Inshore stock assessment : research and management implications for sequential shrimp fisheries

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EVALUATION DES STOCKS CÔTIERS : RECHERCHE ET GESTION POUR LES PÊCHERIES DE CREVETTES

RÉSUMÉ

En matière de pêche crevettière dans les zones tropicales où existent d'importantes variations interannuelles de stocks dues aux fluctuations de l'environnement estuarien, les recommandations en termes de gestion ont tendance à suggérer une clôture des nurseries et l'établissement d'une capacité de flotte en fonction des tailles moyennes de stocks considérées à long terme. Cependant, le travail que nous présentons ici démontre qu'un contrôle de la pêche artisanale basé sur un recensement précis des captures et une évaluation systématique des stocks pourrait conduire à des gains substantiels pour le secteur industriel à travers des ajustements saisonniers ou annuels de l'effort de pêche.

1. INTRODUCTION

When fish stocks are exploited sequentially by artisanal and industrial sectors of a fishery, managers are called upon to make policy decisions on the equitable allocation of fishing effort between the two sectors. Typically, these decisions acknowledge social benefits in exchange for foregone income to the industrial sector. Small-scale fisheries provide employment to rural areas, generate modest income, and introduce valuable supplies of protein into local economies (see CHARLES, 1988 ; CHRISTY, 1986). Allocation decisions based on social welfare may be difficult to sustain, however, when the efficiency losses are large. This is likely to be the case in the tropical penaeid shrimp

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fisheries. Financial gains from the industrial sector are substantial, both in terms of income to boats and fishermen and in export earnings to developing countries. Pressures to intervene, regulate, and curtail artisanal exploitation of shared shrimp stocks are concomitantly large (see PANAYOTOU, 1982 ; GARCIA and LE RESTE, 1981 ; MCGUIRE, 1983). Decisions favoring the social welfare of small-scale fishing communities are constantly under attack by the industrial sector and, quite frequently, questioned by the fraternity of fisheries development experts as well (see GARCIA and LE RESTE, 1981 ; WILLMANN and GARCIA, 1985 ; VILLEGAS and DRAGOVICH, 1981).

PANAYOTOU (1982), however, argues cogently - though without formalization or measurement - that the costs of enforcing regulations on dispersed and remote artisanal fisheries, employing heterogeneous gears and exploiting a multiplicity of species, may outweigh the benefits derived by the industrial sector. His work is a pioneering effort to adapt to the artisanal sector a central theme of much recent literature in fisheries economics. Enforcement - the «neglected element in fisheries management» (SUTINEN and HENNESSEY, 1986) - is neither costless, nor does it result in full compliance. Indeed, enforcement generates non-compliance.

Our primary purpose here is to sketch the research imperatives implied by such a perspective. To preface the argument, we cite one of the few attempts to use catch statistics from an estuarine fishery to forecast the success of the industrial sector: «...in 1982 the Galveston Laboratory of NMFS [National Marine Fisheries Service, U.S. Department of Commerce] predicted landings off Texas of 9800t for the season and actual landings were 9900t. In 1983 the prediction was for 8100t and landings were 8200t...» (LEARY, 1984 : 270) [1]. Our central concern is this: can substantial economic benefits be gained in the industrial sector by an accurate knowledge of the catch levels in the artisanal sector [2] ?

