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FISHERIES ECONOMICS FROM THE ECONOMIC BUREAUCRAT'S PERSPECTIVE

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While the Bureau has a wide involvement in fisheries economics, it sees itself as best contributing in the area of applied economic analysis. An example is given of research in the field of fisheries management, which has to take account of a number of complex biological and economic relationships. Frequently, management decisions have to be made with limited information and an inadequate understanding of the longer term implications. A linear programming model is outlined which incorporates the underlying biological and technical relationships in the northern prawn fishery and which allows the effects of management options to be simulated.

Fisheries economics is a fairly new research area in the Bureau and has only relatively recently commenced publishing major fisheries research studies. This paper outlines the rationale and role for this fisheries research program and provides an example of a major applied study which has significant fisheries management and policy implications.

Over the past year, the Fisheries Economic Research Section of the Bureau has worked on subjects ranging from the social aspects of fisheries adjustment to the effect of management alternatives on the fishing industry (see Table 1). The Section's work program for the next year seems likely to extend into resource rent taxes, and input into a number of planned inquiries into fisheries development, management and marketing. A number of set staffing positions have been assigned to the analysis of both general and specific issues arising in the management of Australian fisheries. As can be appreciated from the diversity of the work outlined in Table 1, a wide range of economic expertise is required. Thus, from the Bureau's perspective, fisheries economics is a very diverse topic.

TABLE 1

Examples of Subjects Studied by the Fisheries Economic Research Section in 1987

Social aspects of fisheries adjustment
Data base maintenance and development
Allocation of access rights
Resource rents
Conflict between commercial and recreational fishing
Importation of secondhand vessels
Fishing power determination
Management alternatives
Price determination
Short and medium term outlook
Value added
Japanese and New Zealand fishing industries
South-East Asian fish demand

This paper first addresses the questions of why it is that the Bureau has such a wide involvement in fisheries economics, and how the Bureau sees itself as best contributing in this field. A single, complex project is then used as an illustration of this contribution: the Bureau's management model of the northern prawn fishery.

Fisheries Research and the Role of the Bureau

Fisheries management

Most countries have endorsed a set of principles and practices for the rational management and optimum use of fish resources which explicitly encompass economic, social and environmental factors (FAO 1984). More specifically, the objectives of the Australian Fisheries Act 1952 (Section 5B) are the 'conservation' and 'optimum utilisation' of Australia's marine resources (Bain 1985). These terms are employed in their social sense as distinct from a biological sense. The biological objectives generally have economic objectives underlying them. For example, a large parent stock may be required because of its economic benefits, not for any biological reason. Thus, if the economic objectives are met, the biological objectives will generally be reasonably well satisfied.

The case for government intervention in fisheries to meet these objectives follows from the fact that open-access or unmanaged fisheries tend to become economically overexploited, with a consequent waste of society's resources. In contrast, a fishery can be managed so as to maximise the use of society's resources. Long term catch levels will then be higher than under open access. Consumers' welfare as well as producers' welfare can be taken into account in this management. The maximisation of rents in the fishery can be thought of as maximising returns to society.

During the 1980s, the extent and degree of management of Australian fisheries, and awareness of the wider effects of this management on other parts of the economy, have steadily increased. There has been a growing realisation that an unmanaged fishery does not necessarily provide the sustained levels of return (either to individuals or to society as a whole) that a properly managed fishery can. There has also been growing experience of management and its wider effects.

Research in rural economics

The rationale for public research on the kinds of topics set out in Table 1 has been subject to considerable debate. Arguments supporting public research - that is, research by public sector institutions - have been noted by Balderstone, Duthie, Eckersley, Jarrett and McColl (1982). Firstly, individual firms may be too small to organise the level of research required. Secondly, there may be 'externalities' (that is, costs or benefits not reflected in market prices), in which case society can gain by modifying market decisions to take those costs or benefits into account. Thirdly, the community, taking a longer term and sometimes different perspective on the benefits of research (especially research on a community resource) than that of private firms, will fund research which the latter would consider 'uneconomic'. Fourthly, private firms are frequently unable to capture fully the benefits of research (especially in the absence of property rights), which they therefore will not undertake. All these arguments have applications in fisheries. In addition, government must obviously take some responsibility - direct or indirect - for research required by its own activities; for example, government has a heavy involvement in fisheries management, which requires a wide range of research inputs, as will be shown in this paper. Moreover, there are benefits in having continuity in research, as is more likely to occur with research by public sector institutions.

