The CEOS Network: A Brief Summary of Experience

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Abstract

The Climate and Eastern Ocean Systems Project (CEOS) 1991-1997 was implemented through an informal network which emphasized exchanges of ideas among colleagues, rather than simple exchange of data. Some of the advances that resulted from these exchanges - many of them during visits and/or workshops organized by the CEOS - are (1) confirmation of the wide applicability of the Cury/Roy hypothesis of 'dome-shaped' recruitment windows vis-à-vis wind intensity; (2) the demonstration of concurrently acting 'global' and 'local' effects on upwelling ecosystems; (3) the usefulness of time series analysis, and of mass-balance trophic models for quantifying some of the effects on (2); and (4) the usefulness of items (1-3) for identifying the causes of recent observed changes in some systems, and for predicting the impact of global change on upwelling systems in general.

Résumé

Le projet sur le climat et les bords est des systèmes océaniques (CEOS) 1991-1997 a démarré à travers un réseau informel qui a mis l'accent sur l'échange d'idées et non sur le simple échange de données. Parmi les résultats issus de ces échanges - et réalisés à l'occasion de visites ou de groupes de tra-

vail organisés par CEOS - on peut citer : (1) la confirmation du caractère opératoire de l'hypothèse de Cury et Roy concernant la relation en forme de 'dôme' entre le recrutement et l'intensité du vent ; (2) la démonstration de l'existence de phénomènes à des échelles globale et locale agissant simultanément sur les écosystèmes d'upwelling ; (3) l'utilité des techniques d'analyse des séries temporelles ainsi que des modèles trophiques pour quantifier certains des effets mentionnés en (2) ; et (4) l'intérêt des points (1-3) pour identifier les causes des récents changements observés dans certains systèmes et plus généralement pour prédire l'impact du changement global sur les systèmes d'upwelling.

1. CEOS: A NETWORK EXPERIENCE

The idea of the CEOS network emerged in 1991, after an informal meeting where some of us had been wondering about the potential usefulness of performing comparative analyses in upwelling systems and arguing about how to initiate the required world-wide comparisons. Few months later the CEOS network started (see Bakun *et al.*, 1992).

1.1. The implicit, unstated rules of CEOS

There are usually important but unstated, implicit rules which make or break a project. Here, we make explicit some of the rules which, we believe, made CEOS the success it was.

The first one was that within the network *we worked with people and not with their data.* During the last five years, small groups of colleagues met to exchange ideas and methods to work on well identified scientific questions, relevant to global and local changes in upwelling systems. Usually, these working groups lasted for ten to fifteen days, sometimes more. Most of the time, the colleagues from developing countries had an excellent knowledge of their fisheries and their dynamics; this was not always the case for scientists working in developed countries. On the other hand, access to good libraries and to new methods was most of the time easier in developed countries. For these reasons, the CEOS network tried to play a role in helping to share field and academic experiences among the different participants. The many multi-authored articles included in this book is one result of this sharing. Our network thus succeeded at facilitating the transfer of expertise, at promoting exchanges within the scientific community, and to help to maintain links among people, which itself gave rise to new ideas and projects.

1.2. A multidisciplinary network designed as an evolving scientific framework

Interesting scientific questions nowadays often require a multidisciplinary approach, especially concerning environmental studies. However, di Castri (1986) notes that "interdisciplinarity, when it is considered and implemented as an end in itself, and not as a tool for addressing new complex problems, leads too often to verbose descriptions and non explanatory results". Thus, another rule of the CEOS research project was to focus not on the definition and the exploration of interdisciplinary linkages, but on jointly addressed questions. Disciplines such as oceanography, ecology, statistics or economy were sometimes put together and lead to new insights within the CEOS network.

Inevitably, in a group with such a diversity of participants, the question of methodology came under close scrutiny. All of us from different points of view, were addressing retrospective analyses and had questions about change. What is a change, how can it be detected and modeled at different scales? Uncertainty, causality links, evolution, scales problem, long- and short-term impacts are all common issues that are addressed by different disciplines and fruitful insights may result through exchanges of methods. However, as the disciplines become more and more technical and specialized, they frequently ignore each other; the techniques that have been developed in one field are neglected by the others. The CEOS network has allowed to share methodology between disciplines. For example this book contains statistical techniques which have been firstly developed in econometrics in order to separate long-term trend from other cyclical and seasonal variabilities and which are presently applied to oceanography. This leads to new insights and helped us to reformulate scientific objectives. Mass-balance models, commonly used to describe 'local' systems were used for inferences on global vs. local effects on upwelling systems (see section 3.2 below). Generalized additive models (Hastie and Tibshirani, 1990) which have been first developed in statistics for medicine were applied to environmental *variability* and *fish* population dynamics (see section 3.1 below). An interactive software (CLIMPROD) was used for choosing and fitting surplus production models including environmental variables (see Mendoza *et al.*, Yanez *et al.*, this vol.). Object-oriented object simulations developed in computing sciences may help to simulate fishery activity facing change (see Le Fur, this vol.).

