namibian exporters have been negotiating these prices, and obtained a price closer to and even higher than the world market.

Production in South Africa itself has been around 90 000 t annually, increasing to 150 000 t in recent years. Its internal demand has been increasing from around 150 000 t to approximately 240 000 t (1990). At most 20 000 t of the fish meal production (1990 : 50 000 t) is used in Namibia as animal feed.

The whole present production of **fish oil** is exported to the RSA, where the annual consumption of around 40 000 t has been greater than the combined RSA/Namibia production. Fish oil must be refined into edible oils and fats or processed to soaps or other products. The only fish oil refinery in Africa is the Unilever subsidiary in RSA, Lever Brothers. Unilever, which dominates the world market in this product, has an on average taken some 80 % of the Namibian output for processing either in RSA or in UK. Consumption inside Namibia is negligible.

In the past, the main **rock lobster** products were frozen tails, which were mainly exported to the United States, and cooked whole lobsters, mainly for the Japanese market. Since 1980, almost all the production has been cooked whole for the more profitable Japanese market. Small amounts are consumed by the high-income groups and tourists in South Africa and Namibia.

Only a small proportion of **white fish** (especially hake) caught in Namibian waters has been landed in Namibia ; most has been taken by foreign fleets and transported to their home countries. Since independence, an increasing amount of hake caught by Namibian registered trawlers in Namibian waters has been landed and processed in Namibia. In addition, varying volumes of snoek, sole, kingclip, etc. have been landed, and are processed into a variety of products like dried, salted and smoked fish, but the bulk of groundfish is market as frozen fish (frozen blocks, frozen and prepared).

While small quantities are consumed by the upper income groups and some are fed to the contract workers living in municipal or company compounds, most is exported to South Africa and marketed there together with South Africa's own production.

The **horse mackerel** (maasbanker) landed in Namibia is all processed into fish meal and oil, except for some new experiments in canning. The foreign trawlers' catches are taken to their home countries. Some is probably sold to West African countries.

Until 1977 Namibia (and South Africa) was the world's leading supplier of **canned pilchards**. As South Africa itself is a relatively small producer (less than 200 000 cartons/year in 1970-78, increasing to 1.5 million in 1989/90), the bulk of these exports came from Namibia. However, South Africa is also a major consumer and it can be estimated that consumption within the South African Union Agreement (SACUA), which includes the Republic of South Africa, Namibia, Botswana, Lesotho and Swaziland, was in the region of 4 million cartons/year in the mid-1970's, increasing to almost 6 million in the late 1980's. Statistics for the Namibian domestic consumption of fish products are wholly lacking, but less than 10 % of the 5-years-average annual production of roughly 3 million boxes of canned pilchards are sold in Namibia itself at present. The rest is transported to South Africa (and SACUA), whose annual market potential is estimated at 6 million boxes.

At present, very small amounts of fish are consumed in Namibia itself and practically all is exported. Excluding freshwater fish, the total consumption of sea fish and fish products in Namibia amounts to roughly 5 000 t-6 000 t p.a which corresponds to a per capita consumption of 4-4.5 kg.

*3.4 Market capacities - local, regional and international*

As the internal consumption of fish will be marginal compared to potential catch, almost the whole catch will have to be exported in one way or another. The industry will be almost completely dependent on foreign markets as consumers

of its products and it will have to produce according to the specifications of these markets. While some products have a well established international market that can easily absorb an expanded Namibian production, other products may have a more limited market. Also, some markets are highly competitive and require products of a consistently high quality, other markets are accessible for low-priced products only.

### *3.5 Domestic market volume*

Fish is an important food resource and can contribute substantially to increased food self-suffiency in Namibia. Namibia will probably first ensure that there is sufficient fish available to cover the needs of its own population. The present demand in Namibia may well amount to 8 000-10 000 t landed weight during the first few years after independence, increasing in long-term to around 20 000 t with population increases. It is assumed that this will consist mostly of canned pilchard and frozen horse mackerel, perhaps some other demersal species, fresh, frozen, dried, salted, or smoked.

The Namibians may also utilize some more of fish meal in Namibia for feeding their livestock. But, even if this should be developed on a large scale, it will still require only a smaller part of the future Namibian fish meal production.

In the longer run, the consumption patterns may change, switching to a higher proportion of white fish, as well as including more canned pilchards when they become available. Even, if the human consumption of fish will increase to a relatively high rate of 30 kg/capita it would make use of around 3 % of the estimated total potential of 1.2 million t, only and it would not have a large effect on the amount of fish available for export.

### *3.6 African market*

Namibia may wish to continue its exports to South Africa, at the same or even at an increased level. But Namibia may also wish to develop alternative markets and trading patterns in southern Africa and the rest of Africa. The development of new trading patterns will partly be influenced by the institutional arrangements entered into.

Within the members of the Southern Customs Union (SACUA) South Africa is here the dominant market, with a relatively developed economy and a population of approximately 30 million. The other three countries Botswana, Lesotho and Swaziland are less developed economically and have a total population of around 3 million. South Africa today imports yearly some 50 000-100 000 t of fish meal, some body oil and around 3 million cartons of canned fish, which, furthermore, may represent a potential market for Namibian exports.

There are other future markets for Namibian fish products in countries like landlocked Zambia and Zimbabwe, in particular, but also the coastal states of Mozambique and Tanzania may become fish importers from Namibia. As these countries have a combined population of 60 million people, and many are inadequately nourished, Namibian fish could contribute to an improved nutritional standard in these countries. The products required for these countries will be mostly low-priced products that can be easily transported and stored, such as dried, salted and smoked fish or canned fish. Possibly some frozen fish can also be exported. To what extent other countries in neighbouring southern Africa and in the rest of Africa will become markets for Namibian fish products does, however, depend also on their ability to pay for these imports or wether they can supply Namibia on barter terms with products needed by Namibia. Exports to these countries will also depend on improved transport and communications.

Informations on the present fish imports of these countries is incomplete but imports are generally rather low. It is very difficult to estimate the possible scale of future Namibian fish exports to other African countries but is unlikely that it can become substantial during the next years.

It should, nevertheless, be possible to develop major Namibian markets in other African countries in the future, as their imports today include such products as frozen horse mackerel, dried and salted white fish and canned sardines. The major African countries today are Nigeria and the Ivory Coast, but also Egypt, Zaire, Angola and Cameroon import substantial amounts.

### *3.7 World market*

There are well established markets for fish meal and oil and Namibia should have no problem in selling its produce, which, when fully developed, will represent only a very small part of present total world exports.

Namibia will also be able to find export markets for hake and other white fish, primarily as whole fish (headed and gutted) and frozen fillets.

It may be more difficult to develop new markets for horse mackerel for human consumption. Increasing amounts are, however, consumed in African countries as noted above.

Likewise, difficult to sell in much larger quantities will probably be canned pilchard. If the pilchard stock is allowed to recover, as assumed in this report, future catches may reach 250 000 t yearly. If the larger part (60 %) of these catches were canned, production may theoretically reach 10 million cartons a year, which is equal to one fifth of total world production today. It is uncertain that there would be a demand for this additional amount, even if new markets were developed. Even this amount will be substantial by world standards and Namibia will have to adhere to strict quality standards in order to develop and maintain such a share of international markets.

## 4. FUTURE STRUCTURE OF THE FISHING INDUSTRY

In Namibia, except Walvis Bay, Lüderitz and sport fishing, particularly in Swakopmund, there are no other permanent settlements along the coast where fishing is undertaken or combined with agriculture as the coast itself is a desert along its entire length. Therefore, small-scale fisheries to a great extent will not be viable ; in the situation, where fish is plentiful, the major fisheries have to be more industrially organized. Small-scale operations may not be profitable at all.

### *4.1 Inshore pelagic fisheries*

For pilchard and anchovy, no realistic alternative to purse seining exists and this method of fishing is probably also superior one for horse mackerel fishing in the shallow inshore waters. Both during the medium- and the long-term periods there will be a fish meal and oil industry based on anchovy and horse mackerel.

### *4.2 Offshore trawl fisheries*

Trawling is probably the only rational fishing method for exploiting the hake resources. Assuming that Namibia in the long run will try to develop her own land-based processing industry, the vessels needed for hake fishing will not be large freezer factory trawlers of the types and sizes until independence fishing off Namibia. What is required are trawl fishing vessels capable of efficient operation in the required depth range and with suitable facilities and storage systems for handling and transportation the fish back to Namibian ports in prime condition.

The extent to which freezing facilities need to be extended in the case of white fish decisively depends inter alia on whether preference is given to land or sea freezing.

The resource base, the scarcity of natural harbours, the absence of a coastal artisanal fishing sector, and the absence of an important domestic fish market, all point in the direction of industrial processing of the resources. Sustained yields of up to 250 000 t of pilchard and 350 000 t of hake should without doubt support industrial food processing methods and modern mass production technologies, regardless of the activity being carried out at sea or on land. This will tend to a vertically integrated organization scheme (same companies owning/managing boats, plants and marketing) in the future fishing industry.

The precise product mix will depend on a variety of factors too complex to predict with any certainty. The type of fish is the most obvious restriction : hake is best suited to processed frozen products, snoek to drying and salting, pilchard to canning, anchovy only to fish meal. The greatest flexibility lies with horse mackerel, which may be reduced or frozen.

The main products from a fully developed Namibian fish processing industry will be : fish meal, fish oil, canned pilchards, frozen hake fillets, round frozen hake, horse mackerel and other pelagic and demersal species.

In the present market situation there is a demand for all these products, although it may be easier to sell some products than others. Marketing of fish meal and fish oil should not be difficult. On the other hand, marketing frozen horse

mackerel in blocks, taking costs of transport into consideration, may be more difficult. For certain products Namibia will have a considerable potential. This will especially be the case in canned products based on pilchard. It is not likely that Namibia can utilize its full potential of pilchard for canned products only. The alternatives are fish meal and fish oil. The various frozen products of the demersal species will never take a big share of the world market.

The existing processing capacity will be sufficient to handle the estimated short- and medium-term pelagic catches. White fish processing presents far greater difficulties. The capacities are well below the maximum medium-term projections for horse mackerel (frozen blocks) and hake (headed & gutted, fillets and prepared foods) respectively.

Plant operation basing on a single species is entirely dependent on its fluctuations in availability. Pilchard may prove to be the only species for which large-scale canning is commercially viable ; but horse mackerel may be marketed both frozen as wet fish and reduced to meal and oil. Since anchovy, the staple supply to the reduction plants, is far more volatile than hake, the main white fish species, the principal advantage of fleet flexibility would be to enable the former to turn to horse mackerel whenever anchovy was in short supply.

A national Namibian fishery sector will have to establish fleet and processing structures of largely the same types which exist today. In addition, to reap the full benefit of a long-term potential they will have to extend the white fish sector considerably both at sea and on shore.

The fact that both pilchard and horse mackerel may be reduced to meal and oil give Namibian investment planning flexibility to adjust to changing market conditions.

## 5. FISHERY POLICY OBJECTIVES

### *5.1 The role of fisheries in the national economy*

During the 1960's and early 1970's the fishery sector was a relatively important part on the Namibian total economy. Fishery products represented close to 25 % of total exports in the mid-1970's and the fish processing industry was the most important manufacturing industry. Total employment in the sector was up to 11 000 workers and fishermen.

With the collapse of the pelagic fishing in the Namibian Sea and the closure of several processing plants the importance of the fishery sector was drastically reduced. In the late 1980's the gross value of output from the fishery sector can be estimated at around R 280 million. Fish products thus represented between 5 and 10 % of total exports and the sector contributed around 3 to 4 % of GDP. Total sector employment could be estimated at around 4 000-5 000 persons during the season, but only a few thousand on a more permanent basis. Many are employed on seasonal contracts only. Whilst the shore based labour force consists mainly of migrant workers from northern Namibia, few non-white workers have been employed in responsible positions either at sea or ashore.

The offshore trawl fisheries never contributed more than insignificant amounts (some servicing of fleets in Walvis Bay) to the Namibian economy. The landed value of the annual catches in the late 1980's was around R 500 million and these values could be substantially increased by processing in Namibia.

The Namibian Government is faced with a variety of options with respect to objectives of fisheries development :

- Optimal Management of the renewable natural resources
- Increasing domestic food supply
- Creation of employment
- Contribution to national income
- Earning of foreign exchange through exports
- Increasing influence and participation of Namibians in the economy

## 6. SHORT- AND MEDIUM - TERM TASKS OF FISHERY POLICY

### *6.1 Research and surveillance*

The volatile nature of the aquatic environment, its biological processes and fluctuating production levels necessitate a permanent research and the introduction of measures aimed at the recovery of the overfished populations in order to ensure an optimal utilization of the resources in the short, medium and long-term.

This is basic prerequisite for fishery management and its decisions regarding protection, conservation and utilization of the stocks. Considering the complexity of the research field and the technology required, no quality research is possible without the very basic facilities such as an adequate research vessel, specialized equipment and well-qualified research personnel.

The setting up of an effective inspection service to supervise fishing legislation within the 200 nautical mile zone, which encompasses an area of almost 500 000 sq. km is not finished until today. Furthermore, this requires several vessels, perhaps aircraft too, and definitely a modern communications system.

### *6.2 Administrative provisions*

Prior to 1984 the administration of the fisheries sector of Namibia formed part of the South West Africa Administration based in the Republic of South Africa. By that time control of the sector was partly transferred to the Administrator General based in Windhoek. In 1986 measures to Namibianise the inshore pelagic fishing industry were introduced by the administration in Windhoek. The stated purpose of these policies was to increase Namibian participation in the fishery sector as workers, managers and owners, to increase income accruing to Namibia from the fisheries, and to ensure that part of the profits were reinvested in Namibia.

These measures led all companies to establish registered offices in Windhoek or Lüderitz, and to sell part of their shares to Namibian residents. Also, all vessels fishing under licence from the Windhoek administration were entered in a registry of fishing vessels kept at Lüderitz.

These arrangements were maintained by the Namibian Government in the first years after independence. In principle under this system the fish caught in Namibian waters remain the property of the Namibian registered companies that "rent" the facilities in Walvis Bay for processing, until the finished products are sold through Namibian-registered marketing companies. Both companies and vessels registered in Namibia are taxed by Namibia, while only the value of processing is taxable in Walvis Bay. Partly as a result of these measures (but also because of good catches), the revenue collected from the fisheries sector increased.

According to provisions implemented by the previous Windhoek Administration in 1986, no commercial catching and/or processing of Namibian fish could take place without a concession from the authorities. Under this system a concession was granted for a period of 7 years. A fishing vessel can only be licensed to fish through individuals or companies possessing a concession. As a result of a Cabinet Resolution of January, 1991, all present concessionaires and licence holders in the fishing industry must apply anew.

Before independence, quotas were allocated to concessionaires on the basis of a proposal from the Directorate of Sea Fisheries to the Administer General. The proposal for a quota allocation was given according to a set of guidelines taking into consideration such factors as :

(i) The special expertise and experience of and/or standard or research done by the applicant as regards the resource,

(ii) the applicant's compliance with legislation and regulations,

(iii) the extent of direct interest in investing or opportunity for direct participation for bona fide Namibian residents to invest in the applicant's enterprise,

(iv) the applicant's investment in the fishing industry of Namibia,

(v) the extent to which the applicant has invested his profit/tax deduction in economically productive industries other than the fishing industry in Namibia, and the nature of such investments.

Since independence, the quotas have been decided upon by the Ministry of Agriculture, Fisheries, Water and Rural Development, and afterwards by the Ministry of Fisheries and Marine Resources. A quota system for horse mackerel was introduced in addition to those for hake, pilchard and rock lobster.

In June, 1990, a new quota levy was introduced for the catching of hake and horse mackerel, only. The basic idea of the system is to ensure income to the Namibian Government from the fish resources and at the same time give incentives for Namibianization of the industry. A rebate is therefore allowed depending on the extent of Namibian shareholding, processing, and employment. In addition, a smaller research fee is levied on all fish catches.

The main objective for licence and quota system is to limit and control fishing for resource management purposes. In addition, the quota allocation system has more recently been used in order to increase Namibianization of the sector. While the main purpose of the quota (and research) levy is to increase Government incomes from the exploitation of a common natural resource, a system of rebates has been introduced in order to give more incentives to Namibianization.

This system regarding licensing of processing plants, the setting of overall quotas and allocation of these among concessionaires based on a number of criteria, and the new system of quota levies and rebates was very difficult to operationalise. The system of allocating yearly quotas on the basis of various performance criteria is complicated to operate, and may not lead to the intended results. The objective of stimulating Namibianization may therefore instead be obtained through exercising preferences in giving or renewing licences, and economic incentives through levies and rebates. While keeping with the objectives of these measures, improvements and adjustments were necessary in order to make them more effective, less complicated to implement, and reduce unintended effects.

It is common practice in many countries to put the main emphasis of fishing regulation on the licensing of vessels and to allocate fishing quotas only to owners of licensed fishing vessels. This create a clear link between fishing efforts and the regulation of fishing, and gives all vessel owners an equal opportunity to obtain quotas. However, there will be a need to regulate carefully the number of vessels licensed, and to distinguish between Namibian, foreign and "mixed"-vessels, e.g. having a mixed Namibian/foreign crew and mixed ownership. Preference when applying for licences should first be given to Namibian vessels. Secondly, "mixed" vessels may be considered, provided that the number of Namibian vessels is not sufficient. Only if the total number of Namibian-registered vessels (including "mixed" boats) is not sufficient, will there be room for chartered or other foreign vessels, on a year-to-year basis. A licence to a "Namibian vessel" may be given on a long-term basis, possibly for a period of approximately 10 years, renewable. "Mixed vessels" may be licensed for a period of 5 years, renewable if there are not sufficient "Namibian vessels". Furthermore, a fishing licence (concession) will only be given to companies, individuals or groups owning a vessel, and the licence will be linked to a particular vessel. All new applicants must therefore either own a vessel or present a clear plan on how to acquire one.

If the above system of licensing is introduced, it may be reasonable to allocate the yearly fishing quotas among the concessionaires having "Namibian" or "mixed" vessels on the basis of certain technical characteristics of the vessel such as size.

In principle there should be no need to control or licence fish processing plants, as this could be left to the free market. Furthermore, there will no longer be a need for allocating yearly processing quotas among the plants. The present double quota system (for pilchard) may represent an additional check and control, but has not proven effective. At the same time it limits competition among companies and boatowners. It would be preferable if fishing quotas are allocated to vessel owners, so that individual boatowners will be free to deliver to any processing company.

### *6.3 General considerations in granting fishing rights*

The granting of fishing rights and the annual allocation of quotas, i.e., the differential shares of the Total Allowable Catch (TAC) should be based on the following considerations :

(i) Fishing vessel, registered and owned locally and flying the Namibian flag ;

(ii) Investment and participation opportunities afforded to Namibians (equity participation)

(iii) Level of fish processing in land-based plants promoting value-adding ;

(iv) Creation of jobs opportunities ;

(v) Establishing wage systems for employees which are partially independent on the quantities caught or processed ;

(vi) Training of and housing, medical and pension schemes for employees ;

(vii) Investment of profits in Namibia.

A concession (fishing right) should be a medium or long-term right to catch fish and the duration should be sufficient as to allow time for a reasonable planning. Investment in the marine fishery is usually highly capital intensive and need an acceptable assurance of protection of the rights granted to him for at least a reasonable period of time (5-10 years).

### *6.4 Size of quotas*

The size of quotas should on the one hand enable a concessionaire to be economically viable in the specific fishery sector and should on the other hand avoid mere speculation with the fishing rights without any intention to participate in the fishing sector. The fishing rights (and quotas) should be allocated only to such persons which are willing and able to start catching (and processing) immediately, at least a substantial share of their quota.

The size of the TAC-shares will differ in the different sub-sectors of the fishing industries.

### *6.5 Levies*

It is becoming more common in many countries to charge a "resource fee" for the use of natural resources. It is also a fully acceptable practice in fisheries to charge a licence fee for foreign fishing. Also for national fishing, the resource represents a value. Since taxing may sometimes prove difficult, a levy will be a more effective form of taxation.

In the past a special quota levy was charged in respect of hake and horse mackerel only, while a smaller research fee was levied on all catches. For the quota levies, rebates were given on the basis of whether the fish was processed on land or not ; for employment of Namibian fishermen on the vessels ; and for ownership participation by Namibians. This system for assessing these factors was difficult to control and in particular the definition of land processing was incomplete, and may lead to distortions.

The new established system is now using simpler criteria in order to give economic incentives to Namibianization of the fishing operations : differential levies for Namibian, "mixed" and foreign vessels, as described above. While the differentiation between national and foreign vessels is quite common also in other countries, the "mixed" category is innovative, but could well be justified in the Namibian situation. Now, there is a model which includes a basic levy for Namibian ships and a surcharge for "mixed" and foreign boats of 50 respectively 100 %.

Furthermore, there was a rebate for land processing, with the objective of stimulating employment in Namibia. This rebate was mainly relevant for hake and other white fish, since for the small pelagic (pilchards and anchovies) there is no real alternative to land processing (canning and reduction). For horse mackerel there may exist alternatives, but today this resource is so abundant that there is no effective quota for the Namibian based inshore vessels. In any case it may be more important to stimulate whole freezing of horse mackerel, which produces a more valuable product, than reduction to fish meal and oil, regardless of whether this is land-based or not.

For hake and other white fish, however, there is a justification to stimulate processing on land, especially if this involves labour-intensive manual filleting. At present most of the catches are frozen (headed and gutted) on board the freezer-trawlers, and exported without further processing. From a Namibian point of view, it will be more beneficial if processing is undertaken on shore, and a rebate on the levy is therefore one option for stimulating this.

For pilchard it might be important to stimulate further the delivery of the catches for canning which is more employment creating than reduction. One possibility is therefore to establish a higher levy for pilchard, to make it less economical to deliver it for reduction.

Now, the current trawling quota levies are :

| | | | Rands/ton |
|---|---|---|---|
| Hake | | Basic levy | 400 |
| | Namibian vessels | | 400 |
| | "Mixed" vessels | + 50 % | 600 |
| | Foreign vessels | + 100 % | 800 |
| Horse mackerel | | Basic levy | 50 |
| | Namibian vessels | | 50 |
| | "Mixed" vessels | + 50 % | 75 |
| | Foreign vessels | +100 % | 100 |

On hake there is a rebate of R 200 per ton if the fish is landed for filleting, but there are no rebates on horse mackerel.

Pelagic quota levies are :

| | | | Rands/ton |
|---|---|---|---|
| Pilchard | | Basic levy | 100 |
| | Namibian vessels | | 100 |
| | "Mixed" vessels | + 50 % | 150 |

No foreign flag boats are allowed and there are no rebates on the levies.

The basic level of the levies should be adjusted from time to time, taking in account the value of the fish, but also factors regarding catch rates, cost structures, and the profitability of fishing operations. In most cases the basic level will vary between 5 and 15 % of the first-hand value. The system of rebates and surcharges should be more permanent.

In principle, all quota-regulated fish should be covered by a levy system, while species for which there is free fishing should not require any levy.

The levy must be charged on the quotas allocated, without regard to the volume of fish actually caught, i.e. they are to be paid every month during the season, whether or not fish has been caught. This will therefore not provide any additional incentive to underreporting. It will also give concessionaires an incentive not to apply for higher quotas than they actually catch.

The granting of licences to foreign vessels to fish the "surplus" quantities which cannot yet be fished by the Namibian fleet could be linked with rights of access to foreign markets (e.g. Spain, Portugal) for Namibian fisheries products ; a granting of licences should at any rate be linked with the training and promotion of Namibian fishermen and scientific personnel.

## 7. OUTLOOK ON THE FUTURE NAMIBIAN FISHING INDUSTRY

With proper supervision of both inshore and deep-sea fisheries, comprehensive conservation, population research and reinvestment in trawlers and processing factories, Namibia could again sustain one of the world's most important fishing industries. Namibian fish, since it is widely available and easily stored, could supply major part of the nation's protein requirements. Fish meal is a valuable feed for stock farming. Since internal consumption would probably account for a relatively small proportion of the total catch, a fully developed industry could be one of Namibia's major export earners.

# The Welfare Impact of Improved Boat Modernisation Schemes (IBMS) in Pemalang Regency, Central Java - Indonesia

**Indah Susilowati** *

Faculty of Economics Diponegoro University, Jl. Erlangga Tengah 17, Semarang 52241, Indonesia

ABSTRACT

*The open market fish model was developed to investigate the factors affecting supply and demand of fish in Pemalang Regency. Furthermore, based on the estimated supply and demand functions the Producers Surplus (PS) and Consumers Surplus (CS) as a welfare measurement of IBMS were estimated. The findings indicate that the IBMS was ineffective to enhance the welfare of Pemalang Society.*

## 1. INTRODUCTION

Agriculture plays an important role in the Indonesian economy. It contributed 24.09 percent to Gross Domestic Product (GDP) and 55.80 percent to employment in 1988 (BPS, 1989). Among the agricultural sub-sectors, the fishery contributed 1.70 percent of the total GDP. Nonetheless the number of people involved in the fisheries sector reached 1.3 million people excluding those engage in the processing plant in 1986 (Martosubroto, 1987).

Fish is the primary source of animal protein. It provides 67 percent of animal protein of the total Indonesian diet, whereas meat, milk and egg contribute 21, 7, and 5 percent respectively (Naamin, 1987). Moreover, it is relatively cheaper compared to other source of animal protein. In capture fisheries, the general impact of government credit schemes has been the modernisation of fishing fleets. To commensurate with the modernisation efforts to enhance production and productivity of traditional fishery, some of the alternatives taken by the Indonesian government were : the introduction of boat modernisation schemes, fishing gear improvement and diversification of multi-gear usage to ensure the continuity of operation throughout year. In consonance to the call to modernize the fishery sector in the country, the fishery authority

* This paper is a part of the master thesis of the author.

I would like to ackowledge Dr. Nik Mustapha Raja Abdullah, at the Faculty of Economics and Management, Universiti Pertanian Malaysia for his useful comments.

of Pemalang Regency, the study area of the research, has chosen the same alternatives as laid out by the central authority, namely through the Improved Boat Modernisation Schemes (IBMS). This programme basically involves providing fishermen with the fishing credit schemes. It is expected that production and productivity will be increased and the fishery industrialization may be achieved much faster.

In Pemalang Regency, the provisions of IBMS which started in 1982, are handed to the fishermen in the form of a package through credit schemes. The report of PELITA IV of Pemalang Fishery Office [1989] observed that the IBMS programme has been working very well since then. This may be due to the fact that fishermen in Pemalang are relatively more responsive to new technologies compared to fishermen in other regions in Central Java. To some the programme is treated as an upgrading of the existing fishing method and to date IBMS has been widely diffused among the fishermen in this Regency (Annual Report of Fishery Office, 1989).

## 2. STATEMENT OF THE RESEACH PROBLEMS

Fish serves as an important source of protein to Indonesian people (providing 67 percent of total animal protein to the Indonesian diet). The current per capita fish consumption in Pemalang Regency of 12.10 kg per year however is still below the national target of 18 kg. Subsequently, to achieve the national target per capita fish consumption has to be increased by 48.76 percent.

It was reported that the minimum requirement for Indonesia averages about 29.5 kg fish per capita per year (Monintja, 1982). Therefore the attainment of high level of sufficiency in fish production has become a major agenda in the development policy. Consequently, a range of programmes to promote increase fish production have been implemented, and one of them is the IBMS.

Improvement of the fishery sub-sector in Pemalang Regency is important since it is characterized by a relatively high level of poverty. In addition, there are about 18,149 fishermen consisting of 56.53 percent marine fishermen and 43.47 percent in inland fishermen in Pemalang Regency. The marine fishermen are basically small-scale operators with low production and productivity (Yamamoto, 1987). Reduction of poverty among marine fishermen has therefore become an important agenda in the development planning of the Pemalang Regency. Invariably, the main objective of poverty reduction policy is to increase the income of fishermen through higher productivity.

Being small-scale fishermen constrained by capital, skill and traditional psychology (Budiono, 1974), it is difficult to improve their productivity. Furthermore, their operations are limited by the traditional technology (gears and boat mechanic) and concentrated in the nearshore fishing grounds which are mostly overexploited. Concomitantly, the production and productivity are not enhanced.

The offshore pelagic and demersal resources offer the best hope for increasing marine production. To reach these fishing grounds, boats must be provided with engines and appropriate equipment (Bailey, 1987). In compliance with these suggestions, the government has issued the Improved Boat Modernisation Schemes (IBMS).

The IBMS is expected to enhance the income, productivity and employment opportunities of fishermen, and at the same time, it also aims at providing sufficient nutrition to the society. Several questions then arise : Is the economic performance of IBMS commensurate with the objectives envisaged ? What is the overall impact of the IBMS programme ? What are the welfare gains to fishermen and consumers ? Does it increase net social welfare or otherwise ? These are some of the questions which have not been fully answered and which need immediate answers.

Unfortunately, very little research work have been conducted in this field, therefore it is a timely attempt in this study to obtain a deeper understanding of the impact of IBMS on the society as a whole.

## 3. OBJECTIVES OF THE STUDY

Overall, this study examined the net welfare impact resulting from the IBMS programme in Pemalang Regency. The scope of this study can be narrowed down as follows : firstly, it examines factors affecting the structural supply and

demand of fish pre-IBMS and post-IMBS. This is followed by the estimation of the elasticity of structural parameters of the supply and demand of fish. Finally, this study attempted to evaluate the distribution of welfare gains/ losses and a change of the net social welfare/ losses that resulted from the IBMS implementation.

## 4. PREVIOUS STUDIES

There are several approaches to estimate the welfare impact and they include the utility approach and /or the surplus approach. This study will adopt the later approach. The surplus concept, is relatively closer to the market situation which in general can be represented by producers and consumers surplus. The estimation of welfare impact involves estimating the supply and demand functions as well as the interaction between the two.

Posadas (1985) carried out a research on fish consumption in Iloilo, Philippines using OLS as an analytical tool of multiple regression. Meanwhile, Yeoh (1975) employed OLS, 2SLS, and 3SLS estimating techniques in evaluating the net welfare of producers and consumers and market intermediaries in the frozen Concentrate Orange Juice (FCOJ) in Florida. Furthermore, the similar technique was adapted to measure welfare changes that result from changes in regulation on trawler fisheries in the Gulf of Thailand (Janekarnkij, 1986). The same technique which accordingly modified also be used to estimate the welfare gains/ losses from fishing modernisation schemes (Susilowati, 1991). Moreover, the later technique will be adopted in this paper and will be discussed in the following sections.

The estimation techniques mentioned above have also been commonly used in other fields to measure the welfare impact of the imposition of various types of policies (Adam *et al.* (1977), Frech *et al.* (1980), Olson *et al.* (1984), Foster *et al.* (1986), and Khalid (1989)).

## 5. METHODOLOGY

In this section the welfare of fishermen (as producers) and fish consumers in the Pemalang Regency will be estimated. The net social benefit of Improved Boat Motorization Schemes (IBMS) was evaluated using Producers' Surplus (PS) and Consumers' Surplus (CS) measurements. These surplus estimations were obtained from the structural equations of supply and demand functions of fish. The welfare impact of a change in supply of fish in the market as a consequence of the implementation of IBMS policy was then examined.

The fish consumption pattern did not fluctuate very much during the period (1976-1990) covered in this study. Therefore, the demand of fish was assumed to be quite stable. Only the supply of fish has a direct effect from change in technology.

Several assumptions are made in this study : (1) the fisheries is assumed to be operating in a perfectly competitive market, wherein many producers as well as consumers in the fish market and boat operators are profit maximizers ; (2) there exists open-access fisheries ; (3) only path independence analysis where a change in single price is allowed, and finally (4) there is constant marginal utility of money (change of gains or loss of PS is equivalent to the change of CS).

## 6. MODEL CONSTRUCTION AND DATA REQUIREMENTS

### *6.1 Model Construction*

The quantities of fish supplied and demanded are related to the same price of fish in the market. The determination of the market price of fish stipulates the jointly dependent variables between the quantities of fish supplied and demanded in the open market. Therefore, a simultaneous equation model is developed to examine the factors affecting both supply and demand of fish in the market.

Data for the variables in the best fit model were first standardized into the deviation transformation using the following formula :

$$X_{ij}^{ST} = (X_{ij} - AX_{ij}) / \{ {}^{1}E(X_{ij}-AX_{ij})^2 \} \quad (1)$$

where :

$X_{ij}^{ST}$ = Standardized variable of $X_{ij}$

$AX_{ij}$ = Arithmetic mean of $X_{ij}$

This transformation was done to eliminate the econometric problem such as multicollinearity which may occur in the model. Thereafter, the models employed for the empirical study are given below.

(1) Supply : LTIQS = f(LTPFI,LTIFE,LCP1,$LTIQS_1$) (2)

(2) Demand : LTIQD = f(LTPFI,LTIPS,$LTPFI_1$ ,$LTIQD_1$,LTIY) (3)

(3) Identity : LTIQS = LTIQD (4)

The definition of variables after standardisation is given in Table 1. Furthermore, this model is also used in the welfare estimation in this study.

Equation [2] expresses the behaviour of fish production which is supplied in the market. The quantity of fish supplied (LTIQS) is hypothesized to be a function of current price of fish (LTPFI), fishing effort (LTIFE), probability to catch fish (LCP1), and the quantity of fish caught in the previous period ($LTIQS_1$). While, the quantity of fish demanded (LTIQD) is hypothesized to be a function of its own price (LTPFI), price of other commodities which can either be a substitute or complement (LTIPS), lagged own price ($LTPFI_1$), lagged quantity of fish demanded ($LTIQD_1$ ), and consumers' income (LTIY).

The model used in this study comprises of three equations, two of which are stochastic and one is an identity equation. In this case, the model consists of 9 variables of which 3 variables are endogenous and 6 variables are predetermined/ exogenous. The LTIQS, LTIQD, and LTPFI as endogenous variables are interdependent (jointly dependent).

### *6.2 Data Requirements*

Quarterly data on fish production, fish consumption, prices of fish, fishing effort, probability to catch fish, price of substitute/ complementary goods and average income before and after IBMS were gathered from the statistics and report from the Pemalang and Central Java fishery and Indonesian Statistical Bureau (BPS) offices for estimation purposes. The relevant data before IBMS started from the second quarter of 1976 to the fourth quarter of 1981, while for the after the IBMS covered the period from the first quarter of 1982 to the second quarter of 1990. These data were aggregated by Geometric Index (GI) method as discussed by Hutabarat (1987).

## 7. ESTIMATION PROCEDURES AND STATISTICAL CONSIDERATION

### *7.1 Estimation Procedures*

#### 7.1.1 Estimation of Structural Supply and Demand Models

The Two Stage Least Square (2SLS) technique using single equation approach with Principle Component (PC), was used to develop structural supply and demand models before and after IBMS.

In utilizing the simultaneous equation method, the model was first checked for identification problem. It was found to be overidentified. Subsequently, the Chow test proved that the estimated relationships before and after IBMS were significantly different. Therefore the sample was divided into before ($N_1$=22) and after ($N_2$=34). The test of

autocorrelation using the Run test showed the absence of autocorrelation problem in the supply and demand models. However, multicollinearity was discovered after diagnosing the correlation coefficient matrix of the demand model. Eventually, the multicollinearity problem was mitigated by estimating the 2SLS with PC method. Lastly, the validity for forecasting performance of the estimated best fit model was examined using Theil's inequality coefficient (U) and Root Mean Square (RMS) prediction. The estimated models were found to have good predictive ability, either in terms of overall models, or equation-wise.

The model was estimated using the data in terms of nominal values (original data), deflated values, and indexed values which were in linear and log-linear forms. However, it was found that the indexed data in the log-linear forms gave the better fit than the others.

### 7.1.2 Determination of Welfare

By simplifying the structural supply and demand functions derived from the best fit model to the form of quantity-price relationships {Q=f(P)}, the derivation of the equilibrium price and quantity in the market can be derived as follows :

$$\text{Supply} : QS = a_0 + a_1 P \quad (1)$$

$$\text{Demand} : QD = b_0 - b_1 P \quad (2)$$

where :

QS, QD = quantity supplied and demanded at price P

$a_0$ , $b_0$ = intercept for supply and demand functions

$a_1$, $b_1$ = slope of supply and demand functions.

$a_1 \geq 0$ and $b_1 \leq 0$

At equilibrium point, QS = QD and the values of equilibrium price (P*) and quantity (Q*) will be :

$$P^* = \frac{b_0 - a_0}{a_1 + b_1}$$

$$Q^* = \frac{a_1 b_0 - a_0 b_1}{a_1 + b_1}$$

In order to calculate the PS and CS, the supply and demand functions should be in the inverse form of P = f (Q) as follows :

$$\text{Supply} : P = -\frac{a_0}{a_1} + \frac{QS}{a_1} \quad (1)$$

$$\text{Demand} : P = \frac{b_0}{b_1} - \frac{QD}{b_1} \quad (2)$$

The supply and demand functions in this model were not in the linear form, therefore, integral calculus approach to compute PS and CS seems to be the much more appropriate. The welfare derived from PS and CS which is accruing to society is given by the NSW which is equal to PS plus CS :

$$NSW = PS + CS$$

(1) When $a_0 \geq 0$

$$NSW = P^* Q^* - \int_{Q=0}^{Q=Q^*} (Q_S)\, dQ_S + \int_{Q=0}^{Q=Q^*} f(Q_D)\, dQ_D - P^* Q^*$$

(2) When $a_0 < 0$

$$NSW = \int_{P=0}^{P=P^*} f(P_S)\, dP_S + \int_{Q=0}^{Q=Q^*} f(Q_D)\, dQ_D - P^* Q^*$$

However, the estimated structural supply function has a $_0 < 0$, and consequently the later formula will be utilized to compute the NSW.

### 7.1.3 Statistical Consideration

Hypothesis testing in 2SLS is complicated by the unknown distributions. This causes the normal t- and F-tests as well as the coefficient of determination ($R^2$) to be invalid because they lack empirical content in simultaneous model. The F-test from the analysis of variance table is also invalid (White *et al.*, 1989). Therefore, in this study the standard error of the estimated parameter was used as the basis for hypothesis testing. Accordingly, if the respective coefficient is greater than half of its standard error value, the null hypothesis (estimated coefficient of parameter is not significantly different from zero) will be rejected. Based on this criterion, it can be concluded that there is a significant relationship between the independent and its dependent variables, *ceteris paribus*. Moreover, the statistical result which has highest numbers of significant variables in the equation, the smallest standard error, and coincidence of its parameters' signs with a priori expectations could be considered as the best fit model.

## 8. RESULTS AND DISCUSSION

The statistical results indicated that the significant level of estimated parameters in the supply were fairly good as shown in Table 2. All variables specified in the model obtained the expected signs for both before and after IBMS. For the supply model, the respective coefficients of all variables are greater than half of its standard error except for fishing effort (LTIFE) and the probability to catch fish (LCP1) before and after IBMS. The supply model was positively sloped with respect to its own price which is consistent with the classical economic theory. This implies that fish supply increases as factor input is added to the production process, *ceteris paribus*. However, the rate of increase in fish production which is brought about by additional input is diminishing.

The 2SLS with PC improved the estimated demand model (using conventional method) in that the sign of the price of fish variable (LTPFI) was as expected while many other variables became more significant. The negative relationship between price of fish and its quantity demanded are also consistent with the economic theory for both before and after IBMS periods as explained by Table 3. The estimated coefficients of all variables are greater than half of its standard errors except for the intercept before and after IBMS and the lagged of quantity supply before IBMS.

The estimation results indicate that The LTIPS and LTIY formed the major determinants of the quantity of fish demanded throughout the study period. The elasticity of the fish demanded with respect to its own price is greater (-0.676) at post-IBMS than at pre-IBMS (-0.295). Implicitly, consumer will tend to consume more fish when the price of fish decrease during the post-IBMS than during pre-IBMS. On the contrary, when the price of fish increases, consumers will decrease their consumption of fish by a greater amount at post-IBMS than at pre-IBMS.

The signs of the estimated coefficient for other commodities (substitutes and complements) were positive. This indicates that the other commodities in this demand model are substitute goods. Lastly, the income elasticity of demand for fish tend to be more elastic before IBMS (0.740) than after IBMS (0.580). This observation indicates that fish is not capturing consumers dollars when income increases. As income increases people tend to spend more on non food items such as clothing, housing, and others. This in fact supported the belief that fish is indeed inferior compared to other goods.

The welfare analysis showed that the IBMS programme was ineffective to augment fish production in Pemalang Regency as indicated in Table 4. The IBMS programme has caused the welfare loss to society amounting to about 142.86 percent from the original situation (pre-IBMS). The larger portion of loss (about two-third) was incurred by consumers while the remainder loss was suffered by producers. The results revealed that consumers consistently lose while the producers always gain but in decreasing amount.

## 9. CONCLUSIONS AND POLICY IMPLICATIONS

### *9.1 Conclusions*

All variables specified in the supply model had expected signs and significant except for the fishing effort and the probability to catch fish. As expected the supply function was found to be positively related with respect to its own price.

At the same time, the demand model had negatively slope with respect to its own price and all of the signs of estimated parameters were consistent with the theory except for the lagged price of fish variable.

The welfare analysis showed that the IBMS programme was ineffective. The overall impact showed that welfare loss to the society was 142.86 percent from the original condition. The biggest loss (two-third) was incurred by consumers and the remainder was incurred by producers.

### *9.2 Policy Implications*

Based on the findings of this study, the following policy implications and recommendations could be considered by the relevant authorities in order to improve the welfare of fishermen and consumers, as well as to maintain resource sustainability in Pemalang Regency.

#### 9.2.1 Fisheries resource management

The availability of relevant information is one of the basic requirements needed for effective fisheries management. At present, however, biological, technical, economic or even social information on the fisheries sector is very limited in Pemalang. Therefore, upgrading of the information or statistics related to resource management is very urgently needed for Pemalang fisheries. Beside improving the fisheries database, more effective enforcement in monitoring, control, and surveillance of resource utilisation are also needed, particularly when the resource is near or at the threshold condition like those in Pemalang.

#### 9.2.2 Implementation of the IBMS

Most fishermen in the study area lacked alternative employment opportunities in non-fishing sectors. At the same time, the IBMS so far was not successfuly implemented in Pemalang Regency due to the fact that the nearshore resource was overfished. Moreover, the schemes were distributed with the same instrument package to the target group. It is therefore recommended that the government or private creditors to diversify the schemes by providing different packages of engines, gears or type of boats to the recipients. Also, the creditors should extend this type of schemes to the large scale operators for deep sea fisheries which is still underutilized. This effort will not only encourage the commercialisation of the fisheries sector but also helps ease off the pressure on the nearshore fisheries resources in this region.

#### 9.2.3 Extension and training

The provision of extension/ training to upgrade the potential human development of fishermen on skill, mentality and psychology aimed at reducing their dependency on the fishery sector should be accelerated. Furthermore, this activity is

addressed to provide the alternative income sources or employment opportunities to fishermen. Similar recommendations for improving fishermen livelihood were also outlined by previous studies (Panayotou, 1985 ; Smith, 1979 and 1981 ; and Budiono, 1974).

