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ECONOMICS OF THE EAST COAST PRAWN FISHERY

A PERSPECTIVE FOR MANAGEMENT

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The East Coast Prawn Fishery extends along the east coast of Australia from Torres Straight in the north to Barrenjoey Point in New South Wales. A limited entry policy was recently introduced to the fishery and a task force comprising industry and government representatives is currently deliberating on the direction of a long-term management strategy.

In theory, the common property nature of commercial ocean fisheries implies that they will eventually become economically overexploited. A previous survey by the Bureau of Agricultural Economics has indicated that returns to capital employed in the fishery were negative, indicating that economic overexploitation has in fact occurred. Scientific evidence suggests that there is no biological threat to the prawn stock, given present levels of exploitation. Economic overexploitation has resulted from the increase in fleet size and capacity which took place in the 1970s and can be regarded as resulting from 'boat crowding' externalities.

The preferred management strategy will be that which maximises the net benefits to society, where net benefits are defined as economic returns less management costs. A technique using mathematical modelling and simulation is suggested for the estimation of net benefits from alternative management policies. Such a method will allow management policies to be ranked on their economic merits and show the distributional consequences within the fishery of each alternative.

Introduction

The East Coast Trawl Fishery is located between Barrenjoey Point in New South Wales and the Torres Strait protected zone at the tip of Cape York. The fishery extends along 3400 km of coastline and in 1984-85 there were approximately 2150 licensed trawlers. The main species taken from the fishery are eastern king prawns and school prawns. Some finfish species and scallops are also taken.

The fishery is currently the subject of a review for the purpose of developing a long-term management plan. This review was initiated because of concern over the rapid increase in catching capacity over recent years. A task force of industry and government representatives was formed in 1984 and is responsible for assessing the need for management and for developing a long-term management plan, if one is required.

In 1983 the BAE carried out an economic survey of the East Coast Prawn Fishery. Due to the size of the fishery and its multifaceted nature, the Bureau survey was confined to those boats which were operating at a commercial level and which were based between Newcastle and Sandy Cape. At the request of the working group which preceded the task force, the survey population was extended further south to include boats operating as far south as Cape Howe. The results of the Bureau's survey have been published (BAE 1984).

The present paper provides some background information on the fishery, defines the nature of the economic overexploitation occurring in the fishery and shows the potential economic benefits from effort reduction. Finally, a method for assessing the relative merits of different management strategies is proposed. The paper is intended as a contribution to the current debate on the desired direction for management in the fishery and the practical application of resource theory to the case of fisheries.

Biological and Economic Status of the Fishery

Two areas with which fisheries managers are generally most concerned are the biological and economic status of the fishery. When the fish (prawn) population is high relative to boat numbers, there is less likelihood of the fishery requiring management attention. However, when good profits are being made in an open access fishery, boat numbers will tend to increase over time, with a subsequent decline in fish stocks and fishermen's incomes.

In this section of the paper the biological and economic status of the fishery are briefly examined.

Biological status

Prawn stocks tend to be independent of previous prawn population levels because they have a short life span and a high reproductive rate (Anderson 1977, p.103). Thus, conservation of stocks is not generally a problem with prawn fisheries (Hundloe 1984) - fishing effort in the current season usually has little influence on catch in future seasons. The latest available evidence in relation to the East Coast Prawn Fishery suggests that there is no biological threat to stocks (Department of Primary Industry 1985). This conclusion is in accord with an earlier report on the biological status of the fishery (Montgomery and Winstanley 1982).

Historical catch data for the fishery supports the general view that, for a developed prawn fishery, there is no statistically significant correlation between catch and the previous season's effort levels. From Table 1 it can be seen that there has been no trend in catch, despite the sharp rise in fishing effort (boat numbers and technology) over the period 1973-84 (Department of Primary Industry 1985). Relatively large annual fluctuations in catch have occurred and are to be expected for prawns, which are known to be highly sensitive to environmental influences (Anderson 1977, p.103).