2. PENAEID LIFE CYCLES, PRICE STRUCTURE, AND MANAGEMENT

Students of the management of tropical penaeid shrimp (*Penaeus spp.*) advocate two regulatory measures: 1) closure of nursery areas for juvenile shrimp, and 2) limitations on the size of the industrial fleet to a capacity sufficient to harvest average (or below average) stock sizes (POFFENBERGER, 1981:305). The logic of this regulatory scheme rests essentially on three interrelated issues. First, penaeids, after spawning in the open ocean, spend several months in estuaries and lagoons, where they are susceptible to variable environmental conditions and fishing mortality by the artisanal sector. Second, there is substantial interannual variation in abundance of shrimp stocks, due largely to year-to-year fluctuations in environmental conditions. Despite much recent debate, most observers still maintain that shrimp stocks are not prone to «recruitment overfishing.» That is, for species with a short life cycle and high fecundity, the annual recruitment does not depend directly on the size of the surviving stock from the previous year. Third, the unit price for shrimp traded in the international market is not constant. Larger sizes fetch higher prices (SRIBHIBHADH, 1984). Thus, shrimp stocks are subject to «growth overfishing» if young shrimp are harvested before they have reached their maximum growth potential. The incentives to intervene in the artisanal sector are thus obvious. As Garcia concisely observes, «in general, it does not seem to pay to catch small shrimp...» (1984 : 146).

3. ENFORCEMENT, AVOIDANCE, AND MONITORING

Optimal fisheries regulation involves more than the specification of a limited number of production (effort) rights. As ANDERSON and LEE (1986 : 680) argue, rational holders of those rights «may be motivated to produce

[1] *The value of such predictive accuracy was lost, however, by the failure to regulate the number of vessels fishing in the offshore fleet (see LEARY 1984; ROTHSCHILD and BRUNENMEISTER 1981).*

[2] *AGNELLO and DONNELLEY (1975) note in a similar vein that much of traditional fisheries economics is concerned with longrun equilibrium models, not with seasonal or annual variations.*

unauthorized effort depending upon the profitability of fishing, the amount of the fine, and the chances of being detected.» Fishermen will, in short, engage in illegal fishing as long as the marginal returns are greater than the marginal costs of harvesting and fine payments. Further, they will undertake avoidance activities (underreporting of catches, fishing in remote locations, landing at night) as long as the marginal reduction in fine payments exceeds the marginal avoidance costs (ANDERSON and LEE, 1986:681 ; see also MILLIMAN, 1986 ; SUTINEN and ANDERSON, 1985).

Compliance, then, is directly related to the level of enforcement. With no enforcement - an open access fishery - avoidance activity will be zero, since in the absence of monitoring there is no incentive to cheat. With the enforcement of a limited entry program and the possibility of increased stock size and increased rents to individual vessels, avoidance activity will initially increase with increases in monitoring levels. But, as Anderson and Lee argue, at high (and prohibitive) levels of monitoring, avoidance will ultimately fall back to zero since the chances of being caught and fined are high (ANDERSON and LEE, 1986:682).

3.1. The Incentive Structure in Artisanal Fisheries

The enforcement/avoidance cost argument is predicated on rational responses to increases in stock size and the range of price incentives in the market. The incentive structure in many artisanal fisheries (and peasant producers in general) may, however, be rather different than that of the industrial sector. Two characteristics of this sector have been highlighted by PANAYOTOU : the lack of alternative employment in rural areas (and thus the low opportunity cost and low mobility of labor), and the pursuit of «target levels» of income (PANAYOTOU, 1982 : 18-21). The importance of the first factor for enforcement costs, PANAYOTOU suggests, is that such costs «are relatively low when alternatives to fishing exist and prohibitively high when fishing is the sole source of income» (1982 : 31). To the extent that the second factor, the pursuit of targeted income, operates in a given fishery, then artisanal fishermen are likely to respond slowly - or inversely - to effort regulations and market incentives. As PANAYOTOU (1982 : 21) observes, «fishermen who go after a target level of income reduce their effort when fishing is very profitable (because fewer trips are sufficient to meet their target) and increase their effort when fishing is poor...»

These factors suggest several modifications - subject to empirical investigation - in the enforcement/ avoidance function operative in industrial fisheries. First, as artisanal fisheries are initially faced with regulatory measures (such as restrictions on gear efficiency, which may lead to increases in inshore stock size), target levels may be more easily attained and avoidance activities will not rise to gain the rents from stock increases. Second, as regulatory measures approach the point where employment in the fishery is curtailed, avoidance activity will peak and remain high: survival and subsistence are at stake. Third, with no regulation and enforcement, the avoidance behavior will be zero, by definition. The level of effort here may be an inverse function of stock size (or catchability) and market price and a direct function of the number of participants in the fishery.