The CEOS project was not defined as a specific program with fixed objectives and tasks but as a multidisciplinary network with scientific questions that were allowed to evolve. Everyone was able to promote new ideas, to use new methods or new data sets, and to explore and develop new objectives. The contributions in this volume illustrate the benefit that results from such freedom being available.

1.3. Data availability within and outside the CEOS network

Making raw data available to a wide range of users is difficult, and a tradition for doing so is lacking in most disciplines (Pauly, 1994). Physical oceanography is one of the few exception, and several institutes followed on the proud tradition initiated by Commodore Matthew F. Maury by compiling and making available the Comprehensive Ocean-Atmosphere Data Set (COADS) (Woodruff *et al.*, 1987). With the help of the National Center for Atmospheric Research (NCAR-USA), CEOS went one step further when we decided to distribute on CD-Rom, as a CEOS product, a full version of the COADS dataset and the accompagning microcomputer based software (see Roy and Mendelssohn, this vol., and Box 1). Data extracted from the COADS were obviously made available to all CEOS participants, and these replied in kind, making their

Box 1: How to obtain and use the COADS

The Comprehensive Ocean-Atmosphere Data set (COADS) was selected by CEOS as key source of environmental data for comparative analyses of upwelling systems.

To support this and similar future effort, CEOS also made available entire COADS, covering the years 1895 to 1990, in form of five CD-Roms, covering the oceans as follows
Vol. 1: North Atlantic Ocean;
Vol. 2: Central Atlantic Ocean;
Vol. 3: South Atlantic Ocean and Indian Ocean;
Vol. 4: Western Pacific Ocean; and
Vol. 5: Eastern Pacific Ocean.

These CD-Roms may be obtained separately or as a complete set by writing to:
- Claude Roy for the Atlantic (email: croy@orstom.fr)
- Roy Mendelssohn for the Pacific (email: rmendels@pfeg.noaa.gov)

These CD-Roms are distributed with a software program (for PC or MAC) for extracting and summarizing time series or other information, for selected area. Please specify in your order whether you use an Apple Macintosh computer or one using an Intel processor. No charge are requested.

Users of the COADS must remain conscious of the limitations of this dataset, whose variable data density and changes in measuring devices induce changes where none occurred, or mask changes which did occur (see Roy and Mendelssohn, this vol.).

local data sets available to their CEOS partners. Having become, through their publication in this book, part of the public domain, the bulk of these data may now also be obtained by the readers of this book, by contacting the first author (c/o ORSTOM), or the original author.

A related, large data set, but pertaining only to the Peruvian upwelling system, and documented in Pauly and Tsukayama (1987) and Pauly *et al.* (1989) may be obtained by contacting the last author (pauly@fisheries.com).

Also, Fishbase the computerized encyclopedia of fishes (Froese and Pauly, 1996), may be consulted for information on the biology of the fish species discussed in this volume (see Box 2).

Box 2: Availability of FishBase and Ecopath

FishBase and Ecopath are two software products developed at, and available from ICLARM, to support the research and assessment work of fisheries scientists. The former tool, FishBase, which is supported by the European Commission, began in the late 1980s as a large database on fish, covering their nomenclature (valid scientific names, synonyms, common names in various languages), their biology (growth mortality, reproduction, food and feeding habits, respiration, etc.), and their uses (through time series of fisheries catches, of recruitment, etc.). Gradually, however, the many crosslinked data sets in FishBase, and the routines created for their display have turned it from a passive data repository into to an analytic tool, allowing for establishing and/or testing relationships and hypotheses not previously documented. This process is being strengthened by extensive provisions for citing and/or otherwise acknowledging external contributions, which have has led to an increasing number of collaborators making complex data set available for inclusion in and analysis through FishBase. Presently covering over 4/5 of all extant marine and freshwater fish species (i.e., 25 000, all to be covered by the year 2000), FishBase is available on CD-Roms that are updated and reissued annually, with FishBase 97 (Froese and Pauly, 1997) as the latest release. FishBase may be obtained for US$ 95 (and US$ 50 for updates), or free of charge (for collaborators). Contact R. Froese at ICLARM (M.C.P.O.Box 2631, 0718 Makati, Philippines; r.froese@cgnet.com) for details.