Economic status of the fishery

Australian prawn production is geared toward the export market, with over 77 per cent of the 1984-85 output (by volume) being exported. As the bulk of Australian prawn production is exported, the price received locally is determined largely by the state of world markets, especially the Japanese market. Of the 19 kt of prawns caught in 1984-85, 15 kt were exported, with approximately 12 kt directed to the Japanese market. In

TABLE 1

Prawn Catch in the East Coast Prawn Fishery

Year	Queensland	New South Wales	Total
	kt	kt	kt
1972-73	1.10	2.13	3.23
1973-74	1.60	2.76	4.36
1974-75	1.01	2.08	3.09
1975-76	1.08	2.47	3.55
1976-77	0.87	2.62	3.49
1977-78	0.82	2.43	3.25
1978-79	0.72	1.98	2.70
1979-80	0.90	2.44	3.34
1980-81	1.00	2.74	3.74
1981-82	0.70	2.70	3.40
1982-83	na	2.77	na
1983-84	na	2.55	na

na, Not available.

Sources: Moxin and Quinn (1984); BAE (1985).

1983, Australia supplied only 7 per cent of total Japanese prawn imports. In terms of world prawn production, Australia accounted for only 1.3 per cent of the 1695 kt produced in 1982 (BAE 1985).

The East Coast Prawn Fishery fleet increased in size between 1971 and 1982. The New South Wales fleet increased from 282 to 718 boats, while the Queensland fleet increased from approximately 300 to 410 over the period. Increased fishing effort has also resulted from greater fishing intensity and by upgrading the technological capacity of vessels over the last decade (Hundloe 1984; Department of Primary Industry 1985).

The economic performance of operators in the fishery is described in the results of the Bureau's survey of the fishery (BAE 1984). In brief, boat cash income was positive in each year covered by the survey (1980-81 to 1982-83) but, after taking account of depreciation, it was found that the return to capital and management was negative in all years.

The low incomes shown by the survey data cannot be explained in terms of a depressed prawn market. Although prices were below the long-term trend at the beginning of the survey period, they rose in each of the survey years. In 1982-83, prawn prices were at their highest historical level. Neither can low incomes during the survey period be explained by abnormally low catches (see Table 1).

The depressed income levels were a consequence of the continued expansion in fishing capacity that had occurred (BAE 1984).

Economic Overexploitation in the Fishery

The common property nature of commercial ocean fisheries indicates that they may eventually become economically overexploited (Gordon 1954), due to the externalities that are inherent in ocean fisheries.

Externalities can occur because individual fishermen fail to take into account the effect of their fishing on the fish population. The parental biomass may be exploited to such a degree that extinction occurs or is threatened. As noted earlier, this problem does not currently appear to exist in the East Coast Prawn Fishery.

Boat crowding externalities can also occur. There is only a finite quantity of fish that can be captured at any one point in time. Consequently, any one individual's catch will affect the quantity available for capture by the others. This results in greater total fishery costs per unit of output caught. In effect, there are unpaid costs in the fishery. If individual fishermen were made accountable for these costs, there would be lower levels of effort expended in the fishery.

What is often called the 'economic problem' is the social misallocation of resources. This is illustrated in Figure 1, which represents a commercial prawn fishery and can be interpreted from both a long-run and short-run perspective. Fishing costs (OALE) are assumed to increase in proportion to effort, while total revenues (OJLF) increases at a decreasing rate, eventually not increasing at all with increases in effort. In the figure, prices are assumed to be constant, so that the shape of the total revenue curve is determined by the total catch, or yield curve.