The Bureau has been the main provider of fishery economics research advice to government since the formation of the Fisheries Economic Research Section. The Industries Assistance Commission has carried out some inquiries into the fishing industry, and recently the Business Regulation Review Unit and Australian Science and Technology Council have commenced studies relating to the industry.

There is evidence that rates of return to research in rural economics can be high (Lindner 1987). This is particularly likely to be true of research in fisheries management, in view of the developing nature of the industry and the dearth of previous economic research. As previous BAE research has shown (Haynes, Geen and Wilkes 1986), the fishing industry as a whole is generally the main beneficiary of management. Thus, the case for public research, as defined here, does not imply a case for total public funding. The industry contributes to the funding of research, including that of the Bureau, through various levy arrangements.

The work of the Bureau

For the Bureau to be effective in contributing to improved performance of the fishing industry and of the wider Australian economy, it needs to ensure that its work program has relevance and that it appropriately disseminates the results of its analyses. To achieve the first of these aims the Bureau initially obtains input from organisations such as the Australian Fisheries Service, CSIRO, the state departments of agriculture, tertiary institutions, fishing cooperatives, management advisory committees, and seafood processing and marketing companies. This information is used as a basis for identifying the most important research issues, which are then considered in detail by the Bureau and project proposals drawn up. The final choice of topics depends on perceptions of priorities within the Bureau, available resources and the extent of industry support. The second aim is achieved by means of formal publications and addresses to the National Agricultural Outlook Conference, management committees and other forums such as the annual conference of the Australian Agricultural Economics Society.

The Bureau contributes to theoretical developments in fisheries economics, but its emphasis is on independent and objective applied analysis. This includes the estimation of economic relationships in fisheries production, processing and marketing (often based on the Bureau's own survey data) and their incorporation into economic models that can be used for analysis of a range of policy options.

Topics which the Bureau's Fisheries Economic Research Section has been requested to study this year include: institutional arrangements for fisheries management; alternative forms of regulation, such as resource rent taxes; the wider effects of regulation, such as resource use conflicts; the role of aquaculture; the impact of fisheries adjustment; and opportunities for value added in fisheries products. Questions relating to management are of major importance.

A serious difficulty facing fishery managers is the lack of detailed information on the many biological and economic relationships within a fishery. A valuable aid to the managers of any fishery would be a model which could be used to simulate the effects of a given policy. Such economic models need to be comprehensible to a lay audience, to be practicable in their data requirements, to capture the fundamental characteristics of the fishery and to be easily updated. The remainder of this paper details a model developed by the Bureau and shows how it contributes to policy development from an economic perspective.

The Northern Prawn Fishery

The northern prawn fishery is one of the largest Australian fisheries, in both extent and value. It extends across almost all the waters of northern Australia, from Cape Londonderry in Western Australia to Cape York in Queensland, and covers an area of approximately one million square kilometres. Annual output has varied between 8.3 and 11.7 kt in the past five years; in 1985-86 the gross value of production was approximately $150m.

Although nearly all prawns caught in the fishery are exported, the quantity is not large enough to influence domestic world prices. Because management policies cannot influence domestic prices, they cannot influence Australian consumers' welfare directly; maximising the value of the fishery to society therefore reduces to maximising its value to the producers.

From the first commercial activity, undertaken in 1966 by just two boats, the fishery expanded rapidly, and within six years over 200 boats were operating. Entry to the fishery has been limited since 1977, when 292 vessels were licensed. Fishing effort continued to increase, notwithstanding the limit on the number of boats allowed to operate. It has been estimated that real effort increased approximately fourfold between 1977 and 1985 (Buckworth 1987).

Currently, 246 vessels are licensed, comprising roughly equal numbers owned by individual operators and by companies which run fleets. Some of these companies are vertically integrated with the processing and marketing sectors, and are therefore responsible for the product from the time it is caught to the time it is sold on the export market.

Five main species of prawns are harvested: banana (Penaeus merguiensis), brown tiger (P. esculentus), grooved tiger (P. semisulcatus), endeavour (Metapenaeus endeavouri) and king (P. latisulcatus). Banana prawns at one time dominated the harvest, but in recent years their catch (although it is still highly variable) has declined. Tiger prawns now constitute almost half the catch by weight, and account for more than half of receipts. The other species are less important, together constituting less than 20 per cent of the annual catch.