The latter of the two software tools mentioned above, Ecopath, based on an approach initiated by J.J.Polovina, Hawaii in the early 1980s, became in the late 1980s an ICLARM project funded by the Danish International Development Agency (DANIDA), devoted to the further development and dissemination of a simple, generic tool for the construction and validation of mass-balance trophic model of aquatic ecosystems. Jarre-Teichmann and Christensen (this vol.) present the master equation of the Ecopath approach. Important developments of Ecopath since their contribution was completed include a Monte-Carlo resampling module for dealing with uncertainty in a Bayesian context (Ecoranger), and a module (Ecosim) which reinterprets the (linear) master equation into a system of coupled differential equations, thus allowing Ecopath files to be used as basis for dynamic simulations, and thus for predictions of the impacts of fishing on the different elements of an ecosystem. A fully documented program (Ecopath 4.0 for Windows) incorporating these and numerous other analytical features is available free of charge from Villy Christensen, ICLARM (see address above, or v.christensen@cgnet.com).

2. ENVIRONMENT AND PELAGIC FISHERIES: WHAT HAVE WE LEARNED?

Huge fluctuations and unexpected appearances or disappearances are not new to this century, and have been reported from past fisheries. During the famous 'sardine crisis', at the end of the 19th Century in France, a scientific commission was mandated by the government to investigate the causes of the fishery's collapse. In a context of almost complete ignorance of ecology and of pressure to reduce fishing effort and to ban the more productive fishing gears, all studies concluded that it was environmental and climatic factors that were responsible (Durand, 1991). Contrary to the initial hypotheses, which assumed large migrations, the scientists admitted the idea of local and regional races with short migrations. To some, it was obvious that sardine had to return where they were hatched. Having discovered that eggs do float, and that larval feeding was pelagic, the scientists conducting these early studies assumed that temperature, winds and currents should be important factors for larvae survival. It appeared that sardine needed moderate and relatively constant temperature and that this species was sensitive to great temperature fluctuations and turbulence associated with the wind. Winds were incriminated both for their deleterious effects on feeding conditions and for spreading the eggs and larvae. For Mader (1909), the main cause of appearance and disappearance of the sardine was the direction and the force of the winds. Almost one hundred years later, after decades of studies, data collection and the emergence and decline of various versions of the Theory of Fishing, the question arise: what have we really learned?

The theories which aimed to control, predict and manage fisheries are now often considered as having a poor rate of success. Doubts are justified since several of the best studied and presumably best-managed fisheries have collapsed, whereas numerous successful and productive fisheries exist, which have been neither well studied, nor are subject to modern management (Francis, 1980). Without minimizing the great scientific advances that occurred in fish population dynamics, we are forced to admit that fisheries management, as defined above, has failed. It may be argued that it is not the classical theory of fishing per se which failed, and that the stock collapses, now put at the feet of this theory, were in fact due to not strictly applying the regulations derived from that theory.

Still, the theory itself can be faulted for its implicit assumption of independence of successive observations and its inability to take into account the qualitative discontinuities and threshold phenomena that are frequently observed (Francis, 1980; Roberts, 1997). Another, perhaps even stronger criticism is that the classical theory of fishing was unabashedly single species, notwithstanding the strong trophic interactions among, e.g., the living components of upwelling system (Jarre-Teichmann and Christensen, this vol.). We have only begun to deal with this issue, which is elaborated upon in section 3.2 below. Global changes that occur at the ecosystem level appear to have a strong effect on fish population dynamics. Yañez *et al.* (this vol.) show that the anchovy and the sardine in North Chile and in Peru between 1950 and 1993 were intensively exploited and affected by global environmental changes such as the El Niño events.

Long-term changes, i.e., decadal wind increase, appear to have strong effects on fish population dynamics in the Canary Current. Kifani (this vol.) showed that a long-term increase in Moroccan coastal upwelling intensity between 1950s and mid-1970s has induced the sardine long-term fluctuation. Binet *et al.* (this vol.) showed that two periods of high abundance and southward spreading of sardines (*Sardina pilchardus*) with accompanying changes affecting others pelagic fishes, appears to be strongly linked to decadal changes in the environment. On the other hand, Pezennec and Koranteng (this vol.) suggested that for a particular and spatially well-defined environment, the strengthening of the minor upwelling appears to be the only likely cause of the drastic changes that occurred in the sardinella fisheries off Côte-d'Ivoire and Ghana during the last decades.