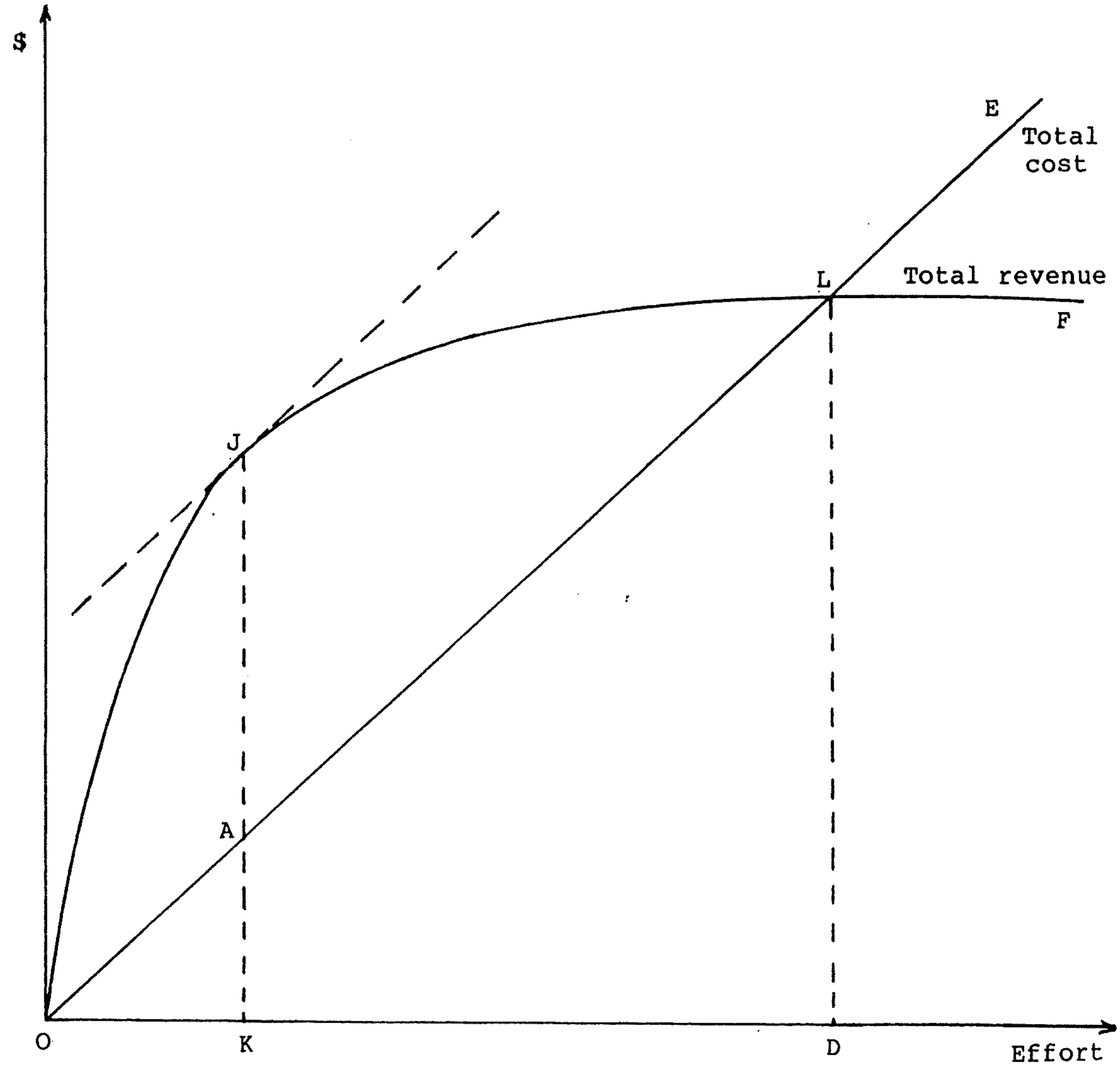

FIGURE 1 - Total Revenue and Costs in the East Coast Prawn Fishery

Total costs are defined to include the opportunity value (economic return) which the resources used in fishing could earn in alternative employment. With this definition, normal returns are being made where total returns equal total costs (point L). For effort levels greater than OD, resources will leave the fishery to seek normal profits elsewhere. For effort levels less than OD, above normal profits are earned and extra resources are attracted into the fishery. Thus, effort level OD represents what is termed the 'open access equilibrium' (that is, the equilibrium effort levels reached in an open access fishery).