### 9.2.4 Enhancement of fish marketing/ distribution and post harvest handling of fish

These are also recommended to improve the consumers and fishermen welfare. Not only will fishermen get better price for their products but also to provide consumers a better quality of fish with a reasonable price.

## REFERENCES

**Adam D.M., R.W. Haynes and D.R. Darr** (1977). "A Welfare Analysis of Long-Term Forest Products Price Stabilization." *American Journal of Agricultural Economics* , Vol. **59**.

**Bailey C., A. Dwiponggo and F. Marahudin** (1987). Indonesian Marine Capture Fisheries. Jakarta : ICLARM, Dirgen.of Fisheries and Marine Fisheries Research Institute.

**BPS** (1989). Statistical Year Book of Indonesia 1989. Jakarta : Indonesian Statistical Bureau (BPS).

**Budiono** (1974). *Pengembangan Masyarakat Nelayan Dalam Hubungannya Dengan Program PELITA II.* Jakarta : Dirjen Perikanan, Departemen Pertanian.

**Foste W.E., L.S. Calvin, G.M. Johns and P. Rottschaefer** (1986). "Distributional Welfare Implications of An Irrigation Water Subsidy." *American Journal of Agricultural Economics.* Vol. **68.**

**Frech H.E. and J.C. Samprone, Jr.** (1980). "The Welfare loss of Excess Non-Price Competition : The Case of Property-Liability Insurance Regulation". *The Journal of Law and Economics.* Vol. **23** (1), April 1980.

**Hutabarat B.** (1987). "An Indexing Attempt of Prices and Outputs of Indonesian Marine Fisheries". In *proceedings of symposium on the Exploitation and Management of Marine Fishery resources in Southeast Asia,* 16-19 February 1987. Darwin, Australia : RAPA and FAO, pp.49-85.

**Janekarnkij P.** (1986). *Welfare Impacts Some Limitation on Trawler Catches and Fishing Effort in the Gulf of Thailand.* M.Sc. Thesis, Faculty of Economics and Management, UPM.

**Khalid Abdul Rahim** (1989). *Trade and Welfare Effect of Unilateral Environmental Regulation : The Case of Malaysian Palm Oil,* Ph.D. Thesis, Urbana Illinois.

**Martosubroto P.** (1987). "The Status of Management of the Marine Fishery Resources of Indonesia. *In proceeding of symposium on the Exploitation and Management of Marine Fishery Resources in Southeast Asia,* 16-19 February 1987. Darwin, Australia : RAPA and FAO, pp.125-131.

**Monintja D. and IPB Team** (1981). "Program Jangka Panjang : Peremajaan Nelayan". *Harian Kompas.* 30 Januari 1981.

**Naamin N.** (1987)."Perikanan Laut Indonesia : Prospek dan Problema Pengembangan Sumberdaya Perikanan Laut", *Seminar Laut Nasional II.* Jakarta, Indonesia, July, 1987.

**Olson C.V. and J.M. Trapani** (1984). "Who Has Benefited From Regulation of the Airline Industry ? ". *Journal of Law and Economics.* Vol. **24** (1).

**Panayotou T.** (1985) *Small-Scale Fisheries in Asia : Socioeconomic Analysis and Policy.* Ottawa, Ont., Canada : IDRC.

**Pemalang, Fishery Office** (1990). *Report of Repelita IV, 1989.* Central Java, Indonesia : Fishery Office.

**Posadas B.C.** (1985). "Fish Consumption in Iloilo : A Consumer Profile and Behaviour Study". Paper presented at the seminar on Small-Scale Capture Fisheries in Ioilo City, 4 December, 1985. UP in the Visayas, Iloilo City, Philippines.

**Susilowati I.** (1991). *Welfare Impact of Improved Boat Modernisation Schemes (IBMS) in Pemalang Regency, Central Java, Indonesia.* M.Sc. Thesis, Faculty of Economics and Management, UPM.

**White J.K. and S.A. Haun, N.G. Horsman and S.D. Wong** (1988). *Shazam Econometrics Computer Program.* McGraw-Hill Book Company.

**Yamamoto T.** (1978). "Broad Classification of Indonesian Marine Fishery for Economic Analysis." In *proceeding of the seminar on Modernisation of Artisanal Fisheries.* Jakarta : 27-30 June, 1978.

**Yeo O.** (1975). *Welfare Gains from Supply Stabilization in the Orange Industry of Florida.* Ph.D. Thesis, the University of Florida.

**TABLE 1.**
**CODE NAMES AND DEFINITIONS OF THE STANDARDIZED VARIABLES USED IN THE MODELS.**

| Code Names | Definitions |
|---|---|
| Endogeous: | |
| LTIQS | Quantity of fish supplied in the open market at period t (in an index) |
| LTIQD | Quantity of fish demanded in the open market at period t (in an index) |
| LTPFI | Aggregated price of fish at period t (in an index) |
| Exogenous/ Predetermined: | |
| LTIFE | Fishing effort, which was proxied from the number of trips of fishing boat at period t (in an index) |
| LCP1 | Probability to catch fish, which was estimated from the frequency distribution of catch at period t (in percentage) |
| $LTIQS_1$ | Lagged quantity of fish supplied in the open market at period t-1 (in an index) |
| $LTIQD_1$ | Lagged quantity of fish demanded in the open market at period t-1 (in an index) |
| LTIPS | Aggregated price of others commodities, namely, meats ( buffalo and mutton ); chicken (hybrid and local); eggs (duck and chicken);and tahu and tempe at period t (in an index) |

**TABLE 1**
**(CONTINUED).**

| Code Names | Definitions |
|---|---|
| LTIY | Income factor, which was proxied from corresponding Gross Regional Domestic Products (GRDP) at period t (in an index) |

Note:
All variables are in the form of log-linear and expressed as an index except for LCP1 which is in terms of percentage. The aggregation method used in analysis is the Geometric Index (GI). In some extent, to compute price aggregation, the GI can be written as follows:

$$P_{i(GI)} = P_{i1}^{ri1} \cdot P_{i2}^{ri2} \ldots\ldots P_{in}^{rin}$$

where : $P_{i(GI)}$ : the price index at period i
$P_{i1}$ : price of good 1 at period i
1,2,..n: kind of goods
ri1 : share (%) of respective price of each good to its total, at period i

**TABLE 2.**
**ESTIMATED SUPPLY MODEL LTQS = L(LTPFI, LTIFE, LCP1, LTIQS1).**

Estimated Supply Model
LTIQS^ = f(LTPFI,LTIFE,LCP1,LTIQS1)

Method 1 : 1/

| Variable Name | Principle Component Used | Estimated Coefficient | Standard Error | Signif.2/ Indicator | Condition 3/ |
|---|---|---|---|---|---|
| Before: | 4 | | | | |
| Constant | | -0.476 | 0.619 | -1.300 | I |
| LTPFI | | 0.224 | 0.227 | 1.015 | U |
| LTIFE | | 0.049 | 0.289 | 5.962 (NS) | U |
| LCP1 | | 0.181 | 0.376 | 2.073 (NS) | U |
| LTIQS1 | | 0.182 | 0.247 | 1.360 | U |
| After: | 4 | | | | |
| Constant | | -0.685 | 0.399 | -0.582 | I |
| LTPFI | | 0.126 | 0.162 | 1.279 | U |
| LTIFE | | 0.025 | 0.131 | 5.315 (NS) | U |
| LCP1 | | 0.005 | 0.156 | 32.297 (NS) | U |
| LTIQS1 | | 0.501 | 0.160 | 0.319 | U |

Notes:
1/ Using Principle Component (PC)
2/ Significant Indicator: (Ratio: Standard Error/Estimated Coefficient)
3/ It was judged by comparing from method 1 with method 0. As a result the significancy becomes: Improved (I) or Unchanged (U)
NS: Not Significant

**TABLE 3.**
**ESTIMATED SUPPLY MODEL LTQS = L(LTPFI, LTIFE, LTPF1, LTIQD1, LTIY).**

Method 1 : 1/

| Variable Name | Principle Component Used | Estimated Coefficient | Standard Error | Signif.2/ Indicator | Condition 3/ |
|---|---|---|---|---|---|
| Before: | 3 | | | | |
| Constant | | 0.109 | 0.794 | 7.290 (NS) | I |
| LTPFI | | -0.295 | 0.341 | -1.155 | I |
| LTIPS | | 0.750 | 0.561 | 0.748 | I |
| LTPFI1 | | 0.268 | 0.170 | 0.634 | I |
| LTIQD1 | | 0.060 | 0.257 | 4.289 (NS) | I |
| LTIY | | 0.740 | 0.559 | 0.756 | I |
| After: | 4 | | | | |
| Constant | | -0.193 | 0.441 | -2.286 (NS) | I |
| LTPFI | | -0.676 | 0.371 | -0.549 | I |
| LTIPS | | 0.742 | 0.407 | 0.548 | I |
| LTPFI1 | | 0.425 | 0.419 | 0.988 | I |
| LTIQD1 | | 0.259 | 0.168 | 0.650 | I |
| LTIY | | 0.580 | 0.293 | 0.504 | I |

Notes:
1/ Using Principle Component (PC)
2/ Significant Indicator: (Ratio: Standard Error/Estimated Coefficient)
3/ It was judged by comparing from method 1 with method 0. As a result the significancy becomes: Improved (I) or Unchanged (U)
NS: Not Significant

**TABLE 4.**
**SUMMARY OF WELFARE ESTIMATION RESULTS.**

| Description | PS | CS | NSW | % Losses |
|---|---|---|---|---|
| Before | PSo: 0.030 | CSo: -0.051 | NSWo: -0.021 | 29.17%[c] |
| % | 100.00% | 100.00% | 100.00% | |
| After | PS1: 0.020 | CS1: -0.071 | NSW1: -0.051 | 70.83% |
| % | 66.67%[a] | -139.22% | 242.86% | |
| Change | #PS: -0.010 | #CS: -0.020 | #NSW: -0.030 | |
| % | -33.33% | -39.22%[b] | -142.86% | |
| Total | | | TNSW: -0.072 | 100.00% |

Note:
# : change
TNSW: Total NSW
a: $\%PS_1 = PS_1/PS_0$
b: $\%\#CS = \#CS/CS_0$
c: $\%NSW_0 = NSW_0/TNSW$

# The Establishment of Chinese Marine Fisheries Laws and their Management Practice

**Guanghua Zhang**

Chinese Academy of Fisheries Sciences, Institute of Fisheries Economics Research,
N150 Quingta Cun, Yongding Road, Beiging 100039 China (PRC)

ABSTRACT

*The chinese goverment has always attached great importance to the establishment and development of marine fisheries laws, in 1986, the state promulgated "FISHERIES LAW", the first law about fisheries ever since the foundation of the People's Republic of China. On the basis of "FISHERIES LAW", a marine fisheries legislation system was formed with six titles : fisheries resources protection and conservation, fisheries management, fishing port superintendence, fishing boat inspection, fisheries telecommunication management and fisheries environment surveillance and protection.*

*Chinese marine fisheries regulations implement the guiding thought of "managing and thriving fisheries with laws", pay attention to advanced experiences of fisheries management in the world and stress the importance of adopting control measures in fisheries management. Between 1955 and 1980, the state stipulated the lines of closed areas for the bottom trawl of marine motor driven fishing boats in the Buohai Sea, the Yellow Sea, the East China Sea and South China Sea, and during the period, the limits for 600 HP fishing boats were also established. Between the years 1979 and 1989, new "REGULATIONS REGARDING FISHERIES RESOURCES PROPAGATION AND PROTECTION" and "TENTATIVE MANAGEMENT MEASURES ON THE ISSUES OF FISHING LICENCES" were issued one after another, and thus the fundamental principles for the protection and development of chinese marine fisheries resources and a system of fishing licensing were established. Thereafter, juvenile fish protection zones and closed fishing areas for the commercially important fish species such as prawn, cutlass fish and big yellow croaker were set up respectively in the Yellow Sea and the East China Sea, and the fisheries resources protection and conservation zones of Xisha and Znongsha were established in the South China Sea. The number of off-shore motor-sdriven fishing boats started to be controled in the 1987. The Buohai Sea has become a region with no trawl nets operation for the whole year round since 1988.*

## 1. THE MAIN CONTENT AND CHARACTERISTIC OF THE CHINESE MARINE FISHERIES LAWS

The Chinese government has always attached a great importance to the establishment and development of marine fisheries laws. In 1986, the state promulgated "FISHERIES LAW", the first law about fisheries since the foundation of

the People's Republic of China. On the basis of "FISHERIES LAW", a marine fisheries legislation system is formed with a content in six respects containing fisheries resources protection and conservation, fisheries management, fishing port superintendence, fishing boat inspection, fisheries telecommunication management and fisheries environment surveillance and protection.

The Chinese government exercises a unified leadership over fisheries management and superintendence and management by levels. In the proceeding of fisheries legislation, the fisheries authority of the state or at the central government level usually decrees significant fisheries legislation as basic law, according to which local governments have formulated specific regulations appropriate for the local conditions. Ever since 1979, various fisheries legislation and legislative documents issued by central government, provincial, regional and county levels approximate over 500 papers, the majority of which are devoted to the context of marine fisheries.

Chinese marine fisheries regulations implement the guiding thought of "managing and thriving fisheries with laws", pay attention to absorb advanced experiences of fisheries management in the world and stress the importance on the adoption of control means on fisheries management. In 1955 and 1980, the state set up the lines of closed areas for the bottom trawl of marine motor-driven fishing boats in the Buohai Sea, the Yellow Sea, the East China Sea and South China Sea, and during the period, the limits for 600 HP fishing boats were also established. In the year 1979 and 1989, new "REGULATIONS REGARDING FISHERIES RESOURCES PROPAGATION AND PROTECTION" and "TENTATIVE MANAGEMENT MEASURES ON THE ISSUES OF FISHING LICENCES" were issued one after another, and thus, the fundamental principles of the protection and development of Chinese marine fisheries resources and a system of fishing licensing were established. Thereafter, juvenile fish protection zones and closed fishing areas for the commercially important fish species such as prawn, cutlass fish and big yellow croaker were set up respectively in the Yellow Sea and the East China Sea, and the fisheries resources protection and conservation zones of Xisha and Znongsha were established in the South China Sea. The number of off-shore motor-driven fishing boats started to be controlled in 1987. The Buo sea has become a region with no trawl nets operation on the whole year round since 1988. The state adopted the principle of strict control and severe punishment in the practice of fisheries law, in line with the pertinent provisions of "FISHERIES LAW" ; the highest fine violation of the fisheries regulations amounts to RMB 50000 yuan and the heaviest penalty is to be put into custody for two years. On the other hand, the Chinese marine fisheries regulations pay great attention to guide and support the healthy development of marine fisheries production pursuant to national conditions. For instance, "FISHERIES LAW" has stipulated that the state shall support the development of off-sea and deep-sea fisheries in terms of capital, materials, technology, tax revenue etc, and the administrative department of fisheries management may levy on the fishing beneficiaries protection fee for fisheries resources enhancement which are devoted to the enhancement, the protection and conservation of fisheries resources. In the recent ten years, the amount of catch has increased to reach 600 000 tons minimum in China regarding off-sea fisheries, deep-sea fisheries and marine enhancement with prominent results.

## 2. FISHERIES LEGISLATION AND ITS MANAGEMENT PRACTICE IN THE EAST CHINA SEA REGION

The East China Sea region still has the highest level catch among the four marine regions in China ; it is also a region, with the participation of Japan and Korea (including South Korea), for fishing operations. Therefore, this region has always been deemed the key marine for the Chinese fisheries management.

In the East China Sea region, China has two fisheries management system : one of them is the central governmental fisheries management system and the other is a local one. They are relatively independent, but interrelated. The composition of the central governmental fisheries management system is shown on the figure attached. The Fisheries Management Bureau of the East China Sea region, a subordinate institution of the Ministry of Agriculture of the People's Republic of China, is located in the municipality of Shanghai. Directly under the Bureau, two fisheries management stations were set up respectively in two key fishing areas of the East China Sea. The major function of the institution is to exercice, on behalf of the state, the right of fisheries management and supervision of both internal and external matters in the East China Sea region and enforce the guidance and coordination in the provincial and municipal activities of fisheries management in the East China Sea region : under the principle of management by various levels, the scope of the jurisdiction covers all the water areas in the East China Sea region outside the limits of closed fishing areas for motor-driven fishing boats with bottom trawl nets. The local fisheries management institutions in the East China Sea

region are attached to the administrative authority of fisheries management in the governments at three levels such as provinces, municipalities (Shangai, Zhejiang province, Jiangsu province and Fujian province), regions and counties ; and their major responsibility lies in the activities of fisheries management and supervision within their administrative jurisdiction, which covers all the water areas within the limits of closed fishing areas for motor-driven fishing boats with bottom trawl nets.

Fisheries legislation in the East China Sea region deals mainly with two key points, one of them is to strengthen the protection and conservation of commercially important fish species ressources, the other one is to control fishing production. Seven major measures are as follows :

i) Setting up limits of closed fishing areas for motor-driven bottom trawler ; its width from the basic line of the territorial sea is about 12 sea miles. Setting the water areas within the limits of closed fishing areas for the operation areas of fixed nets, where motor-driven bottom trawlers are forbidden to enter operation all the year round.

ii) Enforcing closed fishing management to mass fishing trawlers. Four months, from July to October every year, are fixed for the closed fishing season.

iii) Formulating juvenile catchable standard for major commercially important fish species and maxima juvenile ratio allowed for the catch.

iv) In line with the fishing agreement between China and Japan, 6 juvenile fish protection and conservation zones and seven-season-closed fishing areas are set outside the limits line of closed fishing areas.

v) Distinction has been drawn to separate fishing grounds between offshore and offsea, to keep the fishing boat designated for offsea operations from entering into the fishing ground in the offshore.

vi) Identify and determine controlling horse-power criteria to limit the amount of motor-fishing boats allowed for operations in the offshore.

vii) Arranging the production on several major fishing grounds and fishing seasons in a unified manner. Stipulating the operation period and method of fishing operation and the total number of fishing boats in operation.

The fishing management in the East China Sea region has taken up the measures of direct management. On the land, the fishing licences of all kinds are verified and issued by fisheries management institutions and, at the sea, the violations of fishing regulations and laws of fishing boats and their productions are supervised, checked and dealt with by fisheries management boats to keep production order at sea. Apart from routine supervisory management, an on the spot chek-up is sometimes made by both central and local governments, at sea and on land. In the early 1980s, the management was mainly focused on the mesh size of fishing gear, the juvenile ratio in the catch and the closed fishing time for trawl nets of mass fisheries. In the late 1980s, the focus of the management turned to season-closed fishing grounds and protection and conservation zones for major commercially important fish species. With the efforts made over the decade, the velocity of deterioration of the major fisheries resources in the East China Sea has been eased off to some extent and the catch of big yellow croaker and small yellow croaker are beginning to come up again : the cutlass fish resources remain relatively stable. The resources of some species in some areas are rising prominently.

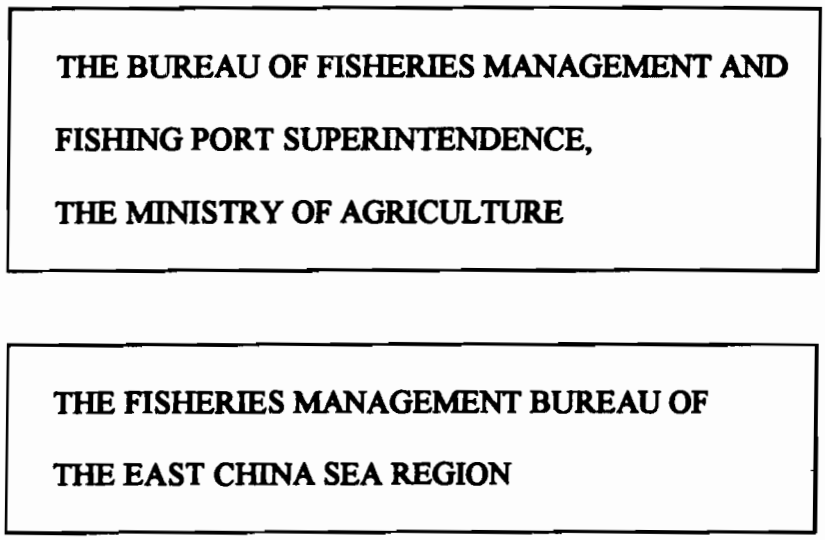
## 3. BILATERAL MARINE FISHERIES AGREEMENTS

In the past, the Chinese government has entered into the bilateral fisheries agreements on the development and utilization of marine fisheries resources with Japan, Korea and Vietnam, but has not yet established a regional marine fisheries agreement exceeding three countries.

In 1956, four countries like China, The Soviet Union, Korea and Vietnam signed an agreement on scientific cooperation and research which included marine fisheries but not productive utilization of fisheries resources. In 1957, China and Vietnam signed a fishery cooperation agreement on the issues of utilization of resources in the Beibu Gulf of the South China Sea (The Gulf of Tong King). In 1960, a similar agreement was also signed between China and Korea in the Yellow Sea. Once again in 1972, China and Korea have signed a fisheries mutual aid and cooperation agreement with further details. However, the agreements mentioned above were terminated at the expiration and were not renewed.

Today, Japan is the only country which enjoys bilateral fisheries agreements with China. The Sino-Japanese people-to-people fisheries agreement was signed in 1955 (it was changed to an intergovernmental agreement in 1975) and has been adjusted many times later pursuant to the changes of fisheries resources. The present executive fisheries agreement is the one adjusted in 1985. It has set up six protection and conservation zones and seven season-closed fishing areas outside the limit lines of closed fishing areas in the Yellow Sea and the East China Sea. Within the protection and conservation zones, the number of Chinese motor-driven fishing trawlers are limited to 624 boats and the number of Chinese purse seiner are limited to 70 groups. The number of Japanese fishing trawlers are limited to 444 ships and the number of Japanese purse seiner are limited to 25 groups. The average of annual fishing time for each protection and conservation zone is less than two months while in the year 1955, it had reached four months.

FIGURE.
THE CENTRAL SYSTEM OF FISHERIES MANAGEMENT IN THE EAST CHINA SEA REGION



# Évaluation de l'Impact de la Flotte des Pays de la CEE dans l'Économie du Sénégal

**Moustapha Kébé**

Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT/ISRA) BP 2241 Dakar, Sénégal

RÉSUMÉ

*L'extension à 200 miles de la juridiction nationale offre à la plupart des pays côtiers de nouvelles possibilités de développer leurs pêcheries et de nouvelles responsabilités ; chaque pays étant libre d'exploiter les ressources vivantes au large de ses côtes au mieux de ses capacités et de l'intérêt national. Ainsi, les pays côtiers qui ne sont pas en mesure d'exploiter toutes ou certaines de leurs ressources cherchent à tirer le maximum de rente économique en signant des accords de pêche avec d'autres pays. C'est également le cas des pays ayant eu quelques expériences nationales malheureuses d'industrialisation de leurs pêcheries.*

*L'objectif de ce papier est de contribuer à la mesure et à l'analyse des bénéfices économiques que les pays côtiers africains tirent de l'exploitation de leurs Zones Economiques Exclusives par la flottille étrangère.*

*Depuis 1979, le Sénégal signe tous les deux ans des accords de pêche avec la CEE qui contiennent trois éléments principaux : l'accès des navires membres à la ZEE sénégalaise, à l'intérieur de certaines limites, une compensation financière versée directement par la Communauté et des redevances calculées sur la base des captures.*

*Il existe différents critères d'évaluation économique de l'impact de cette flotte CEE. Mais la complexité des filières thonière et chalutière de même que la nature des informations disponibles nous obligent à adopter une démarche analytique. Une typologie des agents économiques concernés par l'activité de la flotte CEE au Sénégal a été établie : les unités de pêche, les intermédiaires portuaires, les ateliers et chantiers maritimes, les entreprises de transformation, l'Etat et le secteur tertiaire.*

*Pour chacune de ces catégories ainsi définies, une évaluation économique a été faite. En fonction des informations disponibles, l'accent est mis d'une part sur la contribution au PIB, au PNB, l'influence sur la balance commerciale, et d'autre part sur les coûts (administration, subventions d'exploitation et d'exportation, infrastructures et effets externes).*

## 1. INTRODUCTION

L'extension à 200 milles de la juridiction nationale offre à la plupart des pays côtiers de nouvelles possibilités de développer leurs pêcheries et de nouvelles responsabilités ; chaque pays étant libre d'exploiter les ressources vivantes au large de ses côtes au mieux de ses capacités et de l'intérêt national.

Beaucoup de pays africains côtiers ne disposent pas des capitaux très importants qu'exige le développement d'une pêche industrielle rentable. Ceux qui ne sont pas en mesure d'exploiter toutes ou certaines de leurs ressources halieutiques cherchent à tirer le maximum de bénéfices en autorisant l'accès de leur Zone Economique Exclusive à des flottes étrangères. C'est le cas également des pays ayant eu quelques expériences nationales malheureuses d'industrialisation de leurs pêcheries.

C'est ainsi que les pays africains ont adopté une politique de concession de licences, liée également à des traditions de voisinage.

La conclusion d'un accord de pêche durant la période considérée, peut donner lieu à une série de contreparties économiques, commerciales et techniques, en sus des redevances perçues. Ces redevances qui peuvent revêtir plusieurs formes contribuent à améliorer la situation des Finances publiques des Etats côtiers par une entrée de capitaux.

En plus des marins nationaux à bord des bateaux, l'obligation faite aux flottes étrangères à débarquer tout ou partie de leurs captures contribue à l'approvisionnement des infrastructures locales de transformation et, dans une moindre mesure des populations locales. Par ailleurs, elle permet de créer une valeur ajoutée locale et de stimuler l'emploi.

Les pays signataires peuvent dans certains cas accorder aux pays côtiers des conditions tarifaires préférentielles permettant à ces derniers d'écouler aisément leurs produits.

Les accords de pêche peuvent venir en appoint à la recherche scientifique lorsqu'ils contiennent des dispositions visant à une formation des cadres nationaux chargés de la gestion du secteur des pêches et au transfert de technologie.

D'autres clauses sont stipulées dans les accords de pêche. Les pays signataires peuvent octroyer aux Etats côtiers des prêts à des conditions douces ou des capitaux non remboursables destinés à financer des projets de développement dans le secteur de la pêche. Des contreparties en nature peuvent être octroyées aux Etats riverains comme la construction de quais, de ports de pêche, etc...

Les accords de pêche signés par le Sénégal depuis son accession à l'indépendance peuvent être regroupés en trois grandes catégories (tabl. 1) :

(i) accords de réciprocité avec les pays voisins (Gambie, Guinée Bissau, Cap-Vert et Mauritanie) en raison des stocks partagés, de la migration des espèces et des pêcheurs. Le principe de l'accès réciproque aux ressources halieutiques présentes dans les eaux sous-juridiction des deux pays est souvent de règle ;

(ii) conventions sans protocole avec l'ex URSS et le Nigéria ;

(iii) accords de contrepartie de première génération (France, Espagne, Pologne et Italie) et de deuxième génération (CEE depuis 1979 et Japon en 1991). L'intérêt et les motivations de ces accords se justifient, en sus de compensations financières, par des avantages commerciaux, techniques et scientifiques. Ces accords concernent également des Etats côtiers africains comme la Côte d'Ivoire dont les ressources maritimes sont insuffisantes pour faire face à la demande locale de poissons.

En général chaque accord de pêche signé avec la CEE a une durée de deux ans et comprend trois éléments principaux : l'accès des bateaux européens à la ZEE sénégalaise à l'intérieur de certaines limites, une composante financière versée directement par la Communauté (paiement d'un montant forfaitaire au Trésor Public) et une redevance armatoriale en fonction du TJB (cas des chalutiers) ou des captures (cas des thoniers).

L'objectif de ce papier est de déterminer la contribution de ces accords de pêche avec la CEE au développement économique et social du Sénégal ; il s'agit de mesurer et d'analyser les bénéfices économiques que le Sénégal tire de l'exploitation de sa ZEE par la flottille CEE ainsi que les dépenses effectuées par l'Etat.

Dans un premier temps seront présentées et discutées les différentes méthodes d'évaluation généralement préconisées, puis seront analysés les effets économiques directs au niveau de chaque agent ainsi que les coûts afférents.

## 2. ASPECTS MÉTHODOLOGIQUES

### *2.1 Méthodes d'évaluation*

Parmi les méthodes d'évaluation généralement préconisées, l'approche économique apparaît comme la seule adaptée pour étudier le rôle des flottes étrangères dans le développement économique des Etats africains côtiers. En effet elle offre un cadre d'analyse utile dans la planification du développement des pêches.

La *méthode des effets* consiste essentiellement à rechercher les perturbations entraînées par le projet sur l'économie nationale. L'analyse de flux centrée sur la valeur ajoutée permet de connaître l'ensemble des effets du projet sur les différents agents économiques concernés. La détermination des multiplicateurs d'impact (revenu, emploi par exemple) exige des informations très fines sur la structure économique, en particulier si on utilise les tableaux entrées/sorties.

L'*analyse coûts/avantages* (méthode des prix de référence) fait apparaître les contextes du projet. Elle s'efforce de dire si les avantages (ce que la société obtient d'un projet) sont supérieurs à leurs coûts (sacrifices consentis pour produire ces avantages). Plusieurs ratios sont calculés : coûts/bénéfices, bénéfices nets actualisés, taux de rendement, etc...

L'*approche multi-critères* est basée sur le principe que les décisions ne sont pas prises sur un seul critère ; il faut rendre explicites les critères et les pondérer en fonction des préférences des décideurs. Il n'est pas facile d'établir les critères et la méthode exige de travailler en étroite collaboration avec les décideurs.

Aucune de ces méthodes d'évaluation économique recensées n'est spécifique à la pêche. Toute analyse économique dans ce domaine doit se faire à deux niveaux dans le processus de planification : la détermination du potentiel de capture et de l'effort de pêche, le calcul de l'effet sur l'économie nationale.

Seules les méthodes des effets et les modèles bio-économiques s'intéressent à la pêche. Elles ont fait l'objet d'une utilisation importante dans l'étude des pêcheries de la région COPACE et des Seychelles (Charneau, 1988 ; Francis et Christy, 1979 ; Gladicelli, 1988 ; Greboval, 1988 ; Horemans, 1988 ; Parker, 1986 ; Robinson, 1988 et Sok et *al*, 1987). En réalité les modèles bio-économiques ne constituent pas une méthode d'évaluation des effets de la pêche industrielle sur l'économie nationale. L'accent est mis essentiellement sur la détermination de la rente qu'on peut extraire de la pêcherie. La méthode exige un effort important de collecte de données biologiques et économiques.

### *2.2 Démarche adoptée*

La structure du capital détenu en partie par des intérêts étrangers ainsi que de la diversité des conditions d'emploi dans les différentes entreprises de pêche, rendent difficile l'appréhension rapide et correcte de l'impact de la flotte étrangère pour le Sénégal.

La nature des informations disponibles et la complexité des filières industrielles (thonière et chalutière) justifient la démarche analytique adoptée. Une typologie des agents économiques concernés par l'activité de la flotte étrangère (d'amont en aval) a été établie :

- les unités de pêche,
- les intermédiaires portuaires,
- les ateliers et chantiers maritimes,
- les sociétés de transformation du poisson,
- l'Etat et les établissements publics.

Pour chacune des quatre premières catégories ainsi définies, une évaluation économique a été faite pour l'année 1987 (Kébé, 1989) ; les données ne sont pas disponibles pour les sociétés de transformation du poisson. L'impact économique de la flottille CEE qui a exploité les eaux sous juridiction sénégalaise pendant l'année de référence a été déterminé en évaluant les bénéfices et les coûts liés à l'activité de cette flotte.

Au préalable il nous semble nécessaire de préciser la notion de résidence en vue de mieux cerner le statut juridique des unités de pêche.

Tout agent national ou étranger ayant un centre d'intérêt économique durable sur le territoire, c'est-à-dire y effectuant des opérations pendant un an au moins est considéré comme agent économique résident. En appliquant cette définition aux flottilles, on se rend compte qu'il y a équivalence entre les notions de flottille résidente et de flotte basée ; un bateau basé étant un bateau appartenant à un agent (ou une société) national ou un bateau battant pavillon étranger, mais ayant Dakar comme port d'attache.

Dans ce travail, nous prenons en considération les bateaux CEE aussi bien au niveau de la flottille résidente que de la flotte non basée.

La flottille CEE basée est constituée de thoniers canneurs français et espagnols, de chalutiers français et italiens, travaillant exclusivement à partir du port de Dakar.

Les produits d'exploitation de ces bateaux ainsi que les charges afférentes sont l'objet de transactions entre (ou avec) des agents économiques nationaux. Il faut signaler cependant que, même s'ils sont obligés de débarquer à Dakar pour approvisionner les usines, les bateaux étrangers qui sont immatriculés au quartier des Affaires Maritimes d'origine rentrent dans leurs pays respectifs pour les travaux de gros entretien.

La flottille CEE non basée est composée de thoniers senneurs français et espagnols, de chalutiers italiens, grecs et espagnols qui relâchent occasionnellement dans le port de Dakar. Ils effectuent des escales commerciales (débarquements et/ou transbordements sur un cargo) ou des escales techniques (relève d'équipage en rade extérieure, entretien, réparation, avitaillement...). Leur présence génère des flux physiques ou monétaires. Les dépenses effectuées sur le territoire sénégalais concernent l'avitaillement (carburant, sel pour saumure, vivres pour l'équipage, glace, éventuellement pièces détachées), les petites réparations ainsi que les droits d'utilisation des services portuaires. Les consommations intermédiaires des bateaux étrangers en escale à Dakar constituent des produits d'exploitation des sociétés d'avitaillement et sont autant de demandes indirectes auprès des producteurs locaux.

## 3. EFFETS ECONOMIQUES DIRECTS

### *3.1 Dépenses de la flotte CEE non basée*

Les dépenses totales d'avitaillement de la flotte étrangère ont été estimées en 1987 à près de 481 millions de FCFA dont 39 % pour les chalutiers congélateurs, 32 % pour les thoniers senneurs et 29 % pour les chalutiers glaciers (Kébé, 1989).

Le poste carburant en admission temporaire n'a pas été pris en compte. En effet, depuis le début de l'année 1987, on assiste à un déroutement des navires étrangers et sénégalais à Las Palmas pour souter, en raison de l'enchérissement du pétrole brut importé par la Société Africaine de Raffinage (SAR). Il faut également préciser que les retombées de l'activité thonière sur l'exploitation du gisement de sel de Retba sont sans doute plus grandes encore car une partie de l'approvisionnement en sel des senneurs français et espagnols dans le sud du Golfe de Guinée est assuré par des cargos venant de Dakar (Charneau, 1988). Par ailleurs les autres dépenses effectuées par les senneurs étrangers (gaz, entretien et petites réparations), considérées comme d'importance plus faible, n'ont pas fait l'objet d'une évaluation.

### *3.2 Approvisionnement des usines locales*

Pour la flotte CEE basée à Dakar, les débarquements ont atteint 9 968 tonnes en 1987 : canneurs français 8 028 t, canneurs espagnols 936 t, chalutiers français et italiens 944 t (Kébé, 1989).

Les débarquements et transbordements de la flotte non basée ont été de 27 527 tonnes : thoniers 19 152 t, merlutiers espagnols 667 t, crevettiers espagnols 1033 t, chalutiers italiens et grecs 6 675 t (Kébé, 1989). Les crevettiers sont très souvent contraints à débarquer leurs captures aux îles Canaries pour des raisons commerciales.

Au total la pêche étrangère a contribué en 1987 à l'approvisionnement des usines de Dakar en matière première pour un volume global de 35 795 tonnes dont près de 72 % par les bateaux non basés.

### *3.3 Rémunération des équipages sénégalais*

En 1987, on a recensé 1482 marins sénégalais embarqués à bord des unités étrangères, à des postes d'hommes d'équipage exclusivement. La masse salariale correspondante injectée dans l'économie sénégalaise est estimée à 1,5 milliard de FCFA.

*3.4 Intermédiation portuaire*

La pêche industrielle génère des activités spécifiques avant même la prise en charge du produit par les usines de transformation. Il s'agit de la manutention réalisée en grande partie par les dockers, des fonctions liées au trafic international (consignation et transit) ainsi que de l'aconage.

La plupart de ces fonctions sont assurées par des entreprises intégrées privées sénégalaises. Dans le domaine de la consignation, une concurrence assez forte s'est manifestée depuis quelques années ; certains armements ont créé leurs propres structures à Dakar.

Les dockers qui effectuent la manutention portuaire sont soit des professionnels, soit des occasionnels, soit recrutés ponctuellement sur simple présentation de la carte d'identité.

Les résultats des investigations menées montrent que la manutention du poisson débarqué par la flotte étrangère représente en moyenne 10 % de l'activité du port soit environ 39 000 heures de travail docker et 8 000 heures de travail pointeur. La masse salariale engagée est d'environ 160 millions de FCFA, ce qui correspond à un taux de salaire moyen horaire de 402 FCFA (dockers et pointeurs confondus). Cette évaluation ne tient pas compte de la manutention informelle qui paraît importante ; ce sont soit les équipages qui débarquent eux mêmes souvent le produit, soit des entreprises non agréées qui s'en chargent.

*3.5 Entretien et réparation navale*

Pour la flottille de pêche étrangère, l'activité des chantiers et ateliers maritimes se limite à l'entretien et à la réparation. Le marché est partagé pour l'essentiel entre l'atelier d'entretien des canneurs géré par la coopérative basque Lagun Artean et la société Dakar Marine.

Le niveau d'activités de l'atelier coopératif s'est considérablement réduit au cours de ces dernières années en raison de la baisse sensible du nombre d'adhérents. Actuellement le personnel est limité à 2 personnes.

La société Dakar Marine peut prendre en charge les réparations des senneurs et chalutiers étrangers. L'intéressement au projet de grands chantiers belges et français a permis le financement d'investissements lourds qui font de cet atelier l'un des mieux équipés de la région ouest-africaine. Cependant les tarifs et les niveaux de prestations rendues limitent fortement sa fréquentation par la flotte de pêche étrangère qui lui préfère les chantiers des îles du Cap Vert, d'Espagne (îles Canaries) et de France (Charneau, 1988).

Pour l'année 1987, le montant facturé des interventions de Dakar Marine représentait 42 % du chiffre d'affaires global, soit 1,34 milliards de FCFA dont 72 % pour les bateaux basés (41 %) et non basés (31 %) autorisés à pêcher dans les eaux sous juridiction sénégalaise, et 28 % pour les navires de pêche russes qui n'opèrent pas officiellement dans la ZEE sénégalaise (Kébé, 1989).

*3.6 Recettes publiques*

L'activité des agents économiques dans la pêche fait l'objet d'une fiscalisation de la part des pouvoirs publics. Ces flux sont complétés par la rente économique extraite des partenaires étrangers venant pêcher dans les eaux sous juridiction sénégalaise.

**3.6.1 Recettes fiscales**

Elles se présentent sous quatre (4) formes distinctes :

(i) l'imposition sur le revenu des personnes physiques : la part de la masse salariale revenant à l'Etat sous la forme de l'impôt sur le revenu (IGR), de l'impôt sur les traitements et salaires (ITS) et de la taxe représentative du minimum fiscal (TRIMF). Les marins sénégalais embarqués à bord des bateaux étrangers versent à l'Etat 181,7 millions de FCFA, les dockers et pointeurs 19,2 millions de FCFA ;

(ii) l'imposition sur les bénéfices industriels et commerciaux : le taux est de 33 % mais les entreprises de pêche échappent en grande partie à l'impôt, tant les bénéfices déclarés sont faibles ;

(iii) la taxation sur les biens et services : les données ne sont pas disponibles pour évaluer d'une part les taxes perçues par l'Etat sur la production et les intrants importés, et d'autre part la part à imputer à la flotte étrangère ;

(iv) la perception des droits et taxes de douane : l'Etat est déficitaire à ce niveau. En effet les usiniers ne paient pas de droits d'entrée pour les matières premières importées qui entrent dans la fabrication des conserves. Les consommations intermédiaires importées sont placées sous le régime de l'admission temporaire. La plupart des produits de la pêche exportés sont exonérés de droits de douane.

### 3.6.2 Recettes non fiscales

Elles sont constituées par les contreparties financières de l'accord de pêche ainsi que les recettes de la Caisse d'Encouragement à la Pêche et à ses Industries Annexes (CEPIA).

La compensation financière directe de la CEE est fixée pour l'accord qui couvre la période allant du 01/10/86 au 28/02/88 à 1,7 milliards de FCFA auxquels s'ajoutent 1,55 milliards au titre de l'augmentation des droits de pêche à partir du 1er mars 1987. Le Centre de Recherches océanographiques de Dakar-Thiaroye (CRODT) a reçu une enveloppe globale de 90 millions de FCFA au titre de l'aide à la recherche scientifique et technique. Dix bourses d'étude de 5 ans au plus chacune sont accordées au sein d'établissements de formation pour la CEE.

Pour 1987, le Sénégal a reçu des bateaux de la CEE la somme de 260,6 millions de FCFA correspondant aux droits de licence de pêche, soit 53 % du montant total perçu aux licences. Globalement il faut compter environ 1,6 milliards FCFA au titre des compensations et redevances contre 4,9 milliards FCFA en 1989.

### 3.6.3 Autres recettes publiques

Les autres recettes du compte spécial de la CEPIA sont constituées par 60 % du produit des amendes et infractions à la réglementation (les 30 % vont à la Marine Nationale et les 10 % à l'Administration des pêches (DOPM) ainsi que par les 2/3 des montants des taxes parafiscales (cotisations des exportateurs et professionnels de la pêche). Ces recettes intéressent l'ensemble de la flotte industrielle (nationale et étrangère).

### *3.7 Recettes du port autonome de Dakar (PAD)*

Les recettes enregistrées par le PAD en contrepartie des services fournis à la pêche sont de 4 types :

(i) les recettes sur les navires constituées par les redevances de pilotage, d'amarrage, de séjour et d'utilisation du plan d'eau ;

(ii) les recettes sur les marchandises c'est-à-dire les quantités physiques transbordées ou embarquées. Le thon transbordé bénéficie d'un coefficient réducteur destiné à favoriser le transit des flottes étrangères par le port de Dakar ;

(iii) les recettes domaniales correspondant au droit d'utilisation des terre-pleins, hangars et terrains ;

(iv) les autres recettes perçues pour la cession d'eau, d'électricité et de matériel.

Au cours de l'exercice 1986-1987, les recettes enregistrées par le PAD pour les services rendus à la flotte de pêche s'élevaient à 1,1 milliard de FCFA, soit 16 % des produits d'exploitation du PAD. S'y ajoutent les recettes domaniales hors pêche payées par les usines et frigorifiques traitant le poisson dans l'enceinte du port ainsi que les baux des usines et des différents intermédiaires situés hors enceinte mais sur le territoire du PAD. Ainsi plus de 1,4 milliard de FCFA ont être perçus de la pêche.