Management of the fishery

For most Australian fisheries, the product price is not dependent on quantity supplied, but harvesting costs are highly dependent on fishing intensity, and increase rapidly above some optimum level of effort. Thus, below a certain level of effort, economic rents are earned, but larger efforts do not yield rents. As long as rents are obtainable in an open-access fishery, new boats will enter it. This increase in effort will continue until the rents fall to zero (due to diminishing yields or overcrowding of boats). Assuming - as is in fact observed - that individual operators cannot co-ordinate their efforts so as to maximise their collective rents from the fishery, it is apparent that sustained rents can be generated only by government intervention or by making the fishery the exclusive property of a single owner, who can regulate effort so as to achieve the maximum economic yield.

Thus, the essential objective of fisheries management is economic efficiency. Open-access fisheries tend to be overexploited, and this remains true of the northern prawn fishery, in spite of early attempts at management. Successive modifications have resulted in a somewhat complex management scheme. The current regime includes measures to reduce fleet capacity and fishing effort through removing capital from the fishery, restricting access to the resource and reducing the catching efficiency of the vessels.

The regulations governing the fishery are complex for a number of reasons: because of the way the management system has evolved; because of a willingness on the part of managers and the majority of industry participants to try new policies; and because of the political difficulty of designing policies acceptable to everyone. The regulations have apparently still not overcome excess fleet capacity. This is an indication of the inevitably short time horizon of the decision makers, the political compromises necessary to maintain harmony within the industry, and the narrowness of the information base - particularly the inadequacy of information on some important economic relationships.

Central to the attempt to remove capital from the fishery is the buy-back scheme known as the Voluntary Adjustment Scheme. The main engine power (in kilowatts) and underdeck volume (in cubic metres) of each boat are added to give a non-dimensional measure termed 'Class A' units; each boat also carries one 'Class B' unit, which is essentially an entitlement to operate in the fishery. Operators are levied on the basis of the number of Class A units they hold, and these funds are used to buy back both Class A and Class B units. The scheme is intended to reduce the number of Class A units in the fishery from the present 115 000 (including inactive units) to 70 000 by 1990-91.

The total numbers of Class A and Class B units are fixed, to prevent buildup of capital in the fishery. There is also a 'boat replacement' policy: to replace a boat, an operator must first forfeit one Class B unit and the number of Class A units by which the new boat will exceed 375 units. The operator must then purchase from other operators a Class B unit and sufficient Class A units to meet the requirements for the replacement boat and to make up for the forfeiture.

The fishery is also subjected to seasonal closures. Closure of the tiger prawn fishery is aimed at protecting the pre-spawning prawn stocks and thus increasing recruitment in the following year. A ban on daylight trawling in certain months is intended to protect female tiger prawns. These tiger prawn controls were both introduced at the end of 1987. For many years the banana prawn fishery has been closed for a period to allow the size of the prawns at capture to increase, giving increased returns to the operators.

Recently, restrictions on the number of nets that can be towed were introduced. Where previously most boats towed four nets at a time, only two nets may now be towed. This restriction, along with the tiger prawn controls, was introduced with the intention of reducing effort in the fishery immediately by 30 per cent in the 1987-88 season.

The long term effectiveness of these policies has been examined with a model developed by Haynes and Pascoe (1988). The purpose of the model is to provide the fishery managers with a decision making aid. It is designed to show the consequences of possible policy decisions. A quantitative assessment of the effects and costs of various policies should remove much of the guesswork from decision making and also allow a far greater range of options to be considered.

The Northern Prawn Fishery Model

The model incorporates biological, economic and physical features of the fishery which impinge on, or are affected by, management decisions. Since the model can incorporate only the most important relationships, the solutions that it provides are indicative of broad effects rather than being precise estimates.

On the biological side, the relationship between catch and effort is modelled in two parts: banana prawns, and all other species. (Measurement of fishing effort will be described later.) Ideally, there should be a separate relationship for each species, but lack of data precludes this possibility. The behavioural and harvesting patterns of banana prawns are particularly distinctive.

For the 'other species' group, a distinction is made between long term and short term catch-effort relationships. The long term relationship specifies the levels of catch that are sustainable with each level of effort, whereas the short run relationship between catch and effort is simply taken to be that observed in 1985-86, and is thus not necessarily sustainable. In contrast, because recruitment to the banana prawn stock appears to be independent of fishing effort in previous seasons (Staples, Dall and Vance 1982), no distinction between long and short term relationships was made for that species.

The fishery comprises vessels of different sizes, physical performance and profitability. In the model, all vessels are classed into a number of relatively homogeneous groups, based on a number of physical and operating characteristics (for example, age, engine size, underdeck volume, hours trawled and catch). By the use of a clustering technique (Weighted Automatic Interaction Detector), the fleet was sorted into groups such that variances between groups are maximised and variances within groups are minimised. The current model contains twelve groups of boats. Details of the groups are given by Haynes and Pascoe (1988). Each of these groups is represented in the model by its average values of such boat characteristics as number of Class A units, hourly cost of trawling, and fishing power for each species.