If effort levels could be reduced to below OD, above normal profits could be earned from the resources employed in the fishery. Assuming that resources leaving the fishery can earn normal profits elsewhere, then total economic returns to society's resources will be increased overall. (The distribution of these above normal profits, or rents, between individuals in the fishery and society is an important issue facing policy makers, but one that is not considered in this paper.) This process of effort reduction could continue until level OK was reached, at which point, total economic returns would be maximised (at J). Effort levels less than OK would reduce total profitability and would be suboptimal.

An open access fishery which has been operating commercially for a considerable period of time should settle into a situation approximating the open access equilibrium, where normal profits are made. Fluctuations around this equilibrium could be expected in any given season because of the seasonality associated with catch and the lag between investment levels and profit changes. The level of effort corresponding to the open access equilibrium point can be regarded as 'excessive' because, at this point, there is economic overexploitation. (See Anderson 1977 for a detailed discussion of the common property problem as it relates to ocean fisheries.)

Historical catch data (see Table 1) and biological evidence suggest that a maximum sustainable yield has been reached in the fishery and that this can be maintained over a large range of effort levels. That is, operations in the fishery are, and have for some time, been in the flat part of the total revenue curve (as indicated by point L in Figure 1). In that case, fluctuations in total catch (and revenue) in any one season results from environmentally induced vertical shifts in the total catch curve, rather than from changes in effort levels (that is, shifts along the curve). Therefore, the negative returns to capital and management identified over the period 1980-81 to 1982-83 (BAE 1984) have resulted from short-run levels of effort in the fishery being beyond the long-run open access equilibrium level.

However, a situation where negative returns are made cannot persist indefinitely. Effort will eventually be cut back to the open access equilibrium level. This will occur as a result of free market forces and does not require intervention by a government or a management body for its achievement. The rate of adjustment may be inhibited to some degree because of the specialised nature of the resources involved in fisheries. Boats are normally purpose built and the gear used is generally specific to individual fisheries. Further, most Australian fisheries have limited access regulations. Intervention may be justified on social grounds, however, if the period of adjustment during which incomes are low is lengthy, or on economic grounds if adjustment can be facilitated and returns to factors of production increased (BAE 1983).

To obtain any further and permanent reduction in effort beyond this open access equilibrium requires some form of intervention. Management is therefore necessary if the point of maximum economic yield in the fishery is to be achieved. In other words, economic forces will cause effort in the fishery to contract to the level where normal profits are being made on the fishing inputs. Even higher (economic) returns could be achieved if effort were to be reduced further, but this could only be sustained if effort-controlling management measures were implemented.

Implications for Policies for the Fishery

The long-run open access equilibrium will occur naturally as a result of existing economic pressures. However, in a world of uncertainty about future catches, prices, and effort levels of competitors, total fishery effort can exceed the equilibrium level for some period of time. If the purpose of management is to overcome the problems associated with slow rates of adjustment, then a wide range of intervention policies can be considered.

A word of warning is appropriate here. It is possible that active management intervention to reduce effort may in fact work to keep the levels of effort greater than would exist under open access conditions in the short term. The expectation of a management regime leading to more profitable fishing (and/or increased value of licence endorsements) may encourage some unprofitable boats to remain in the fishery for some period of time.

Management proposals also need to be flexible enough to accommodate changes in seasonal catches or returns. Both the state of the breeding stock and market developments need to be monitored so that any fundamental change can be incorporated into the calculation regarding the need for restrictions on effort. Because restrictions impose controls on effort (or output) at a predetermined level, changes in those factors which influence effort levels need to be known. If management proceeds inflexibly and in ignorance of these factors, optimal levels of effort will not necessarily be achieved.