### *3.8 Cotisations sociales*

Les cotisations sociales sont versées aux caisses de sécurité sociale, de retraite et d'assurance maladie par les armements. Les charges sociales pour le personnel sénégalais représentent 45,4 milliards (forfait patronal de 3 % de la masse salariale). Les marins français, bien qu'affiliés au régime social français versent une cotisation à la caisse de sécurité sénégalaise de même qu'un forfait patronal de 5 % de la masse salariale.

## 4. ANALYSE DES COUTS INDIRECTS

On peut distinguer trois niveaux de coûts liés à l'activité de la flotte étrangère : coûts administratifs, coûts d'investissement et facteurs externes.

### *4.1 Coûts administratifs*

Ils sont liés à la négociation, la gestion et la surveillance des activités de pêche.

#### 4.1.1 "Subventions"

L'Etat alloue aux entreprises de pêche deux types de "subventions". La subvention d'exploitation concerne le carburant consommé par les bateaux (gazoil mer). Elle se décompose en une détaxe (manque à gagner constitué par la TVA SAR et la TVA sur le "prix économique stabilisé") et une intervention positive de la Caisse de Péréquation et de Stabilisation des prix. Le montant des subventions totales sur le gazoil mer consommé par la flottille étrangère a été estimé à 275,5 millions de FCFA.

Les produits de la mer bénéficient du régime général d'incitation à l'exportation au même titre que les produits transformés. Cette prime d'incitation est passée de 10 % de la valeur FOB à l'exportation du produit en 1980 à 15 % en 1983, puis à 25 % de la valeur ajoutée industrielle nationale (VAIN) incorporée dans le produit fini à partir de 1986. La VAIN est déterminée par application directe d'un coefficient technique à la valeur FOB à l'exportation du produit, soit 15 % pour les poissons, crustacés et mollusques frais, réfrigérés ou congelés, 15 % pour la farine de poisson et 30 % pour les préparations de poisson, de crustacés et de mollusques.

Par ailleurs certains produits halieutiques (crevettes et calmars) bénéficient du système de stabilisation des recettes d'exportation (STABEX) existant entre la CEE et les pays ACP liés par les accords de Lomé. Il existe également des conditions préférentielles pour les importations provenant des pays ACP telle l'absence de taxe douanière lorsque les produits répondent à un certain nombre de critères quant à l'origine et la salubrité.

#### 4.1.2 Autres coûts administratifs

La cotisation du Sénégal à l'ICCAT [1] est calculée chaque année en fonction des déclarations de prises de la flotte nationale et des quantités traitées par les conserveries. Elle est de l'ordre de 5 millions de FCFA.

Le budget alloué au projet Protection et Surveillance des Pêches au Sénégal (PSPS) était de 200 millions de FCFA pour l'exercice 1987-1988 dont 23,4 milliards comme masse salariale des 98 observateurs à bord des bateaux étrangers.

### *4.2 Coûts d'investissements*

Ces coûts concernent essentiellement les infrastructures et services à terre. Il n'est pas possible de définir la proportion de ces investissements qui sont directement et uniquement liés à la pêche étrangère CEE.

### *4.3 Facteurs externes*

Les coûts sociaux sont liés à la compétitivité entre les bateaux CEE et les pêcheurs sénégalais pour l'accès à la ressource et éventuellement aux marchés. Ces frais ne sont pas négligeables mais leur évaluation est difficile.

Il y a également les rejets en mer effectués par les chalutiers crevettiers. Ils constituent une perte de production sur les long et moyen termes. Le rapport poissons rejetés/poissons conservés est de 2,5 en saison chaude contre 1,6 en saison froide (Caveriviere et Andriamirado, 1988).

1. ICCAT : International Commission for Conservation of Atlantic Tuna

## 5. CONCLUSION : QUELLE STRATEGIE DE DEVELOPEMENT DES PECHES

Au total les entreprises de pêche CEE intéressent à divers titres l'économie sénégalaise. Le produit intérieur brut (PIB) n'est affecté que par les unités basées. La présence des marins sénégalais à bord des chalutiers et thoniers étrangers génère des paiements de facteurs qui interviennent en partie dans le produit national brut (PNB). Les retombées économiques de la flotte CEE sont loin d'être négligeables pour le Sénégal.

La politique de concession de licences, adoptée par la plupart des pays africains côtiers au lendemain des indépendances, était considérée comme une situation provisoire, un premier pas dans le processus de développement national. L'objectif à moyen terme était de constituer une flotte nationale capable d'exploiter de façon optimale leurs ressources halieutiques.

Mais force est de constater, 30 ans après, que les flottes étrangères continuent à pêcher dans leur ZEE et semblent donc réaliser des profits. Dès lors on peut se demander en toute logique si leur présence ne peut pas constituer en soi un frein au développement des capacités nationales.

Par ailleurs, malgré l'augmentation des bénéfices indirects que ces pays étaient en droit d'attendre de l'exploitation de leur ZEE par les flottes étrangères, cette stratégie de développement est marquée principalement par le manque de contrôle qu'ont ces pays sur les ressources halieutiques et les marchés de consommation finale de leurs produits.

La politique de développement mise en oeuvre dans le secteur de la pêche par un Etat côtier influence fortement les résultats économiques du secteur dans les Etats voisins. Il est nécessaire alors de mener une analyse régionale de l'impact de la flotte étrangère dans les pays africains côtiers qui partagent les mêmes stocks de poisson. Ceci aiderait à harmoniser les politiques en matière de négociation des accords de pêche, notamment avec la CEE.

La flotte industrielle sénégalaise est confrontée actuellement à d'énormes difficultés liées à sa vétusté et à une mauvaise gestion. En revanche la pêche artisanale a connu d'importants développements durant ces dernières années grâce à son dynamisme et à sa capacité d'adaptation aux changements. Son impact dans l'économie sénégalaise n'est plus à démontrer. Les emplois générés sont importants : 150 000 (soit 10 % de la population active nationale) dont 35 000 pêcheurs contre 10 000 pour l'industriel (Chaboud et Kébé, 1990). La valeur ajoutée dégagée par ce sous-secteur artisanal en 1987 est de 71,5 milliards de FCFA représentant 62 % de la valeur ajoutée induite totale du secteur des pêches au Sénégal (Brendel et *al*, 1992). Loin de reposer sur une économie de subsistance, la pêche artisanale contribue largement à l'approvisionnement des usines de la place (cette filière représente 20 % de la valeur ajoutée induite par le sous-secteur), et par là au rééquilibrage de la balance commerciale du pays.

Assurant plus des 2/3 des débarquements de poisson (250 000 tonnes en moyenne), elle couvre une part relativement importante des besoins en protéines animales des populations aussi bien rurales qu'urbaines.

Dans le souci de protéger ce sous-secteur dont le développement est considéré comme prioritaire et de permettre une gestion rationnelle des ressources halieutiques, l'Etat a pris un certain nombre de mesures pour mieux contrôler leur exploitation :

(i) instauration d'un Code de la pêche (Loi du 18 août 1987) qui arrête les droits d'usage et les normes d'utilisation des potentialités halieutiques nationales ;

(ii) élaboration d'un système de surveillance aérienne et maritime des eaux relevant de la juridiction du Sénégal, pour le respect des réglementations en vigueur ;

(iii) mesures d'allégement fiscal dans le cadre du Code des investissements (Loi 87-25 du 18 août 1987) : exonération des droits d'entrée des navires et des équipements de pêche, assouplissement de la législation sociale pour tenir compte du caractère saisonnier des activités, liberté de transfert des capitaux et revenus générés pour les armateurs.

## REFERENCES

**Brendel R., C. Chaboud et F. Foucault** (1991). Bilan économique du secteur de la pêche au Sénégal en 1987. *Doc. int. Cent. Rech. Océanogr. Dakar-Thiaroye* , 36 p.

**Caveriviere A. et G.A. Andriamirado Rabarison** (1988). Captures secondaires et rejets de la pêche de la crevette *A Penaeus Notialis* au Sénégal. *Doc. sci. Cent. Rech. Océanogr. Dakar-Thiaroye*, **111,** 113 p.

**Chaboud C. et M. Kebe** (1990). Les migrations de pêche maritime au Sénégal : impact sur la dynamique de la pêche piroguière, essai d'approche quantitative. *In Haakonsen J.M. et Diaw M.C. (eds.) : Migrations des pêcheurs en Afrique de l'Ouest. DIPA/WP/36 sept 1991 :* 56–74.

**Charneau D.** (1988). L'économie du thon : intégration nationale et internationalisation de la filière. *Doc. Sci. Cent. Rech. Océanogr. Dakar-Thiaroye*, **109,** 192 p.

**Francis T. et F.T. Christy** (1979). Bénéfices économiques et accords avec la pêche étrangère dans la sous-région septentrionale du COPACE : évaluation préliminaire. *FAO-COPACE série/79/19* (Fr).

**Gladicelli** (1988). Preparation of the in-depth study of the development and managment of industrial fisheries in Africa.

**Greboval** (1988). Major economic considerations for the preparation and negociation of fisheries joint-ventures.

**Horemans B.** (1988).- Eléments pour l'analyse de l'impact de flottes de pêche lointaine sur l'économie des pays côtiers de la zone COPACE. *CECAF/FD/88/Inf.9,* nov. 1988, 17 p.

**Kebe M.** (1989). Impact de la flotte étrangère dans l'économie sénégalaise. *Rapport FAO*, 19 p.

**Parker** (1986). The economic benefits to Seychelles of the industrial tuna fishery.

**Robinson** (1988). Finance and other considerations affecting the development of industrial fisheries in West Africa.

**Sok M., O.A. Fall, O.S. Boudbouda et J.P. Gaudechoux** (1987). Analyse économique du secteur pêche en Mauritanie. Cellule d'Appui au Ministère des Pêches et de l'Economie Maritime, Mauritanie, 151 p.

**TABLEAU 1.**
**ACCORDS DE PÊCHE SIGNÉS PAR LE SÉNÉGAL ENTRE 1960 ET 1991.**

| ETATS SIGNATAIRES | ANNEES |
|---|---|
| Accords de réciprocité | |
| Gambie | 1967 et 1982 |
| Guinée-Bissau | 1978 et 1982 |
| Cap-Vert | 1982 |
| Mauritanie | 1974, 1980 et 1983 |
| Accords de contrepartie | |
| Côte d'Ivoire | 1976, 1977 et 1979 |
| Espagne | 1972, 1974, 1975, 1979, 1982 |
| France | 1960, 1974 |
| Italie | 1975 |
| Pologne | 1976 |
| CEE | depuis 1979 |
| Japon | 1991 |
| Conventions sans protocole | |
| Nigéria | 1982 |
| URSS | 1965 |

# Bioeconomic Considerations regarding the Opening of a Autumn Fishery on Capelin in 1991

**Per Sandberg and Peter Gullestad**

Directorate of Fisheries, Box 185, 5002 Bergen, Norway

ABSTRACT

*North-East Artic Cod preys on Barents Sea Capelin. Knowledge about this multispecies effect is important when deciding when to fish Capelin.*

*This poster deals with relevant bioeconomic variables in such a decision process. In lack of formal bioeconomic models, bioeconomic reasoning was used when deciding whether or not to open a fishery on Capelin. Quantitative and qualitative arguments in this reasoning are briefly discussed.*

## 1. INTRODUCTION

North-East Arctic Cod preys on Barents Sea Capelin. Both species are of great commercial value in Norwegian fisheries, Capelin mainly for reduction purposes. Due to an abrupt change in the Barents Sea ecosystem combined with a too high fishing mortality, the Capelin stock was at a historically low level in 1986. As a consequence, the cod stock lost its main diet. In lack of Capelin, the growth rate for cod went down, cod behaved cannibalistic and the stock was severely reduced. A moratorium on the Capelin fishery was established.

A harsh economical climate began for Norwegian fishermen. Several meal factories were forced to close business. Five of these factories, situated in the north of Norway, were in the years of the moratorium given subsidies from the government to be able to function in an expected future Capelin fishery.

## 2. ACFM'S ADVICE ON A AUTUMN FISHERY OF CAPELIN AUTUMN 1991

Due to the moratorium imposed in 1986, the Capelin stock recovered to an exploitable level in 1991. With the consequences of overfishing in 1986 in fresh memory, one was anxious to know ACFM's recommendation on an autumn

fishery of Capelin in 1991. Relevant arguments for such a TAC would be the net benefits of a Capelin fishery versus the potential negative effects (costs) this fishery might have on the cod fishery. Besides, an autumn fishery should be no threat to the Capelin target spawning stock biomass, and should be regulated to avoid fishing mortality on immature Capelin.

Such considerations involves bioeconomic arguments. With its role as a biological advisor, ACFM did not give a clear recommendation about whether or not to open an autumn fishery on Capelin.

## 3. RELEVANT BIOECONOMIC VARIABLES

In lack of formal bioeconomic models, the Directorate of Fisheries had to rely on bioeconomic reasoning when advising the Minister of Fisheries about whether or not to open the fishery. In this analysis we focused on gross value, or prices. Harvesting costs were set to zero. The most important variables in the decision process were identified (see table 1).

### *3.1 Quantitative analysis*

With the expected values shown in table 1, we calculated the present value (PV) of opening a autumn fishery on Capelin under a TAC of 300.000 tonnes (a quota allocation of about 180.000 tonnes to Norway). The figure 1 shows how the value of opening a autumn fishery depends on the probability of fishing Capelin that otherwise would have been eaten by cod.

After consulting the Institute of Marine Research (IMR) in Bergen, we found that with the prevailing stock sizes of cod and Capelin in the Barents Sea, the probability that a TAC on 300.000 tonnes should conflict with the cod's food demand was close to zero.

### *3.2 Qualitative analysis*

A autumn fishery on Capelin would strengthen the financial position of the fish-meal factories in the northern part of Norway by prolonging their annual operation time. The existence of these factories is a precondition for participation of a part of the fleet fishing Capelin in the winter (small vessels using trawl and purse seine). A autumn fishery on Capelin would therefore be a support to the continued participation of this fleet.

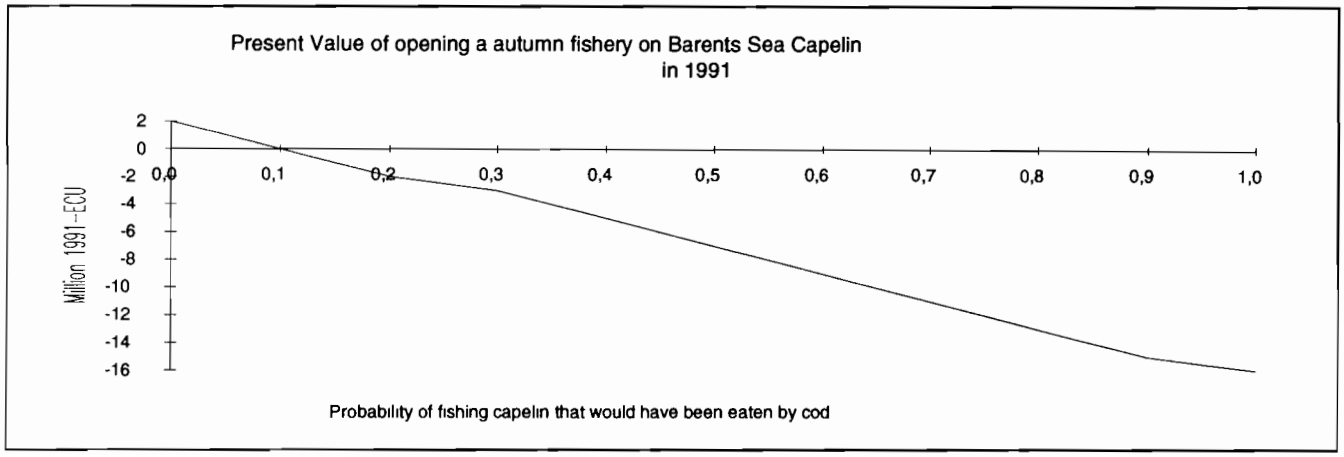
## 4. DECISION

Regarding both quantitative and qualitative factors, the Directorate of Fisheries recommended the Minister of Fisheries to negotiate with the USSR to open a fishery under a TAC at about 300.000 tonnes. Quantitative arguments did not favor strongly either position. This recommendation was therefore principally based on the qualitative arguments dealing with the need for the fish-meal factories' role for a continued participation of the small vessels in the Capelin fishery.

**TABLE 1.**
**IMPORTANT VARIABLES.**

| Important variables | Expected value |
|---|---|
| 1. Loss of capelin biomass by postponing autumn catch until winter | 0 |
| 2. Probability of fishing capelin that would have been food for cod | ? |
| 3. Feed factor capelin – cod | 0,20 |
| 4. Price on cod | 1188 ECU/ton |
| 5. Price on autumn–fished capelin | 75 ECU/ton |
| 6. Price on winter–fished capelin | 65 ECU/ton |
| 7. Minimum acceptable TAC for the fish–meal factories to start production | 300.000 tons |
| 8. TAC–allocation of capelin to Norway | 60 % |
| 9. TAC–allocation of cod to Norway | 50 % |
| 10. Time–span from cod eats capelin to fishermen catch cod | 2 years |
| 11. Natural mortality on cod (per year) | 0,2 |
| 12. Discount rate | 7% |

**FIG. 1.**
**PRESENT VALUE OF OPENING A AUTUMN FISHERY ON BARENTS SEA CAPELIN IN 1991.**



# "Sevryka" - A new Competitor in the European Seafood Market ?

**Frode Nilssen**

FORUT (Foundation for Applied Research at The University of Tromsø). P.o box 2806, 9001 Tromsø, Norway

ABSTRACT

*The paper gives an overview of the political/economical changes in the former Soviet Union, and on the basis of this makes a brief presentation of "ARP Sevryba's" competitive conditions. According to Porter (1990) a nation's competitiveness depends on the capacity of its industry to upgrade. During the last decade the former Soviet Union has been subject to extensive political changes and hence rather comprehensive changes in the enterprises national factor conditions. This fact is believed to have a significant impact to the economic performance of "ARP Sevryba" as a potential competitor on the European seafood market.*

## 1. INTRODUCTION

During the last years the former Soviet Union and Russia has gone through extensive political and structural changes in the hope to both improve her internal and external economic performance. One of the sectors affected by the reforms is the fishing industry. Although the former Soviet fishing industry is referred to as a strategic sector due to its importance as a food supplier to the domestic market, the industry also plays an important role as an exporter of seafood, and to a certain extent a valuable cash cow of foreign currency.

Taking this into account it is likely to believe that the changes has led to some adjustments of the strategy - or goals - of the Russian enterprises. One of the possible changes is that they will head towards a more aggressive performance in the international (European) market for cod-fish and shrimps, which are two major species in the northern fishing grounds, both related to volume and value. To examine this hypothesis we are looking into the Soviet seafood company of the northern areas, "ARP Sevryba" as a case study.

The main focus of the study is to analyse the organisation "Sevryba" and identify to what extent the changes in the national environment (attributes) have influenced on the export performance of the "Sevryba" association and its member

companies. Hence the study will place its main emphasis on the process of reorganisation of "Sevryba" and the implications thereof leading to potential changes in the producton and marketing of seafood i Russia and the Western Europe.

The aim of this paper is to present some prelimenary results from the ongoing study of the Northern Fishery Association "ARP Sevryba". This paper provides an overview of the economic reforms in the former USSR and the organisational development of "Sevryba" through the last decade. The paper will hopefully contribute to a better understanding of the organisation of the North-West Russian fishing industry both as a potential trade partner and as a competitor in the European seafood market. The results presented here are prelimenary and due to the early stage in the project the main export data will be related to the USSR export of seafood to Norway. It is beyond the scope of this first draft to analyse this problem within a theoretical framework. More detailed information and thorough analysis will be presented in the main report from the study and in later papers.

## 2. RESEARCH DESIGN AND DATA COLLECTION

The work with this study started during the late summer 1991. The "first round" in our data collection effort was carried out during the fall, prior to the dissolution of the Soviet Union. Hence both the terms Soviet Union and Russia are used throughout the text. In the study we are focusing on the organisational changes and the development of "Sevryba" as an industrial organisastion and a managerial instrument to the central administrative planning system. Through the many and in some respect radical changes during the last years the 1980-ies and the beginning of the 90es several new potential possibilities for the development of the Russian seafood industry have occurred. Studies of Eastern Europe and especially the former Soviet Union brings up several both methodological and practical problems which one normally do not face in similar studies in the western world. The most decisive amongst these factors are language barriers, time, validity and availability of information especially related to figures and statistics.

The main emphasis of this study is to provide insights into the North-West Russian fishing industry both as a potential trade partner and as a competitor in the European seafood market. The written material available about the russian seafood industry is scarce. Hence this study is conducted as an expolorative study with the goal both to gain insights and to be able to breaking our vague problem statements into a more precise form as in a specific hypotesis.

The empirical data in this paper are based on both primary and secondary data. The primary data obtained consists of unstructured interviews with 14 senior officers and other key personel in "Sevryba" and her member companies. As complementary datasources several journals, newspapers, official statistics and other available material are used.

Central national plans, like in Russia, are with few exceptions broken down to the enterprise level and the plans are carried out by the enterprises as obligatory plan directives. Nove (1986 p. 9) states the following distinction between the centrally planned economy and the more market driven economies :

> *".....The essential distinguishing feature is that the producing enterprise are **told** what to do, whereas in a different model (eg. Yugoslavia, Hungary) they have much greater power deciding what to produce through contractual relations with customers".*

As a theoretical basis for this study we have chosen the theories about organisational behaviour and industrial buying behaviour with special emphasis on Decisison System Analysis (DSA) (Møller 1985, Webster 1984, Wind and Thomas 1980, Sheth 1973). This approach provides, to the authors opinion, a more flexible theoretical fundament for the study. The outline of the theories will be presented in later papers as indicated in the introductory chapter.

## 3. CENTRALLY PLANNING AND ECONOMIC REFORMS

The socialistic (command-) economy was introduced in the Soviet Union after the period of New Economic Policy (NEP - lasting from 1921 to 1928). Even though there have been several reforms and formal changes during the period from

1928 and up til the beginning of the 1980-es[1], it can be fair to say that the basic idea and the execution of the Soviet economic system have not changed notably. The evolution of the central planning in the Eastern Europe have led to a different industry structure, industrial behaviour and management than we know from the industrial organisations in the western world. Critical factors as input, output, prices and wages, sales and purchases and so on was and are still (to a large extent) determined and planned by central political and planning authorities.

> *"...in this manner, planners preferences supplant consumer souveregnty by taking rescource allocation out of the hands of the consumer and placing it on the hands of the administrative apparatus* (Gregory and Stuart 1986 p. 9).

To complement and support the planning system there are an intricate system/apparatus for supervising and controlling the enterprises and their performance, particularly in respect to their fulfillment of the directed plans for production. Likewise the export activities has been correspondingly subject for the system of centralised decision making. As a consequence of the taut central planning and control the soviet enterprises have not paid very much attention to other companies and/or local buyers and potential customers or consumers (Freris 1984). On the other hand the planners and planning authorities have received substantional attention from the enterprise managers.

From the mid 1980ies the need for more far reaching economic reforms have been at the core of political discussions in the Soviet Union. These discussions and the following process ended up with a new law proposal regulating the soviet enterprise. The legislation was finished and implemented in the mid 1987 (The USSR law on State Enterprises).

The main objectives of the economic reforms for internal economic activity are to enlarge the independence of state enterprises and collective farms, and to extend the possibility of economic activity for other co-operative enterprises and individuals. In addition one sought to incourage co-operartion between the above mentioned soviet enterprises (ADECO 1989).

One of the driving forces for the perestroika has been the decision to provide selected Soviet industries and enterprises with direct access to foreign markets (United Nations 1988). Further the new economic mechanisms concerning foreign economic relations was in principle aiming towards a system for more decentralised foreign trade, and to link the enterprises performance more closely to wages and profits connected to their (foreign) trade activity. But even though the reform process for restructuring of the soviet economy was ment to lead to an increased local autonomy and decentralisation there still are many both legislative and practical barrieres for independent economic performance of the single enterprise. One of the interconnected problems tied to this fact is the presence and status of the planning apparatus and central bodies still striving for fullfilment of plans and regional needs/demands (Dyker 1992).

## 4. "SEVRYBA"

### *4.1 Introduction*

Like other soviet economic organisastions "Sevryba" have been submitted to central planning and control and represents a part of the total soviet economic system. In the total measure of the Soviet Union economy, foodstuffs and raw material for production of foodstuffs only represents 1.5 % of the total export value in 1988 (ITC 1989). In this respect Seafood does not represent a major sector in the soviet economy as an export commodity. However the fishing industry together with agriculture is considered as important to the former Soviet Union and have a relatively strong strategic significance. The main reason for this is tied to the all union goal to be self supplied with foodstuffs based on these two branches. As concerned to the fishing industry the national goal is to raise the per capita consumtion of seafood (to 19 kilograms a year by 1990). The strategic significance have been underscored several times by official spokesmen, and also in a report presented by the USSR ministry of foreign relations (Op cit p. 55) :

> *"The fishing industry has a prominent role to play in the implementation of the country's food programme".*

As related to "Sevryba", the Kola region which is the home base for "Sevryba", is the second largest supplier of seafood to the domestic Soviet market (Doiban et al 1992). According to the "Sevryba" association the total output represents

1. Especially in the late 50ies and early 60ies

20 % of the total seafood production of the USSR. The administration and the main fishing and processing facilities are located in Murmansk, the capital of the Kola region. Hence Murmansk is the site of the largest soviet fish processing combine (Murmansk Fish Processing Plant) and also the home base of the three largest fishing fleets (Murmansk Trawl Fleet, "Murmanrybprom" and "Sevrybcholodflot").

Even though the main base of "Sevryba" is situated in Murmansk the association also have several units in Arkhangelsk regions and in the Karelian republic[2]. The association which was founded in 1990 consists of 24 production units, fleets and other independent companies. The association employed by mid 1990 about 77.800 people, and was by that one of the largest regional fishing associations in the former USSR. "Sevryba" is a vertically integrated structure and consists of both catching, processing, subsidiary and research units. In addition there also is a "marketing" or sales unit called Sevrybsbyt. In 1990 the total catch was ca 1,6 million tons of which edible products amounted ca 900.000 metric tons. The export represented about 10 % (120-140.000 metric tons) of the total catches. The most important fish catches (in volume) are pelagic fish like macrel, sardines, herring and anchovy. Other important species are whiting, cod fish and some shellfish. These fish species, especially cod fish scallops and shrimps are the major items for export, and represents by that the main source of hard currency to the "Sevryba" association and her member enterprises.

*4.2 Organisational changes in "Sevryba" through the reform process : Structure and decision making nodes in the process.*[3]

As noted earlier the fishing industry have had a central place in the food supply in Russia/Soviet Union like in other nations for hundreds of years. But the development of the fishing industry have to a much larger extent been subject to severe central planning and control in Russia than in other countries.

Through the period up till 1970 several economic reforms was implemented, but only minor organisational changes in the fishing industry followed as a direct consequese of these. But in 1973 the central adminstration introduced a new system called the *all union production association (VPO)*[4], so called obedineniie, as the industrial organisation of the future, (Dyker 1992 p. 60) :

> *"This created a highly complex system of sub-intermediate level, in which the norm was so called* ***production*** *associations to group together fairly small numbers of associated enterprise, which the latter sometimes losing their juridical independance, and* ***industrial*** *associations taking over the role of of the old glavki".*

The aim of forming these (obedineniie) associations was to improve the industrial performance, especially in the areas of labour productivity, quality, costs and use of advanced technology (Gorlin 1974). Figure 1 shows the structure of the economy and the decision lines in the fishing industry after the 1973 reform.

As the figure shows the system is built up after a model consisting of several levels both in the vertical and horizontal direction. But very simplyfied the hierarchy is basically consisting of six vertrical levels ; the communist party/presidium (CPSU), the Council of Ministers, the Planning Commitees, Ministries, industrial associations, and the production units.

In this structure the party had a superior position as the formal instance both executive and political decision maker. Nove (1986 p. 7) has described this fact as following :

> *"The politbureau is at the same time the supreme arbiter of politics and the board of directors of the USSR Ltd., the largest firm in the world".*

The production associations became a very common pattern of organizing the fishing industry throughout the entire union, and by this they took over most of the task from the directorates (Glavkis) organising the most important sea basins. According to Sysojev (1974 p. 49) the following associations (VRPOs) [5] was established as a consequence of the 1973 reform :

(i) VRPO "Dalryba", for the far East

2. The information presented in this passage is mainly based on information official data presented by Sevryba.
3. This part is based on two main sources : Sysojev, N.P. Economics of the Soviet Fishing Industry, and Davidsen, T. An historical overwiew of the USSR/Russian seafood Industry.
4. VPO ( Vsesojuznoe Proizvodstvennoe *Obedinenjie* )
5. VRPO - Vsesojuznoe *Rybnoe* Proizvodstvennoe Obedineniie

(ii) VRPO "Zapryba", for the Baltic sea areas

(iii) VRPO "Azcherryba[6]", for the fisheries around the Azov sea and the Black sea

(iv) VRPO "Kaspryba", for fisheries in the Caspian sea area

(v) VRPO "Sevryba" ("Northfish"), for fisheries in the north western Russia.

VRPO "Sevryba" consisted in broad of the enterprises and organisations composing the former Murmansk sovnarchoz [7] beeing the main part of the fishing industry in the Murmansk, Arkhangelsk and Karelia regions. In this period most of the seafood was probably exported by the organisation Sevrybsbyt through the three foreing trade organisations V/O Lenfintorg, V/O Prodintorg and V/O Sudoimport (Anon 1971).

As earlier noted one of the reasons for this reorganisation was to give the ministries and planning organisations more time to deal with the over all planning and control and hence transmit the the more "day to day" like tasks to the industrial associations.

> *"The rational is that the associations are better qualified than central planners and ministries to make planning and resource allocation decisions at the enterprise level, because associations are closer to the sources of information on which these decisions are made".* (Gorlin 1974 p. 5).

Even though the party have executed great power throughout the differrent levels in the decision process to the industrial organisation and single enterprise, the Primary Party Organisations (PPOs) do not normally have the over all responsiblity for the economic behaviour of the single enterprise any more.

> *"Most political scientists agree that the power of the PPOs is limited and does not strongly influence the operation the Soviet enterprises"* (Gregory & Stuart 1986 p. 157)

In addition to the political level the different planning organisations have played a very important role by instructing and supervising the industrial associations. In particular the state planning commission Gosplan have had great impact to the process of decision making and control on production (figure 1).

In the planning of production the top political planning and executing level have received help and input from amongst others the planning organisations, the branch ministery (ministry of fisheries in the RSFSR) the industrial organisation "Sevryba" and the different member enterprises. Through this process the planning organisations have been able to submit instructions leading to a total satisfaction of the all union demand for products and services, in this case seafood. The taut plans have been very detailed even down to the single enterprise both related to input and output and the pricing of the commidities and labour all through the process. Freris (1984 p. 164) has stated as a conclusion on his study of the soviet enterprise that :

> *"....There is every indication that the degree of centralisation is increasing both in terms of the growing role of associations and in terms of the concentration of production in the hands of a smaller number of enterprises and/or associations. An analytical approach of the behaviour of the firm must therefore consentrate even further on the role and games of the planners and the planned and the "unofficial" degree of freedom that the enterprises either are allowed to enjoy or manoeuvre themselves to enjoy".*

In figure 2, the arrows shows the direction of the directives and instructions (the weighted arrows) and the basic information or feedback from the enterprises and industrial association stating their estimated production for the next period of planning and also statistics from the historical production[8]. As noted earlier in this chapter, the enterprise havethe possibility to influence the plan demands through their feedback to their supervisory instance even though the command lines points in one direction only. This because the process of setting the plans goes through a iterative process between the relevant instances until the total needs (both locally and on republic/union level) is satisfied.

From 1987 to 1990 the reorganisation and reform processes have led to several formal changes of the organisation of the seafood industry in the Soviet Union and Russia. In 1990 the association "ARP Sevryba" was established. The association

6. Have later changed the name till Yougryba
7. Sovnaschoz was an earlier form of industrial organisation (1957) attempting to change the Soviet planning scenario from a ministerial to a regional basis.
8. The statistics is delivered to the ministry of statistics Goskomstat who collect and refined/accumulate tem for use both for control and planning purposes.

was now consisting of member enterprises (voluntary membership) and each of the enterprises was their own juridical person. Figure 3 shows how the association was (and still are) organised. As the figure shows "Sevryba" was organised into a self supplying structure consisting of vertically or horizontally integrated enterprises delivering different kind of input to each other. After 1990 the advantage of this type of formal structures do not have the same significance. The main reason for this is the changes in the impact of the centrally planning system.

One of the consequences is that "Sevryba" now is much more independant in relationship to central bodies, especially the former ministry of fisheries. One of the important changes is that the former plan demands have been substituted by state orders. Now the ordering institution have to compete with other (potential) buyers on a contract basis. This means that the single member company *in principle* is free to select buyers and vendors based on their own needs and criterias for price and quality etc. But still "Sevryba" do have an important function as a coordination element and also to a certain extent an intermediate link between the single enterprise and the central authorities. One of the important functions of "Sevryba" is the administration and distribution of quotas. It is interesting to note that "Sevryba" seems to have the responsibility both for member and non menber enterprises in this case, and both processors, transportation, and fishing fleet enterprises are "granted" with quotas. This gives a unique power to the "Sevryba" organisation and hence gives the membership (and obedience) a special value.

### *4.3 Sevryba as an exporter - motives and constraints*

So far in this presentation nothing have been said explicitly about the reform process and its impact on the foreign trade. Some elements of this aspect will be briefly discussed in this chapter. One of the most important factors to keep in mind when discussing the export performance of "Sevryba" and her member enterprises, is that the over all goal has been and still are, to provide the domestic market with (sea)food. Further there are two more factors that also plays an important role and seems to have a significant impact on the export behaviour of the enterprises. These are the enterprises need to operate on "khosrachot[9]" basis on the one hand and their need for foreign currency and technology on the other hand.

As indicated earlier, the volumes of the total fish catch mainly consists of the pelagic species. These are low priced products and does, with few exceptions only, go to the domestic market for consumption. According to "Sevryba" cod represents only 6 -10 % of their total annual catches. Estimated from the official total catches for "Sevryba" in 1990 this constitutes about 96.000 - 160.000 thousand metric tons. Primary results indicate that cod and haddock (and also fish oil, scallops and shrimp) represents the main items of export. As regards the cod (and other whitefish) it is by the russian enterprises evaluated equivalent to foreign currency. The importance of codfish as an export commodity is supported by studying the export and import statistics for the former Soviet Union. So far we are only able to present the foreign trade between Norway the former USSR. Figures 4 and 5 show the trade pattern as related to species.

It must be emphasised that the trade pattern shown in figures 4 and 5 only consists data about trade between Norway and the former Soviet Union. In this bilateral trade it can be fair to say that the trend is like describes above. More generalised one can say that high value products are often exported out of the former USSR to generate hard currency earnings.

But even though the demand and need for hard currency is strong in Russia, it is not necessarily so that the enterprises in Russia finds it favourable to do these earnings. This is connected to the legislation on foreign trade and taxation of foreign currency. The new legislation regulating the foreign trade have in principle provided the enterprises with less stringancy during the last 3 years. One important factor is the abolition of the plan demands for production and delivery to "dedicated buyers" which gives the enterprise the possibility to choose whether they want to sell to a domestic or foreign buyer.

Selling to a foreign buyer would generate foreing currency and lead to the possibility of buying other and lower priced seafood for distribution to the domestic market, or buying new technology for catching, processing of seafood. But at the same as the legislation opens up for foreign trade they also creates new barriers. One of these are the law on foreign currency and taxation which gives the local and central bodies (in practice) the right to "withdraw" 50-90 % of the currency earnings. This is one of the many contradictions that the "new" russian industry have to face in their new economic system. Like in other countries the industry seeks to adapt to the environment in order to maximise their (economic) perfomance. And it will indeed be interesting to watch the future development of the industry.

9. self financing - without governmental financial support.

## 5. CONCLUDING REMARKS

During this brief presentation of "Sevryba" and the development of the Russian economic system there are only presented a broad picture of the scene. So far it is hard to say if the export performance of "Sevryba" will or can affect the European market for codfish, due to its limited quotas of North Atlantic cod and other whitefish. At present the main commodities within the whitefish export are either fresh chilled H & G fish or frozen (cod)block fillets. The block export represents a minor contribution to the total supply to this market. On the other hand large amounts of fresh chilled cod have been exported to (Northern) Norway during the last years, and a change in this pattern could certainly harm the seafood industry based or partly on these landings, but there is no trend towards a negative shift in this trade. So far the russian industry seems to find alternative adaptions to the potential legislative barriers to export which speeds up the export rather than limiting it.

## REFERENCES

**ADECO** (1989). *Economic Reforms in the European Centrally Planned Economies*. UN Economic Commission fort Europe, New York, NY10017 USA.

**Anon** (1971). Sovietunionen - en marknadsredogjørelse sammansteld av den Svenska Ambassaden i Moskva.

**Caves R. E.** (1980). Industrial Organisations, Corporate Strategy and Structure. In *Journal of Economic*. Mars 1980 vol **XVIII** : 64-92.

**Doiban V., M. Pretes and A. Sekarev** (1992). Economic development in the Kola region, USSR ; an overview, *Polar Record* 28 (164) : 7-16, Great Britan.

**Gorlin A. C.** (1974). The soviet economic associations. *Soviet Studies* vol. **26** : 3-27.

**Gregory P.R. and R.C. Stuart** (1986). *Soviet Economic Structure and Performance*, 3rd Ed. Harper & Row, Publishers, New York .

**ITC** (1989). USSR : *A market for products from developing countries*. International Trade Center Unctad/GATT, Geneva.

**Møller K.E.** (1985). Research Strategies in Analyzing the Organizational Buying Process. *Journal of Business Research*, **13,** 3-7 : 3-17.

**Nove A.** (1986). *The Soviet Economic System.* Allen Unwin, Inc, Winchester MA, USA.

**Porter M.E.** (1980). *Competitive Strategy. Techniques for Analyzing Industriens and Competitiors*. The Free Press, New York, USA.

**Porter M.E.** (1985). *Competitive Advantage. Creating and Sustaining Superior Performance*. The Free Press, New York USA.

**Smith G.B.** (1988). *Soviet Politics*, Macmillan Education LTD, Houndmills, Hampshire, London.

**UN Conference on Trade and Development** (1988). USSR : *New management mechanism in foreign economic relations*, New York, USA

**Webster jr. F.E.** (1984). *Industrial Marketing Strategy*. 2. ed. John Wiley & Sons, USA

**Webster jr F.E. and Y. Wind** (1972). A General model of Understanding Organizational Buying Behavior. *Journal of Marketing*, Vol. 36 : 12-19.

**Wind Y. and R.J. Thomas** (1980). Conceptual and Methodological Issues in Organisational Buying Behaviour, *European Journal of Marketing* Vol. 14, 5/6.

FIG. 1.
STRUCTURE OF THE SOVIET ECONOMY (ADAPTED FROM SMITH 1988 P. 196).

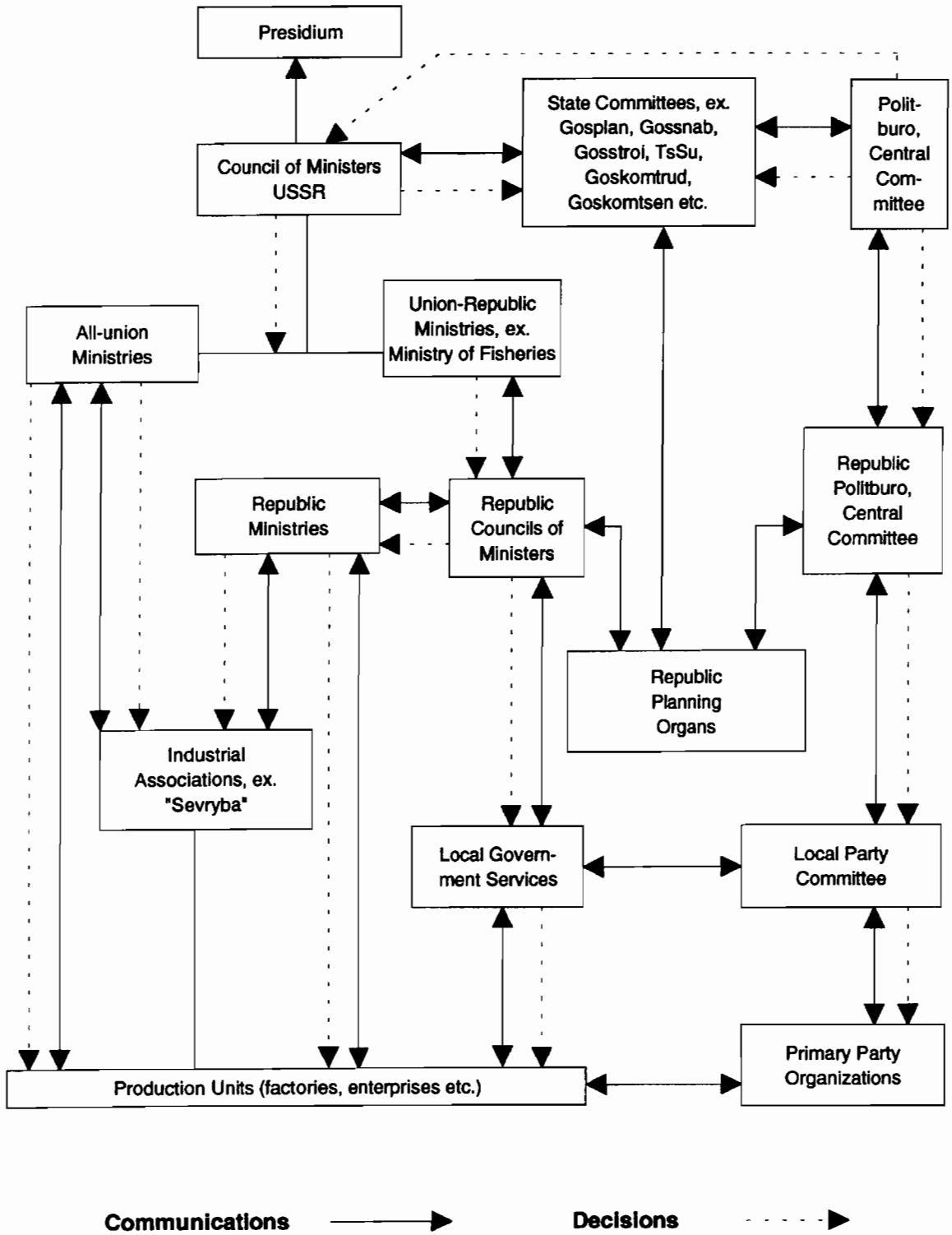


FIG. 2.
FLOW OF AND PLAN DIRECTIVES AND INFORMATION (ADAPTED FROM DYKER, 1992 P. 7).