Extrapolations of stock abundance may thus be skewed by these behavioral responses to incentives and disincentives. Accurate determination of an «index of recruitment» (GARCIA and LE RESTE, 1981:48) - a critical measurement for predicting the magnitude of the offshore shrimp population - requires the computation of catch per unit effort (c.p.u.e.). While we will not review the difficulties in standardizing effort units in a multigear artisanal fishery (GARCIA and LE RESTE, 1981), we simply note that regulatory measures, in addition to potentially altering behavioral responses to the catchability of shrimp stocks, are likely to exacerbate the problem of obtaining accurate catch data [3]. A brief example follows.

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(3) We are aware, of course, that there will be costs associated with stock assessment activities. However, we assume that such costs would not be onerous if «legal» fishermen (in critical nursery areas for offshore stock recruitment) willingly report true catch and effort. This assumption requires empirical confirmation.

3.2. Enforcement and Distortion in the Mexican Artisanal Fishery

Mexico exports 30 000 tons of shrimp yearly, providing annual earnings of roughly $ 460 million (U.S.). Although the artisanal sector accounts for only 6 % of the total catch, by law the output of the small-scale fisheries must be channelled through government-controlled processing plants. Prices paid to fishermen are fixed (not varying with the international price schedule of higher prices for larger shrimp) and well below the price offered in the local black market. Moreover, black market activity (and prices) increase substantially with the imposition of the veda, the closed season on estuarine fishing designed to enhance recruitment to the offshore stock (McGoodwin, 1987 ; see also McGuire, 1983).

Not surprisingly, anthropologist James McGoodwin found it exceedingly difficult to monitor the black market. But the distorting influences on fishing activity are clear: artisanal fishermen have an incentive to deliver as little as possible of their catch to the processing plants, thus significantly «underreporting» actual stock abundance. Moreover, due to the pricing structure of the processing plants, the «reported» catch is unlikely to reflect actual age/ size distributions in the estuary stock, compounding problems of population estimation. Finally, a substantial - but unknown - amount of actual fishing effort will remain hidden.

3.3. Conclusion

We have invoked enforcement/avoidance cost analysis for two purposes. One, following Panayotou (1982), is to suggest that the expense of regulating the artisanal sector is likely to be high, and compliance low. Second, we raise the rather obvious point that regulatory measures compound the difficult task of estimating seasonal stock sizes in shrimp populations. We now examine possible economic benefits to the industrial sector of accurate stock assessments.

4. ECONOMIC VALUE OF STOCK SIZE INFORMATION IN THE INDUSTRIAL SECTOR

Returns to a given level of fishing effort (c.p.u.e.) depend primarily upon the size of the stock. Thus, the choice of the appropriate (or optimal) fishing effort for the fleet depends on knowledge of current stock levels. To the extent that the relationship between juvenile stock size and offshore stocks can be quantified, information about inshore stocks can be used to estimate offshore stocks and more appropriate effort levels can be identified (see Garcia, 1984 ; Willmann and Garcia, 1985).

In order to analyze the potential benefits of information on stocks, consider the fishery-level production function (see Anderson and Lee, 1986) of the following form : $y = f(e,x)$, where y is catch size, e is effort, and x is stock size. The function is assumed to exhibit the form shown in Fig. 1. For a given level of stock, say x_1, the size of the catch increases with fishing effort, but at a decreasing rate. This relationship is shown by the curve labelled x_1. However, the returns to a given level of fishing effort also increase with stock size, represented in the figure by a shift to the curve labelled x_2. At effort level e_1, for example, the catch increases from y_1 to y_2.