One final aspect of active management intervention that should be considered is the question of timing, given that fishermen can have a wide variation in income from one season to the next. Fishermen who have had poor seasons in the immediate past will be disadvantaged if management imposes a high initial cost on fishermen, such as taxes and quotas (unless quotas are allocated on an auction basis rather than by historical involvement). Fishermen may be having cash flow difficulties or be unable to qualify for a larger quota. In fact it may be hard to identify the least efficient operator in the fishery or those operators who would be affected if effort reduction programs were implemented.

Potential benefits from management in the fishery

In the past, resource economists have concentrated on the gross benefits that can be gained from reducing effort levels to maximise economic returns or 'rents'. These returns are determined by the difference in the costs saved and the loss in revenue that may occur. The gross benefits from reducing effort to somewhere between the open access equilibrium and the point of maximum economic yield within the fishery can be readily calculated.

If it is assumed the reduction in effort does not affect the total catch level, then the gross benefit equals the cost savings achieved by reducing effort. If the effort reduction reduces the total catch from the fishery, then the net benefit will be reduced by the loss in industry revenue. Therefore, by assuming that changes in effort levels do not affect catch (effort levels still correspond to a position on the flat part of the total revenue curve in Figure 1), the benefits gained from effort reduction are the maximum possible. The benefits that can be gained from effort reduction are calculated and reported in Table 2.

The benefits from a 10 per cent 20 per cent, and 30 per cent reduction of effort in the fishery in 1982-83 and the implied exit rates and the increase in returns to capital and management per boat are given in Table 2. Here, effort is defined as the total costs incurred in harvesting the resource. If total catch remains unchanged following a reduction in effort, the potential benefits will equal the savings in total costs. A savings in total costs is achieved by the removal of vessels from the fishery.

TABLE 2

Benefits from Effort Reduction in the East Coast Prawn Fishery: 1982-83

Decrease in effort	Benefit	Exit rate(a)	Increase in average boat returns
	$m	%	$
10 per cent	3.9	15	8 963
20 per cent	7.8	30	21 732
30 per cent	11.7	40	38 137

(a) Exit rates are calculated on the departure of marginal boats which are defined as those having the lowest rate of return.

Note: Calculations are based on BAE survey data (BAE 1984).

A 10 per cent reduction in effort , as shown in Table 2, implies an exit rate of 15 per cent of the number of vessels present in the fishery at the time of the survey. The economic benefit of such a reduction would be a $3.9m saving in total costs, or an improvement of nearly $9000 in net returns for those boats remaining (assuming the quantities landed by boats leaving the fishery are spread equally across the remaining vessels). From a greater reduction in effort, there is a substantial loss of boats from the fishery and a large positive gain in the income of those boats remaining. However, there is a limit to this reduction in the number of boats because of the limited capacity of the remaining vessels to harvest the resource.

The value of potential rents that can be earned is only one aspect of active intervention in a fishery. There are costs associated with all management regimes, and the effectiveness of different regimes to achieve a desired level of effort reduction will vary. Policy makers should attempt to quantify all aspects of management rather than base decisions on only one such as potential rents.

Modelling Approach for Policy Appraisal

The selection of a management strategy for the fishery is by no means an easy task, given the limited data available to decision makers. The merits of individual management policies should be assessed in terms of the net benefits they yield and the policy that maximises the net benefits through time would be economically preferable.

Anderson (1984) identified three specific points, these being: the open access equilibrium; the 'bioregunomic' equilibrium, or the point where marginal benefits and marginal costs of management are equal; and the point of maximum economic yield. The implication of the 'bioregunomic' equilibrium position is that static maximum economic yield is not necessarily the point at which to aim. The greatest net benefit may, in fact, be achieved at levels of effort somewhat greater than implied by the point of maximum economic yield because of the costs associated with effort reduction measures.