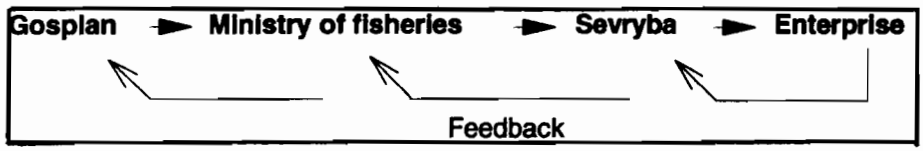



FIG. 3.
ORGANISATIONAL FLOWCHART OF ARP SEVRYBA.

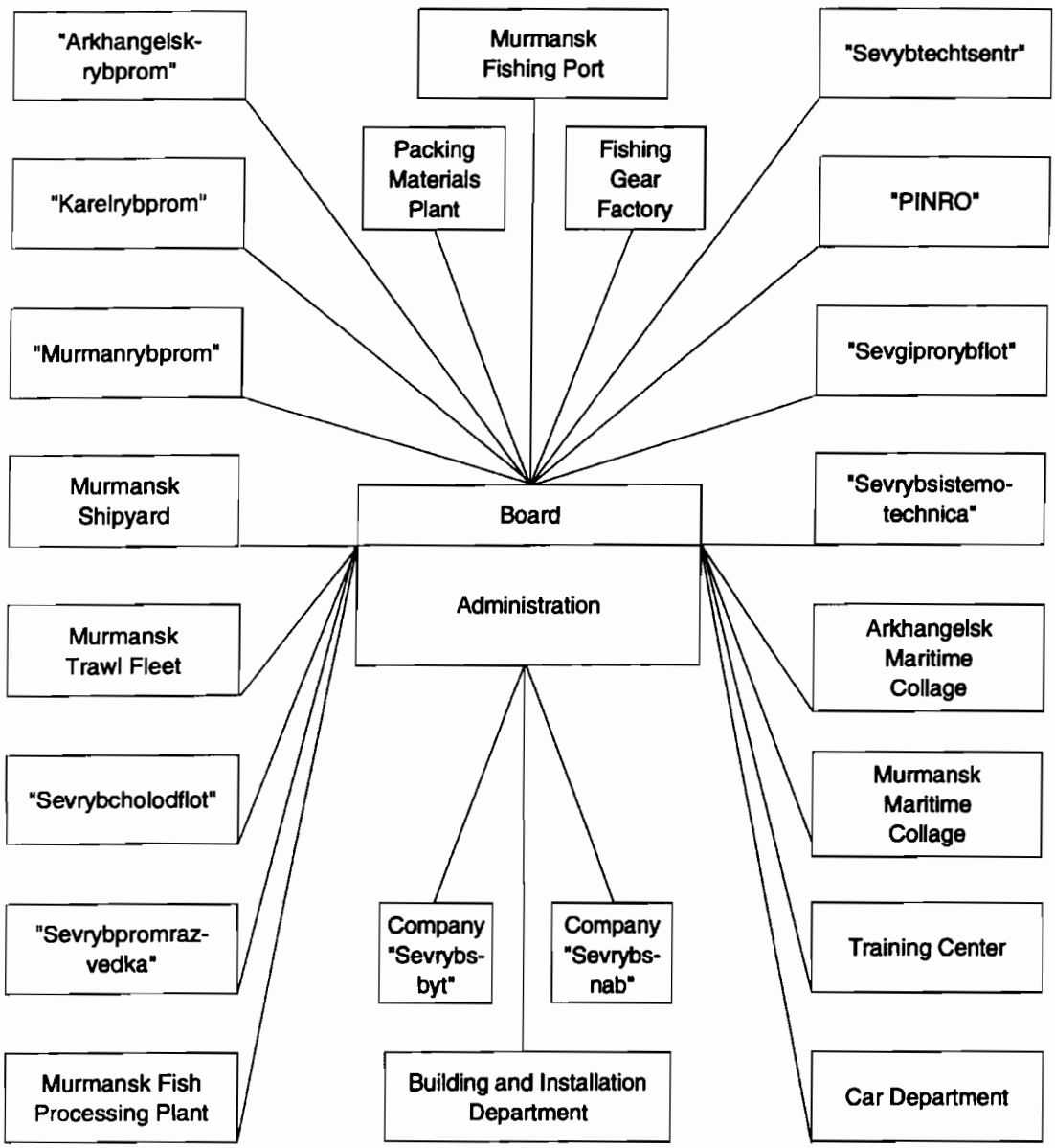
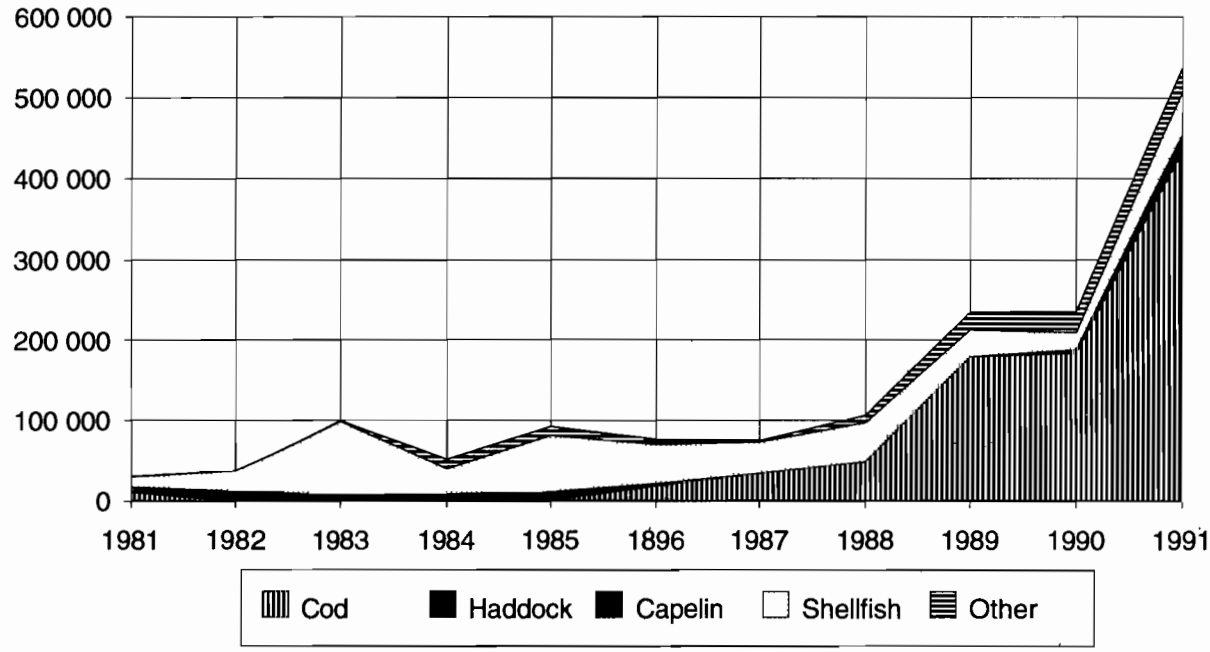
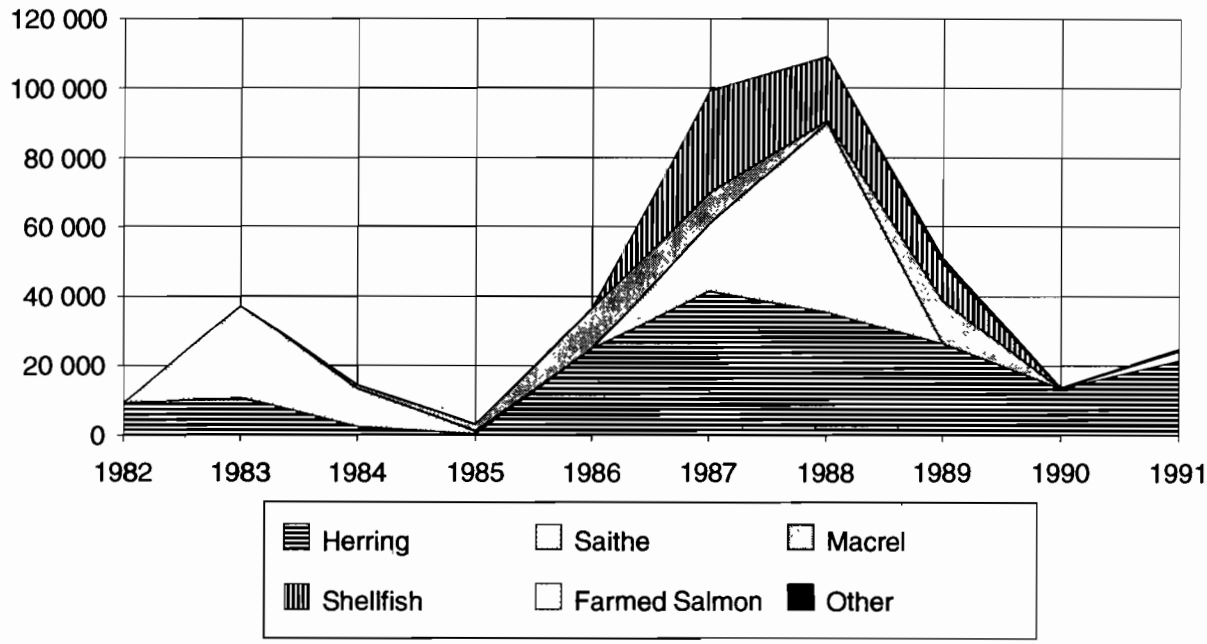


**FIG. 4.**
**NORWEGIAN IMPORT OF SEAFOOD FROM THE USSR 1981-1991 VALUE (1000 NOK).**




Source: The Norwegian Central Bureau of Stratistics/FORUT

**FIG. 5.**
**NORWEGIAN EXPORT OF SEAFOOD TO THE USSR 1981–1991 VALUE (1000 NOK).**




Source: The Norweagian Central Bureau of Statistics/FORUT

# Contraintes Économiques et Sociales et Développement de l'Aquaculture extensive et diversifiée dans un Pays en Voie de Développement. "Le Cas de la Côte orientale de Madagascar"

**Georges Rafomanana**

ENSAR, Laboratoire d'Economie Halieutique, 65, rue de Saint-Brieuc, 35042, Rennes Cedex, France

RÉSUMÉ

*Il existe des contraintes internationales et nationales tant au plan économique qu'au plan social dont doivent tenir compte des producteurs pour développer leurs activités. L'objet de la communication est d'identifier ces contraintes et de préciser les modalités de développement de ces activités en fonction de trois types de développement :*

1. *Type de développement villageois dont les objectifs consistent en l'augmentation de la production et en l'amélioration des revenus de la société rurale.*
2. *Type de développement industriel qui ne peut éviter certaines contraintes nationales et internationales.*
3. *Type mixte qui combine les deux premières approches.*

*Dans tous les cas, cela induit des comportements des producteurs différents et une prise en compte de l'hiérarchie des contraintes différentes. L'étude de cette diversification du système de production va permettre d'analyser et d'approfondir davantage les problèmes de développement dans le monde rural d'un pays du Tiers Monde à économie typiquement agricole orientée vers les cultures de rente. L'identification de nouveaux paramètres contribue à infléchir les styles de vie et les styles de développement. Quel type de planification exige cette nouvelle méthode ? Quelles nouvelles manières d'occuper l'espace et le temps, elle requiert ? Comment elle ne peut être mis en oeuvre sans une certaine indépendance technologique ?*

ABSTRACT

*Producers have to account for international and national limitations from the social and economic point of wiew to work out these activities. The purpose of this paper is to describe conditions for the development of these activities according to three models :*

*1. Rustic model with objectives to increase production and to improve rural incomes.*

*2. Industrial model with international limitations relative to the market.*

*3. Model mixing to the aspect before.*

*Producers must take different attitudes in the face of these situations. The diversification of the production system can be analysed to understand the increasing problems of development in the Third World agricultural economy. The identification of new parameters enables us to find means of subsistence and models for development. What is the type of planification required for the new system ? How can the necessary time and space be taken ? What to set in practice without technological independence ?*

## 1. CONTEXTE ECONOMIQUE ET POLITIQUE ET ENJEUX

L'indépendance, **en 1960**, a hérité d'une économie fondée uniquement sur les cultures d'exportation. Les événements de **1972** ont complétement changé les lignes politiques, financières, économiques et sociales qui ont été réaffirmées, **en 1975**, par les nationalisations, les restrictions de change, les investissements pour l'industrialisation et les restructurations sociales et administratives.

Mais l'inefficacité des mesures prises et les revers de la dépendance économique issue des conjonctures internationales de la décennie 70, précipitent le pays dans une crise profonde. Depuis 1980, l'application de la politique de stabilisation et d'ajustement économique, politique dictée voire imposée par le Fonds Monétaire International et la Banque Mondialepour assainir l'économie et restructurer le système de planification ne fait que contribuer à l'extension de l'appauvrissement des différentes couches sociales particulièrement les plus démunies aussi bien en milieu urbain qu'en milieu rural. Et, les difficultés s'amplifient davantage et la situation économique et sociale se détériore durant l'année 1990. Ce qui précipite les mouvements populaires de 1991 qui mettent un terme au régime mis en place depuis 1975.

## 2. PROBLEMATIQUE

Face à la détérioration des conditions de vie à Madagascar, il s'avère nécessaire de déterminer les lois qui président à la paupérisation en milieu rural afin de proposer des pôles de développement aquacole qui permettent aux ruraux de lutter contre cette tendance. A Madagascar, l'appauvrissement se manifeste de différentes manières selon les régions et les particularités des populations concernées. Cela justifie le choix d'un type de combinaison d'activité (aquaculture et diversification) dans une zone géographique de l'Est du pays.

## 3. METHODOLOGIE

Dans cette perspective, il s'agit d'identifier les groupes cibles et de coordonner la mise en oeuvre des opérations de développement d'une façon effeciente et adaptée au contexte du pays. La méthode consiste à élaborer une base de données de manière à disposer d'indicateurs qui permettent de repérer les changements de comportements et d'habitudes des producteurs ruraux afin de mieux intégrer dans les méthodes culturales les activités aquacoles en milieu rural. L'investigation s'inscrit donc dans le cadre de la dimension sociale de l'organisation-développement des activités aquacoles du monde rural. Les objectifs en sont multiples :

- Analyser l'impact de la politique de redressement sur les conditions de vie des producteurs ruraux.
- Etudier les réactions des paysans ruraux face à la dégradation de l'environnement socio-économique.
- Essayer d'analyser le processus de repli du monde rural sur une économie de subsistance.

- Elaborer des pôles de développement à l'intention des producteurs ruraux et en adéquation avec leurs besoins.

La recherche donnera des réponses aux objectifs ainsi posés et, à travers les résultats obtenus, proposer des actions de développement. Les pôles de développement identifiés doivent répondre aux potentialités ainsi qu'aux contraintes observées. Il s'agit de l'intégration de l'aquaculture extensive et diversifiée dans les activités agricoles, qui peut se présenter sous divers types de développement :

- Type de développement villageois dont les objectifs consistent en l'augmentation de la production et en l'amélioration des conditions de vie de la société rurale.
- Type de développement industriel qui ne peut éviter certaines contraintes nationales et internationales.
- Enfin, Type mixte qui combine les deux premières approches.

## 4. RESULTATS

**Les politiques de développement du régime en place, d'une part, et le redressement économique** du Fonds Monétaire International et de la Banque Mondiale, d'autre part, n'ont fait que contribuer à **l'appauvrissement de certains groupes sociaux ruraux menacés de marginalisation :**

- Depuis l'application de la politique de libéralisation de l'économie en 1983, le taux d'inflation se stabilise à deux chiffres.
- Les dévaluations successives du franc malagasy ont fortement réduit les pouvoirs d'achat des différentes couches sociales et plus particulièrement celle des producteurs ruraux.
- Les fluctuations des cours mondiaux des produits de rente ont affecté véritablement les conditions d'existence des petits producteurs ruraux.
- A tout cela s'ajoute l'accroissement rapide de la population qui accentue les difficultés en milieu rural.

Le poids des contraintes institutionnelles ( programme d'ajustement structurel, legislation, insécurité... ) se traduit par la détérioration des conditions de vie et surtout par le repli du monde rural sur une économie de subsistance. Ces phénomènes constituent des blocages à toute forme de développement.

Toutefois, des résultats tangibles ont été obtenus par la mise en oeuvre de la politique d'assainissement économique malgré certaines conséquences néfastes sur les populations rurales. De plus, des changements se manifestent dans les comportements et les habitudes des acteurs économiques et se manisfestent par :

- L'émergence d'un certain esprit d'entreprise au sein de la population rurale, le développement d'initiatives privées et la prise en charge des responsabilités.
- L'éveil d'un certain esprit de développement régional, généré par des flux migratoires de la ville vers les campagnes :(retour à la terre, apport de techniques nouvelles...).
- De façon induite, une modification profonde des comportements culturels : (désaffection de certaines coutumes et traditions...).

Ces changements de comportements et d'habitudes des paysans ruraux se traduisent par des actes concrets qui peuvent constituer des éléments de base pour l'intégration des activités aquacoles en milieu rural traditionaliste. Ils essaient de diversifier leurs activités agricoles. Ils appliquent les méthodes culturales plus performantes et efficaces. Ils commencent à associer l'élevage à l'agriculture pour tirer profit de leur complémentarité. Les résultats de l'évolution des productions témoignent les efforts réalisés pour diversifier le système productif. Mais les rendements restent souvent aléatoires au profit des calamités naturelles et faibles par manque d'encadrement. (Graphiques de l'évolution des différentes catégories de produits agricoles durant la période 1985-1990).

## 5. CONCLUSION

Ainsi, la prise en compte des contraintes sociales et économiques constitue un des éléments de base de l'étude pour définir et orienter les actions de développement de l'aquaculture extensive et diversifiée en milieu rural. L'intérêt

nouveau des producteurs ruraux pour certaines innovations techniques marque la fin des mythes sur les sociétés traditionnelles rurales et économiquement sous-développées. La situation qui prévaut pour les producteurs ruraux de la région orientale malagasy constitue un des cas d'opportunité de l'application des actions de développement économique en milieu rural. Cette approche permet de mieux apprécier la logique paysanne et les réalités socio-économiques des sociétes rurales traditionalistes afin de déterminer leur capacité tant géographique qu'écologique à accueillir des actions de développement. Ce type d'approche présente l'intérêt de faciliter le passage de la théorie à la pratique en s'inspirant de l'observation de François Perroux : "Le développement, c'est l'organisation". C'est seulement à cette condition que les pays à économie sous développée ont une véritable chance d'assurer leur développement économique.

## REFERENCES

**Badouin R.** (1975). *Les agricultures de subsistance et le développement économique.* Pédone, Paris, 204 p.

**Bellemans M.S.** (1990). Estimation première de la production des pêcheries des eaux intérieures malagasy. Bilan diagnostic des caractéristiques structurelles. Rapport de terrain n° 12. Projet MAG/85014. Avril 1990 : 28-36.

**Kasprzyk Z. et N. Randriamiarisoa** (1990). Production et consommation des produits halieutiques à Madagascar. Tome I. Rapport de terrain n° 14a. Projet MAG/85014. Octobre 1990. 74 p.

**Kasprzyk Z., N. Randriamiarisoa and D. Ravomana** (1990). Commercialisation et consommation des produits halieutiques à Madagascar. Etude socio-économique de la commercialisation et de la consommation des poissons. Tome II. Rapport de terrain n° 14b. Projet MAG/85014, Mars 1990. 112 p.

**Rabelahatra A.** (1991). La rizipisciculture en Afrique. Circulaires sur les pêches, n° 836, FIRI/C836, Juin 1991, 64 p.

**Cahier d'information des pêches** n° 3. DPA/MAG/85014.

**Rabelahatra A.** (1990). *Le développement de l'aquaculture à Madagascar.* Avril 1990, 64 p.

**Rafalimanana T.** (1990). Enquête-cadre sur les principales pêcherie traditionnelles côtières malagasy. Bilan diagnostic des caractéristiques structurelles. Avril 1990 : 28-36.

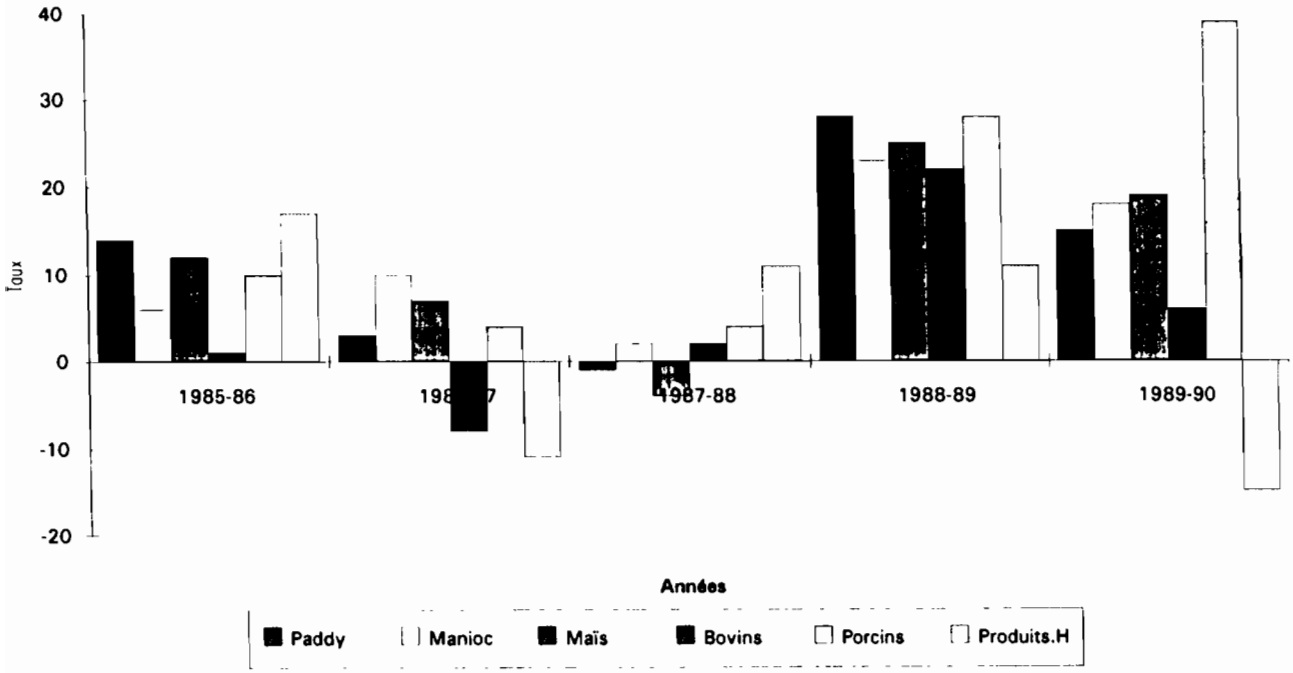
**Freyssinet J.** (1966). *Le concept du sous-développement.* Paris, Mouton, 369 p.

**DGBE** (1985–1990). Direction Générale de la Banque des Données de l'Etat. Situation économique, 455 p.

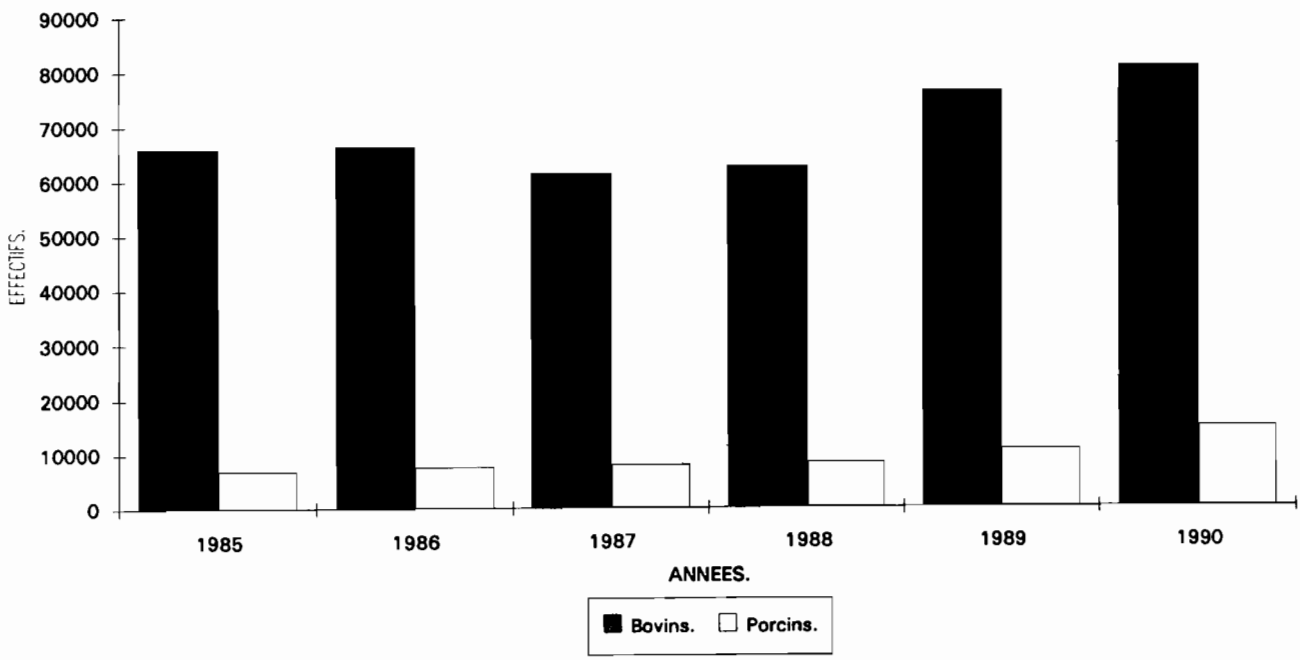
**MPARA** (1991). Ministère de la Production Agricole et de la Réforme Agraire. Récensement national de l'agriculture et système permanent des statistiques agricoles de 1985-1990. Antananarivo, Madagascar. 425 p.

**Perroux F.** (1953). *L'économie des jeunes nations ; industrialisation et groupements de nations*, Paris, PUF, 252 p.

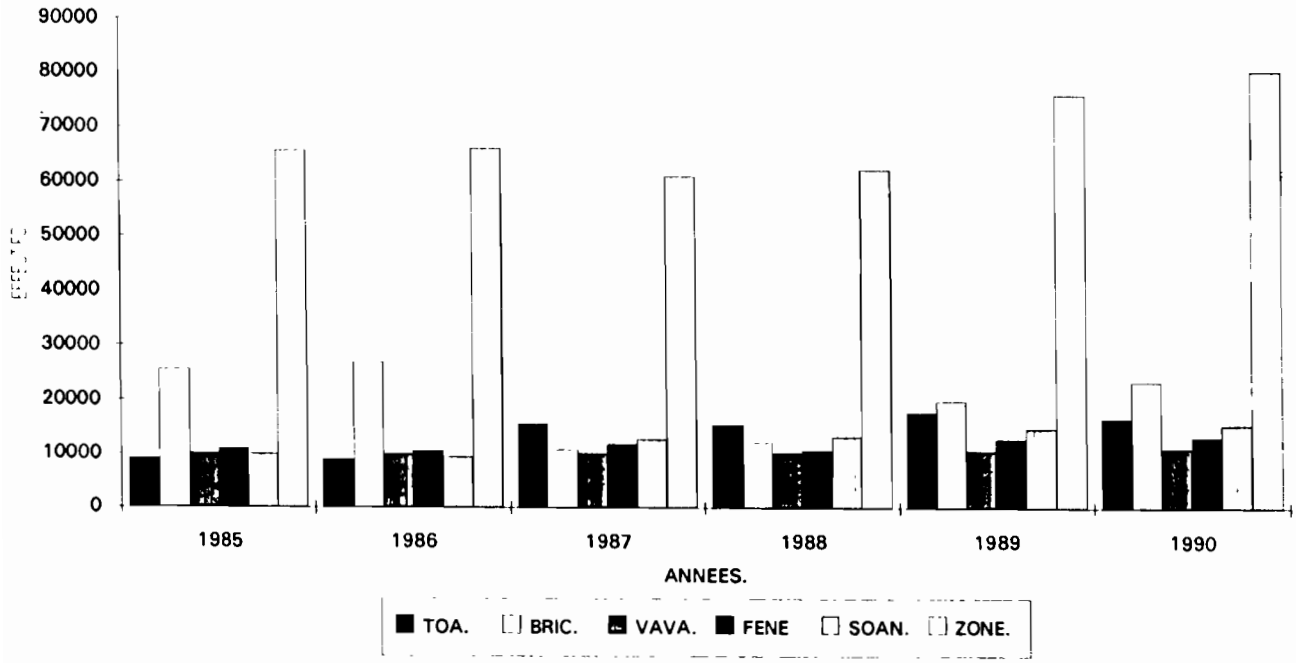
## CROISSANCE PRODUCTION AGRICOLE. PÉRIODE 1985–1990.



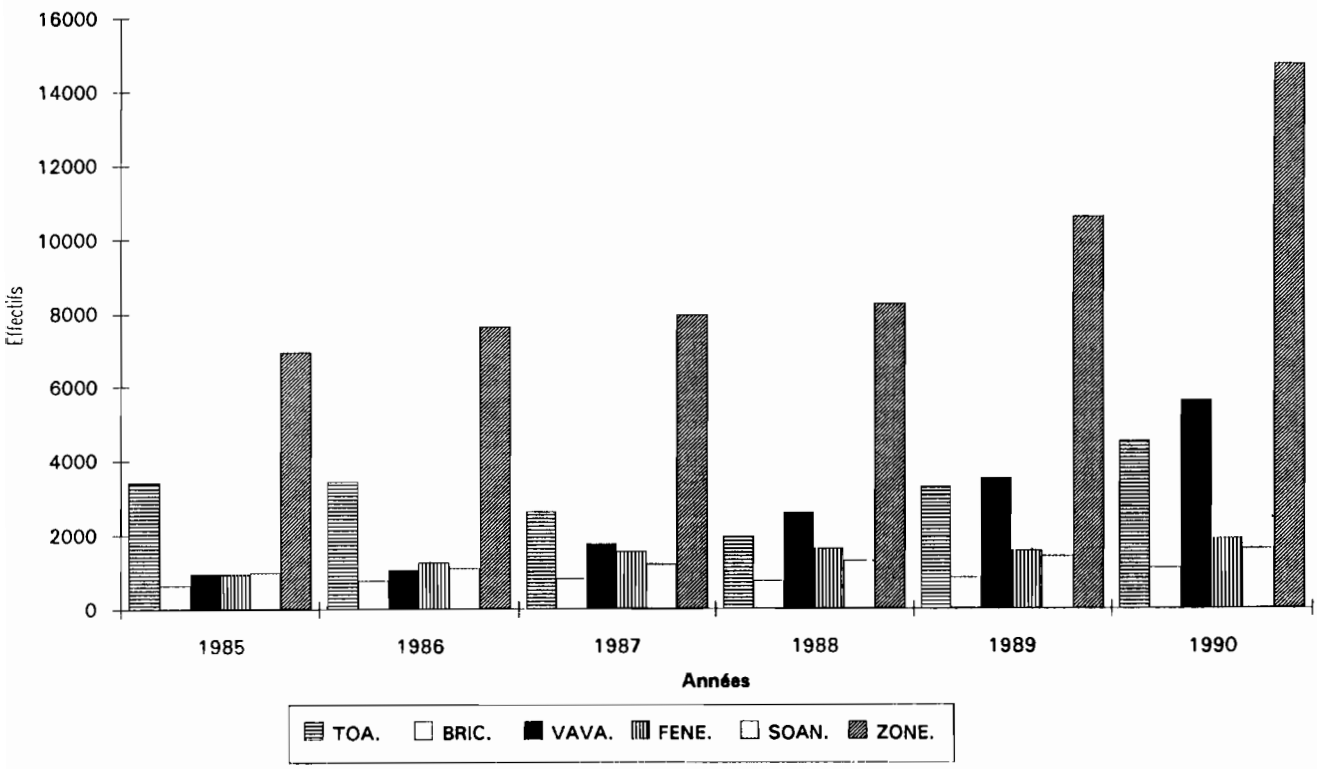

## EVOLUTION PRODUCTION ANIMALE. PÉRIODE 1985–1990.



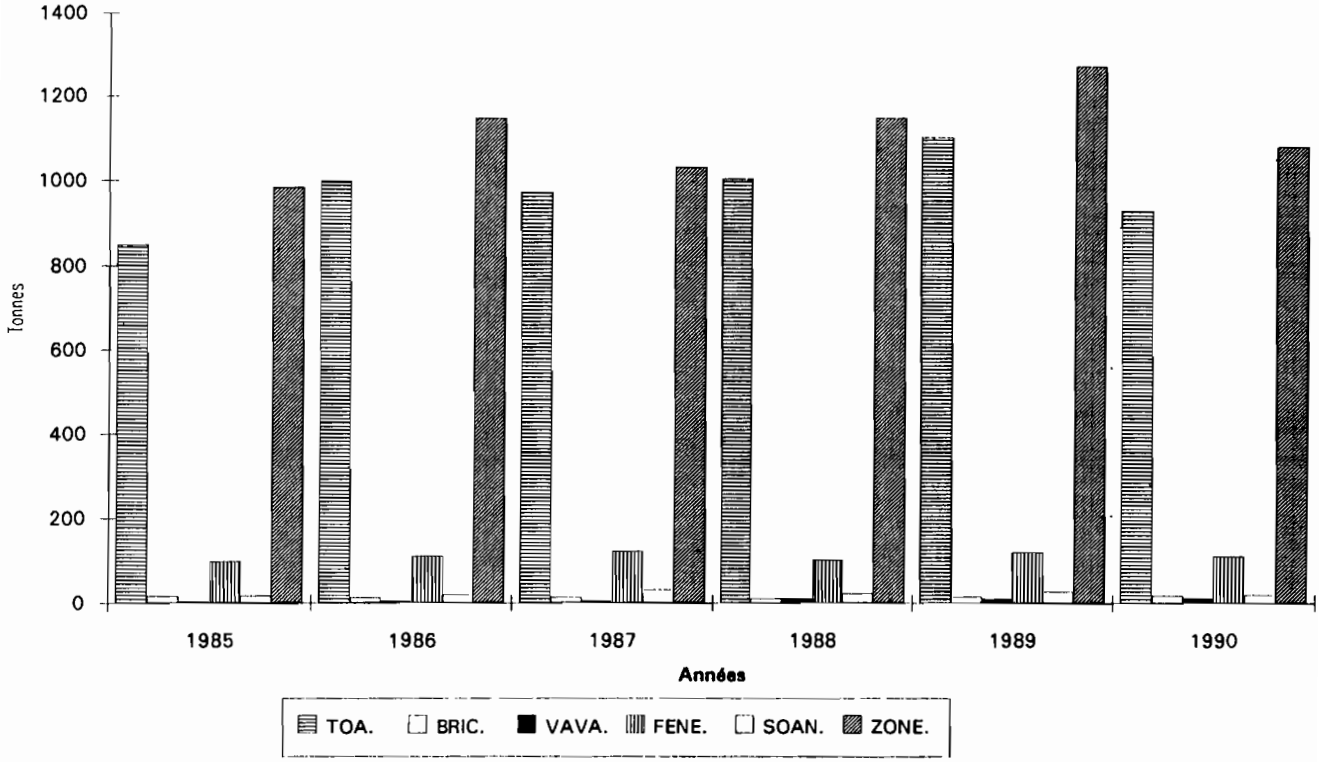
**PRODUCTION BOVINS DES FIVONDRONANA. PÉRIODE 1985–1990.**



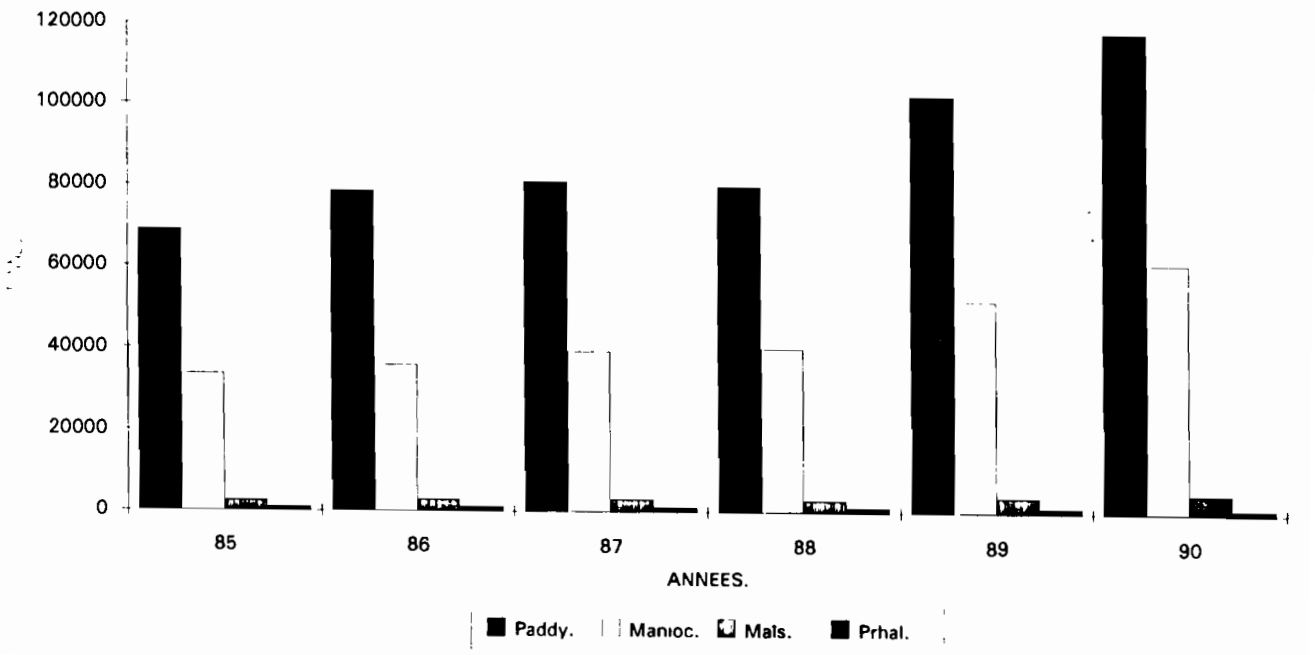

**PRODUCTION DE PORCINS DES FIVONDRONANA.**



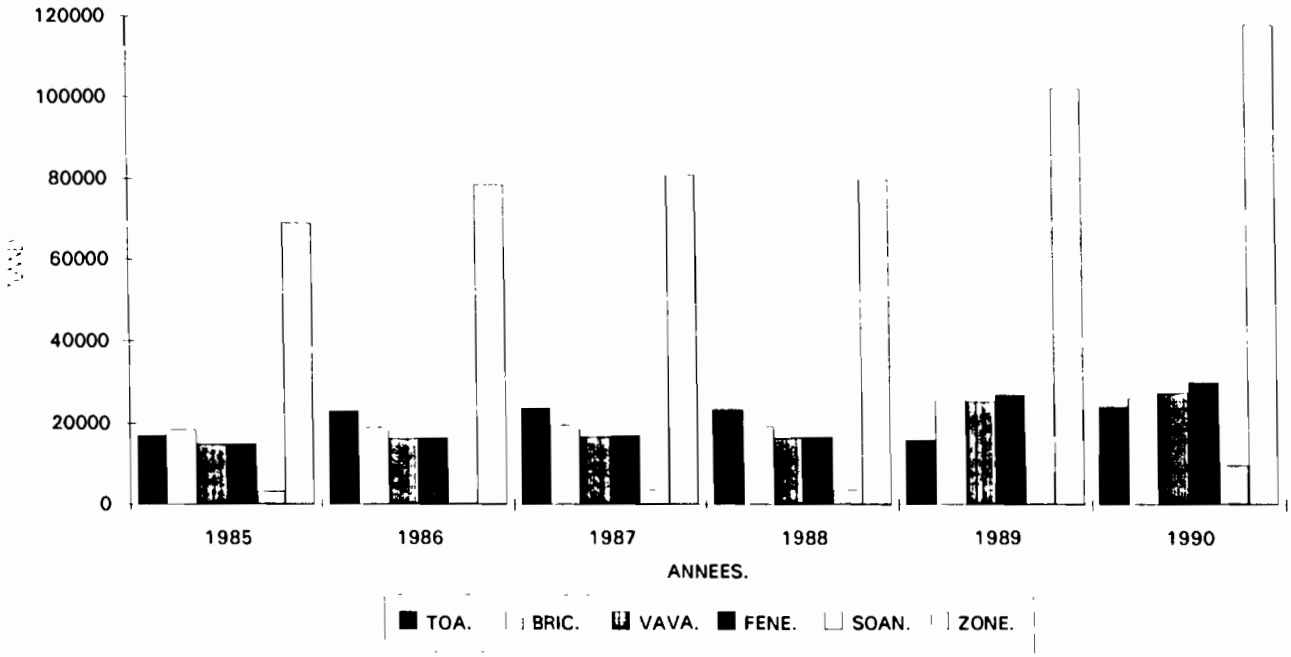
**PRODUCTION HALIEUTIQUE DES FIVONDRONANA.**