Both local or global environmental changes that frequently happen within an ecosystem at a scale of the last decades of observations may drastically affect fish population dynamics. The example of an anomalous migration of *Sardina pilchardus* in Senegal led Demarcq (this vol.) to hypothesize that the mean seasonal intensity or the 'precocity' of the upwelling is not sufficient to initiate an abnormal southward migration and that the seasonal transition is a key parameter in this process. Béné and Moguedet (this vol.) suggested that both a global environmental factor (the effect of Amazon River) and a local environmental factor (local river outflow) have an effect on the Guyana shrimp fishery dynamics. Daskalov *et al.* (this vol.), Prodanov *et al.* (this vol.) as well as Stergiou and Christou (this vol.) presented ecological changes that appeared in related upwelling systems and the effects of the environmental factors that are suspected to produce these changes at different scales of observation.

These and related oceanographic processes are now relatively well understood and their relationships with fish behavior better explained. Great advances also have been made to link reproductive strategies, feeding habits and fish behavior (Cury and Roy, 1991; Pauly and Tsukayama, 1987; Pauly *et al.*, 1989). Much of this knowledge is now explained by the 'triad' concept, which shows that enrichment, concentration and retention processes appear to be key factors that affect fish recruitment (Bakun, 1996). This concept also inspired many of the studies of the CEOS project presented in this volume.

3. COMBINING LOCAL AND GLOBAL RESEARCH STRATEGIES: THE CEOS ACTIVITIES

The results of CEOS research in West and South-West Africa, North and South America and in Europe are extremely valuable by themselves. Comparisons between sites is, however, a major scientific task. Drawing valid scientific inference requires multiple realizations of the process of interest, preferably over a range of differing conditions, in order to separate causality from happenstance with a reasonable degree of confidence. Marine ecosystems are hardly amenable to experimental controls. Fortunately, the comparative method represents a powerful method (Bakun, this vol.), and its use was another tacit (sometimes explicit) rule within the CEOS network.

3.1. Environmental impact on fisheries: Optimal Environmental Windows, the Climprod software and the ACE algorithm

The Optimal Environmental Window (OEW) concept relates the recruitment of the fish of upwelling systems with their environment (Cury and Roy, 1991). Previously established during a research project in West Africa, the OEW hypothesis needed corroboration from other areas. Boyd *et al.* (this vol.) and Serra *et al.* (this vol.) present corroborations of the OEW hypothesis for anchovy in South Africa and Chilean sardine, respectively, while Bakun (1996) generalized the OEW in the context of his 'triad' theory. Also Faure and Cury (this vol.) showed that a combination of several environmental factors determine the level of pelagic fish catch within upwelling system, and that winds appear to have a dome-shaped relationship to the fish production of these systems. Mendoza *et al.* (this vol.) examined the ability of environmental factors to explain the variability of catch time series from the upwelling system off eastern Venezuela using the CLIMPROD software of Fréon *et al.* (1993), which again confirmed the crucial role played by the wind.

This crucial role of the wind is, in retrospect, not surprising: fishes, in upwelling as well as elsewhere tend to have tiny eggs, in the order of one millimeter, whatever their adult sizes. Winds determine the rate at which the surface waters are mixed and transported in which these eggs hatch into larvae, and must find suitable food at high densities. Theses winds have to be 'just right' -not too weak and not too strong, and hence the importance of non-linear, dome-shaped relationships such as the OEW.

This brings us to ACE (Alternating Conditional Expectation; Hastie and Tibshirani, 1990), used by numerous contributors to this volume to 'tease out' non-linear relationships among data sets that would otherwise have seemed unrelated. Based on this experience, which confirms earlier work by Mendelssohn and Mendo (1987) and Mendelssohn (1989), we conclude that any attempt to relate biological and physical time series - and not only in the context of the OEW hypothesis - must consider non-linear techniques such as ACE or GAIM (Generalized Additive Models ; Hastie and Tibshirani, 1990), lest it will fail to identify crucial, non-linear relationships.

3.2. Capturing interspecies and ecosystem relationship through trophic mass-balance models

Living species, whether exploited or not, interact in various ways, some of them very hard to quantify. Fortunately, the strongest interactions between organisms — eating, or being eaten — belong to a class of interactions that are straightforward to quantify, notably through mass-balance models of ecosystems (Christensen and Pauly, 1992). Indeed, this approach, implemented through the ECOPATH software, is so easy to apply that to date, nearly hundred applications have been published (e.g., in Christensen and Pauly, 1993), or are in press, thus allowing comparisons among different types of ecosystems, or global analyses (Pauly and Christensen, 1995). Here the mass-balance approach was applied for comparisons among upwelling, i.e., in a context previously thought not amenable to this type of approach (Jarre-Teichmann and Christensen, this vol.).