The questions of who should receive the benefits, who should pay the costs and who should be given access from any effort reduction program have also been raised. Tisdell (1985) argues that the distribution of economic returns, incurred through effort reduction, should be assessed when determining the merits of different policy alternatives.

To date there has been no published work which includes the costs associated with management and, more importantly, there has been no attempt to quantify the effectiveness of alternative management strategies. A methodology is proposed below which illustrates a way in which the net benefits from alternative management strategies can be calculated. The impact of the implied lower effort levels are then simulated across the fleet.

Calculation of net benefits

In recent studies the use of mathematical programming and simulation techniques have been used to calculate maximum economic returns that can be achieved through effort reduction (Anderson, Ben-Israel, Custis and Sarabun 1979; Meuriot and Gates 1983). A linear programming approach which incorporates the costs associated with effort reduction is suggested for the calculation of net benefits from different management regimes in the fishery.

In a given time period, such as one season, the net benefits from management intervention are determined by total fishery revenue, total fishery costs and costs of management.

Total fishery revenue, Y_i, is given as total output times price. Total output, Q_i, is a function of the level of effort, E_i, applied in the fishery and the sustainable yield that can be harvested. Unlike the traditional Schaefer yield curve, sustainable yield in the fishery is thought to be an exponential function of the parental biomass, and therefore, output can be described by some exponential function of effort levels. The price, P_i, received by fishermen will be dependent on the quantity of prawns landed, assuming all other things remain constant. In the case of the East Coast Prawn Fishery, however, α_i will equal zero.

(1) $$Y_i = Q_i * P_i$$

(2) $$Q_i = \exp(f(E_i))$$

(3) $$P_i = \alpha_0 + \alpha_1 Q_i \qquad i = 1,2,...,n$$

The cost incurred in harvesting the prawn stock, X_i, is assumed, at this stage, to be constant per unit of effort expended. Algebraically, total costs can be written as;

(4) $$X_i = \gamma_0 + \gamma_1 (E_i)$$

The difference between Y_i and X_i represents the economic returns or rent that can be extracted from the fishery through intervention policies (equal to AJ in Figure 1) and has been the basis of the development of 'bioeconomic' models. Offsetting these potential economic returns, however, are the costs of achieving the desired level of effort reduction.

It is a reasonable assumption that the marginal costs of management would be increasing for given levels of effort reduction (Anderson 1984 also recognised this concept but made no attempt to incorporate it in a formal model). The model developed in this paper explicitly incorporates this assumption. One possible functional form of the management cost curve would be a logarithmic function, although different functional forms may exist for each type of management strategy (and their applicability in the model would have to be tested). Management costs incurred in reducing effort levels in the fishery (from E_N to E_i; where E_N equals effort levels corresponding to the open access equilibrium) is given by equation (5) and different management strategies would obviously have different beta coefficients.

(5) $$Z_i = \beta_0 + \beta_1 \log(E_N - E_i)$$

The net benefits from management can now be expressed as:

(6) $$NB_i = Y_i - X_i - Z_i$$

Equation (6) is maximised for each proposed management strategy and the one yielding the highest net benefit would be deemed most appropriate. The model is maximised subject to the non-negativity condition on X_i, Y_i and Z_i that total output from the effort reduction does not exceed output at the open access level, Q_N, and that total effort levels achieved from implementing strategy E_i do not exceed effort levels corresponding to the open access equilibrium, E_N.

Once this mathematical problem has been maximised (equation 6), each management strategy can be ranked in order of the net benefits they each yield. However, in solving this problem the estimation of some of the parameter coefficients described in the above equations is required.

Cross-sectional data on vessels operating in the fishery over the years 1980-81 to 1982-83 are available from the BAE (1984) economic survey of the fishery. These data include the physical characteristics of individual boats and their financial statistics. Using these data it would be possible to estimate the parameter coefficients in equation (4) on total fishery costs. Likewise, total output, equation (2), could be estimated for different levels of effort.