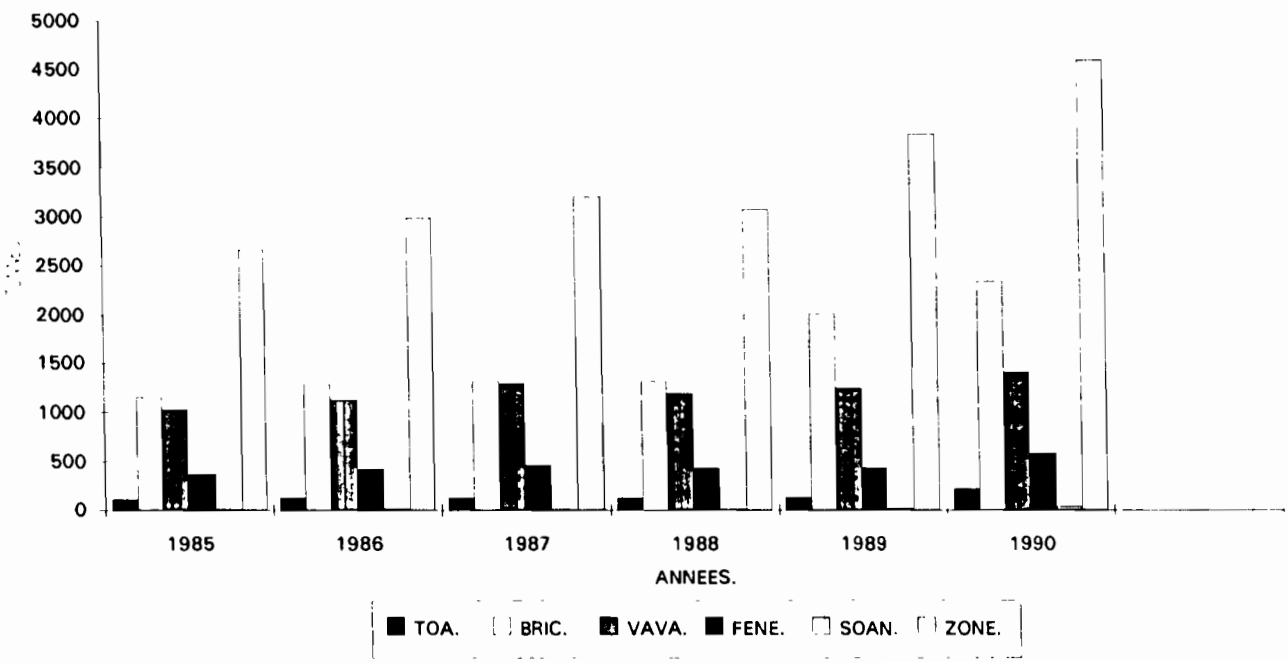

**EVOLUTION PRODUCTION AGRICOLE. PÉRIODE 1985–90.**



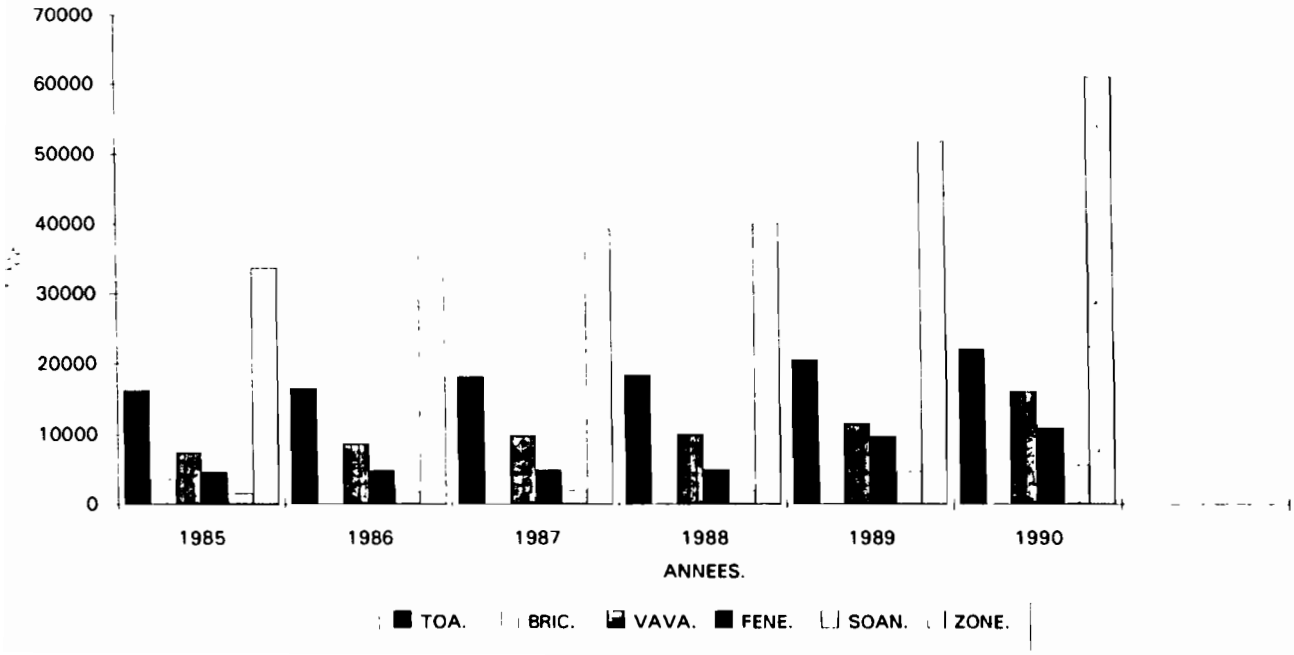
**PRODUCTION PADDY DES FIVONDRANA PERIODE 1985-1990**




**PRODUCTION DU MAIS DES FIVONDRANA PERIODE 1985-1990**



**PRODUCTION MANIOC DES FIVONDRANA PERIODE 1985-1990**



# Canadian Household Demand for Protein : a Lifecycle Approach

**Don J. DeVoretz[a] and Kjell G. Salvanes[b]**

[a]Dept. of Economics, Simon Fraser University, Burnaby, British Columbia, V5A1S6 Canada

[b]Institute of Economics, Norwegian School of Economics and Business Administration, Helleveien 30, N-5035 Bergen, Norway

ABSTRACT

*A recent conference on the state of the art in salmon demand studies (DeVoretz, 1990) heard several participants criticize the long-standing findings derived from aggregate time-series data. With the aid of the Canadian 1986 Food Expenditure Survey, we will refocus Canadian fish demand studies at the retail level using cross-sectional household expenditure data. The major aim of this study will be to provide the first systematic investigation of the demand for several Canadian individual and aggregate fish products at the retail level using household Census data.*

*Our major findings include an estimated meals equivalent model which agrues that the life cycle stage of the household is central to understanding Canadian protein expenditure patterns. In sum, in this augmented model the traditional economic variables of price and household are equal in importance to head of household age and family size and composition in explaining protein demand.*

## 1. AIMS AND OBJECTIVES

Several recent studies covering a variety of protein products have estimated demand functions utilizing household level data[1]. This study will add to the existing literature by estimating the Canadian demand for fish, dairy and meat products at the household level. In addition, we will propose a family life cycle model to measure the impact on protein demand of age, place of birth, education, marital status, and other household features. We employ this approach since the

1. These studies include : Heien and Wessells, 1988 ; Capps *et al*,1985 ; Moschini and Meilke, 1989 ; Bewley and Young, 1987 ; Burton and Young, 1992 : Haden, 1990 ; Chesher and Rees, 1987 ; Hassan and Johnson, 1977 and Chesher, 1991.

omission of these life cycle variables leads to econometric problems as well confusing the roles of taste and economic variables in understanding the change in Canadian protein demand. For example, Atkins, *et al.* (1989) argue that the Canadian debate over changes in the demand for beef is clouded by imprecise definitions of key variables. This study through the use of panel data will be able to provide a more satisfactory definition of key household variables. Furthermore, R.L. Thomas (1987) outlines the inherent econometric problem if we omit household economic-demographic interaction terms ;

*"The major difficulty in estimating total expenditure elasticities from cross sectional data is the existence of a number of nuisance variables.....Possibly the most important of these (nuisance variables) are size and composition of the households."* (R. Thomas,1987 p. 19)

The difficulty in estimating this relationship of taste changes to household characteristics is illustrated by Burton and Young (1992) when they state :

*"Our methodology...does not allow one to determine the underlying causes of taste changes in consumer preferences. But many factors could be suggested to explain changes in taste. These might include changes in household constraints....., in demography (age, sex, and ethnic composition of population) and the structure of the outlets of meats."* (Burton and Young,1992 p. 10)

This paper will directly measure the effects of these individual demographic factors in the changing Canadian demand patterns for protein source products.

## 2. METHODOLOGY

The logic of the method is as follows. First, under the assumption of fixed relative prices Engel curves or total expenditure functions will be estimated for three major (meat, fish and dairy) Canadian protein groups and a residual food category. Next, prices will be introduced and share equations will be estimated under an *Almost Ideal Demand System* (hereafter, *Ideal* ). Restrictions on the share equations will be imposed to test for rationality of the Canadian household. In particular, we will test the demand system for homothicity, homogeneity, concavity and symmetry in prices. In addition, under the total expenditure or Engel curve analysis the adding up restriction will be imposed.

## 3. LIFE CYCLE AND ENGEL CURVES

We initially describe the life cycle food/protein consumptionpatterns of a Canadian household *circa* 1986 with the aid of adjusted Engel curves. Standard Engel or expenditure curves will be augmented with demographic variables to capture the life cycle effects on food consumption *patterns*. The life cycle approach argues that demographic forces alter the levels and expenditure patterns of households (Marr and McCready, 1989). One demographic force ; age, has particular relevance to this food expenditure study. It is often argued that age is a proxy variable for changing tastes within the household especially with respect to protein source foods (i.e. meat, fish, and dairy products). Both the food category (meat, fish or dairy) and place of purchase (away from or at home) are argued to be systematically affected by age. In addition, aging directly affects family income. Finally, marriage and family formation are directly related to age. In sum, age can interact with income (savings), marital status and ultimately family size. All these demographic features vary systematically throughout the family's life cycle and could have an independent effect on food expenditure levels. Table 1 highlights the importance of the age variable in the family food expenditure decision.

First, we note from Table 1 that the typical Canadian household spends eight times more on meat than on marine products over its lifetime. Moreover, as the representative Canadian household head ages ; meat consumption rises (on average) by 1 per cent (of the food budget) for each elapsed 5 year interval. Contrary to conventional wisdom meat consumption does not decline with age, but peaks at age 50 at 18 per cent of total food expenditures. On the other hand, family fish consumption experiences two discrete growth spurts at age 35 and after 50 years of age. However, fish expenditures in the family budget always remain significantly below meat's share of the food budget.

One standard question emerges from an inspection of Table 1. What portion of these changing life cycle patterns for meat and fish consumption are due to demographic forces (family size, age of head, education, marital status, number of dependents) and how much of these differences are owing to the economic forces of relative prices and income ? Estimating food share equations at different stages in the life cycle will identify the relative importance of demographic forces (e.g. age, family size, location,etc.) and economic forces (relative prices, income) in explaining food consumption patterns. Our stylized household model presented below will expand on our arguments for the timing and direction of these demographic effects.

Figure 1 depicts the typical life cycle consumption pattern for a hypothetical food commodity. Initially holding family income and relative prices constant and starting with a unattached male head of household aged O, the act of marriage and child rearing during the interval O-A increases the consumption of the (ith) good at an increasing rate. This rate of increase would be even larger if the household head were foreign born and assimilation occurred during O-A. At point A the household begins to mature and although family expenditure on the (ith) good will continue to rise, household size is fixed and for the foreign born consumption assimilation is almost complete. From B to C household size is constant with (any) older children assumed to still live at home. Finally, after age C is reached, total household consumption is reduced as dependents leave and the aging process continues and less food is required.

Now if there exists no interaction between the demographic variables and income then, superimposing the income effect on these demographic variables would leave the diagram unchanged[2].

However, we agree with Thomas (1987) and Chesher (1991) that there exists interactions between income and demographic variables. The two most obvious are when children enter the labour force and raise household income and when the opportunity cost of leisure of the parents is altered with more children. In the latter case, depending on the relative income and price effects the labour supply of the adult household members may rise or fall. Hence, income and food expenditures may rise or fall. Thus, we argue that demographic variables have a direct and indirect set of effects. The direct effects are unambiguous. However, the indirect effects especially on income are ambiguous and must be determined empirically via the inclusion of interaction terms in our model.

## 4. ESTIMATION MODEL : ALMOST IDEAL DEMAND

Deaton and Muelbauer (1981) argue for an Almost Ideal Demand system (*Ideal*) with restrictions to satisfy the properties of homogeneity, adding up and symmetry. This demand system which is owing to Working and Leser can be written as :

$$W_{it} = a_i + B_i \log (Y_t / P) + \Sigma G_{ij} \text{ Log } P_{jt} \qquad (1)$$

where :

$W_t$ is the ith expenditure share of product i in total expenditures and $Y_t$ is total family per capita income with $a_i$ and $B_i$ parameters to be estimated[3]. P is an index which in its linear approximation equals :

$$\text{Log } P^* = w_i \log p_i \qquad (2)$$

where $w_i$ is the mean of the budget share. Thus, the approximation of (1) now becomes (2)

A system of share equations (i.e. eq. 2) are then estimated to yield parameter estimates which in turn are converted into elasticities.

Estimating Engel elasticities requires that we assume that prices are fixed. This yields a budget share equation for a cross section (i.e.the subscript t is dropped) of

2. As long as the income effect is positive then given that age income profiles have the same slopes as the food age profiles the income effect will simply raise everywhere the age food profiles.
3. This imposes the restriction of homogeneity of scale.

$$W_i = a_i + B_i \log Y \tag{3}$$

When estimating Engel elasticities Philps (1983) argues that additivity (i.e. total shares equal unity) is the crucial restriction. Adding up requires that :

$$\Sigma W_i = 1 \text{ and this will occur if}$$

$$\Sigma a_i = 1 \text{ and } \Sigma B_i = 0$$

This implies that the (ith) good is a luxury if $B_i > 1$ ; a necessity if $B_i < 1$ but $> 0$ and inferior if $B_i < 0$.

When prices and income are free to vary and we estimate the entire food demand system we further restrict the system to satisfy symmetry ($G_{ij} = G_{ji}$) and homogeneity ($\Sigma_i = {}_1 G_{ij} = 0$). The adding up property will hold if $\Sigma_{i=1} a_i = 1$ and $\Sigma_i = 1$ and $B_i = 0$. Concavity or monotonicity are difficult to impose and harder to interpret and thus are omitted[4]. If the imposed conditions of additivity, symmetry and homogeneity empirically hold then the weak separability of our food group aggregations is valid. For our sample weak separability implies that non-food prices do not influence the household's consumption of meat, fish, dairy or the residual food products[5].

The computational formulae for the total expenditure and price elasticities are :

$$\eta_i = 1 + B_i / w_i \text{ and} \tag{4}$$

The Marshallian or uncompensated price elasticity of demand for good $_i$ is[6]

$$\eta_{ij} = d \log Q_i / d \log P_j = -D_{ij} + d \log w_i / d \log P_j \tag{5a}$$

or in terms of the share equation parameters

$$\eta_{ij} = - D_{ij} + 1/S_i [G_{ij} - B_i (a_j + \Sigma G_{jk} \log p_k)] \tag{5b}$$

where $D_{ij}$ is the Kronecker delta and $D_{ij}$ equals 1 when i=j and 0 otherwise. The estimates for $G_{kj}$, $G_{ij}$, $B_i$ and $a_j$ can be obtained from the estimates of the linear approximation of the full model i.e. equation 2.

## 5. DATA

The data source is the *1986 Family Food Expenditure Survey* which consists of two public use sample tapes. The detailed file contains the quantity, expenditure, place of purchase (home, store, restaurant) and week of purchase for 240 individual food categories compiled by the (stratified) randomly selected 10,919 households. The summary file contains the demographic variables collected under the interview process. The actual expenditures on the 240 individual food categories were recorded throughout Canada over the entire year thus, insuring a reasonable amount of price variation. Households (both individuals and families) in different monthly sub-samples kept expenditure records for two consecutive weeks. The summary and detailed versions of the food expenditure tapes were merged by the authors to facilitate estimating the food share equations[7]. The key descriptive statistics are reported in Table 2.

The typical household in the *1986 Food Expenditure Tape* closely conforms to the 1986 Census values. The average household had 2.7 members with 55 % of these units located in large urban areas and 19 % in Quebec and 24 % in Ontario. Sixteen percent of the head of households were foreign born while 25 % of the heads had greater than secondary education. Females headed only 29 % of the households.

4. See Chalfant,Gray and White (1991, p.478) for a more complete rationale for omitting these restrictions.
5. If the imposed conditions do not hold then this implies that we have an omitted variables problem i e. some non food price should have been included in our system.
6. See Green and Alston (1990, p.443) for this and the compensated price elasticity derivations.
7. This merger was required since the summary tape contains the relevant household demographic variables while the price and household expenditure data are contained on the detailed tape. Given the fact that both tapes continued one common vector for the household ID number the merging was possible.

The average household total food expenditure was $148.77. Their food budget shares were 20 % for meat (i.e. beef, pork, veal, chicken and turkey) ; 2.5 % for fish cod, halibut,tuna and salmon), 17 % for dairy products (cheese, milk, butter and ice cream) with 58 % of the remaining food budget spent on other food categories. There existed substantial variation in the key prices for dairy, fish, meat and the residual group ( i.e. DP,FP,MP,RP ) as well as large variations in household total food expenditures[8]

Several data problems were encountered. First, many households reported zero consumption for some of the 240 detailed items. Hence, to reduce this problem we aggregated data into three major protein groups (meat, dairy and fish) and a residual food category[9]. To aggregate we summed over all the household's purchases within that commodity group from the detailed tape. This procedure still left approximately 50 % of the surveyed households with no fish consumption over the two week period. For the remaining groups ; meat, dairy and residual food the number of zero consumption level households were well below 10 % of the total households. Since the price variable was computed as expenditure divided by quantity we had to adjust for zero consumption levels. When a household had zero expenditures for any aggregate we used a regression procedure owing to Heien and Wessels (p. 221)[10].Thus, we were able to use all 10,919 reporting households in every regression.

Other constructed variables included an estimate of the number of meals served in the household. This variable was defined as a meals at home equivalent and was computed as the ratio of all meals actually served at home divided by a multiple of 21 meals. Thus, if the average household with 2.7 members served the maximum (21*2.7) or 56.7 meals at home per week then the ratio equalled unity[11]. The actual value for the meals equivalent variable was 1.01. This indicates that there was no significant trend to eat meals away from home *circa* 1986 in Canada and contradicts the reported descriptive statistics of Goddard (1983, p. 289-290.). We will reflect on this phenomenon in detail in a meals equivalent model of consumption. We also define a spouse at home variable to capture the opportunity cost of the labor involved in preparing meals at home. If a spouse was present in the household and worked less than 20 hours outside the home the dummy variable for spouse at home equalled unity. Otherwise, the dummy assumed a zero value.

## 6. ESTIMATION AND TESTING

### *6.1 Expenditure Elasticities*

We estimate this system with Zellners Seemingly Unrelated (*ZUR*) technique since the adding up criterion implies that shares are interrelated[12]. We report our results for the *Ideal* system with and without demographic variables[13].

Panel A reports the calculated expenditure elasticities for the four chosen product groups. These expenditure elasticities were derived from the estimated share equation (i.e. equations 3 and 4) parameters without demographic variables. Only meat is a luxury with an elasticity significantly above unity. All the remaining groups are either below unity and necessities (fish and dairy) or normal i.e. residual food group.

Following Thomas (1987) and Chesher and Rees (1987) we correct for omitted variables and include the intercept terms for age and family size and the demographic interaction variables : i.e. Age*Exp and Family size*Exp. As expected with omitted variables the adjusted expenditure elasticities drop significantly (see Panel B) with the inclusion of demographic

8. Following Chesher (1991) we plotted income against total food expenditures. The large variation in total expenditures by household income is disturbing since this no doubt reflects the fact that higher income families hold larger inventories. Thus, the greater variation in food expenditures for the two surveyed weeks as household income grew.
9. We could have omitted the residual food category and invoked weak separability vis a vis any food in the residual group and meat, fish or diary products. This is an empirical question. However, the prevalence of meat and potatoes ( with gravy) as a stable food dish in Canada intuitively argues against separability.
10. We estimated the following equation : $Pi = a + B^{*}$ income $+T^{*}_{jR + ik^{*}Q1}$ where R=1 if not Atlantic province and Q is quarterly dummy.
11. Meals equivalent was computed as : [(a*21*family size)+guests-(a*restaurant)]/[a*21*family size] where a=2 for the two week coverage ; Guests = meals served at home to guests,boarders or domestics ; Restaurant= the number of meals household members ate in restaurants the previous month divided by two.
12. There is no obvious simultaneity since the purchase of any (ith) group does not affect income.
13. In order to estimate every food groups expenditure equation the residual equation was first omitted from the system and then the fish equation was omitted in a subsequent estimation.

variables. Now the expenditure elasticities for meat, and dairy products are less than unity indicating that these food groups are necessities. Fish and dairy goods are inferior given their negative expenditure elasticities. Using a similar model for the United Kingdom with household panel data Chesher and Rees (1987, Table 4, p.446) also, report very low meat income elasticities of.21 and.31. On the other hand, Chesher (1991) reports a positive total expenditure elasticity for U.K. fish demand however, his demographic arguments were insignificant (Table 6.5, p. 63).

### *6.2 Complete Model*

Given the large regional and seasonal variation in prices (see Table 2) the assumption of constant prices used to derive the above Engel or total expenditure elasticities is incorrect. In this section we report the findings for a complete *Ideal* model (equation 2) which includes prices. In addition, we (partially) imposed the restrictions of homogeneity in prices and income, adding up and symmetry[14] We also estimate the system under the *ZUR* technique for reasons given above. This produces estimates which are equivalent to maximum likelihood results.

Following the traditional approach in the literature (Philps, 1983) for treating demographic variables we now decompose the household's family size variable into three age groupings (SPEND or ages 0-5, 6-16,17-65 ) to partially reflect the household's stage in the life cycle. The head of household's gender (sexh) and education (educat) are also included. In addition, we add regional (R) and seasonality (Q) variables. The geographical variables include an urban/rural (City) dummy, dummies for maritime versus hinterland divisions (R) and a foreign birth status (birth) dummy. The basic model's parameter estimates for the share equations are reported in Table 4.

## 7. RESULTS : COMPLETE MODEL

Table 4 reports the Marshallian uncompensated own price and total food expenditure elasticities. All the uncompensated own price elasticities are approximately unitary or less except for the residual food group. The demand for meat is inelastic (-.77) while fish and dairy are near unitary elastic. All food commodity groups are luxuries with respect to total expenditure variations. We now turn to a comparative analysis.

### *7.1 Meat*

Our meat (i.e. beef, pork, veal, chicken and turkey) own price elasticity is well below unity (-.77). Hassan and Johnson (1977, Table 1, p. 57) estimate with earlier Canadian panel data (i.e. *1974 Food Expenditure Survey*) much larger own price elasticities for various meat products. In general however, studies using Canadian time series report own price elasticity estimates for meat similar to our findings. With Canadian time series data (1968-1986) Atkins *et al.* report Canadian own price elasticities in a range of -.5 to -.7 ( Table 2,p.520). Chalfant, Gray and White (1991) for a longer Canadian time series (1960-1988) also support our findings. Their estimated (Table 2, p.485) Marshallian demand elasticities were respectively :beef -.95 ; poultry -.9 and pork -.7.

The total expenditure elasticities for meat in Table 4 is higher under the full *Ideal* model (1.78) then under the earlier Engel estimates (1.27) which assumed constant relative food prices. Atkins *et Al.* (1989) found negative Canadian income elasticities for meat (Table 1, p.516) when they used real income per head for the 1968-1986 period and subsequently question the relevance of this times series income measure. Chalfant *et Al.* (1991, Table 3 Part A, p. 486) using Canadian time series data report similar (to our Table 4) total expenditure elasticities for meat (beef=1.6). However, Chan (1983) using Canadian time series data for 1949 to 1969 with a double logarithmic static model report a low range of meat income elasticities of.02 to.44 (Table 4, p. 45).

14. Since we employ Zellner's Seemingly Unrelated approach we must drop one equation. Thus, the adding up criterion can only be indirectly satisfied by imposing simultaneously homogeneity i.e. 1-sum of constant terms = 0. Several cross price elasticities are also lost and hence the restriction is limited to three (out of six possible) pairs of cross price parameters.

*7.2 Fish*

This study's estimated fish own price elasticity ( i.e. -.97) is within the range reported by Hassan and Johnson[15]. However, DeVoretz's (1988) study which reviews a variety of Canadian fish products cites generally higher own price elasticities (-20 -fresh to -1.4 Pink canned) for estimates at wholesale level with time series data[16].

In addition this study found fish to be a substitute for meat (.467) and a complement to dairy products (-.98) and other foods (-2.5). In their Canadian times series findings Chalfant *et al.* report (Table 4, p. 486) fish to be mild substitutes (.3 to.08) for a variety of Canadian meat products.

This study's total expenditure elasticities for fish is normal (1.43) and considerably larger than the Engel estimates (.78) reported in Table 3. Previous Canadian studies report a wide range of values for income elasticities. DeVoretz (1990, Table 1, pp. 90-92) cites a range of salmon income elasticities from 9.8 to.49 depending upon the specific specie product type. Chan (1983) using Canadian time series data (1949 to 1969) with a double logarithmic static model reports a range of fish income elasticities of -.02 to.49 (Table 4, p. 45).

*7.3 Dairy Products*

In this study dairy products obtained an own price elasticity of -1.00 which is well above the price elasticity values (-.06 to -.90) reported by Hassan and Johnson for Canada in 1974. In addition, this study found that Canadian dairy products were gross complements for fish (-.98) and all other foods (-1.33) while being a mild substitute to meat (.189). Total expenditure elasticities under our complete model for dairy products are normal (1.23) and considerably larger than the Engel estimates (.89) reported in Table 3. Chan (1983) using Canadian time series data (circa 1949 to 1969) with a static double logarithmic model cites a range of income elasticities of -.047 to.33 (Table 4, p. 45) for dairy products.

Non-Economic variables :

We argued earlier that life cycle features of the household would also affect food consumption in Canada. The standard version of the life cycle model captured few demographic effects[17]. Thus, we must incorporate more fundamental changes in our household model. First, following Goddard (1983) we measure the number of meals served at home and eaten away. Next, we incorporate the effects of spouse at home on food consumption patterns. Also, the foreign born assimilation phenomenon is more fully captured with a years in residence variable. Finally, an F-test is conducted for various age groups (for head of household) to detect household structural changes at different epoches.

## 8. MODERN HOUSEHOLD MODEL

Table 5 presents the results for our agumented model which argues that the household food consumption level depends on the presence or absence of a full time spouse in the household *ceteris paribus*. The process occurs in two stages. First, with a spouse at home the opportunity cost of meal preparation falls and raises the consumption of labour intensive foods. In addition, the number of meals prepared at home will rise with a spouse at home and this in turn will influence food consumption. Table 5 summarizes these findings. The elasticity measures generally indicate a uniform pattern. With a one percent rise in the number of at home spouses less meat (-.73) and less of the residual food category (-.42) is served per meal equivalent. On the other hand, with a one per cent rise in households with at home spouses more fish (.45) and dairy products (.17) are eaten at home. Given the strong significance of these heretofore omitted household variables the predicted decline in the economic arguments appears. Total expenditure elasticities fell substantially for all food groups but, all food products remained normal. The own price elasticities remained constant for all products in the augmented model except for the residual food category. The pattern of substitution (or complementarity) remained in the augmented model but in general the cross price effects fell.

15. Aggregate fish is defined as fresh, frozen or smoked cod, halibut and salmon and canned salmon and tuna.
16. This result is counter intuitive since we expect higher own price elasticities as we move up the distribution chain from the wholesale level to the retail level
17. Results available upon request.

Given the general strength of this augmented model's spouse and meal equivalent variables we now explore the effects of the remaining key household characteristics of age, foreign birth status and education. A one percent rise in the number of households with heads aged 35 or more leads to a decline in each food group with the smallest decline for fish (-.16 %) and largest decline in dairy products (-1.22 %). Increased growth in the foreign born in Canada's population will raise meat consumption and lower all other types of food consumption[18]. Foreign born assimilation or duration in Canada has a differential effect on food consumption. The longer the foreign born reside in Canada the less meat, fish and other food products are eaten[19]

Finally a comparison of the first three rows of Table 5 (i.e. economic elasticities) *vis a vis* the last five rows (i.e. demographic elasticities) indicates that the relative impact of spouse at home, education of head of household and foreign birth status equal or exceed the own price or cross price effects. Only the total expenditure elasticities generally dominate the demographic arguments.

## 9. SUMMARY AND CONCLUSIONS

We first summarize the traditional results derived from the Engel estimates and then draw conclusions from the standard *Ideal* model. Next, we summarize the findings and implications of the meals equivalent model. The total expenditure elasticities initially had an upward bias (unrealistically) indicating that all food categories were luxuries. But when demographic variables were included absurd expenditure elasticities were obtained. Fish became an inferior good (i.e.negative elasticity) with meat, dairy and other food products being strong necessities. The complete Ideal model with both prices and standard household demographic arguments yields generally price inelastic (meat) or near unitary elastic demand for other protein products (fish and dairy). The inelastic nature of meat indicates that fish and dairy products are not strong substitutes for meat. This is confirmed by the cross price effects with fish a weak substitute for meat (.47) and dairy products even a weaker substitute (.18). In sum, under the standard *Ideal* model meat has an inelastic demand with no real substitutes[20]. The total expenditure elasticities are unrealistically high. It is theoretically unlikely that all food is a luxury (i.e. every elasticity exceeds unity). More specifically it is difficult to find evidence in the literature that the residual food category is income superior to meat, fish or dairy products. Finally, contrary to the literature the typical demographic arguments of household size or composition are trivial in this standard version of the *Ideal* model.

Our augmented model with both spouse at home and meals equivalent produces the theoretically expected values for both total expenditure elasticities (all approximately unity) and significant demographic arguments. In addition, the own price and cross price effects are generally stable indicating that the impact of the formerly omitted variables (meals equivalent and spouse at home) interact with household income and not relative prices. Thus, we conclude that the crucial life cycle effect to capture in the 1986 cross section is primarily the presence or absence of a spouse at home in the household. With a spouse at home then both household money income and the relative cost of meals at home decline. Family size and composition are now more accurately captured through a larger meals equivalent variable *ceteris paribus*. Other traditional demographic arguments, age and education obtain theoretically correct signs. Age reduces all food consumption but fish is reduced the least. Being a foreign born head of household in Canada alters tastes when compared to the Canadian born in favor of meat *vis a vis* the other protein source products. The duration in Canada variable indicates that assimilation with respect to the Canadian born consumption pattern occurs for only meat and dairy products[21].

The relative impact of economic and demographic variables can be deduced for the augmented model. Total expenditure elasticities still dominate with particular demographic effects important for individual products. For example, age and the

18. This does not imply that assimilation does not take place. The one percent raise evaluated for the elasticity measures the effect of more immigrants with the same average years resident in Canada.
19. Conversely the amount of dairy products consumed rises with longer residence.
20. Note the residual category is a complement.
21. Assimilation occurs only if the foreign born and the years in Canada parameters differ in sign. For example, more meat is initially eaten (.23) by the foreign born but as time passes less meat is eaten (-.004) each successive year by the foreign born.

meal equivalent variables have large effects on dairy and the residual food categories. Meat consumption is affected by spouse at home and birth place of the head. In sum, the cross, own price and income effects still dominate for every food category but just marginally in the dairy and residual categories[22].

## REFERENCES

**Anderson G. and R. Blundell** (1983). "Testing Restrictions in a Flexible Dynamic Demand System : An Application to Consumer's Expenditure in Canada", *The Review of Economic Studies*, Vol. **50** : 397-410.

**Atkins F.J., W.A. Kerr and D.B. McGivern** (1989). "A Note on Structural Change in Canadian Beef Demand", *Canadian Journal of Agricultural Economics* , Vol. **37** : 513-524.

**Bewley R. and T. Young** (1987). "Applying Theil's Multinomial Extension of the Linear Logit Model to Meat Expenditure Data", *American Journal of Agricultural Economics*, February : 862-869.

**Blanciforti L. and R. Green**(1983). "An Almost Ideal Demand System Incorporating Habits : An Analysis of Expenditures on Food and Aggregate Commodity Groups", *Review of Economics and Statistics*, Vol. **65** : 511-515.

**Burton M. and T. Young** (1992). "The structure of changing tastes for meat and fish in Great Britain", *European Review of Agricultural Economics*, forthcoming.

**Capps O. Jr., J.R. Telford and J. Havlick Jr.** (1985). "Household demand for Convenience and non-convenience Foods", *American Journal of Agricultural Economics*, November : 862-869.

**Capps O. Jr. and J. Havlick Jr.** (1984). "National and Regional Household Demand for Meat, Poultry and Seafood :A Complete Systems Approach", *Canadian Journal of Agricultural Economics*, March : 93-107.

**Chalfant J.A., R. Gray and K.J. White** (1991). "Evaluating Prior Beliefs in a Demand System :The Case of Meat Demand In Canada", *American Journal of Agricultural Economics*, May, 1991 : 476-490.

**Chan M.W.** (1993). "A Principle Component Analysis of the Income Elasticities of Demand For Food Commodities", *Canadian Journal of Agricultural Economics,* Vol. **31** : 77-93.

**Chesher A.** (1991). "Household Composition and Household Food Purchases", in *Fifty Years of the National Food Survey : 1940-1990.* H.M.S.O.

**Chesher A.D. and H.J.B. Rees** (1987). "Income Elasticities of Demand for Food in Great Britain", *Journal of Agricultural Economics,* Vol. **38** : 435-448.

**DeVoretz D.J.** (1992). "An Econometric Demand Model for Canadian Salmon", *Canadian Journal of Agricultural Economics*, March : 49-60.

**DeVoretz D.J.** (1988). "The Demand For Fish : A Review of Some Econometric Demand Literature for 1970-1988", Working Paper No. 1/1989, Centre for Applied Research, Norwegian School of Economics and Business Administration, Bergen.

**DeVoretz D.** (editor) *Salmon Price Forecasts for the 1990's*, Canada, Dept. of Fisheries and Oceans, Vancouver, p.108

**Doll J.P.** (1972). "An Econometric Analysis of Shrimp Ex-Vessel Prices", *American Journal of Agricultural Economics*, Vol. **54** : 431-40.

**Goddard D.** (1993). "An Analysis of Canadian Aggregate Demand for Food at Home and Away from Home", *Canadian Journal of Agricultural Economics*, Vol. **31** : 77-93.

**Hassan Z. and S.R. Johnson** (1977). "Direct Price Elasticity Estimates from Family Budget Data", *Canadian Journal of Agricultural Economics*, Vol. **25** (3) : 54-61.

22. We arrive at this conclusion by summing up the own price, cross price and total expenditure effects for each category and compare this to the collective total by food category for all the reported demographic variables.

**Hassan Z. and S.R. Johnson** (1983). "Quarterly Demand For Meat in Canada with Alternative Seasonality Hypotheses", *Canadian Journal of Agricultural Economics*, Vol. **31** : 77-93.

**Marr W. and W. McCready** (1989). *The Effects of Demographic Structure on Consumption and Savings Patterns in Canada*, Institute for Research on Public Policy.

**Philips L.** (1983). *Applied Consumption Analysis,* New York : North -Holland.

**Statistics Canada** (1974). *Urban Family Food Expenditure in Canada*, Catalogue 62-542.

**Tsoa E., W.E. Shrank and N. Roy** (1982). "U.S. Demand for Selected Groundfish Products : 1967-1980.", *American Journal of Agricultural Economics,* Vol. **64** : 483-489.

**Thomas R.L.** (1987). *Applied Demand Analysis*, London, Longman.

TABLE 1.
FISH/MEAT HOUSEHOLD CONSUMPTION PROFILES BY AGE.

| Age Interval | Fish Share | Meat Share |
|---|---|---|
| Entire Population | .018 | .15 |
| 20-25 | .013 | .10 |
| 26-30 | .015 | .13 |
| 31-35 | .016 | .14 |
| 36-40 | .020 | .15 |
| 41-45 | .019 | .16 |
| 46-50 | .019 | .17 |
| 51-55 | .023 | .18 |
| 56-65 | .022 | .18 |

Source: Authors' computer run under SPSSX 1986 Food Expenditure Tape:Summary file.

TABLE 2.
DATA : DESCRIPTION STATISTICS.

| NAME | MEAN | ST. DEV | NAME | MEAN | ST. DEV |
|---|---|---|---|---|---|
| FAM | 2.7254 | 1.3968 | CITY | 0.55124 | 0.49739 |
| R0 | 0.913E-03 | 0.302E-01 | R2 | 0.19095 | 0.39307 |
| R3 | 0.24086 | 0.42763 | R4 | 0.13609 | 0.34290 |
| R5 | 0.10129 | 0.30173 | R6 | 0.12941 | 0.33567 |
| Q1 | 0.25744 | 0.43724 | Q2 | 0.24847 | 0.43214 |
| Q3 | 0.24535 | 0.43032 | BIRTH | 0.16219 | 0.36865 |
| EDUCAT | 0.25039 | 0.43326 | SEXH | 0.29609 | 0.45655 |
| AGEH | 0.34188 | 0.47436 | MP | 525.16 | 179.36 |
| ME | 3300.5 | 4003.0 | FE | 809.25 | 276.92 |
| FE | 416.37 | 852.24 | DP | 171.77 | 95.805 |
| DE | 2462.4 | 1937.8. | RP | 326.22 | 304.84 |
| RE | 8697.3 | 6230.1 | MS | .19828 | 0.13730 |
| FS | 0.254E-01 | 0.45E-01 | DS | 0.17293 | 0.10947 |
| RS | 0.58324 | 0.17838 | Mel | 1.0201 | 0.111111 |
| Total food expenditures | | | | 14877 | 10290 |

N=10919

TABLE 3.
ELASTICITIES FOR THREE PRODUCT TYPES UNDER AN ALMOST IDEAL DEMAND SYSTEM.

| Elasticity/food group | | | | |
|---|---|---|---|---|
| Panel A: | MEAT[b] | FISH | DAIRY | RES |
| No other variables: | | | | |
| Total food Exp. | 1.27 | .78 | .89 | 1.06 |
| Panel B: | | | | |
| Demographic Variables: | | | | |
| Exp. | .36 | -.16 | -.40 | .06 |
| Age | -.04 | .02 | -.01 | -.03 |
| Size | .14 | -.02 | .09 | -.21 |
| Exp*size | -.10 | .015 | .03 | .12 |
| Exp*age | .09 | -.01 | -.02 | -.10 |

Notes:
a. The elasticity was calculated by $N_i = 1+(B_i+/S_i)$ where $S_i$ is the budget share of the ith good and $B_i$ is the associated parameter estimate.
b. All reported parameter estimates are significant at the .05 level or better.

TABLE 4.
ELASTICITIES FOR THE BASIC MODEL.

| | Meat | Fish | Dairy | Res | Total |
|---|---|---|---|---|---|
| Meat | -.77 | .467 | .189 | -.94 | 1.78 |
| Fish | ---- | -.97 | -.98 | -2.5 | 1.43 |
| Dairy | --- | ---- | -1.00 | 1.33 | 1.23 |
| Residual food[a] | --- | ---- | ----- | 1.12 | 2.50 |

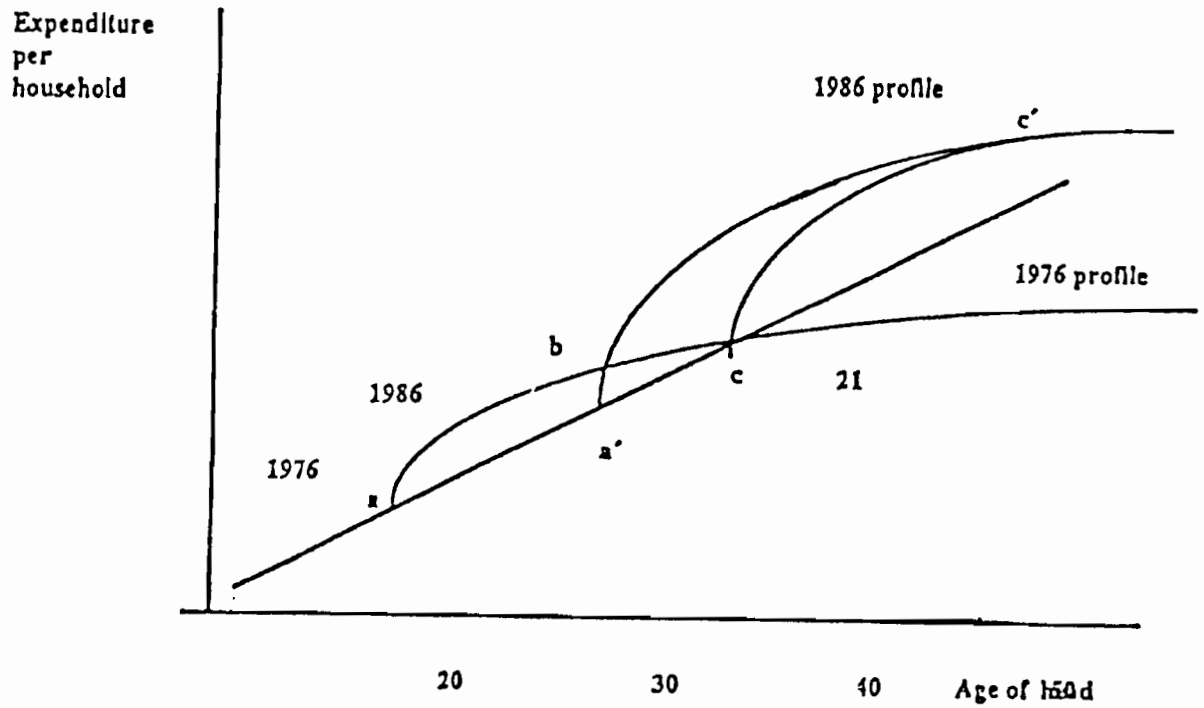
Notes:
a. The parameters and resulting elasticities were derived when the fish equation was omitted and replaced by the residual food share

TABLE 5.
ELASTICITIES FOR THE AUGMENTED MODEL.

| | Meat | Fish | Dairy | Resd | Total |
|---|---|---|---|---|---|
| Meat | -.75 | .027 | .189 | -.43 | 1.18 |
| Fish[a] | --- | -.95 | -.92 | -.86 | 1.07 |
| Dairy | --- | ---- | -1.33 | 1.33 | .00 |
| Residual food[a] | ---- | ---- | ----- | -.11 | .09 |
| Spouse | -.73 | .45 | .17 | -.42 | N.A. |
| MealsEq. | -.06 | .03 | -1.02 | -.81 | N.A. |
| Age | -.26 | -.16 | -1.22 | 1.00 | N.A. |
| FBirth | .23 | -.91 | -.82 | -.33 | N.A. |
| FBdur | -.004 | -.005 | -.0008 | -.002 | N.A. |
| Ed | -.66 | .33 | -1.02 | .81 | N.A. |

Notes: a). All the fish elasticities are derived from the unreported elasticity estimates of the model per Table 6 ith the exception that the residual equation is dropped in lieu of the fish equation.

**FIG. 1.**
**AGE, PERIOD AND COHORT EFFECTS FOR A HOUSEHOLD.**



# La pêcherie artisanale maritime des filets dormants à sole (*cynoglossus sp.*) en Casamance (Sénégal)

**Hamet Diaw Diadhiou**

Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), B.P 427, Ziguinchor, Sénégal

RÉSUMÉ

*La présentation de la pêcherie artisanale en mer des filets dormants à sole (Cynoglossus sp.) est proposée. Les aspects liés à la pêche et à la ressource sont abordés. L'historique du développement de la pêcherie, les caractéristiques des engins de pêche utilisés et des marées, les captures, les rendements et les potentialités de la ressource sont cernés. Dans la dernière partie, les différents circuits de commercialisation sont identifiés et décrits. Mots clés* : Sénégal, Casamance, pêche, filets dormants à sole.

ABSTRACT

*The purpose of this paper is to present the frame fishing nets sole (Cynoglossus sp.) of the small-scale hand line sea fisheries. Its starts with the aspects related to the fisheries and an analysis of this resource. Then it goes on with a review of the fishery development, the characteristics of fishing gear, going out fishing, catches, output, resource potentialities. Finally there is an identification and description of the different sale channels. Key words* : Senegal, Casamance, fishing, frame fishing nets sole.