The relative prices of output (shrimp) and input (fishing effort) are given by the slope of the straight lines P, P', and P". Thus, with stock level given by x1, the economically optimal level of fishing effort is given by e_1. However, with a higher stock level, x_2, the optimal level of effort is given by e_2. This example demonstrates that the determinationof the economically optimal level of effort depends on relative prices of inputs, outputs, and the given stock size. In practice, fishermen have only limited information about stock levels. In this situation, decisions about effort levels must be based on estimates of actual stock. One likely strategy would be to assume current stocks are equal to the mean value of previous years, $\bar{x}$. The level of effort would thus be chosen at $\bar{e}$ in Figure 1.

In this situation of uncertainty about current stock levels, the selected level of effort would rarely correspond to the economically optimal value (only when the stock level equals the mean, $\bar{x}$). There will be efficiency losses arising from the «incorrect» application of fishing effort (Fig. 2). Since these efficiency losses are due to lack of information about current stock levels, better information should reduce such losses.

The potential benefits from stock assessment, however, depend on a number of industry-specific factors. Of paramount importance is the flexibility with which the industry can adjust effort levels from one year to the next. If the sector is characterized by a high proportion of fixed assets (boats that cannot be transferred to other fisheries, for example), adjustments will not be possible. Here, the only viable strategy is to select an effort level close to which will be correct on average. The flexibility of the sector, however, depends on additional factors such as the technological mix (share of capital versus running costs; see WILLMANN and GARCIA, 1985, for the Suriname shrimp industry), and institutional features (labor contracting, for example, may be on a short-term or a long-term basis). Detailed information about the offshore sector is thus necessary to quantify the benefits that could be gained by adjusting fishing effort to stock size.

The distribution of potential gains will likewise depend on a variety of industry-specific factors. These include the technological characteristics of the sector, access to other fisheries, and the institutional arrangements of fleet ownership and regulatory instruments. For example, if the fleet is under foreign ownership and licenses are distributed at a fixed price through a lottery system, benefits of stock size information will accrue to the foreign boat owners. However, if fishing permits must be purchased through an auction system and thus priced at their expected value in a given year, some or all of the gains will go to the national treasury [(4)].

5. DISCUSSION

We are not convinced that social welfare arguments alone are sufficient to sustain the artisanal sectors of high-valued shrimp fisheries. Thus we have explored the logic of enforcement costs and avoidance activity, a logic which suggests that enforcement may be costly, may stimulate the very activity it seeks to curtail, and may compound the difficulties of obtaining accurate data on the artisanal sector. We suspect that even this logic may not be sufficient to uphold allocation decisions favoring the artisanal sector - when that sector develops to a point where it significantly reduces the catches and profits of the offshore fleet. That is a critical point, but the thrust of our argument is that we have no way of knowing where that point lies, given the current status of information on artisanal fishing and the propensity toward inefficiencies in the industrial sector. Thus we raised a question which is infrequently addressed in the fisheries management literature: can accurate predictions of annual stock size generate efficiencies in the offshore industry ?

Theoretical arguments suggest that substantial benefits can be gained by fine-tuning the annual effort of the industrial sector, benefits which must be weighed against the costs of monitoring activities in the artisanal sector. But we are suggesting, again largely on theoretical grounds, that these information costs will very likely be lower than the costs entailed in regulating the small-scale fishery.

The research agenda posed by these hypotheses is clear, but by no means easy. Nonetheless, the answers are critical to the survival and persistence of artisanal shrimp fishermen and their communities.

[(4)] *Once such information is available, the appropriate technique to measure potential gains would be to simulate net industry incomes under alternative assumptions about available knowledge of current stock size.*

REFERENCES

AGNELLO R.J., DONNELLEY L.P., 1975. Prices and Property Rights in the Fisheries. Southern Econ. J. 4 : 253-262.

ANDERSON L.G., LEE D.R., 1986. Optimal Governing Instrument, Operation Level, and Enforcement in Natural Resource Regulation : The Case of the Fishery. Amer. J. Agr. Econ. 68 : 678-690.

CHARLES A.T., 1988. Fishery Socioeconomics: A Survey. Land Econ. 64 : 276-295.