Data are not available on the marginal costs of management. Further research is needed so that the beta coefficients in equation (5) can be determined, or at least estimated with some degree of accuracy. Research on this is currently being undertaken by the Bureau.

Data available from the BAE (1984) survey of the fishery could also be used to analyse the distributional effects of different management strategies across the fleet. A reduction in effort brought about by the removal of units of capacity will have a different impact on individual vessels than say a landings tax or quota regime. To monitor the effects of management in the fishery through time, access to individual operator data would be required.

Distributional effects of management

The model outlined earlier allows the calculation of the optimal level of effort reduction and the net benefit that results. Individuals in the fishery will be affected differently from the imposition of any management strategy because there is a substantial variation in operators' returns, costs, physical boat characteristics and area of operation. It is proposed that the effect of different management strategies on individual operators can be determined by simulating each operator's, or group of operators', response to management.

Initially, all vessels will be expending a given level of effort, B, prior to the imposition of any management strategy. Operators will expend effort to maximise their profits, that is:

$$(7) \qquad \Pi_F = \sum_{k=1}^{N} \Pi_k$$

Total fishery profit (Π_F) equals the sum of the profits of all individual (k) fishing units. At the open access equilibrium, $\Pi_F = 0$ and:

(8) $$\Pi_k = (P_k Q_k) - (\gamma_0 + \gamma_{1k} B_k)$$

which reflects the behavioural pattern of individuals (or groups of individuals).

As it is assumed that each individual has no influence over the market, price can be treated as a constant given by P_i (equation 3). The desired level of total effort expended, E_i, and the quantity, Q_i, of prawns landed are also calculated from the earlier model and included as constraints to the aggregate behaviour of all individuals.

Equation (7) is then maximised subject to the non-negativity condition for all B_k variables. This does not preclude the possibility that an individual expends no effort. Obviously, Π_F equals the total rent that can be taken from the fishery, given that net benefits to society are at a maximum (or the total value of a tax or the total value of transferable quota entitlements). Further, Π_F divided by Q_i represents the value of restricting effort per unit of output.

Both the linear programming problems described here are based on a static analysis of the fishery. The models illustrate a way in which the net benefits from various management policies can be estimated and what the distributional consequences are from imposing a given policy in the fishery. Once effort reduction has occurred, however, there would be a change in total fishery costs. This change results from a shift in production to more efficient units and, consequently, lower total harvest costs (equation 4). Therefore, the actual rent, or Π_F, will be greater than that assumed by the static analysis. It would be possible to re-estimate the net benefits of restricting effort as the marginal cost per unit of effort changes, that is, the gamma coefficients given in equation (4), are varied.

One final consideration that needs to be incorporated in any approach that addresses fishery dynamics is the discount rate. All net benefits and those variables upon which it is dependent should be expressed in present value terms.

Conclusion

Low returns in the East Coast Prawn Fishery were identified in a previous economic survey of the fishery. This situation cannot be attributed to a depressed prawn market or to a decline in the total catch availability, but rather as a consequence of the rise in fleet size and capacity which took place during the 1970s.

To maximise economic returns or 'rents' in the fishery, some form of intervention is required. The potential gains from such an approach were shown to be considerable. However, the narrow definition of maximum economic returns, which does not internalise management costs or take distributional effects into account, should not be the sole criterion upon which managers base their decisions. Different management strategies should be ranked by the expected net benefits they yield. In estimating these net benefits the economic returns and management costs associated with effort reduction need to be calculated.

It is proposed that mathematical programming and simulation techniques be used to estimate these net benefits. Further, the impact of different management strategies on individuals can be determined using the same approach. Lack of data on the costs of management prevent such an approach from being implemented at this stage.

While it can be argued that any reduction in effort in the fishery is a step toward maximising economic returns, the judgment that the benefits will actually be achieved in practice and that they will not be exceeded by costs remains inherently subjective. The methodology outlined in this paper highlights the areas in which further data collection and research are required and outlines a way in which management policies can be assessed more objectively.

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