## 1. INTRODUCTION

La pêche de la sole en mer en Casamance s'est développée à partir des années 1984 avec l'existence d'un marché à Dakar (Diaw, 1985). Mais son essor remonte au début de 1986 lorsque les usines de crevettes de Ziguinchor ont commencé à

s'intéresser au poisson pour diversifier leurs activités (Deme & Diadhiou, 1990). Aujourd'hui, c'est un pêcheur sur trois qui s'adonne à cette activité. Depuis 1988, des pêcheurs s'installent en saison des pluies (de juillet à octobre) dans la zone située en aval de Ziguinchor pour pêcher la sole.

Les données utilisées pour écrire cette article sont tirées des résultats du mareyage de la sole du plus grand mareyeur de cette espèce installée à Kafountine. La consultation des carnets d'achat de ce mareyeur a permis de réunir des données sur le rendement par sortie de pêche des différents pêcheurs qui vendent au mareyeur.

Un programme fortran a été écrit pour sortir les résultats. Les figures d'évolution des rendements sont dessinées grâce au logiciel STATGRAPHICS.

Les objectifs de l'étude sont multiples. Il s'agit dans un premier temps de réaliser une analyse descriptive de la pêcherie pour dégager après des problèmatiques de recherches. Un autre objectif est la description des relations qui peuvent exister entre mareyeurs et usiniers d'une part et entre mareyeurs et pêcheurs de l'autre au niveau de l'accés à la ressource pour les usines.

Plusieurs aspects liés aux captures, à l'effort, aux rendements, aux potentialités ainsi qu'à la commercialisation sont abordés.

## 2. PRÉSENTATION DU MILIEU

La Casamance s'étend sur une façade maritime de près de 70 kilomètres du nord au sud (fig. 1). Son plateau continental est l'un des plus larges des côtes du Sénégal, il s'étale sur 54 miles. La superficie de ce plateau est de l'ordre 30 000 kilomètres carrés (Citeau et *al* , 1985). Les fonds sont constitués de sédiments meubles composés de vasières au niveau des zones d'embouchure. Des fonds durs existent et sont constitués de larges bandes de plaques rocheuses continues ou discontinues à des profondeurs de 50 mètres.

L'hydroclimat de la Casamance maritime est caractérisé par une saison froide de janvier à avril, une saison chaude de juillet à octobre et deux saisons de transition entre mai-juin et novembre-décembre (Chabanne, 1987 in Reber, 1983). La saison froide s'installe à l'arrivée des alizés sur le frange côtière, la saison chaude à leur chute brutale à leur passage au niveau de la zone intertropicale de convergences. Quant aux saisons de transition, elles apparaissent avec l'influence des eaux tropicales et la chute des alizés. Les dates d'apparition de ces trois saisons sont variables suivant l'installation plus ou moins tardive du régime des alizés d'une année à une autre. Cette situation est observée sur tout le littoral sénégalais. Les alizés sont à l'origine d'une importante production primaire et des fluctuations saisonnières et interannuelles de celle-ci. L'existence de courants marins entraîne une accumulation de cette biomasse dans les zones côtières peu profondes. Au niveau des zones d'estuaires, cet enrichissement par l'effet des courants est doublé par les apports des fleuves.

La saison d'upwelling démarre vers février et dure jusqu'en juillet. Son intensité est maximale entre mars et avril. D'une année à une autre, l'intensité de ces saisons varient suivant l'importance des alizés.

La salinité est marquée en fin de saison chaude par une dessalure importante sensible jusqu'à 50 mètres sur les fonds de Roxo.

## 3. PRÉSENTATION DE LA PÊCHERIE

La sole est exploitée le long de la façade maritime de Casamance par les flottilles chalutière et crevettière basées à Dakar et par les pêcheurs artisans sur place à partir des principaux ports de pêche de la région en mer, Kafountine, Cap Skirring, Diembéreng et Bukot. La pêche artisanale produit l'essentiel de la production achetée par les usines locales (plus de 97 % de la production totale).

## 4. LA PÊCHE

### *4.1 Les saisons de pêche*

Actuellement, on distingue trois saisons de pêche :

- de la fin de l'hivernage en octobre au tout premier mois de la saison sèche en décembre. Cette période correspond à l'installation des pêcheurs migrants [1]
- entre février et mai
- en hivernage (de juin à octobre). Les pêcheurs formés par le Projet de Développement de la Pêche Artisanale Maritime en Casamance (PAMEZ) sont les premiers à essayer la pêche de la sole pendant cette saison. Cette opération fut un succés. Depuis, de nombreux migrants ne retournent plus chez eux pour les travaux des champs pendant la saison des pluies.Ils n'arrêtent de pêcher pour rentrer dans leur village d'origine qu'à l'approche de la fête musulmane de l'*Aïd El Fitr* (ou fête du mouton). La durée de cette pose est d'environ un mois. Au Nord Sénégal, il n'y a qu'une seule saison de pêche. Elle est située au mois de mai.

### *4.2 Les pirogues utilisees*

Les embarcations utilisées sont les pirogues sénégalaises de mer (fig. 2). Ces pirogues sont motorisées.

### *4.3 Les caractéristiques des équipages*

Les équipages des pirogues à sole sont formées de 4 à 5 pêcheurs, appartenant à la même famille (frères ou cousins) ou non (cas des pêcheurs autochtones diola utilisées au niveau des unités de pêches Lébou et Ouoloff au Cap Skirring).

### *4.4 Le filet dormant à sole*

En Casamance, le filet dormant à sole est formé de plusieurs nappes de filet (30 et plus), de mailles différentes. Le nombre et la longueur de celles-ci varient suivant les communautés de pêcheurs et les possibilités financières des unités.

Les nappes de filet ont des longueurs qui vont de 3 à 12 m. Leur hauteur de chute est d'environ 1,5 m, leurs mailles sont de 40, 46 et 50 mm. Un filet est constitué de nappes de mailles différentes.

Jusqu'à une date récente en 1988, la campagne de pêche se déroulait essentiellement en saison sèche d'octobre à mai-juin avec l'installation des pêcheurs migrants venus du Nord Sénégal. De nos jours, elle s'étend sur toute l'année. La pêche de saison sèche est toutefois de loin la plus importante (c'est la période pendant laquelle il y a le plus grand nombre de pêcheurs).

### *4.5 Les marées*

Les pêcheurs de sole sortent le matin très tôt (entre 3 et 5 h) récupérer leurs prises. Les filets sont laissés en mer en début de campagne et sont visités tous les jours. Lorsqu'ils sont déchirés, les nappes correspondantes aux parties abîmées sont retirées pour être ramendées et remplacées.

Le filet est déplacé chaque fois que le rendement baisse.

La durée de pêche du filet dormant à sole est d'environ 24 heures, rarement au delà, 48 à 72 heures. Cette dernière situation est observée pour certaines unités de pêche du Cap Skirring en temps normal (les pirogues glacières), à Kafountine en période de mauvais temps (période de mer agitée : entre décembre et mars). Les prises (poisson pourri) sont alors transformées en produit semi fini : "guedj".

1. Ces pêcheurs constituent la principale composante de la population de pêcheurs en mer (plus de 90 % de l'effectif total d'après les différents recensements du service des pêches DOPM).

*4.6 Les prises*

Elles sont constituées principalement d'une seule espèce de Cynoglosses (*Cynoglossus monodi* : plus de 95 % des captures de soles), de mâchoirons, d'otolithes, d'ethmaloses, de plexiglasses... Les captures du second groupe constituées pour la plupart de juvéniles de mâchoirons, de pomadasys, d'otolithes bobo (*Pseudotolithus elongatus*) représentent une part importante des débarquements de la pêcherie (entre 40 et 80 % de la pêche suivant les saisons). Les adultes de ces poissons sont les cibles d'autres pêcheries (pêcherie des filets à gros poissons).

A Kafountine, les maximums de prises de sole sont observés entre février et mars et en octobre (fig. 3).

Pour l'ensemble de la pêche dans la région, les statistiques de la Direction de l'Océanographie et des Pêches Maritimes (DOPM) indiquent des captures de l'ordre de 165 tonnes en 1985 et 810 tonnes en 1990.

*4.7 L'effort*

La DOPM qui a la prérogative de la collecte des statistiques de pêche n'estime que l'effort potentiel, l'activité de pêche et sa répartition spatio-temporelle. Pour ce qui concerne l'effort potentiel, au niveau des engins de pêche les données sont relevées par type de pêche, filet maillant dérivant, filet dormant sans distinction des espèces cibles. Pour donc apprécier l'évolution de l'effort de pêche filet dormant à sole de ces dernières années, on utilisera les données du CRODT de 1985 et 1990 où cette distinction existe. Pour illuster cette augmentation, on peut citer le cas de Kafountine et du Cap Skirring où le nombre de filets à sole est passé de 695 à 1585 et de 429 à 3602 entre 1985 et 1992.

A Kafountine, le maximum de sortie est observé entre février et mars et en octobre (fig. 4).

*4.8 Les rendements*

Dans le principal port de débarquement de la sole, Kafountine, les rendements les plus importants sur deux périodes : entre janvier et avril et entre octobre et novembre (fig. 5). Ces périodes d'abondance correspondent à la saison de transition et à la saison froide.

Dans le sud au niveau du Cap Skirring, les PUE maximales de sole (55 et 41 kg) sont observées en juin et juillet pendant les tous premiers mois de la saison des pluies. Une baisse progressive des PUE s'installe ensuite jusqu'au début de la saison froide en janvier. L'augmentation des PUE débute durant la saison froide (de février à avril) (fig. 6 ; tabl. 1).

Au niveau de l'effort, il est intéressant de noter sa diminution synchrone avec l'augmentation des PUE à l'exception du mois de février.

Enfin à titre de comparaison, on peut noter que les PUE maximales de cette espèce dans ses principaux ports de pêche du Nord Sénégal, Saint Louis et Kayar sont plus importantes, 50 et 80 kg respectivement pour le premier et le second en 1985 (Laloe & Samba, 1990).

## 5. LES POTENTIALITÉS

Le potentiel de la sole pêchée par la pêcherie artisanale n'est pas connue mais au vue des résultats de la pêche il serait important. Partant des données d'exploitation de ces dernières années, le minimum de ce potentiel est évalué à 750 tonnes en 1991 (production totale de cette année).

## 6. LA COMMERCIALISATION DE LA SOLE

La sole pêchée en Casamance est achetée sur place par les usines locales. Elle est vendue pour l'essentiel (plus de 95 % de la production) sur le marché étranger, en France, en Allemagne... et constitue une source de devises pour l'économie nationale. La part de la production absorbée par le marché local est achetée par les hôtels de la région et les particuliers (les restaurateurs surtout).

En 1988, ces usines se procuraient la sole directement auprès des pêcheurs à qui ils avaient prêté du matériel de pêche et des fonds de campagne. Les montants équivalents au matériel prêté ainsi que les sommes d'argent données sous forme d'avance de campagne étaient récupérés sur la vente des produits suivant un taux fixé en commun accord entre 5 et 10 % sur le prix de vente du kilo de sole. Mais très vite, les usiniers allaient dénoncer le manque de sérieux de nombreux pêcheurs qui n'amènent pas l'intégralité de leurs prises à l'usine et quittaient même souvent clandestinement la région pour d'autres lieux de pêche.

Devant une telle situation, les usiniers allaient réagir en développant une autre stratégie limitant le risque de non remboursement de leur prêt. Pour cela ils allaient nouer des relations de confiance avec des mareyeurs installés pour leur propre compte sur les plages de débarquement. A ces derniers, ils apportent gratuitement la glace et font des prêts de campagne.

Les mareyeurs travaillent avec des groupes de pêcheurs (10 à 50 pêcheurs) auxquels ils fournissent gratuitement la glace et consentent des prêts d'équipement en matériel de pêche et en espèces pour leur permettre de faire face aux dépenses de campagne. Le matériel et l'argent prêtés sont récupérés sur le prix de vente du kilo de sole comme ceci se faisait avec les usiniers. Les pêcheurs doivent leur vendent en retour leur production de sole.

La production collectée par les mareyeurs travaillant en contrat avec les usines est ramassée chaque jour par les camions frigorifiques affrétés par l'usine au niveau des principaux ports de débarquement de la sole.

Depuis plus de trois ans aujourd'hui les pêcheurs de sole en mer en Casamance vendent à ces mareyeurs la production de leur pêche concernant cette ressource. Une infime partie moins de 2 % de la production va à la transformation artisanale (il s'agit des débarquements de la sole non frais).

## 7. CONCLUSION

Le filet dormant est le seul engin de pêche utilisé principalement pour la capture de la sole au niveau de la pêcherie artisanale maritime casamançaise. Ses captures sont très diversifiées et relativement abondantes avec espèces dominantes les mâchoirons et les otolithes. La proportion de ces dernières espèces dans les débarquements est plus importante dans les captures du filet dormant à sole en saison chaude entre mars et juin.

Les rendements de saison de pluie sont importants mais du fait que l'effort de pêche est en diminution pendant cette période avec le retour de la plupart des pêcheurs migrants dans leur village d'origine, il est difficile de lier cette situation à une abondance de la ressource pendant cette période. Des campagnes d'évaluation sont nécessaires à ce stade ceci d'autant plus que le potentiel de sole (*Cynoglossus sp.*) connu ne concerne que les espèces capturées au niveau de la pêche industrielle. Le potentiel de la sole exploitée par la pêche artisanale (*C. monodi*) n'est pas connue.

Au niveau de la commercialisation, le rôle de banquier joué par le mareyeur auprès des pêcheurs et de l'usinier auprès des mareyeurs est à souligner. L'efficacité de l'approvisionnement des usines de Ziguinchor en sole tient à la solidité de ces relations.

## REFERENCES

**Chabanne J.** (1987).- Le peuplement des fonds durs et sableux du plateau continental sénégambien. Etude de la pêcherie chalutière. Biologie et dynamique d'une espèce caractéristique : le rouget (*Pseudupeneus prayensis*). Edition de l'ORSTOM, Collection Etudes et Thèses, Paris, 355p.

**Cormier-Salem M. C.** (1991). - Gestion et évolution des espaces aquatiques : la Casamance. *Thèse de doctorat (nouveau régime) de géographie* soutenue à l'Université de Paris-Nanterre le 22/12/1989, 583p. *Ed. ORSTOM.*

**Citeau J., J. Pages and D. Touew** (1985).- Environnement hydroclimatique. *In Plan Directeur Sud, Approche globale du système pêche dans la région du Sine Saloum et de la Casamance.* ISRA/CRODT, 674p. multigr. (diffusion restreinte).

**Diaw M. C.** (1985). - Formes d'exploitation du milieu, communautés humaines et rapports de production. Premières approche dans l'étude des systèmes de production et de distribution dans le secteur des pêches en Casamance. *Doc.Sci.Centre de Rech. Océanogr. de Dakar-Thiaroye*, 104, 107p.

**Rebert J. P.** (1983). - Hydrobiologie et dynamique des eaux du plateau continental sénégalais. *Doc.Sci.Centre de Recherche Océanogr. de Dakar-Thiaroye*, 89, 99p.

**Deme M. and H. D. Diadhiou** (1990). - Pêche des pirogues glacières à la ligne en Casamance. Aspects biologiques et socio-économiques. *Doc.Sci.Centre de Recherche Océanographique de Dakar-Thiaroye*, 120, 28 p.

**Laloe F. and A. Samba** (1989).- La pêche artisanale au Sénégal : ressource et stratégie de pêche. *Thèse de docteur en science*, Université de Paris sud, centre d'Orsay.

**Seck P. A.** (1980). Catalogue des engins de pêche artisanale du Sénégal. Service de la technologie des pêches ; division des industries de la pêche FAO, Rome.

**TABLEAU 1.**
**PÊCHE DE LA SOLE PAR LES UNITÉS DE PÊCHE DU PAMEZ AU CAP SKIRRING (UNITÉ DE PÊCHE DE 12M, 14 CV UTILISANT 8 FILETS DE 100 MÈTRES) (SOURCE : PAMEZ, VOLET FORMATION).**

| Rubriques / Mois | Sole (kg) débarquée | Autres espèces | Nombre de sorties | Total débarqué | PUE sole par sortie | PUE sole par engin |
|---|---|---|---|---|---|---|
| Juin 90 | 1 103,0 | 38,5 | 20 | 1 141,5 | 55,150 | 6,894 |
| Juillet 90 | 863,0 | 47,0 | 21 | 910,0 | 41,095 | 5,137 |
| Août 90 | 561,0 | 45 | 24 | 606,0 | 23,375 | 2,922 |
| Sept. 90 | 394,0 | 43,0 | 25 | 437,0 | 19,700 | 2,463 |
| Octobre 90 | 219,0 | 48,0 | 23 | 267,0 | 9,522 | 1,190 |
| Nov. 90 | 236,0 | 42,0 | 18 | 278,0 | 13,111 | 1,639 |
| Déc. 90 | 316,5 | 42,0 | 20 | 358,5 | 15,825 | 1,978 |
| Janvier 91 | 99 | _ | 16 | 99,0 | 6,187 | 0,773 |
| Février 91 | 558 | 57 | 28 | 615,0 | 19,928 | 2,491 |
| Mars 91 | 543,5 | 48 | 21 | 591,5 | 25,881 | 3,235 |
| Avril 91 | 667,5 | 33 | 20 | 700,5 | 33,375 | 4,171 |
| Mai 91 | 194,5 | 5 | 9 | 199,5 | 21,611 | 2,701 |

**FIGURE 1.**
**LA FAÇADE MARITIME DE LA CASAMANCE SUR LA CÔTE SÉNÉGALAISE (SOURCE CORMIER-SALEM, 1991**

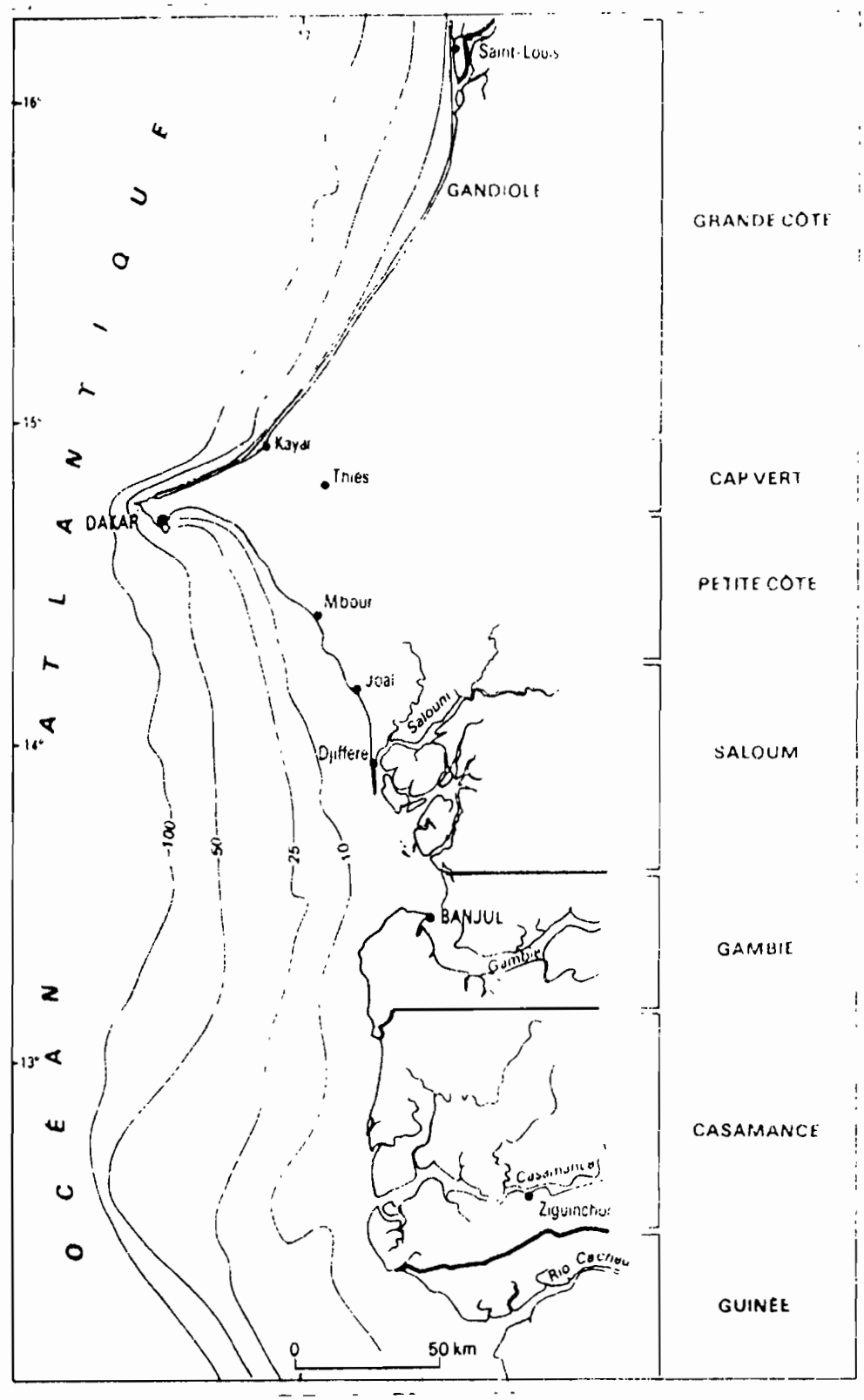


**FIGURE 2.**
**PIROGUE SÉNÉGALAISE TYPIQUE (SOURCE SECK, 1980)**

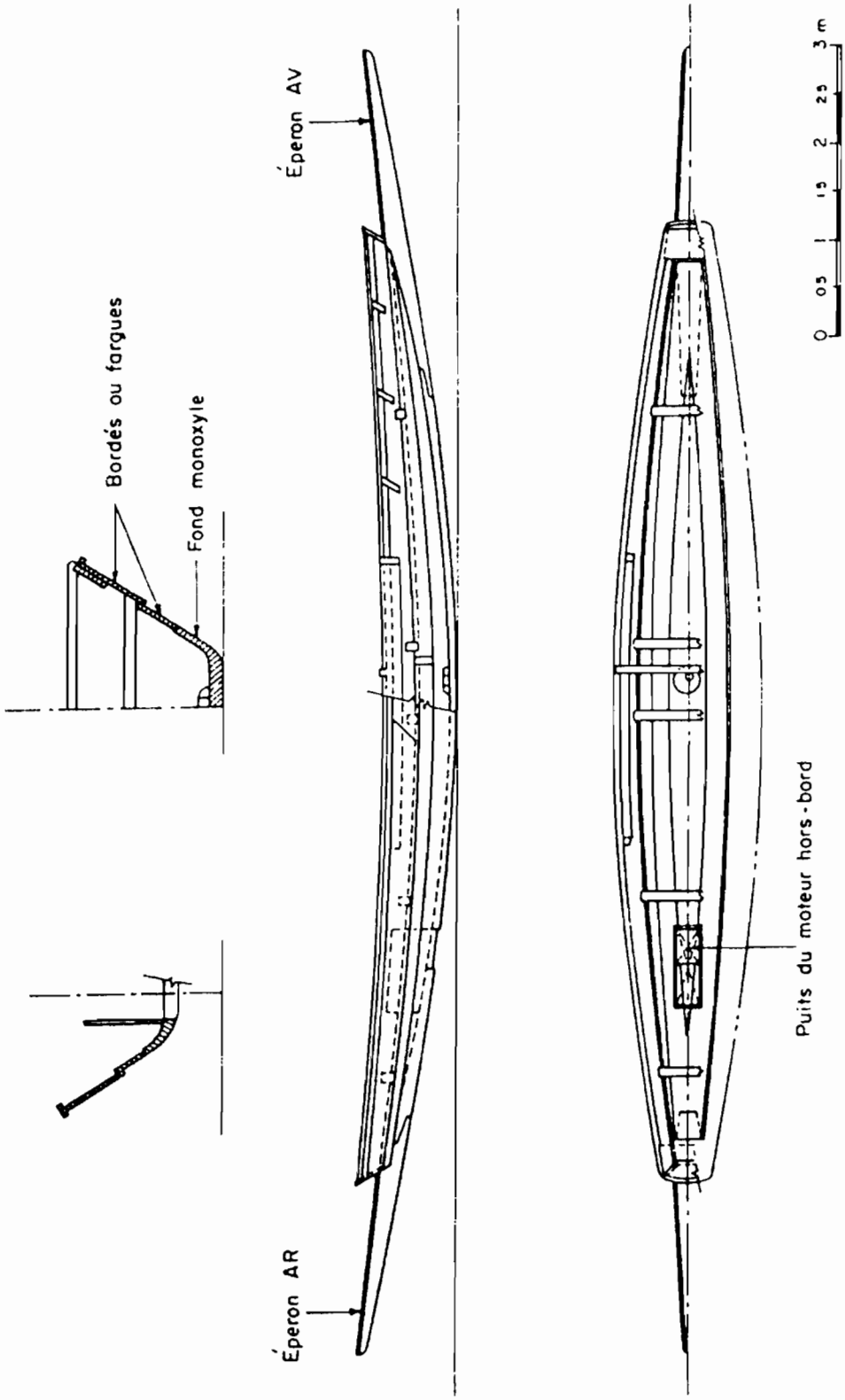


**FIGURE 3.**
**ÉVOLUTION DES DÉBARQUEMENTS MENSUELS DE SOLE**

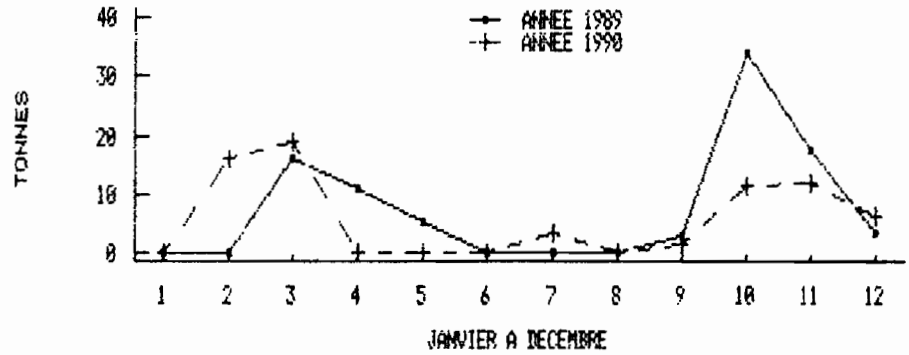



**FIGURE 4.**
**ÉVOLUTION DU NIVEAU D'EFFORT SPÉCIFIQUE DE LA PÊCHE DE LA SOLE**

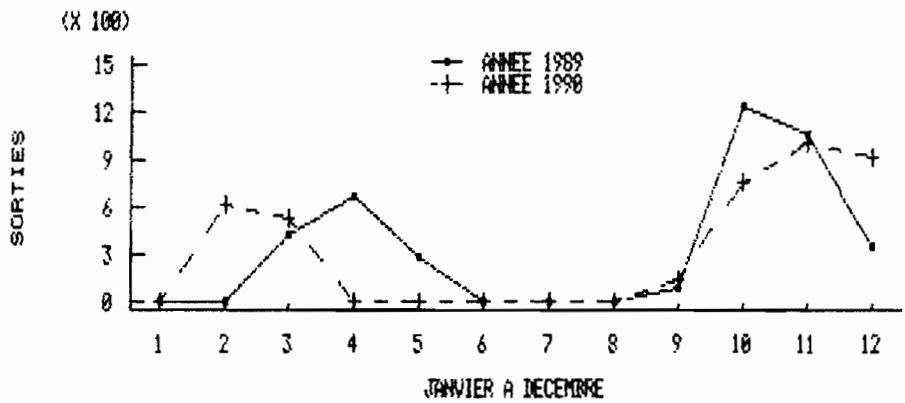



**FIGURE 5.**
**ÉVOLUTION DES PUE MOYENNES SPECIFIQUES**

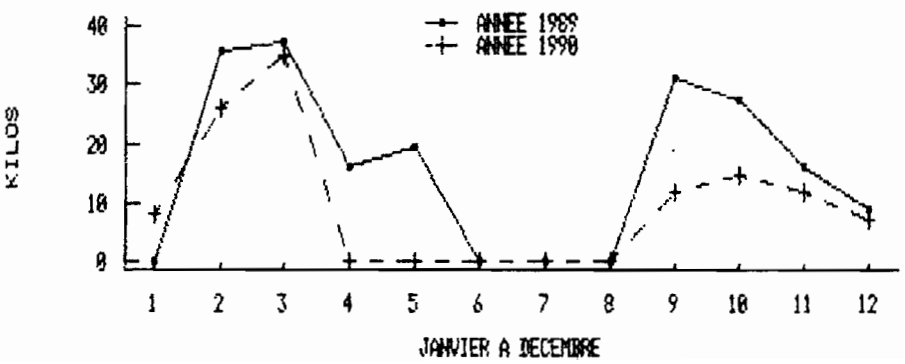
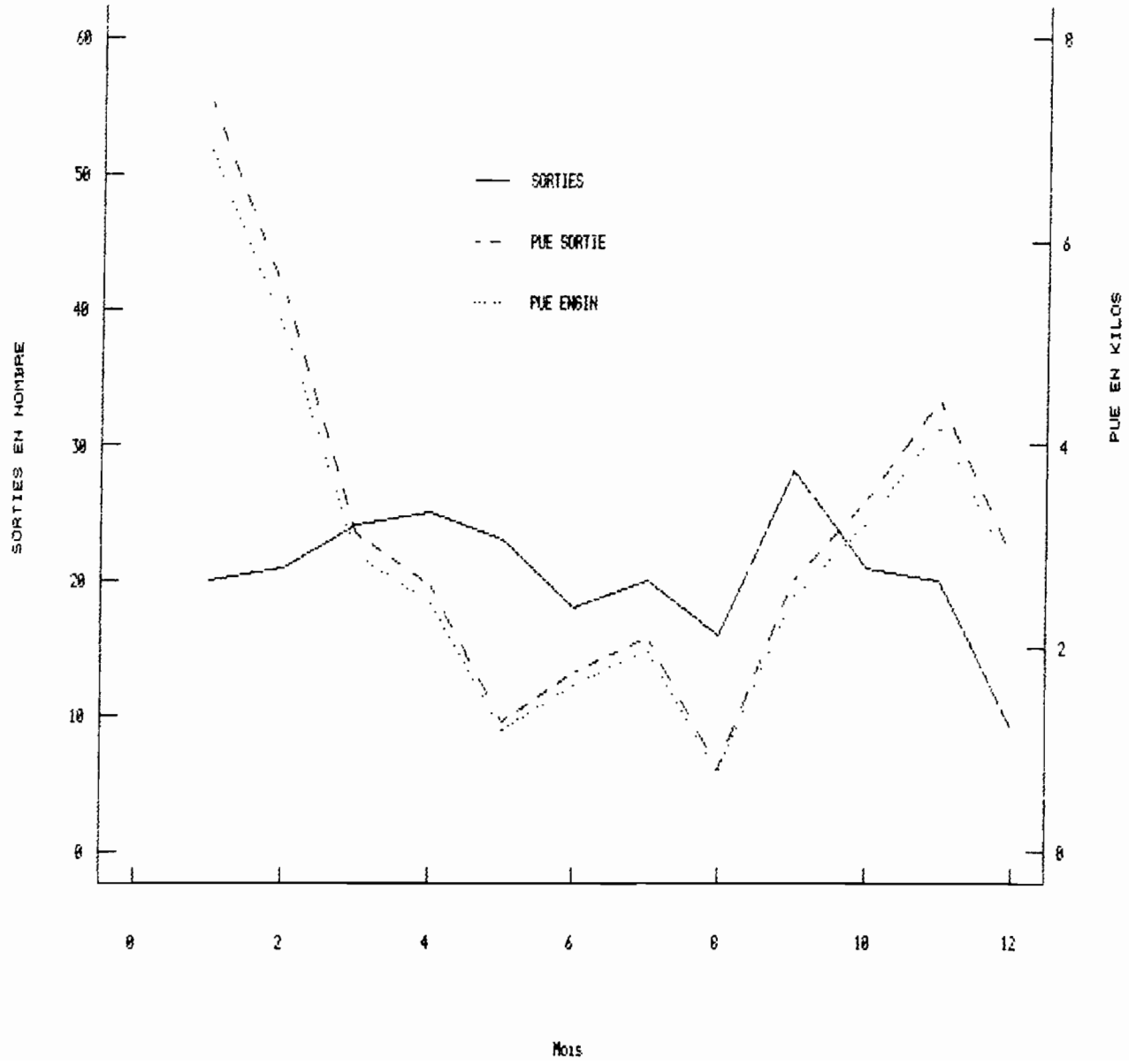


**FIGURE 6.**
**ÉVOLUTION DU NOMBRE DES SORTIES ET DES PUE DE SOLE AU CAP SKIRRING EN 1990-91**



# Skipjack Pole and Line Fishing in East Indonesia

**James Kevin McElroy[a] and Jacobus C.B. Uktolseja[b]**

[a]Landell Mills Management Consultants, Jl. Plaju 6 - Jakarta Pusat 10230, Indonesia

[b]Research Institute for Marine Fisheries, Jl. Muara Baru Ujung Complex Pelabuhan Baru Samudera, Jakarta-Utara 14440, Indonesia

ABSTRACT

*Given the geographic spread of existing skipjack pole and linefishing bases in east Indonesia, the paper analyses the relative importance of several interactive factors on pole and line vessel catch performance, including the effects of vessel size, horse power and age ; crew size and skill ; availability and abundance of bait ; season ; weather ; use of Fish Aggregating Devices (FADs) ; location of the fishing ground, and 'fleet congestion'. Partly from this comparative analysis, it is postulated that the resident stock of skipjack in this area is supplemented by large seasonal migrations from the western Pacific stock. As the bulk of this immigration must pass through the waters north of Irian Jaya, this region must offer some of the best fishing opportunities, and hence will have the highest priority for the future development of skipjack pole and line bases in Indonesia.*

## 1. PRODUCTION

### *1.1 National Production*

The Indonesian skipjack pole and line industry operates only in east Indonesia, and in 1989 accounted for about 63 % (71,400 mt) of the Indonesian skipjack catch (113,850 mt). About 80 % of the total skipjack catch is taken in east Indonesia.

This method of fishing has shown a dramatic increase in the number of vessels and production in recent years (Table 1).

### *1.2 Breakdown by Provinces*

Between 1980-1989, skipjack pole and line fishing in east Indonesia accounted for 92 % of the growth in the skipjack catch in that region ; and three quarters of the increased skipjack catch in the country as a whole (Table 2).

Table 2 also shows the relative importance of the different fishing regions in east Indonesia,as subdivided by McElroy (1989). Almost all the skipjack catch is taken by the northern group comprising Irian Jaya, Maluccu and Sulawesi ; only 8 % is taken in the southern group provinces of Bali, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT) and East Timor (TT).

It is postulated here that the 'resident' stock of skipjack in east Indonesia is supplemented periodically by large migrations from the western Pacific Ocean stock, which occurs in large concentrations north of Papua New Guinea for most of the year (Marcille et al, 1984 ; FFA, unpublished catch/location data, and SPC, 1991). Some supporting evidence for this hypothesis is presented here, based primarily upon an analysis of the pole and line fleet's fishing performance at six strategic locations in east Indonesia (see Figure 1 and Table 3).

There are eight principal pole and line fishing bases in east Indonesia. These are :

- in the northern provinces : *Sorong* (11,500 tons) and *Biak* (2,500 tons) in Irian Jaya ; *Penambuan* (6,200 tons), *Ambon* (2,000 tons) and *Ternate* (2,000 tons) in Maluku ; *Bitung* (2,500 tons) and *Kendari* (5,700 tons) in Sulawesi.

- in the southern provinces : *Maumere* (2,000 tons) in East Nusa Tenggara (The tonnages in brackets represent actual or estimated skipjack landings in 1990).

A number of factors affect the performance of any skipjack pole and line fleet. The principle factors are vessel size (gt), horse power (Hp) and age ; crew size and skill ; availability and abundance of bait ; season ; weather ; use of Fish Aggregating Devices (FADs) ; location of the fishing ground ; and 'fleet congestion'. These factors are all interrelated, some being more important than others under specific circumstances.

Table 3 summarizes available data on several of these factors for six locations in east Indonesia. Some of the most important relationships are identified below.

## 2. VESSEL SIZE, HORSE POWER, CREW SIZE AND SKILL

### *2.1 7.5gt and 15 gt*

Three vessel sizes are shown in Table 3, namely 7.5 gt (30-45 Hp, 8-10 crew), 15 gt (80-105 Hp, 12-15 crew), 30 gt (160-240 Hp, 15-17 crew). As indicated, both the propulsion unit (Hp) and crew size increase with vessel size. Not surprisingly, therefore, so does the catch. At Penambuan, where both 7.5 gt and 15 gt vessels were in operation on FADs at the same fishing ground between March 1987 through March 1991, a 50 % increase in the average number of crew fishing from 9 to 13.5 led to a 71 % increase in catch/operating day, from 461 kg/d to 790 kg/d.

The larger vessels used somewhat more bait per kg of skipjack landed, the relative values being 28.4 kg fish per bait bucket for the 7.5 gt vessels against 23.9 kg fish per bait bucket for the 15 gt vessels. In taking the greater catch, the larger vessels may have carried out more 'open water' fishing, which tends to absorb a greater amount of bait per kg of fish landed.

### *2.2 15 gt and 30 gt*

An increase in catch/operating day was less obvious between these two size groups. Unfortunately, none of the six locations operated both vessel sizes.

Comparing 15 gt and 30 gt vessels operating *without FADs*, as shown below, at Maumere (15 gt), Ambon, Bitung and Sorong (all 30 gt), the catch per effective fishing day, which is defined as an operating day with non-zero catch, was similar for these different vessel sizes, suggesting other factors probably had a greater influence on catch than the factors of vessel size, Hp and crew size.

| | Vessel Size (gt) | Catch Kg | Coefficient of variation % |
|---|---|---|---|
| Maumere | 15 | 792 | 30.7 |
| Ambon | 30 | 730 | 26.7 |
| Bitung | 30 | 808 | 34.7 |
| Sorong | 30 | 890* | 16.8** |

Source: Table 3
Notes: Coefficient of monthly variation in catch.

* estimated catch/effective fishing day from catch/operationnal day data for Bitung.
** applies to catch/operationnal day data.

Specifically, the performance of the Maumere 15 gt vessels between 1983-1987 was on a par with the larger vessels (30 gt) at Ambon and Bitung, all of which suffered from problems of bait availability, but was some 12 % below the larger vessels (30 gt) at Sorong, where bait availability was generally not a problem. However, the high coefficient of variability (C.V.) at Maumere is considered to be more a function of the highly seasonal nature of that fishery rather than strictly a result of a shortage of bait during the period in question.

There is a similar lack of any clear difference for the situation *with FADs*, again most likely because of the swamping of this influence by other factors.

| | Vessel Size (gt) | | Catch Kg | Coefficient of variation % | No. of operationnal days no bait available % | Catch/bucket (kg/B) |
|---|---|---|---|---|---|---|
| Penambuan | 15 | EFD | 790 | 27.6 | | 23.9 |
| Kendari | 30 | EFD | 1,118 | 19.3 | | |
| Bitung | 30 | EFD | 1,004 | | | |
| | | OD | 868 | 15.4 | 12 | 18.9 |
| Sorong | 30 | EFD* | 1,270* | | | |
| | | OD | 1,096 | 11.7 | | 26.8 |

Source: Table 3

EFD : Effective Fishing Day (operational day with non-zero catch)
OD : Operational Day
* estimated from ratio of catch/OD to catch/EFD data for Bitung

It is possible the differences that do exist between Penambuan and Kendari (both use 15 gt vessels) reflect more the skill of the crew, as Penambuan fishermen are generally less experienced as theirs is a relatively new fishery.

## 3. AVAILABILITY/ABUNDANCE OF BAIT AND THE IMPACT OF FADS

There is sufficient numerical evidence to compare this influence only between 30 gt vessels operating 'open water' fishing at Ambon and Bitung ; and at Bitung, between the situation *before* and *after* the introduction of FADs.

### *3.1 Availability/Relative Abundance of Bait*

As Table 3 shows, the proportion of operational days when no bait was available was twice as high (34 %) at Ambon compared to Bitung (17 %), despite the appreciably lower variability in the size of the average catch between months at Ambon. The catch/operating day is one third lower at Ambon (being only 68 % of the catch/OD at Bitung), which may partly be explained by the higher number of operational days at Ambon (19.6 days/month) compared to Bitung (16.0 days/month). Assuming that availability and abundance of bait changes over the course of a lunar cycle in a predictable way, the additional 3.6 operational days/month will generally be during the poor bait period, when catches will presumably be lower. This is best illustrated by comparing the difference in average catch /effective fishing day, when

at least some fish was caught, at both locations. Here, the catch/operational day in Bitung is only marginally higher (10 %) over Ambon, viz. 808 kg compared to 730 kg. As the number of effective fishing days in Bitung is also higher than in Ambon, 13.5 days against 12.3 days, it would appear that, *ceteris paribus,* Bitung benefits from having a better bait supply compared to Ambon with yields of 16.9 kgs of fish per bucket and 68 kgs per bucket respectively. This finding is also supported by anecdotal evidence.

This comparison is between two areas operating 'open water' fishing.

### *3.2 Abundance of Bait and the Effect of FADs*

The comparison is drawn here between the catch efficiency of 30 gt vessels *before* and *after* the introduction of FADs at Bitung.

While the number of operational days/month is the same, at 16, the number of effective fishing days is increased marginally using FADs, being 13.8 days with FADs against 13.5 days without. More striking, perhaps, is the increase in the weight of fish landed per bucket of bait ; with FADs, this is 18.9 kgs, without FADs, 16.9 kgs. Also the number of operational days when no bait was available was higher before the introduction of FADs, 17 % of the operational days against 12 % after their introduction. This may simply reflect more the need for a lower weight of bait to justify economically a trip to the fishing grounds with FAD compared to the weight required without FAD. Hence the proportion of 'insufficient bait' days as opposed to 'no bait' days is probably reduced using FADs.

### *3.3 The Effect of FADs*

Given that the above differences (item 3.2) are relatively small at Bitung, we can compare reasonably directly the catch efficiency of 30 gt vessels *before* and *after* the introduction of FADs at Bitung.

| | Without FAD | | | With FAD | | |
|---|---|---|---|---|---|---|
| | Average/month (days) | Average catch/ operating day (kg) | C.V. % | Average/month (days) | Average catch/ operating day (kg) | C.V. % |
| Operational Days | 16.0 | 673 | 34.7 | 16.0 | 868 | 15.4 |
| Effective Days Fishing | 13.5 | 808 | | 13.8 | 1,004 | |

Source : Table 3
Note : C.V. Coefficient of variation in average monthly catch.

The two outstanding features, resulting from the introduction of FADS as highlighted in the table above, are (a) the increase in catch/day of between 24 % to 29 % on operational days and effective fishing days respectively, and (b) the reduction in average catch size variability between months by more than half (15.4 compared to 34.7).