CHRISTY F.T. Jr., 1986. Special Characteristics and Problems of Small-Scale Fisheries Management in Developing Countries. Natural Resource Economics and Policy Applications. E. Miles, R. Pealy, and R. Stokes, (eds.), Seattle,WA.: University of Washington Press, pp. 118-151.

GARCIA S., 1984. Reproduction, Stock Assessment Models and Population Parameters in Exploited Penaeid Shrimp Populations. Second Australian National Prawn Seminar. P.C. Rothlisberg, B.J. Hill, and D.J. Staples, (eds.), Queensland, Australia : NPS2 : pp. 139-158.

GARCIA S., Le RESTE, L., 1981. Life Cycles, Dynamics, Exploitation and Management of Coastal Penaeid Shrimp Stocks. FAO Fish. Tech. Pap., 203 : 215 p.

GULLAND J.A., 1981. Introductory Guidelines to Shrimp Management: Some Further Thoughts. Penaeid Shrimps -Their Biology and Management. J. Gulland and B. Rothschild, (eds.), Surrey, England: Fishing News Books, Ltd., pp. 290-299.

LEARY T.R., 1984. Review of the Gulf of Mexico Management Plan for Shrimp. Second Australian National Prawn Seminar. P.C. Rothlisberg, B.J. Hill, and D.J. Staples, (eds.), Queensland, Australia: NPS2 : pp. 267-274.

McGOODWIN J.R., 1987. Mexico's Conflictual Inshore Pacific Fisheries: Problem Analysis and Policy Recommendations. Human Organization. 46 : 221-232.

McGUIRE T.R., 1983. The Political Economy of Shrimping in the Gulf of California. Human Organization. 42 : 132-145.

MILLIMAN S.R., 1986. Optimal Fishery Management in the Presence of Illegal Activity. J. of Envir. Econ. and Manag. 13 : 363-381.

PANAYOTOU T., 1982. Management Concepts for Small-Scale Fisheries: Economic and Social Aspects. FAO Fish. Tech. Pap., 228 : 53 p.

POFFENBERGER J.R., 1981. An Economic Perspective of Problems in the Management of Penaeid Shrimp Fisheries. Penaeid Shrimps - Their Biology and Management. J. Gulland and B. Rothschild, (eds.), Surrey, England: Fishing News Books, Ltd. : pp. 299-308.

ROTHSCHILD B.J., BRUNENMEISTER S., 1981. The Dynamics and Management of Shrimp in the Northern Gulf of Mexico. Penaeid Shrimps - Their Biology and Management. J. Gulland and B. Rothschild, (eds.), Surrey, England: Fishing News Books, Ltd. : pp. 145-172.

SRIBHIBHADH A., 1984. International Shrimp Marketing Situation. Second Australain National Prawn Seminar. P.C. Rothlisberg, B.J. Hill, and D.J. Staples, (eds.), Queensland, Australia: NPS2 : pp. 297-304.

SUTINEN J.G., ANDERSON P., 1985. The Economics of Fisheries Law Enforcement. Land Econ. 61 : 387-397.

SUTINEN J.G., HENNESSEY T.M., 1986. Enforcement: The Neglected Element in Fishery Management. Natural Resources Economics and Policy Applications. E. Miles, R. Pealy, and R. Stokes, (eds.), University of Washington Press, Seattle, WA : pp. 185-213.

VILLEGAS L., DRAGOVICH A., 1981. The Guianas - Brazil Shrimp Fishery, Its Problems and Management Aspects. Penaeid Shrimps - Their Biology and Management. J. Gulland and B. Rothschild, (eds.), Surrey, England: Fishing News Books, Ltd. : pp. 60-70.

WILLMANN R., GARCIA S.M., 1985. A Bio-Economic 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.