Indeed, these comparisons, in spite of the lack of time dimension in ECOPATH model, added to the main theme of his volume — the disentangling of global vs. local impacts — a trophic perspective which the analysis of catch time series could not have contributed. Moreover, it has recently emerged that ECOPATH-type mass-balance models can be used to parameterize the differential equations of full-blown simulation models (Walters *et al.*, 1997). This allows explicit consideration of the temporal dimension, e.g., to examine the effect of fishing one component of an upwelling ecosystem, via its trophic linkages, on the other components of that same ecosystem.

Vasconcellos *et al.* (in press) present comparisons of the dynamics of various ecosystems (including the upwelling systems studied by Jarre-Teichmann and Christensen, this vol.) showing that following a disturbance (a five-fold increase, for ten years of the fishing mortality of the major species of small pelagics), the system return time is an inverse function of detritus recycling within a system. Upwelling ecosystems have a low degree of internal detritus recycling (see Jarre-Teichmann and Christensen, this vol.) and hence their food webs do not dampen well shocks due to fishing or other disturbances (Vasconcellos *et al.,* in press).

Clearly, investigations of this sort are germane to questions such as tackled by the CEOS project and network, and it is hoped that studies of this sort will be continued.

3.3. Long-term environmental changes and human responses

Decadal environmental changes are a reality. Using new state-space statistical models, Schwing *et al.* (this vol.) present evidence that environmental parameters are significantly correlated in the California Current system, in a manner consistent with increased upwelling (SST and sea level have decreased, and salinity has increased). The analysis of several temperature data set by Koranteng and Pezennec (this vol.) documents multi-decadal changes in the Côte d'Ivoire-Ghana coastal ecosystem. Mahé (this vol.) estimated the total annual yield of freshwater flowing into the Atlantic Ocean from West and Central Africa, and showed a global change between two periods, a 'wet' period before 1970 and a 'dry' period afterwards.

Human responses to changes are numerous; sometimes they appear to be similar, sometimes they do not. The Senegalese and the Ghanaian ecosystems have many ecological similarities. Comparing the strategy and tactics developed by the small-scale fishers to the variability of their environment, Ferraris *et al.* (this vol.) found flexibility and adaptability in both communities. Using an artificial intelligence model, Le Fur (this vol.) formalized the communication between actors at the local level and their collective response to changes at larger scales. Global and local changes also affect markets. Durand (this vol.) found that prices in the soybean meal market induce short-term fluctuations in the fishmeal price because of speculative effects, while fishmeal price longer trends influence soybean meal price through their impact on the demand for soybean meal. Sharp (this vol.) analyzed the constraints that appear in fisheries at different levels and scales, from the ecological to the institutional. Parrish (this vol.) hypothesized a long term view of what fisheries will lead to in terms of biodiversity. Cury and Anneville (this vol.) focused on the intraspecific diversity of fisheries based on a generalization of the natal homing hypothesis in Cury (1994). As it turns out, all of these different approaches are based on evolutionary considerations and stressed the importance of fisheries diversity, both implicit subthemes of CEOS.

4. New challenges

Overall, it appears that fishery science is better at dealing with the biological dimension of fisheries — including their interactions with the biotic and abiotic environment — than with the human dimension (hence the rather pessimistic account of Parrish, this vol.).

The world marine fish catch was about 20 million tonnes in the early 1950s, and about five times higher in the early 1990s - not counting a staggering discarding rate of by-catch, estimated at about 30 plus or minus 10 million tonnes (Alverson *et al.*, 1994). Whether present catches are 'sustainable' or not is a moot point: it is already obvious that these catch levels are 'sustained' at only a very high ecological (damage to demersal habitats, coral reefs, massive changes in species compositions), and economical costs (massive subsidies, Malthusian overfishing, Pauly, 1994). Moreover, it is unlikely that the soaring demand for fish and related marine products will continue to be accommodated; this is thus bound to create new tensions.

Ecosystem variability, induced by local and global changes will add to these difficulties. We hope that at least some of the concept and methods presented here will turn out useful for dealing with ecosystem variability, and to help us keep upwelling systems and other fisheries resources systems as one of the source of food that our succeeding generations will so badly need.

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