The reduction in 'month-to-month' variability in average catch size has another important feature. Relative to the average catch level *without FADs*, the number of 'above average fishing' months is higher *with FADs, than without FADs.* By way of example, at one location the number of significantly 'above average' months rose from 4 to 7 after FADs were introduced (Figure 2). This has important implications on the economic viability of the P & L fleet and also of shore-based processing facilities.

## 4. OTHER FACTORS

### *4.1 Vessel Size and Weather*

The number of operational days per month tends to be higher the larger and more seaworthy the vessel, although the differences at more protected locations may not be very large (Table 3).

*4.2 Vessel Age and Crew Experience*

In principle, the longer a vessel and crew are together the higher tends to be the catch, at least during the first few years of a vessel's economic life. As it ages, the average number of operational days/month of a fishing vessel tends to decrease, although the catch/operational day may remain unchanged. Wooden pole and line vessels have an economic life of between 7-15 years in Indonesia. The effect of vessel and fleet age on percentage operational days and average catch performance is shown in Figure 3 for the State Fishing Company PT. Usaha Mina, at Sorong.

*4.3 Bait Availability, Geographic Location and Fleet Congestion*

In the case of pole and line fishing congestion' can occur as a result both of (a) a shortage of bait/vessel or (b) too much fishing power in one area. The effect may be general, seasonal or limited to a certain period of each month.

Good virgin fishing areas, which yield 'above average catch' rates, attract more vessels. Over time, this tends to cause a decline in average catch/vessel.

Because of a number of natural factors, some grounds tend to have a higher productivity (refer Table 3 and Figure 2). In the waters of east Indonesia, this is a notable feature. In the eastern part of the northern group, i.e. around Sorong, Irian Jaya, average catch per unit effort (C.P.U.E.) is high with a low seasonal variability. Moving westward but still in the northern sector of east Indonesia, there is a marked decline in average catch and increase in seasonal variability. To the south and west of Irian Jaya, i.e. in the Flores and Banda Seas, the average CPUE also declines and seasonal variability increases. This result would appear to corroborate the hypothesis that the skipjack resources of the northern waters of east Indonesia are supplemented seasonally, at least in part, with fish from the western Pacific skipjack stock.

This finding has important implications for the development of skipjack fishing bases (whether pole and line or purse seine) within east Indonesia. Indeed, it is a central plank of recent proposals for fishing port and processing industry development within east Indonesia.

## 5. CONCLUSIONS

Because of the geographic spread of existing skipjack pole and line fishing bases in east Indonesia, it has been possible to analyse here several important interactive factors on pole and line vessel catch performance.

(i) The significance of FADs in (a) substantially increasing the average skipjack catch/vessel and (b) reducing seasonal variability of the average size of the catch/vessel has been demonstrated here. FADs provide a useful method to increase vessel productivity and reduce vessel operating costs, thereby increasing disproportionately the economic performance of the pole and line vessel.

(ii) The central importance of bait to skipjack pole and line fishing is well known and has again been demonstrated here. FADs can help to increase catch levels for a given amount of bait, thereby enabling a fishery where bait is a limi tation to increase its total catch.

(iii) The skipjack resource of east Indonesia is in part derived from the western Pacific Ocean stock through migration. As the bulk of the fish entering the east Indonesian ar- chipelago first must pass through the waters north of Irian Jaya, this region must offer some of the best fishing opportunities, and hence will have the highest priority for the development of skipjack pole and line and purse seine bases. After Irian Jaya, in importance, comes Maluccu, and then Sulawesi. In the southern waters of east Indonesia, there is a highly seasonal skipjack fishery. As such, it may have the lowest priority for developing a dedicated skipjack pole and line fishery. Its greatest potential for development may be through a seasonal skipjack pole and line fleet or the use of the same vessels for multi-purpose fishing operations such as longlining or gill net fishing during the low season for skipjack pole and line fishing.

## REFERENCES

**McElroy J.K.** (1989). Indonesia's tuna fisheries : past, present and future prospects. *Marine Policy,* October 1989: 285 - 308.

**Marcille J.** (1984). Tuna fishing in Indonesia, Collection Travaux et Documents No 181, ORSTOM, Paris.

**SPC** (1991). Review of the western Pacific skipjack tuna resource and fisheries, South Pacific Commission, Noumea, New Caledonia.

**TABLE 1.**
**DEVELOPMENT OF INDONESIAN SKIPJACK POLE AND LINE (P & L) CATCH IN THE 1980S.**

| | 1980 | 1982 | 1984 | 1986 | 1988 | 1989 |
|---|---|---|---|---|---|---|
| No. of P & L vessels (no.) | 673 | 541 | 683 | 1,307 | 1,720 | 1,204 |
| P & L catch (mt) | 25,600 | 27,100 | 45,600 | 49,800 | 73,200 | 71,400 |
| CPUE (mt/vessel/year) | 38 | 50 | 67 | 38 | 43 | 59 |
| Skipjack catch (mt) | 41,888 | | | | | 91,633 |
| East Indonesia (mt) | (80.8%) | | | | | (80.5%) |
| Total (mt) | 51,800 | 61,600 | 80,700 | 85,200 | 127,500 | 113,800 |

Source : DGF, 1982 and 1991. Fisheries statistics of Indonesia, 1981 and 1989.

Note : Derived values may not compute exactly due to rounding.

**TABLE 2.**
**SKIPJACK POLE AND LINE PRODUCTION BY PROVINCE IN 1989.**

| | No. of P & L vessels (No.) | Skipjack P & L Catch (mt) | Proportion of total skipjack P & L catch (%) | Total skipjack catch taken in east Indonesia (mt) | % |
|---|---|---|---|---|---|
| Irian Jaya | 39 | 16,700 | 23 | 21,370 | 23 |
| Maluccu | 572 | 26,535 | 37 | 22,975 | 25 |
| Sulawesi | 311 | 24,675 | 35 | 40,355 | 44 |
| - North | 151 | 6,160 | | 8,245 | |
| - Central | - | 0 | | 1,941 | |
| - South | 88 | 10,140 | | 21,640 | |
| - South-east | 72 | 8,370 | | 8,530 | |
| East Kalimantan | 195 | 105 | 0 | 115 | 0 |
| Northern Group | 1,428 | 68,155 | 95 | 84,816 | 92 |
| East Nusa Tenggara | 87 | 3,380 | 5 | 4,251 | |
| Southern Group (Bali to East Timor) | 87 | 3,380 | 5 | 6,935 | 8 |
| Total | 1,515 | 71,395 | 100 | 91,635 | 100 |

Source : DGF, 1991. Fisheries statistics of Indonesia 1989.

Notes: 1a. Note the high number of P & L vessels (195) reported for East Kalimantan relative to the small skipjack catch (105 mt), equivalent to 0.5 mt/vessel/year.

1b. Note the low number of P & L vessels (39) reported for Irian Jaya relative to the high skipjack catch (16,700 mt), equivalent to 428 mt/vessel/year.

2. Total skipjack catch for east Indonesia includes East Kalimantan.

3. Note the discrepancy in the official statistics for East Kalimantan.

4. Figures may not add up due to rounding.

**TABLE 3.**
**SUMMARY OF MAIN FACTORS AFFECTING SKIPJACK POLE AND LINE VESSEL PERFORMANCE.**

| | | Without FAD | | | | | With FAD | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No Location | Vessel size (gt) | Average no.of operational days/ month (d/m) | Average catch/ day (Kg) | Coefficient of variation (%) | No.of operation days no bait available (%) | Catch/ bait bucket (Kg/B) | Average no.of operational days/ month (d/m) | Average catch/ operating day (Kg) | Coefficient of variation (%) | | Catch/ bait bucket (Kg/B) |
| 1. Sorong | 30 | OD 16.1 | 750 | 16.8 | na | 28.7 | 14.6 | 1,096 | 11.7 | na | 26.8 |
| 1977-84 nFAD<br>1985-90 wFAD | | | | | | | | | | | |
| 2. Bitung | 30 | OD 16.0 | 673 | 34.7 | 17 | 16.9 | 16.0 | 868 | 15.4 | 12 | 18.9 |
| 1977-81 nFAD | | EFD 13.5 | 808 | | | | 13.8 | 1,004 | | | |
| 1982-90 wFAD | | | | | | | | | | | |
| 3 Ambon | 30 | OD 19.6 | 359 | 26.7 | 34 | 68 | | | | | |
| 1968-90 nFAD | | EFD 12.3 | 730 | | | 68 | | | | | |
| 4. Penambuan/ Labuha | 15 | EFD | | | | | 11.9 | 790 | 27.6 | na | 23.9 |
| 1987 (Mar) | 7.5 | EFD | | | | | 14.1 | 461 | 16.9 | na | 28.4 |
| 1991 (Sept) | wFAD | | | | | | | | | | |
| 5. Kendari | 15 | EFD | | | | | | 1,118 | 19.3 | na | |
| 1988-90 | wFAD | | | | | | | | | | |
| 6. Maumere | 15 | EFD | | 792 | 30.7 | | | | | | |
| 1983-87 | wFAD | | | | | | | | | | |

Source : Derived from fishing company data

Notes : 1. OD : Operational Day,
EFD : Effective Fishing Day
(i.e. operational days when catch is non - zero).
2. nFAD: no FAD; wFAD : with FAD
3. Coefficient of monthly variation in catches

**FIG. 1**
**POSTULATED SKIPJACK MIGRATION ROUTE FROM WESTERN PACIFIC OCEAN AND THE LOCATION OF THE 6 POLE AND LINE PARTS USED IN THE ANALYSIS OF CATCH PERFORMANCE**

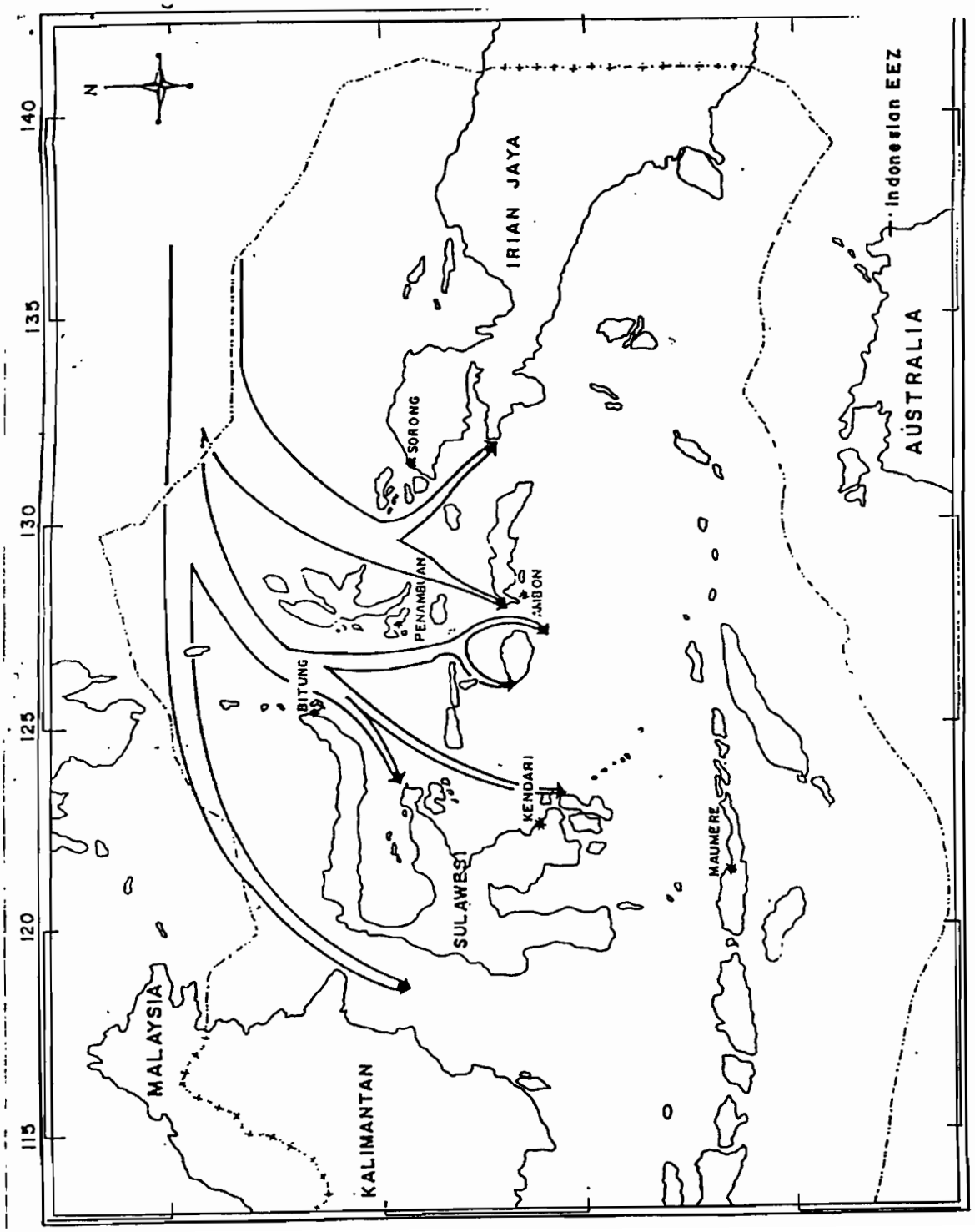


FIG. 2A.
INDEX OF VARIATION IN AVERAGE MONTHLY SKIPJACK POLE AND LINE CATCH, WITHOUT FADS (WEIGHTED 3 MONTHS MOVING AVERAGES).

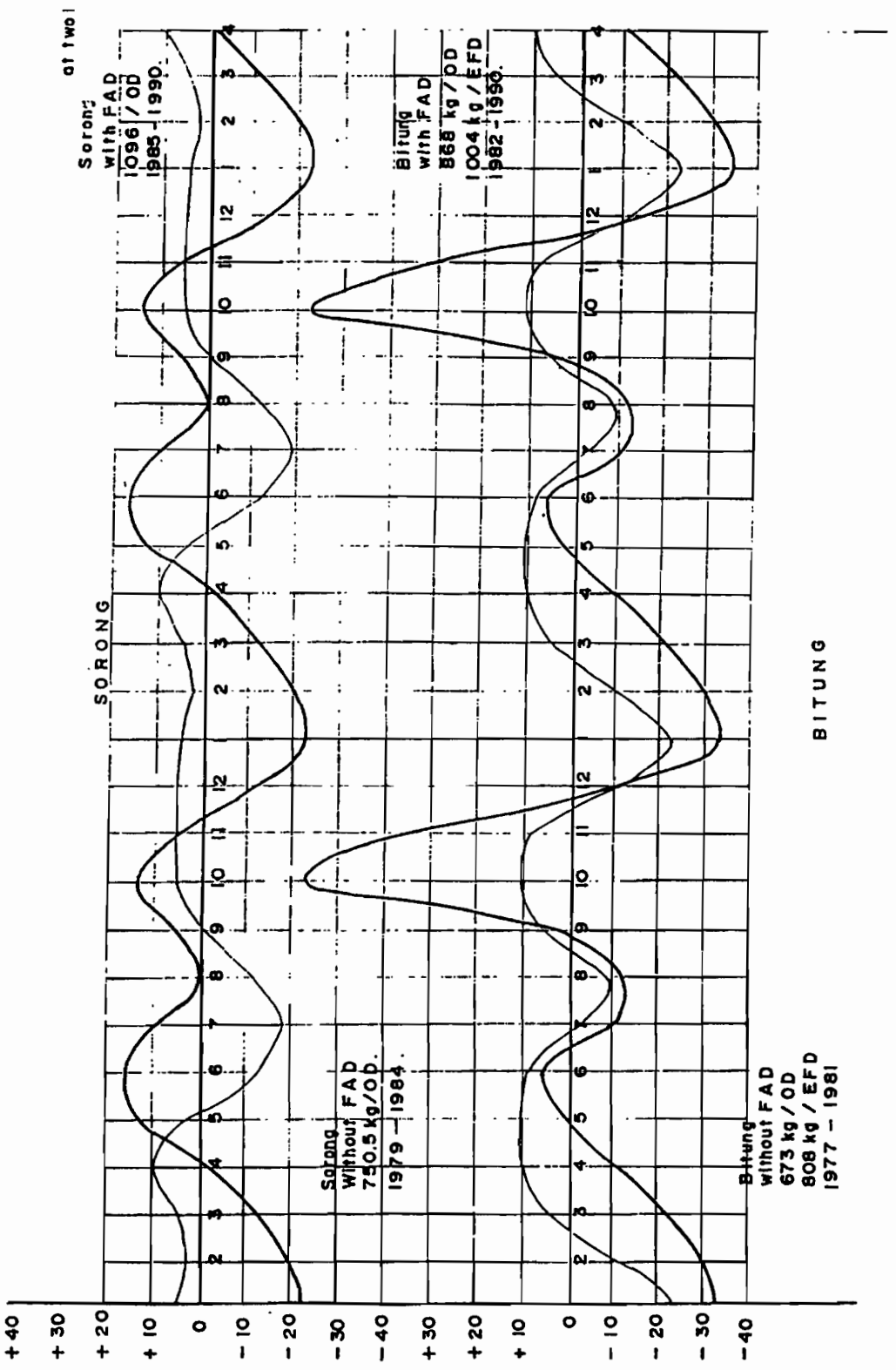


FIG. 2B.
INDEX OF VARIATION IN AVERAGE MONTHLY SKIPJACK POLE AND LINE CATCH, WITHOUT FADS (WEIGHTED 3 MONTHS MOVING AVERAGES).

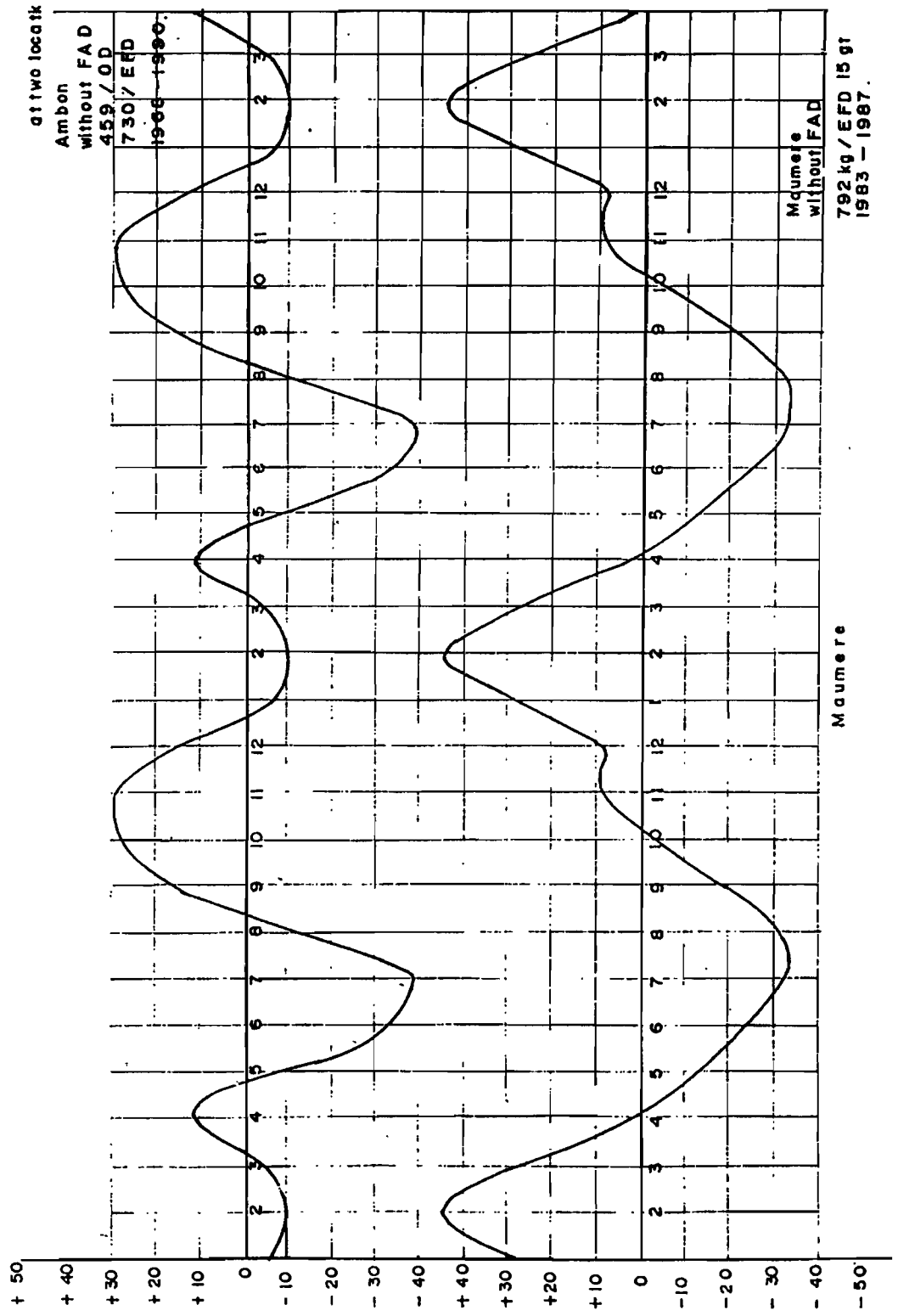


FIG. 2C.
INDEX OF VARIATION IN AVERAGE MONTHY SKIPJACK POLE AND LINE CATH IN THREE LOCATION.

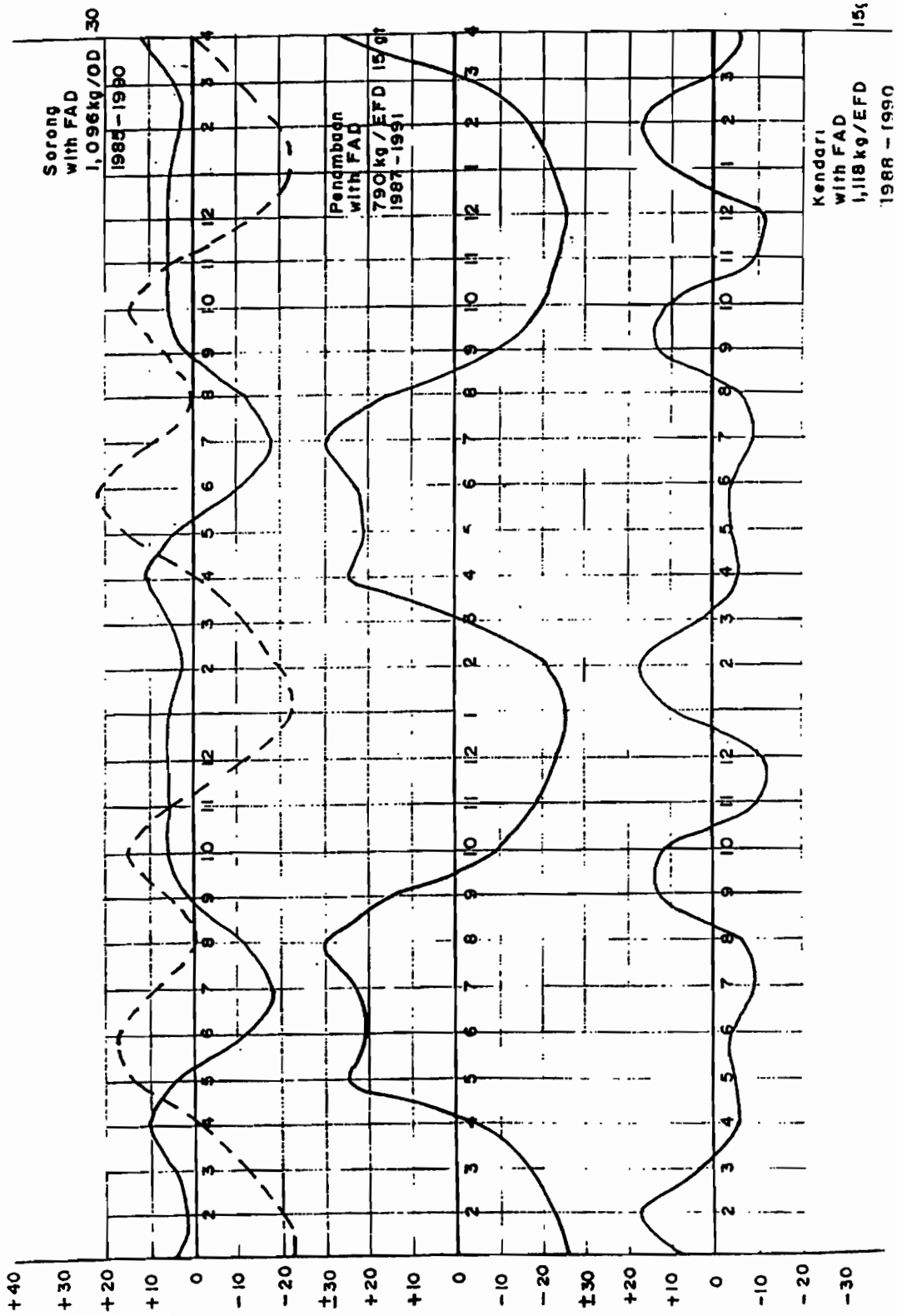
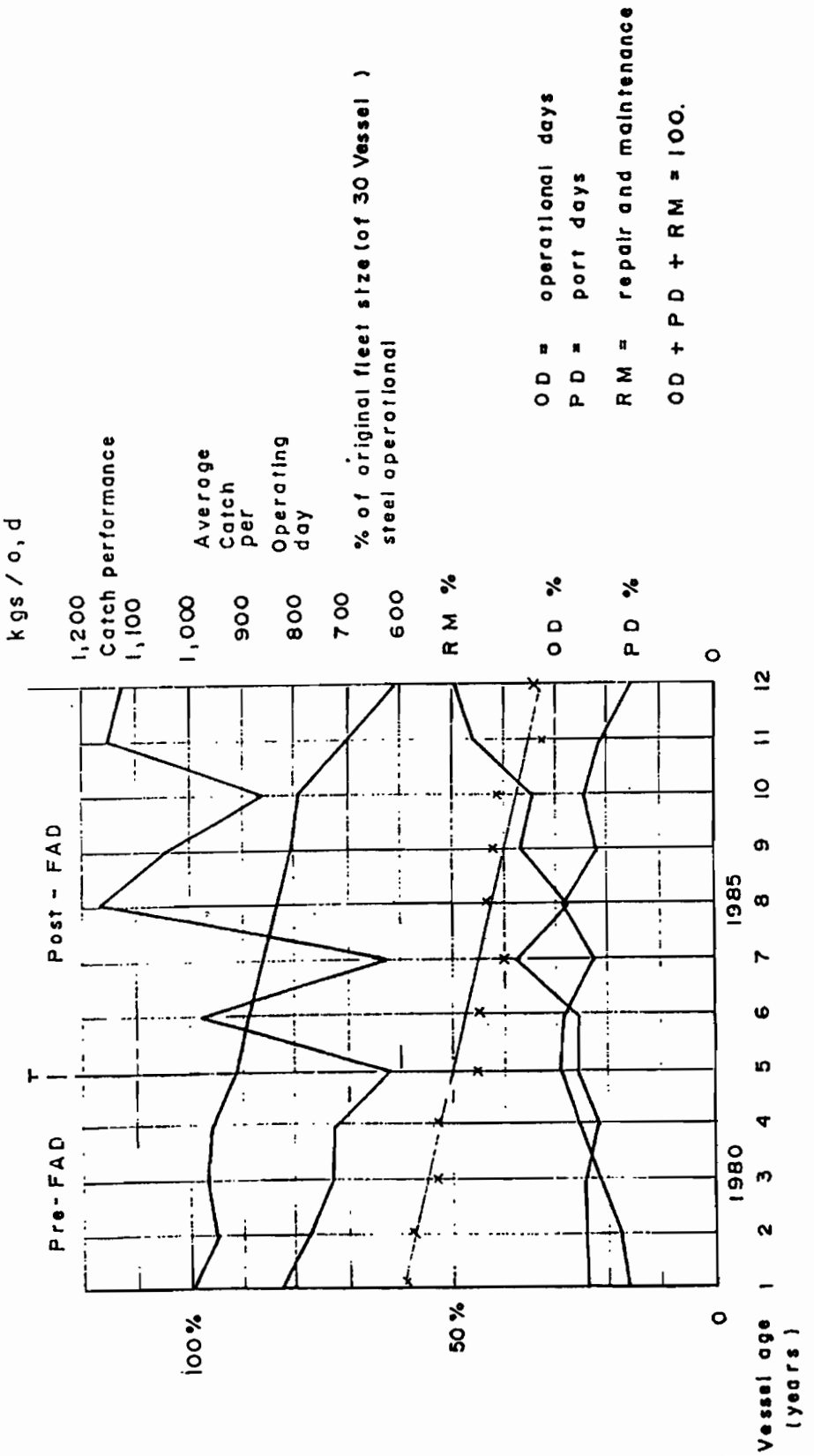


**FIG. 3.**
**THE EFFECT OF VESSEL AGE ON OPERATIONAL DAYS AND CATCH PERFORMANCE.**



# Production planning and the managerial behaviour of the fish-farm entrepreneur in Italy

**Carla Iandoli[a], Eugenio Alaio[a], Rosario Bianco[b] and Giuseppe Vito[c] ***

[a]ICRAM, P.zza Istria 3, 00198 Roma, Italy

[b]Research Institute on Services Activities National Research Council, Via M.Schipa 115, 80122 Napoli, Italy.

[c]Istituto Universitario Navale, Via De Gasperi 5, 80133 Napoli, Italy.

ABSTRACT

*In order to optimize fish production factors and realize viable production process, a sample of sea bass, sea bream, eel and trout farms has been carried out during 1991.*

*Questionnaires have been sent to farmers or presented direcly to them by interviewers ; questions relate to wide-ranging information on ownership status, cultural background, decision making process, role of collaboration, regular and part-time labour, investment aspects, support and marketing policies.*

*The survey focuses on the interactions between the cultural matrix and the background, to determine wheter they, together with the competitive environment, influence the managerial behaviour of the entrepreneur. In order to identify similar groups of farms and relating behaviours the cluster analysis has been applied to the matrix of global variables.*

*As far as the managerial aspect is concerned, two points have been focused on : the level of internal centralization of the decision-making process and the existence of a management planning logic. Results showed a low level of delegation in the decision-making process and only a number of entrepreneurs were profit oriented, with a management planning logic.*

*Generally speaking, the entrepreneur is well educated, experienced, focuses on the objectives of profits and investments and is aware of foreign competition in the sector. However, the existence of occasional entrepreneurs whose only aim is profit, has been evidenced ; they are not concerned with problems related to the market, and only consider investments in aquaculture as a means of making money.*

* The authors all contributed to this report, but in particular, during the preparation of the draft, Carla Iandoli wrote paragraph 3, Eugenio Alaio paragraph 2 and 4.2 with the collaboration of Rosario Bianco, R.Bianco paragraph 4, and Giuseppe Vito paragraph 1. Conclusions were drawn from the common work of all authors.

*As far as producer organizations are concerned, great concern is shown on the subject in the trout sector, due to a long-lasting tradition ; on the contrary, farmers involved in the eurhialin species sector lack a sense of collaboration, even though they may realize that it could help them solve most problems related to the aquaculture sector.*

## 1. INTRODUCTION

Aquaculture in Italy is a growing sector, which has recorded high rates of development in the last few years. At present, this sector consists of about 1,300 fish farms and 60,000 hectares of lagoons, the production of which in 1991 reached 161,000 tons for a value of 417 billion liras. The strong dynamic of development of the activities of this sector has aroused the interest of researchers who, according to different lines of approach and interests, have investigated the production sector with the view of determining the characteristic qualities of the sector. If we consider the approach from an economic and corporate point of view, in this historic period of development, aquaculture activities in Italy can be investigated from two standpoints.

As far as the first aspect is concerned, we deem it interesting to determine the structural characteristics of the sector, the dynamics of the economic factors, the evolution of the natimortality of firms, the conditions of competition, the role and the importance of the research activity on company performances, the level of foreign trade, the characteristics of the demand for services by firms and all that is necessary to define the industry specific features of this productive activity.

The second aspect, more specific and limited and which offers particular opportunities of interest for the company's economist in the approach to analysis, is connected with the thorough investigation of the determining factors of entrepreneurial ability in the sector. The concomitance of the development of a « new » activity in a « new » settlement area, offers researchers the opportunity to make out the determining factors of the phenomenon according to two « vectors », which influence the characteristics of entrepreneurial ability : the economic characteristic qualities of the sector and the socioeconomic characteristics of the areas of location.

By conforming to this line of approach in the present report, we have first analyzed and described the structural characteristics of the fish farms which make up the sector. The productive activities of the sector appear extremely different in the technologies adopted, in the species raised, as well as in management and production plans. Another difference concerns the level of capital intensity for the setting up and management of fish farms, the level of which varies according to the production and organization models adopted, of which heterogenous productivity rates are the counterpart.

While the management of the activities connected with « valli », lagoons and ponds requires limited capital, the facilities for intensive fish-farming are characterized by capital intensity. Such characteristics seem to be of great importance in a moment in which the industrial policies of the sector are necessarily oriented to the realization of favourable conditions for the start-up of fish farms.

The study has then analyzed the relationship between the training processes of entrepreneurs and some characteristic qualities of their managerial ability, in order to determine the similarities and differences present in the entrepreneurial « culture » of the sector. Such knowledge, in this case too, becomes instrumental with respect to the possible public actions of intervention especially in relation to the characteristics of the services offered to fish farms. The scientific literature has widely illustrated the evolutionary characteristics that the contents of the firms services have to take on in order to optimize the growth of the activities of a specific sector/area.

By approaching this analysis plan from the two above-mentioned standpoints, we think we have offered an initial contribution to the description of economic and corporate characteristic qualities of the aquaculture sector, which is by no means complete but offers incentives and opportunities for further checks, developments and critical investigation.

### *2. Materials and Methods*

The survey was carried out by interviewing those who are engaged in the management of a fish farm for a sample of fish farms operating in the sector of mussel-farming, trout-farming and the farming of euryhaline species.

The output of fish farms amounts to 63,000 tons, equal to about 40% of the national output (161,000 tons in 1991). The interviewees were asked a series of questions the purpose of which was to gather elementary variables for the working out of global, yet qualitative indicators, which could allow interviewers to sketch the profile of the entrepreneur of the sector in order to determine the origin of the interviewees, their background, the development of the fish farm and the influence of the strategies adopted. The data thus obtained were carefully analysed in order to free the answers obtained from the inconsistencies which may derive from the intention of the interviewees to give an idea of themselves different from the real one. Control questions were asked and more significant answers were obtained by cross-checking elementary answers. Cluster analysis was then applied to the matrices of global variables in order to identify groups of fish farms which met the same requirements for belonging to the group and determine standard behaviour and trends of the universe surveyed.

In relation to the variables representative of training and cultural values, the analysis of training processes was carried out by separating the processes connected with learning by instruction from the processes of empirical nature, that is to say based on learning by doing. This analysis was made more precise through the pursuit of any possible direct relationship between activities carried out and training path.

## 3. SECTOR'S STRUCTURE AND DYNAMICS

The aquaculture sector in Italy is deeply differentiated and characterized by the influence of environmental, technological, organizational and managemental variables.

The most active section, characterized by a heavier technological and managemental impact, is that of brackish waters aquaculture in which sea bass, sea bream, mullet, eel and mussel are cultured.

The Italian output for 1991 amounted to about 161,000 tons, distributed as follows : 66% of molluscs, 23.4% of trout, 3.3% of euryhaline species and 2.2% of eel ; it is sold especially on the home market, and in particular 52% on the national market and 27% on the local market ; only 21% of the total output is exported. The value of the production (Lira of 1991) is equal to 417,5 billion liras ; such data point out the prevalence of low-unit-value cultures such as mussels and eel. However the most profitable species, more appreciated by the Italian consumer, are euryhaline species.

1285 aquaculture facilities were registered for assessment in 1990, with a regional distribution characterized by a high concentration in Veneto (about 25% out of the total) and in Emilia-Romagna (about 16% out of the total).

The growth trend of the Italian aquaculture sector is the result of two major phenomena : on the one hand, the new diet which leads to an average demand per capita equal to 15 kg of fish, which is still far from reaching European averages, and on the other the difficulties connected with fisheries and the excessive exploitation of the sea. If we connect these phenomena with the preference of consumers for fresh food products, we can clearly see the need to concentrate on aquaculture and on the processing industry of fresh food products connected with it. Indeed, we have not made good use of the opportunities and the supply of fish products from foreign markets amount to almost 50% of home consumption among fresh, quick-frozen and deep-frozen products in 1989. The situation relating to foreign trade did not improve until 1991, but the data of the first six months of 1992 seem to show a trend in the opposite direction compared to the same data of 1991.

In spite of the difficulties related to setting up the facilities, workers do not have specialized functions and there are gaps in the technical knowledge of employees. 55% of the personnel are hired, but considerable percentages of positions are held by the families and partners.

We notice an insufficient presence of phenomena of vertical integration, either of the backward type, represented by the possibility of carrying out the activity of reproduction as well as of growing-out, or of the forward type towards the distribution phases. As far as the last phenomenon pointed out is concerned, it comes out that only 9% of the fish farms has their own distribution centre, whereas the largest portion of trade is controlled by wholesalers (52%), followed by fish markets (24%), retailers (3%) and game-fishing (2%). The remaining 18% are represented by other forms of marketing.

The description of the sector given above is characteristic of growing sectors (except for mussel-farming), characterized by the continuous pursuit of a proper economic/financial balance on the one hand and a production/distribution balance on the other.

As far as short-term strategies are concerned, we see emerging primary objectives of facilities' expansion, aiming at economies of scale, minimization of cost and improvement of the quality of the product.

In the last five years, entrepreneurs have increased their productive capacity in order to minimize costs, purchased equipment and hatcheries. In this period only 4% of the entrepreneurs did not invest.

The financing sources used are mainly self-financing (44%), public funds (23%), loans and soft loans (20% and 12% respectively).

In support of the requirements for the economic, financial and managemental start-up of the sector's operators, the European Economic Community contributed by financing in Italy, according to Reg. 2908/83, in the period 1983/86, 38 facilities for a total value of 12,333,967 ECU and another 41 facilities, according to the subsequent Reg. 4028/86, in the period 1987/90 for a value of 21,460,990 ECU.

## 4. ENTREPRENEURIAL PROBLEMS

### *4.1. Introductory remarks*

The study of the entrepreneurial characteristics of the aquaculture sector offers opportunities of analysis for the main lines of investigation of the debate. In particular, there is a potential connection with the line of analysis which studies the connections between the characteristics of the economic environment of settlement and the start-up dynamics of fish farms, in order to determine the « objective » factors which affect the growth of successful fish farms, with the purpose of identifying the determining factors of development and growth of entrepreneurial ability. In relation to certain lines of investigation, national or international and/or within or among sectors, and with a firmly-established quantitative approach, such line of analysis breaks down into a series of lines of investigation connected with the identification of the main difficulties encountered by the new fish farms, with conditions of optimal balance among internal resources and environmental opportunities (Norman 1979, Coda 1984) and with the analysis of motivation and incentive values for personnel through an approach of organizational matrix [1].

In the panorama of the specific literature, in addition to these areas of investigation, there has been an increase in the analysis efforts of the « cultural » line, which analyzes the role of corporate

culture, intended as the whole of guidelines, in the company's dynamics (Gagliardi 1986, Bosche 1984, Thevenet 1984), trying to connect its importance to the company's performances (Lemaitre 1984, Kotter, Heskett 1992), even investigating the relationship existing between vocational-training path and typologies of entrepreneurial ability (Calvelli 1990).

However, the possibility of applying the last line of analysis to the aquaculture sector turns out to be limited by the fact that this activity has only recently appeared, thus preventing the sector from acquiring its own cultural features.

At present two prevailing dynamics seem to emerge from the paths which led the entrepreneurs of the sector to undertake the activity. The first path comprises those who have undertaken the activity by virtue of the « technical » skills they possess and consider suitable for determining favourable conditions for their activities. In particular, this group consists of the operators who previously worked as researchers or fishermen, or carried out other fishing activities. On the other hand, the second path seems to apply to those who possess real estate, plots of land and/or « assets » which can be used to make profits in the aquaculture sector.

1. « Studies on entrepreneurship in Italy » seems to be representative of the different lines of systematization and investigation of the theme ; published by Lorenzoni and Zanoni (1988) it contains recent systematized studies coming from different matrices and therefore aimed at investigating different aspects of the theme. In particular, it includes contributions of social matrix (Dalla Chiesa) and of statistical-quantitative matrix (Brasini, Tassinari), while in the group of economic-corporate approach, it can be seen lines of environmental analysis (Dubini, Schillaci), of the analysis of the determining factors of the entrepreneurial phenomenon (Colombo, Lorenzoni) and of the analysis of the mechanisms of diffusion (Del Monte). Other elements of investigation are the dimensional variable, which leads to investigate characteristic qualities connected with the small-scale firm (Boldizzoni), and the territorial/functional/sectorial components (Stampacchia, Lorenzini and Fabbriciani, Carlesi, Manaresi and Zanoni).

Such evidence points out then the possibility of going on with the research with the objective of constantly monitoring in the next future the performances of fish farms characterized by the presence of entrepreneurs coming from the two groups, established in order to evaluate and measure the dynamics of the relationship between the specific preparation of the entrepreneur and the success of his enterprise. Furthermore, in perspective, we see the possibility of studying the possible birth and growth of a « homogeneous » entrepreneurial culture within the sector, which can be evaluated through the formation of « myths » (Calvelli 1990) and common values. In particular, it seems possible that the two geneses of the current distinctive skills of entrepreneurs, determine new and common characteristics or the predominance of an approach over the other ; moreover, new connections could emerge between the entrepreneurial activity and the economic environment capable of affecting the prevailing entrepreneurial culture.

*4.2. The Results of the Survey*

As for the objective of specifically identifying whether vocational training, either empirical or strictly didactic, is somehow correlated with the activity carried out or it is completely independent of it, the application of the analysis of the main components to the identifiers of vocational training (education, specialization, previous experiences, years of practice of the current activity, reasons for becoming an entrepreneur, father's job, place in which the interviewee lives, opportunities of refresher courses, opportunities of trips) has made it possible to identify two basic clusters, on the basis of two components which together account for 40% of the total variance of the sample observed (Fig.1).

The first cluster includes the experts of the sector (20%) whose characteristics are a wide specific experience in the section, a degree in scientific disciplines (48%), followed by a postgraduate specialization in 45% of the cases ; the previous work experiences, when present, have been acquired in the same sector (21%), whereas in 39% of the cases it is the first job. The second cluster comprises the self-made men represented by 27% of the subjects who are former employees of the same fish farm or of rival fish farms, and in some cases sons of fishermen (6%) that, by virtue of a new choice (28%) or to go on with the family's activity (18%), have decided to work on their own.

The self-made man is a person who acquires his training day by day, that is he acquires his skills from his daily work and from the unconscious application of heuristic to a high technical-scientific content activity. The level of instruction is however influenced by the age of the subject, due to the fact that the degree of school attendance has considerably increased. 30% of the subjects interviewed has on the average 4 years of experience in the sector, whereas 24% has been working for more than 20 years : 91% is aged between 25 and 56. The activity carried out by the father has only a minimum influence on the cultural values, only 30% comes from a family of entrepreneurs, that in 12% of the cases carries out an activity completely different from the activity of the son.