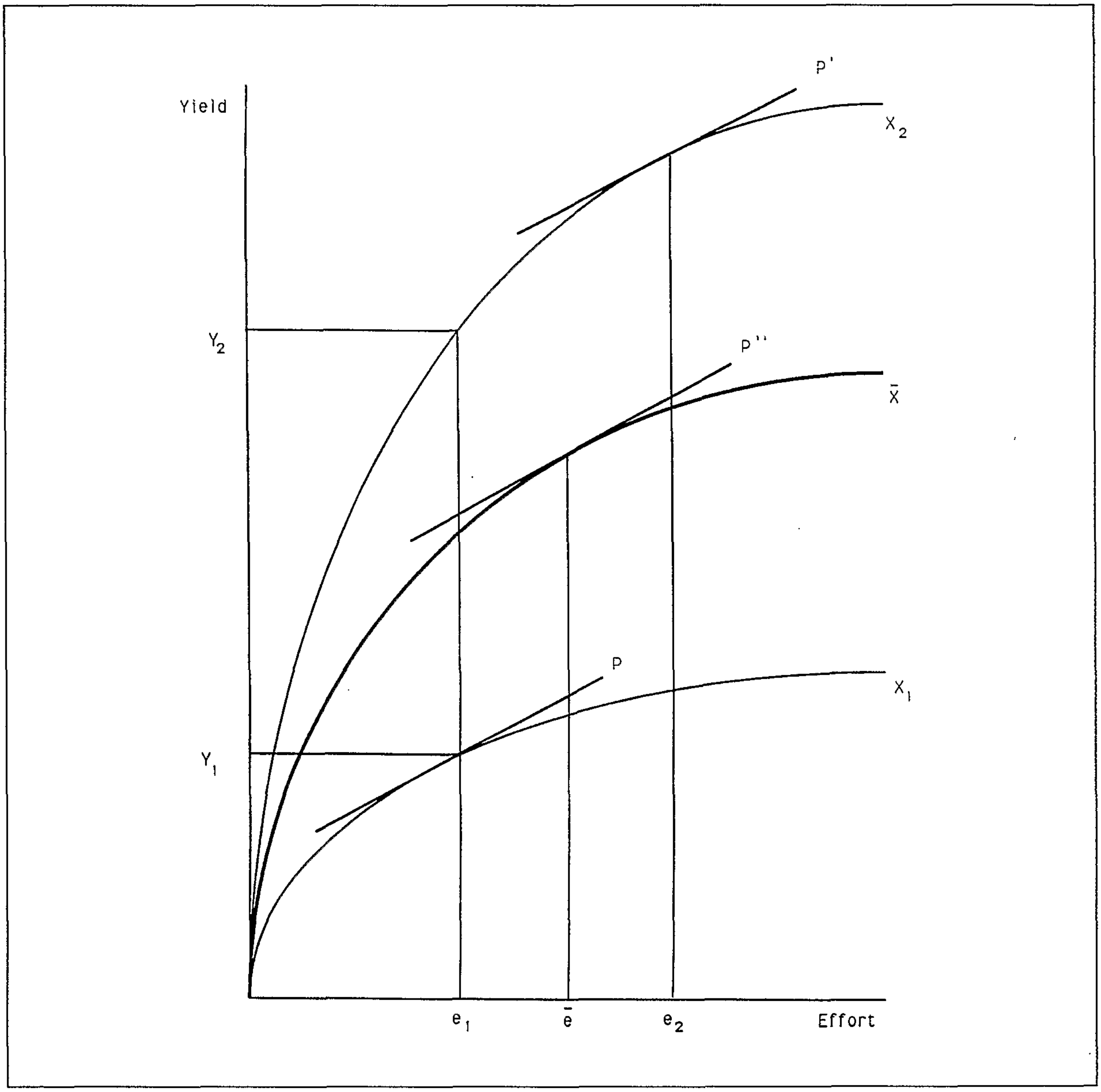

Fig. 1 - Representative shrimp production functions

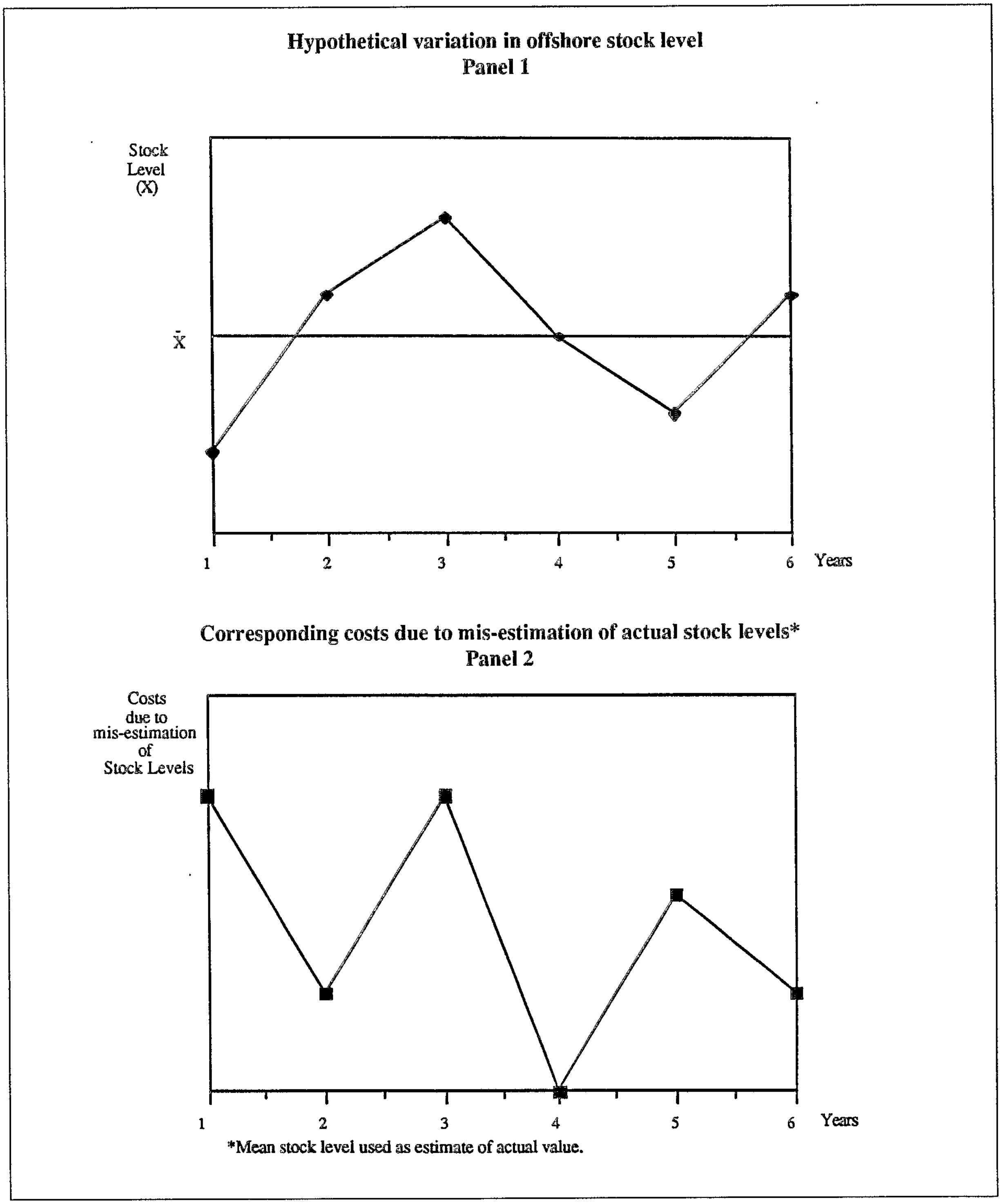
Hypothetical variation in offshore stock level
Panel 1
Stock
Level
(X)
X̄
1
2
3
4
5
6
Years
Corresponding costs due to mis-estimation of actual stock levels*
Panel 2
Costs
due to
mis-estimation
of
Stock Levels
1
2
3
4
5
6
Years
*Mean stock level used as estimate of actual value.

Fig. 2