The close examination of the cultural values has been carried out by analyzing the factors considered hindrances to the development of the activity and to the propensity to forms of cooperation. With reference to the last aspect, the opinion of entrepreneurs on the prospects of cooperation existing in the sector has been correlated with the knowledge the subjects possess of the forms of cooperation between firms (relations among firms and trade unions, real evaluation of motives which are the basis for belonging to a certain trade union, knowledge of the other forms of cooperation) (Fig.2).

The main components which are the most representative ones account for 54% of the total variance and include the references to the cooperation factor and the emotional and motivational factors which have led the subjects to choose this activity. The basic motive is profit, and there is frequently an excessive elevation of the goodness of one's own choices in terms of production which stands out among the others. The clusters identified include, respectively, 19% and 42% of the firms interviewed. The first cluster comprises the subjects who are clearly opposed to cooperation and that in substance refuse to transfer knowledge and experience to the other operators of the sector. The second cluster includes those who are in favour of cooperation but who do not pursue it, since they constantly tend to preserve their firm from external stimuli. This is to be attributed to the firmly-established tendency to mistrust the other operators and to the lack of distinctive skills capable of saving their competitive position.

In relation to the managerial behaviour, the size of the firms examined (only 12% have more than 30 employees, 45% has no more than 5) is unsuitable for a precise analysis of the factors which may identify the lack or presence of a managerial component ; we have then focused on the aspects relevant to the degree of centralization of the decision-making process and to the management control.

The level of delegation was put in relation with the tendency to spread information within the firm, considering it a good indication of the tendency to involve all the personnel in the decision-making process of the firm which can, within certain limits, increase management efficiency (Fig.3).

The duties delegated usually concern administration and production ; however, in 68% of the cases it is necessary to have the prior authorization of the top-level decision-makers. Such a form of delegation has been given a reduced weight with reference to the characteristics previously adopted as well as for the specificity of the duties delegated.

The clusters identified represent firms which have a low level of delegation and which are characterized by low employment, in which there is a high centralization of the productive functions and a limited propensity to changes, in consideration of the fact that the transfer of knowledge within the firm may damage the efficient behaviour. On the contrary, there are firms for which, even in the presence of a low level of delegation, there is the participation of men in favour of changes and interested in the changing corporate sociology and in the surrounding environment. The first group includes centralizers (33%), the second group innovators (18%), subjects with good managerial contents and in favour of innovations and changes, a tendency which is more in keeping with medium-scale and big firms. The main components used account for 45% of the total variance.

The management planning logic has been analyzed with reference to the adoption, within the firm, of any instrument of preventive analysis and concomitant or subsequent control. 82% of the firms declare that they carry out management control. The instruments used are budgets (18%), cost accounting (30%), production statistics (24%), asset and liability statements (3%), cash situation (15%).

The clusters identified are the following :

1.bigger labour-intensive firms with a large share of the market over the national territory, which use planning and control high-statistical-content instruments and cost accounting (45%) ;

2.firms operating on the local or regional market, run by a family with 3 to 5 employees on the average. The company's leadership is concentrated in the hands of one only person with low-level education ; advanced forecasting and control techniques are not used (30%) (Fig.4).

Obviously in every firm the entrepreneur and/or the manager (Schumpeter distinguished between the manager and the entrepreneur, but we can object that it is the manager that runs the firm, by holding a position connected with specific duties within the firm, but the manager can act in his capacity as entrepreneur, if we exclude that in a firm there must necessarily be a decision-making hierarchy among subjects employed to make decisions of vital importance) may affect, with their personalities and the decisions they make, the life of the firm itself. For this reason we decided to study how the behaviour of the decision-makers identified may affect the corporate strategies in progress and being advanced.

Two major components were correlated, representative respectively of the personalities which make it possible to identify the entrepreneur/manager as centralizer or decentralist and make remarks on the strategies. The two components account for 45% of the total variance (Fig.5).

The firms belong to a macroaggregate representative of the moderately decentralizing tendency of decision-making processes. Such aggregate, in turn, can break up into two subsets which differ in the strategies they pursue and for the level of the mentioned decentralization. We find strategies aiming at the extension of the corporate size and thus of the productive capacity with the objective of attaining technical and economic efficiency by involving all the personnel of the firm. They are typical strategies of investment, at least in the initial phase, which then translate into strategies of growth in the intermediate phase. On the other hand, there are firms with a greater centralization of the decision-making process in which they pursue technical and economic efficiency by the use of traditional techniques oriented to the optimization of plants and production processes, but not considering the motives of personnel and their possible innovative stimuli. Nevertheless, the type of strategy pursued and the results obtained depend on the external or internal ties of the firm.

The application of the cluster analysis by variables representative of internal/external ties (used and available technical assistance, important factors for the growth of the activity, profits, company control, initiatives of the public administration, factors boosting the development of the sector, relations with banks and insurance companies, cooperation) has focused attention on such limiting factors as : insufficiency of the bank credit, due to the high rate of return required by the firm as well as to the technical difficulties in distribution ; inadequacy of public contributions, which do not meet the real requirements of corporate management ; lack of a real and efficient consulting network for firms (which, although it is present, contributes to the rise in running costs) ; loose ties between scientific research and entrepreneurial world (which neither boosts nor contributes to the formation of micro industrial zones or pseudo industrial areas) (Fig.6).

The components employed in the analysis account for 40% of the total variance of the sample. The clusters identified represent, respectively, 52% of the firms projected into the real situation proposed, and 18% of the firms which have a rosier future for different reasons. They have a greater profitable capacity, they succeed in self-financing to a greater extent, they have better relations with the credit system. Ties, the cultural background of decision-making centres, and strategies affect the competitive position of the firms.

The combined analysis of the strategies in progress and the competitive position of firms yielded the following results. The prominent strategic objectives are the pursuit of the quality of the product, aimed at innovative success on the market, and the traditional pursuit of technical and economic efficiency.

Factors representative of the competitive position are the production trend chosen, the segments of the market in which the firm operates, the services offered and scheduled, investments (Fig.7).

Concerns are divided into two main groups. The first group (27%) includes the efficiency-oriented firms which work on the local or national markets, the objective of which is to increase their productive capacity (investment strategies), even by the optimization of intensive forms of production, which in substance do not offer any important service to the customers. The second group (10%) comprises the firms working also on foreign markets, but only to a limited extent (16%), oriented to the quality of the product and to the customer (punctuality in delivery, quality of the product, satisfaction of the customer) without investments for the purchase of fixed assets, the production trend of which is well established.

### *4.3. Relationship between Fish Farms and Support Measures*

There are two types of aquaculture farms in Italy : the traditional fish farms, which are not capital-intensive, including many extensive systems, and the innovative fish farms, which on the contrary are capital-intensive, characteristic of intensive systems.

All the interviewees expressed themselves very favourably towards a research applied to the real problems and needs of the sectors, even hoping for public-private integration.

Among the criteria which serve to describe the figure of the entrepreneur, such as risk, duties of promotion and coordination, decision-making power, what seems to be fundamental and necessary for the aquaculturist entrepreneur and for the entire sector is the definition given by Schumpeter in 1912 : « The entrepreneur is the one who introduces innovations, and this characteristic may apply to every man, apart from the position held and the time spent to reach such a position ». Since the gap existing between the Italian system and the foreign system is attributed not only to high production costs but also to an insufficient cooperation among « entrepreneurs of little initiative », for the years to come everyone hopes for an innovative entrepreneurial and managerial orientation, market-oriented, cooperating, characterized also by joint ventures and particularly sensitive to the quality of the product.

Within this aim, the setting up of family businesses may represent a factor of great success.

Every type of aquaculture is suitable for, to some extent, being carried out or introduced in family fish farms, without prejudice to the integration of the fish farms themselves into a wider production cycle, which includes reproduction and weaning centres, plants for the production of foods, services for technical assistance, etc.

The possibility of carrying out an activity of this type in the same way as a family business has therefore its positive aspects not only for agriculture near bodies of water (complementarity) but also for the fisheries sector (professional evolution of the employees). In fact, fisheries carried out at present in our country is to a great extent an activity of the inshore type, which makes use of small fishing boats and employs people with limited professional qualification, within a considerable unbalance between productive capacity (a large number of fishing boats) and actual fish output.

Furthermore, if we examine the status of those who operate for example in the lagoons of Veneto and Emilia-Romagna, we discover a not very favourable situation : labour force ageing little by little, marginal incomes, insufficient propensity to invest, etc.

The measures in credits and contributions introduced by the European Economic Community, by the Ministry of the Merchant Marine and by the regions contribute only very little to solve the problem : on the one hand, there are those

who introduce innovations thus making fisheries more productive in the short term but impoverishing the sea resources (or lagoon), on the other there are those who, in the majority, are little by little cast out and pushed back towards situations of economic marginality or part-time.

It is for these reasons that aquaculture, once its compatibility with the environment has been ascertained, can become a method of rational exploitation of wetlands and also a moment of professional qualification and social evolution of fishermen, at least for some forms of fisheries. The fisherman would be described not as user of a natural resource which is little by little becoming extinct but rather as actor of a productive process, thus also changing the traditional attitude towards water, now seen as field of action instead of reservoir. In the fish farm of the aquaculture sector the ex-fisherman becomes in this way an entrepreneur able to manage the cycle and phases of production and to put to good use his particular knowledge and sensitivity.

As far as the relationship between the age of employees and their professional qualification is concerned, it is well-known that many activities of the primary sector do not suit the younger members of the family, since those activities belong to the tradition of « unpleasant jobs » ; this should not apply to the aquaculture sector, since it offers the young people the possibility of a personal as well as a professional improvement.

The opportunity to carry out an activity which so far has been the privilege of few people in possession of this technology will be an incentive not to be underestimated in the new investment plans.

Aquaculture, as clean highly technological zootechnics, can be a winning factor if the objective is to exploit, in the form of family business, the various wetlands of our country : the development of aquaculture is not only compatible with the size and organization of the family business, but it also represents an incentive of great interest to stabilize young workers in the primary sector.

But it should be taken into account that the professional figure of the aquaculturist may originate from the specialization of the farm worker as well as from the evolution of the traditional fisherman. The latter shows positive aspects from the socioeconomic point of view, since it enables the employee to carry out a full-time professional activity.

A family management will be a good barrier against the risks for « industrial » concentration of investments and mummification of the environment, which could occur if the territory is left « natural » and if the task of preventing production fragmentation is remitted to a reform on wetlands to be hoped for.

## 5. CONCLUSIONS AND IMPLICATIONS

Every production-oriented firm has its corner-stone in two main factors : the human and the technological factor. The optimization of these two components can be realized through the identification of their initial status (start-up phase) and the continuous attention to their evolution.

The results of the analysis carried out so far have pointed out the existence of hidden or manifest potentials for the optimization of human resources and the existing technology, but also a marked lack of coordination between operating policies and structures which could realize the optimization and the synergism of the available resources.

The formation of distinctive skills which can contribute to increase the growth of the aquaculture sector in the Italian economy can be fulfilled in the pursuit of a prudent community support policy to be intended as a real basis for intervention for the Public Administration and producers' associations, in the pursuit and fulfillment of a consolidation and a continuous exchange between scientific research and firms, in the increase of relations among firms for an entrepreneurial cooperation which may give rise to a continuous transfer of knowledge and skills. The cultural changes must be accompanied by a sound and prudent investment policy, which represents the point of junction between investments in human resources (managerial operating level) and investments in technologies and structures.

We have to mention as well the need for pursuing the so-called global quality in order to improve the competitiveness of the product so as to create a factor for the protection of the national production of increasingly competitive imports.

But this does not mean that we have to neglect the pursuit of technical and economic efficiency which has to be an instrument for the attainment of sought-after objectives such as the pursuit of a better product from a qualitative point of view and the use of increasingly competitive technologies.

The short-term strategies can therefore be effectively supported by national and EEC contributions which, at the moment, lack only a clear definition of standard reference criteria to guide the choice of investments in economical farms. Such plants are intended to recover productivity according to criteria of efficiency and effectiveness in such a way so as to make the final product qualitatively and economically competitive compared to the imported product. The contributions will depend on the phase of life of the plant, in view of the final market.

It will be advisable to distinguish the outlet according to the destination of the product, considering it divided into the following segments : market of the final consumer, catering, market of the industrial processing.

Therefore, from a strategic point of view, it is necessary for entrepreneurs to switch from a production-oriented position (as suggested by factors such as crisis in the fishing sector, increase in per capita consumption, rise in imports) to a market-oriented position, or to be more exact oriented to outlets suitably divided into segments and evaluated from an economic point of view.

The achievement of these values depends on the actors of the aquaculture system, their experience acquired in the sector or elsewhere, their background and on their culture, which can make it possible to increase their skills and determine a possible cooperation among firms.

## REFERENCES

**Ansoff H.I.** (1989). « Strategia aziendale ». Etas Libri

**AA.VV.** (1987). « L'imprenditore e la cultura imprenditoriale ».

**Bosche M.** (1984). « Corporate culture. La culture sans histoire ». Revue Francaise de Gestion. Septembre-octobre

**Calvelli A.** (1990). « Profili manageriali e sviluppo d'impresa », Serie Monografie n.2, Istituto di Ricerca sulle Attività Terziarie, Consiglio Nazionale delle Ricerche, Napoli.

**Coda V.** (1984). « La valutazione della formula imprenditoriale » ; Sviluppo e organizzazione n.82

**Dalla Chiesa N.** (1988). « Teorie socio-economica dell'imprenditore » in « Gli studi sull'imprenditorialità in Italia » a cura di G. Lorenzoni e A. Zanoni.

**Gagliardi P.** (1986). (a cura di) « Le imprese come culture », Isedi, Torino.

**Hofer Ch.W and D. Schendel D.** (1988). « La formulazione della strategia aziendale », Collana SDS, Scuola di Direzione Aziendale, Università Bocconi, Franco Angeli.

**Kotter J.P. and Heskett J.L.** (1992). « Corporate culture and performance », The Free Press, New York.

**Iandoli C. and R. Bianco** (1992). « Stato dell'acquacoltura in Italia e ruolo della politica comunitaria di supporto », Quaderno ICRAM n.4.

**Invernizzi G., Molteni M. and A. Sinatra** (1988). « Imprenditorialità interna », Etas Libri, Milano.

**Lemaitre N.** (1984). « La culture d'enterprise, facteur de performance », Revue Francaise de Gestion, Septembre-octobre.

**Lorenzoni G. and A. Zanoni A.** (1988). (a cura di) « Gli studi sull'imprenditorialità in Italia », Bulzoni Editore, Roma.

**Normann R.** (1979). « Le condizioni di sviluppo dell'impresa », Etas Libri, Milano.

**Porter M.E.** (1982). « La strategia competitiva », Tipografia Compositori, Bologna.

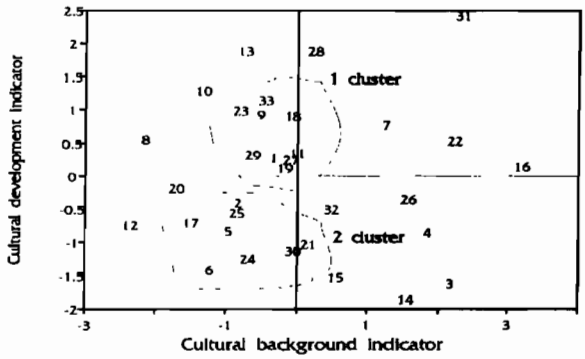
**Schumpeter J.A.** (1934). « The theory of economic development » Cambridge, Mass., Harvard University Press.

**Spagnolo M.** « Le condizioni e i fattori di sviluppo » in L'Italia agricola n.4 1990 « Acquacoltuta : una prospettiva per l'Italia »

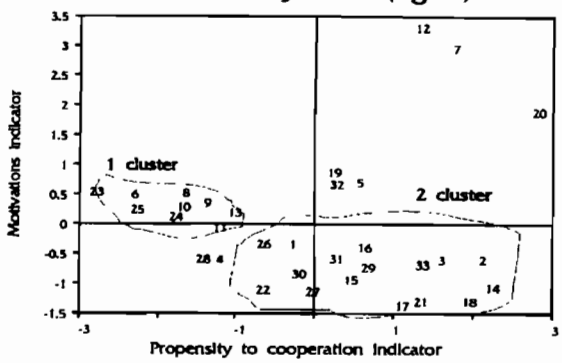
**Thevenet M.** (1984). « La culture d'entreprise : en neuf question », Revue Francaise de Gestion, septembre-octobre.

## Cluster analysis results for a sample of farms.

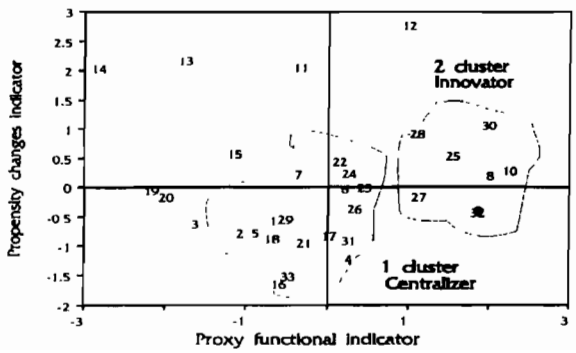
Training processes analysis. (Fig. 1)



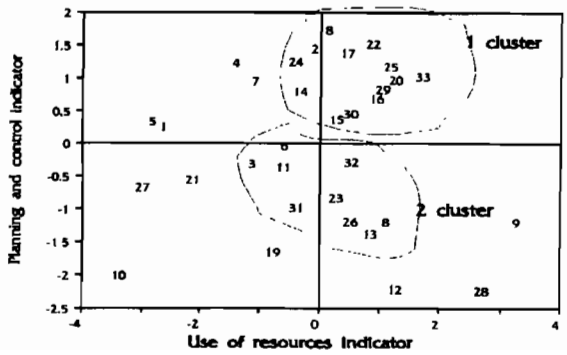

Propensity to entrepreneurial relations analysis. (Fig. 2)



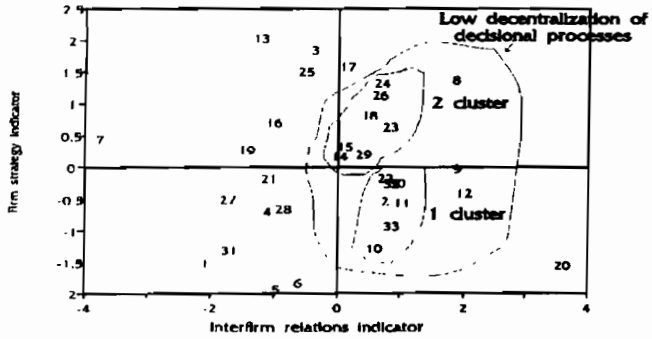

Company relations analyis. (Fig. 3)



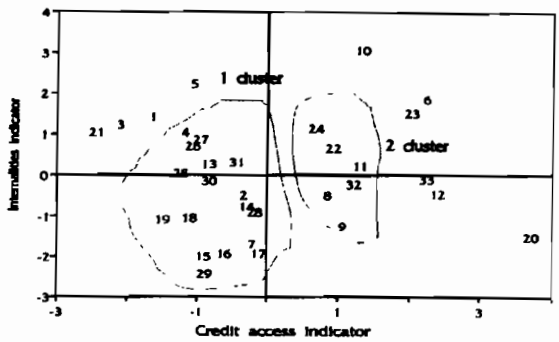

Managerial component (Fig. 4)



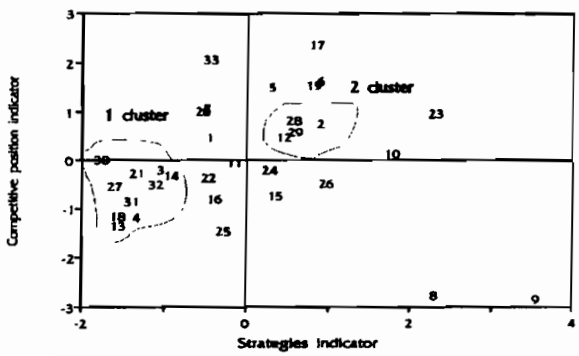
Relationship between interfirm relations and managerial strategies. (Fig. 5)




Hindrance to the management of a productive activity analysis. (Fig.6)




Strategies and competitive position analysis. (Fig. 7)



**SESSION 1 : FISHERIES COMMON POLICY**

**A : PLENARY SESSION**

The EEC-Common Fisheries Policy and the 1991-Report
P. Andersen ..... 15

The Fisheries Structural Policy on the Horizon of the Year "2000"
E. Mastracchio ..... 19

Définition et mise en œuvre de la Politique Commune des Pêches de la CEE : le point de vue d'un Etat membre
C. Bernet ..... 25

**B : INSTITUTIONS AND FISHERIES COMMON POLICY**

The Relationship between Fleet Capacity and Fishing Effort
G. Valatin ..... 29

The European Community Decision Making Process : Fisheries with Reference to the Role of the European Parliament
D.I.A. Steel ..... 37

The Common Fisheries Policy and the Role of Producer Organisations in South West England : Economic Considerations
J. Slaymaker, A. Hatcher and S. Cunningham ..... 45

**C : EVALUATING THE SOCIO-ECONOMIC IMPACT OF THE E.E.C. FISHERY POLICY**

Evaluating Socio-Economic Impact of EEC Fishery Policy Using a Social Accounting Matrices Approach
G. Cella, V. Placenti and M. Spagnolo ..... 53

**SESSION 2 : AQUACULTURE SECTORAL DYNAMICS**

**A : GENERAL SESSION**

A Comparative Study of the Development of Mussel Farming in Scotland and Ireland with Emphasis on the Development of Marketing
M. Gabbot, S.A. Shaw and J. Gibbs ..... 77

Economic Evaluation of the Red Sea Bream Ranching in Kagoshima, Japan
J.R. Ungson, H. Hirata and Y. Matsuda ..... 87

Adoption of Innovations in the Norwegian Aquaculture Industry - Perceived Attributes
K. Hansen ..... 97

Scandinavian Aquaculture in a Global Perspective. A Study Concerning Structural and Marketing aspects
R. Cedrins ..... 109

**B : PANEL SESSION - SALMON PRICE AND MARKET**

What is the "Right" Price of Norwegian Salmon?
R. Hannesson ..... 119

Why 1991 Alaskan Salmon Prices Crashed
M. Herrmann and J.A. Greenberg ..... 129

SESSION 3 : FISHERIES MODELLING

A : MULTI-OBJECTIVES MODELLING

Multi-Objective Programming : an Application to the Pacific Whiting (Merluccius productus) Fishery
R.R. Enriquíez and G. Sylvia ..... 145

A Multiple-Criterion Optimization Approach for the Management of a Multispecies Fishery with Ecological and Technological Interdependencies
J.C. Seijo, O. Defeo and A. de Alava ..... 161

The Role of Multiobjective Policy Models in Fisheries and Aquaculture Development
G. Sylvia ..... 171

Bioeconomic Multispecies Modelling of the Barents Sea Fisheries
A. Eide and O. Flaaten ..... 183

B : FISHERMEN BEHAVIOUR

A Bioeconomic Model for Fish Harvest Technology
D.B. Sampson ..... 197

Dynamics of Resource and Fishermen Behaviour in Coastal Invertebrate Fisheries
J.C. Seijo and O. Defeo ..... 209

C : OTHERS

Analysis of Some Management Options for a Small Pelagic Fishery in Central Philippines
J.E. Padilla and P. Copes ..... 223

The Usefulness of Bioeconomic Models under biological Uncertainty : a Case Study of the Australian Southern Shark Fishery
S. Pascoe, T. Battaglene and D. Campbell ..... 237

Simulation Model of Factory Trawler Operation
I. Arnarson and P. Jensson ..... 247

The Nordic Fisheries Management Model - Themodel and the data for the Icelandic version
A. Danielsson ..... 261

Sources of Variance in the Economic Performance of New England Otter Trawl Vessels
I.J. Anwar, P. Lallemand and J. M. Gates ..... 273

A General Bioeconomic Simulation Model ofthe catching Sector of a Multispecies Fishery
P. Rodgers ..... 283

BEAM 4 - A Bio-Economic Model for the Simulation of Space-Structured Multi-Species and Multi-fleet Fisheries
P. Sparre and R. Willmann ..... 293

Gérez Vos Pêcheries
C. de Verdelhan ..... 305

**SESSION 4 : AQUACULTURE ENTERPRISE MANAGEMENT**

**A : GENERAL SESSION**

Profitability of Catfish on a Representative Multiple Enterprise Farm in the Southeastern United States Under Conditions of Risk
R.S. Pomeroy, S.M. Carlier and C.E. Curtis ..... 315

The Management Schemes for Brackishwater Pond Production
Mudiantono ..... 331

Dynamic Cash Flow Models in Aquaculture: Amplifying the Scope of Managers
C.S. Wright ..... 343

**B : PANEL SESSION**

Elaboration d'un modèle bio-économique dynamique relatif à l'élevage de la palourde de l'Atlantique *(Spisula solidissima)*
M. Martin, J.R. Wilson, L. Adambounou and R. Bouchard ..... 355

A Model for the Optimal Management of Sea-Bass Aquaculture
G.F. Rizzo and M. Spagnolo ..... 367

Simulation of Aquaculture Production for Economical and Environmental Impact
M. Spratt ..... 401

**SESSION 5 : CONSUMPTION AND DEMAND**

**A : CONSUMPTION AND DEMAND**

Consumer Ability to Discern Seafood Quality : Results of Experimental Studies
J.G. Anderson, C.R. Wessels ..... 417

Conjoint Analysis of the Japanese Salmon Market
Y. Kusakabe and J.L. Anderson ..... 427

Seafood Consumption and Giffen Behavior
R.S. Johnston and D.M. Larson ..... 437

The Changes Affecting the Demand for Fish and Fishery Products in Poland
A. Gwiazda ..... 449

Testing the Consistency of Fish Consumption Data with Neo-Classical Demand Theory
M. Burton and T. Young ..... 457

**B : FOOD SAFETY**

The Northeast United States Market for Blue Mussels : Consumer Perceptions of Seafood Safety and the Demand for Mussels
P.M. Brooks and J.L. Anderson ..... 463

Seafood Safety Assurances : Implications for Seafood Marketing and International Trade
C.R. Wessels and J.G. Anderson ..... 475

**SESSION 6 : INTERNATIONAL EXCHANGES**

**A : INTERNATIONAL TRADE POLICY AND COMPETITION**

Development of the International Trade in Seafood Products in the Context of European Economic Integration
J.P. Boule and P. Guillotreau ..... 485

U.S. Demand for and Canadian Supply of Fish Products
R.L. Mazany, N. Roy and W.E. Schrank ..... 501

Price Fluctuation and Substitution in the Groundfish Market
T. Trondsen ..... 517

The Icelandic Cod Trade : An Econometrically Based Simulation Model
R. Arnason and T. Felixson ..... 531

An Approach to the Management of Market and Resource Uncertainties : The Globalisation of Trade Information
J.-F. Mittaine ..... 555

The Market Outlook for Shrimp
M.-C. Yang ..... 561

Changes in Poland's Foreign Trade Management and Impacts on the Foreign Trade of Fishery Products
H. Nakonieczna-Kiesiel and J. Zieziula ..... 573

Le commerce extérieur français des produits de la mer en 1991
J. Dari ..... 581

Monopsony, Trade Restrictions and International Markets for Intermediate Seafood Products : The U.S.-Canada Herring Dispute
A. Emami, L.E. Queirolo and R. Johnston ..... 589

Price Linkages between Japanese and United States Markets for Sablefish and Thornyheads
J.D. Hastie, D. Squires and J.A. Elston ..... 599

The Alaskan King Crab Industry - An Industry in Transition
J.A. Greenberg, S.C. Matulich and M. Herrmann ..... 609

Java Sea purse seiners : the impact of innovation on performance
J.K. McElroy and Wijoprono ..... 617

**SESSION 7 : FISHING ENTERPRISE MANAGEMENT**

**A : ACADEMIC**

Coastal State Fisheries Management : Fleet Development Versus Trade in Fisheries Services
S. Cunningham and D. Whitmarsh ..... 639

La théorie économique de l'investissement dans le rétablissement des ressources naturelles renouvelables, avec référence spéciale au cas de la pêche du pétoncle géant aux Iles-de-la-Madeleine, Québec (Canada)
J.R. Wilson, F. Mendez and M. Fréchette ..... 647

Fishermen's Time Discounting Rates and other Factors to be Considered in Planning the Rehabilitation of Depleted Fisheries
J.P. Hillis and B.J. Whelan ..... 657

Hysteresis et comportements adaptatifs des pêcheurs artisanaux
H. Rey ..... 671

Prediction of Financial Distress in the Norwegian Fish Processing Industry
B. Dreyer and T. Vassdal ..... 683

**B : FISHING ENTERPRISE MANGEMENT**

Unemployment Insurance and the Length of the Fishing Season
N. Roy, E. Tsoa, W.E. Schrank and L. Mazany ..... 693

Multiproduct Tuna Fisheries in the South WestPacific
H.F. Campbell, A. McIlgorm and R.B. Nicholl ..... 715

Portfolio Selection in Fishing Strategies in a Multispecies Trawl Fishery
S. Hanna ..... 727

Un essai d'identification des stratégies de pêches : le cas de la pêche artisanale dans le nord de la France
F. Lantz, M.-O. Allard and R. Junaueir-Lopez ..... 745

The effect of government subsidies on the formation of collusions in an oligopolistic fishery
P. Mickwitz and M. Hildén ..... 759

Productivity Measurement in Common Property Resource Industries : an Application to the Pacific Coast Trawl Fishery
D. Squires ..... 769

**SESSION 8 : FISHING REGULATORY TOOLS**

Fundamental Issues in the Design of ITQ Programs
L.G. Anderson ..... 787

Marketing Losses in Regulated Open Access Fisheries
J.E. Wilen and F.R. Homans ..... 795

The Role of Economics in the Development of Limited Entry Programs : Two Examples from Groundfish Fisheries in the Western United States
J.D. Hastie ..... 803

Exvessel Price Behavior in West Coast U.S. Groundfish : Implications for the Choice of Fishery Management Technique
S. Hanna ..... 813

Multiproduct Supply under Production Quota : an Application to Pacific Fisheries
D. Squires ..... 827

The potential Benefits of Individual Transferable Quotas and their Effects on Industry Structure
D. Squires ..... 839

Productivity and Efficiency of the Fishing Fleet : the Case of the Small Scale Fishing Enterprises in Boulogne
C. Ioannidis and F. Lantz ..... 851

Setting Total Allowable Catches based on Market Conditions : Economics of Atlantic Herring Roe Production
R. Nowak ..... 859

Fisheries Regulation and the Incentives to Overfish
R.L. Mazany, A.T. Charles and M.L. Cross ..... 873

Fixed or Variable Catch Quotas with Irreversible Investments
S.I. Steinshamm ..... 881

Renewable Resource Market Obeying Difference Equations : Stable Points, Stable Cycles, and Chaos
C.C. Duarte ..... 891

Individual Fishing Rights : Some Implications of Transferability
P. Copes ..... 907

Considerations for an Individual Transferable Quota Program for the South Atlantic Mackerel Fishery
K.F. Wellman, J.W. Milon and J. Gauvin ..... 917

From Open Access to Communal Property : the Case of the Fishing Community in Muxía.
A.G. Allut ..... 929

Impact of Product Mix on Optimal Fishing Quota
I. Arnarson and P. Jensson ..... 937

**SESSION 9 : DISTRIBUTION AND PROCESSING**

UK Fish Processing Industry Strategies: From the CFP Decade to the Single Market
J.A. Young and J.F. Muir ..... 955

Stratégies des industries de transformation et approvisionnement en produits halieutiques : le cas du Sénégal
M. Dème and M. Bakhayokho ..... 971

Stratégies technologiques dans les industries de transformation
L. Temri ..... 979

Consumption of Seafood, Poultry and Meat in Restaurants vs. Supermarkets
T. Naito, R.S. Johnston and A.L. Shriver ..... 989

Cross-Hedging Fishmeal with Soybean Meal Futures
T. Vukina and J.L. Anderson ..... 1001

Market Analysis Institutional Behaviour and Marketing of Fish in Portugal
S. Cruz ..... 1015

Monopolistic Aspects of Word Trade of Fishing Industries in Portugal
S. Cruz ..... 1029

**SESSION 10 : MARKET, PRICE AND PRODUCTION SYSTEMS**

**A : GENERAL SESSION**

Market Structure and Prices : the Marseille Fish Market
A. Kirman ..... 1051

Relative Price Variability in Fisheries some Policy Implications
C. Ioannidis ..... 1059

The Market Interaction of Wild Salmon Fisheries and Salmon Aquaculture
C.S. Wright and P. Copes ..... 1071

Determinants of Price in the Portland, Maine Fish Auction
N. Ty and J.M. Gates ..... 1093

The Price Equalization Fund of the Fisheries in Iceland A Descriptive Study
O.Ö. Klemensson ..... 1105

**B : MARKET ORGANIZATION AND FISHERIES STATISTICS IN JAPAN**

Fish Marketing System Developed in Japan and Price Maintenance Mechanism
K. Miki and T. Yamamoto ..... 1115

Fishery Cooperative Association in Japan and its Vital Role in Fish Marketing
N. Odaka and T. Yamamoto ..... 1125

Supply and Demand of Fish and Fisheries Products in Japan
G. Bourguignon ..... 1131

Dual Structure of Japanese Marine Fisheries and Role of Fisheries Statistics in Fisheries Administration
T. Yamamoto ..... 1143

**SESSION 11 : RESOURCES VALUE AND CONFLICTS**

**A : RESOURCE VALUATION AND CONFLICTS**

On Inferior Goods and Giffen Effects in Recreation Demand Analysis
D.M. Larson and R.S. Johnston ..... 1163

International Issues in Valuation of Commercial and Recreational Fisheries
R.S. Johnston and A. Emami ..... 1175

Production Domestique, Absence de Marchés et Marchés Manquants dans les Economies en Développement : Analyse d'Impact de Projet dans le Secteur des Pêches
P. Failler and J.R. Wilson ..... 1189

Commercial Fisheries and Sport Fishing: Conflict and Cooperation
T. Kusakawa ..... 1201

Subsistence Fisheries in Alaska : Conflicts Within a Multiple Use Resource
H.T. Geier, J.A. Greenberg and M. Herrmann ..... 1213

**B : INFORMATION**

Information Needs and the Management of Joint Commercial and Recreational Fisheries : the UK Fishery for Sea Bass (*DicentrarchusLabrax*)
S. Potten, M. Dunn and D. Whitmarsh ..... 1223

The New Institutional Economics (NIE) Applied to the Fisheries : the Role of Information in the (Continuing) Solution of Resource Problems
J.R. Wilson and R. Lent ..... 1233

Cooperative Fishing Arrangements between Coastal Countries and Distant Water Fleets
L.E. Queirolo and R.S. Johnston ..... 1249

La comptabilité des ressources naturelles: une application aux ressources salmonicoles
A. Webster ..... 1259

**SESSION 12 : FISHING AND DEVELOPMENT**

Quelle Place pour les Pêches Africaines dans le Cadre de la Nouvelle Donne Mondiale ?
S.C. Nana Sinkam ..... 1273

Problématiques du Développement des Pêches
J. Weber ..... 1293

La Pêcherie de Crabe des Neiges au Canada en tant que Système : Variables, Interactions et Incertitudes
J.C. Brêthes and R. Dufour ..... 1301

Development and Diversification : Sustainability Strategies for a Costa Rican Fishing Cooperative
A.T. Charles and A. Herrera ..... 1315

Structure, Constraints and Development Options of Fish Processing and Marketing in Namibia
R. Lasch ..... 1325

The Welfare Impact of Improved Boat Modernisation Schemes (IBMS) in Pemalang Regency, Central Java - Indonesia
I. Susilowati ..... 1337

The Establishment of Chinese Marine Fisheries Laws and their Management Practice
Z. Guanghua ..... 1351

Évaluation de l'Impact de la Flotte des Pays de la CEE dans l'Économie du Sénégal
M. Kébé ..... 1357

**SESSION POSTER**

Bioeconomic Considerations regarding the Opening of a Autumn Fishery on Capelin in 1991
P. Sandberg and P. Gullestad ..... 1367

"Sevryka" - A new Competitor in the European Seafood Market ?
F. Nilssen ..... 1371

Contraintes Économiques et Sociales et Développement de l'Aquaculture extensive et diversifiée dans un Pays en Voie de Développement. "Le Cas de la Côte orientale de Madagascar"
G. Rafomanana ..... 1381

Canadian Household Demand for Protein : a Lifecycle Approach
D.J. DeVoretz and K.G. Salvanes ..... 1391

La pêcherie artisanale maritime des filets dormants à sole (*cynoglossus sp.*) en Casamance (Sénégal)
H.D. Diadhiou ..... 1405

Skipjack Pole and Line Fishing in EastIndonesia
J.K. McElroy and J.C.B. Uktolseja ..... 1417

Production planning and the managerial behaviour of the fish-farm entrepreneur in Italy
C. Iandoli, E. Alaio, R. Bianco and G. Vito ..... 1431

# Index des auteurs


## A

Adambounou L., 355
Alaio E., 1431
Alava A. de, 161
Allard M.-O., 745
Allut A.G., 929
Andersen P., 15
Anderson J.G., 417, 475
Anderson J.L., 427, 463, 1001
Anderson L.G., 787
Anwar I.J., 273
Antona M., 73, 311, 1047
Arnarson I., 247, 937
Arnason R., 531

## B

Bailly D., 73
Bakhayokho M., 971
Battaglene T., 237
Bernet C., 25
Bianco R., 1431
Bouchard R., 355
Boule J.P., 485
Bourguignon G., 1131
Brêthes J.C., 1301
Brooks P.M., 463
Burton M., 457

## C

Campbell D., 237
Campbell H.F., 715
Carlier S.M., 315
Catanzano J., 5, 11, 781, 1159, 1269
Cedrins R., 109
Cella G., 53
Charles A.T., 873, 1159, 1315
Copes P., 223, 907, 1071
Cross M.L., 873
Cruz S., 1015, 1029
Cunningham S., 45, 635, 639
Curtis C.E., 315

## D

Danielsson A., 261
Dari J., 581
Defeo O., 161, 209
Dème M., 971
Diadhiou H.D., 1405
Dreyer B., 683
Duarte C.C., 891
Dufour R., 1301
Dunn M., 1223

## E

Eide A., 183
Elston J.A., 599
Emami A., 589, 1175
Enriquíez R.R., 145

## F

Failler P., 1189
Felixson T., 531
Flaaten O., 183
Fréchette M., 647

## G

Gabbot M., 77
Gates J.M., 139, 273, 1093
Gauvin J., 917
Geier H.T., 1213
Gibbs J., 77
Greenberg J.A., 129, 609, 1213
Guanghua Z., 1351
Guillotreau P., 485, 949
Gullestad P., 1367
Gwiazda A., 449

## H

Hanna S., 727, 813
Hannesson R., 119
Hansen K., 97
Hastie J.D., 599, 803

Hatcher A., 45
Herrera A., 1315
Herrmann M., 129, 609, 1213
Hildén M., 759
Hillis J.P., 657
Hirata H., 87
Homans F.R., 795

## I

Iandoli C., 1431
Ioannidis C., 851, 1059

## J

Jensson P., 247, 937
Johnston R.S., 437, 589, 989, 1163, 1175, 1249
Junaueir-Lopez R., 745
Josselin C., 7

## K

Kirman A., 1051
Klemensson O.Ö., 1105
Kusakabe Y., 427
Kusakawa T., 1201
Kébé M., 1357

## L

Lallemand P., 273
Lantz F., 745, 851, 1047
Larson D.M., 437, 1163
Lasch R., 1325
Lent R., 1233

## M

Martin M., 355
Mastracchio E., 19
Matsuda Y., 87
Matulich S.C., 609
Mazany R.L., 501, 693, 873
McElroy J.K., 617, 1417
McIlgorm A., 715
Mendez F., 647
Mickwitz P., 759
Miki K., 1115
Milon J.W., 917
Mittaine J.-F., 555
Mudiantono, 331
Muir J.F., 955

## N

Naito T., 989
Nakonieczna-Kiesiel H., 573
Nana Sinkam S.C., 1273
Nicholl R.B., 715
Nilssen F., 1371
Nowak R., 859

## O

Odaka N., 1125

## P

Padilla J.E., 223
Papon P., 1
Paquotte P., 311
Pascoe S., 237
Placenti V., 53
Pomeroy R.S., 315
Potten S., 1223

## Q

Queirolo L.E., 589, 1249

## R

Rafomanana G., 1381
Rey H., 671
Rizzo G.F., 367
Rodgers P., 283
Roy N., 501, 693

## S

Salvanes K.G., 1391
Sampson D.B., 197
Sandberg P., 1367
Schrank W.E., 501, 693
Seijo J.C., 161, 209
Shaw S.A., 77
Shriver A.L., 989
Slaymaker J., 45
Spagnolo M., 53, 367

Sparre P., 293
Spratt M., 401
Squires D., 599, 769, 827, 839
Steel D.I.A., 37
Steinshamm S.I., 881
Susilowati I., 1337
Sylvia G., 145, 171
Sutinen J.G., 781

## T

Temri L., 979
Trondsen T., 517
Tsoa E., 693
Ty N., 1093

## U

Uktolseja J.C.B., 1417
Ungson J.R., 87

## V

Valatin G., 29
Vassdal T., 683
Verdelhan C. de, 305
Vito G., 1431
Voretz D.J. de, 1391
Vukina T., 1001

## W

Weber J., 1293
Webster A., 1259
Wellman K.F., 917
Wessels C.R., 413, 417, 475
Whelan B.J., 657
Whitmarsh D., 639, 1223
Wijoprono, 617
Wilen J.E., 795
Willmann R., 293
Wilson J.R., 355, 647, 1189, 1233
Wright C.S., 343, 1071

## Y

Yamamoto T., 1115, 1125, 1143
Yang M.-C., 561
Young J.A., 955
Young T., 457

## Z

Zieziula J., 573




Avec la participation de :

With the support of :

CEE DGXIV Programme FAR
Secrétariat d'Etat à la Mer, Direction des Pêches Maritimes et des Cultures Marines
Comité Central des Pêches Maritimes
Institut Français de Recherche Scientifique pour le Développement en Coopération
Crédit Maritime Mutuel
Fonds d'Intervention et d'Organisation des Marchés des Produits
de la Pêche Maritime et des Cultures Marines
Fédération des Organisations de Producteurs de la Pêche Artisanale
Union des Armateurs à la Pêche de France
Confédération de la Coopération, de la Mutualité et du Crédit Maritimes
Caisse Centrale de Crédit Coopératif
Centre Français du Commerce Extérieur, Direction des Produits Agro-alimenta
ORMES
International Institute of Fisheries Economics and Trade
Institut Français de Recherche pour l'Exploitation de la Mer.