'Effort' is defined as hours trawled per year. Because catch per hour depends on many variables, effort actually applied by each boat group was adjusted using their relative fishing powers, so that hours fished by all groups could be combined into a single number of 'effective hours' applied to the fishery (for each species).

Fishing power can be defined thus: when two boats fish in the same place, at the same time, for the same species, their relative catches will be proportional to their fishing powers for that species. Measurement of fishing power is difficult, because of the variety of fishing conditions and the impossibility of conducting controlled experiments on an entire fishing fleet. Available data give only the apparent ratios of fishing powers among small numbers of boats on particular occasions. That is, the data give the fishing power of each boat in terms of those of a few others, themselves unknown.

To overcome this problem, an iterative method was used to determine the relative fishing powers of the boats. Initially, the fishing powers of all boats were taken to be proportional to their numbers of Class A units. Using daily log book data on catch, hours and location, the fishing power of each boat was estimated on the basis of its catch per hour relative to those of the other boats fishing on the same day in the same area, for each day of the season. The resulting estimates of fishing power for all boats were then used as the new starting estimates, and the program was re-run in this way until the estimates converged.

The average fishing power of each group, together with its actual effort, gives the aggregate effective fishing effort, and this, in conjunction with the catch-effort relationships, allows output to be determined.

As has been mentioned, existing policy tools include the compulsory surrender of units of capacity whenever a vessel is replaced by another above a certain size. Hence, the upgrading of one boat is, in theory, more than compensated by the downgrading or elimination of another boat, given that there is a ceiling on the number of units of capacity in the fishery. Relationships are therefore specified which link vessel size with forfeiture provisions.

Data on the average capital value of boats in each group, and the maximum number of hours that each boat can trawl during the season (either practically or legally) are also incorporated. The amount of capital in the fishery under any specified circumstance is used in the calculation of the rents that could be earned in the long run.

Model format

The model is specified as a linear programming problem, and shows the fleet compositions and yields likely to result from each set of policies if the operators act so as to maximise either fishing effort, revenue or profit. A number of allocation questions in fisheries management have been answered by the use of linear programming techniques, and the particular problems in the northern prawn fishery appear to lend themselves to analysis in this way.

Previous linear programming studies have focused on the optimum quantities of boats, effort or output for a fishery, and these are the variables of most concern at the current stage of development of northern prawn fishery management. Clarke and Kirkwood (1979) used linear programming to determine the optimum number of freezer or brine trawlers for the northern prawn fishery under specified conditions. Murawski and Finn (1986) used the technique to determine optimal effort levels in a North American otter trawl fishery. Optimal output levels, and the distribution of that output between different fleets or boats, were problems tackled by both Meuriot and Gates (1983) and Sinclair (1985) - again for North American fisheries.

Three objective functions are used in the model. Profit maximisation - under the assumption of single ownership - is used to estimate the rents potentially obtainable from the fishery in the long run, and the requisite level of effort and fleet configuration. For all other long run simulations, maximisation of effort is used (within the constraint that net returns do not become negative), because effort tends to increase in the absence of defined property rights (under limited entry regimes as well as open access).

In the short run simulations, the tendency for output to increase was represented by the third objective function: revenue maximisation, again subject to the constraint that net returns do not become negative. This is akin to the effort maximisation used in the long run simulations.

The key variables that are used in determining the relative success of the various policies are rent (the returns in excess of costs), effort, catch, boat numbers and number of Class A units.

While most of the functions and constraints in the model are linear (for example, the cost per unit effort, the amount of capacity forfeited on upgrading, and the capital investment in the fishery relative to boat numbers), the key relationship between catch and effort is not. Linear programming requires this relationship to be expressed as a set of linear segments. Though this procedure would be expected to involve a loss of accuracy, the uncertainty at present associated with the relationship outweighs the loss of information from linearising the curve. (Uncertainties in the catch-effort parameters, and also in the stock-recruitment relationship, do however require the model to be tested carefully to determine its sensitivity to assumptions in these areas.)

The major differences between the long and short run simulations are the treatment of costs, constraints on the rates of adjustment and, for the 'other species' group, the catch-effort relationship. Costs are separated into variable costs and fixed costs for the short run simulations, whereas all costs are treated as variable in the long run simulations (except for capital, as the boats are grouped into twelve fixed classes). In the short run simulations, where the model simulates adjustment from year to year rather than going directly to an optimum mix, the rate of adjustment is assumed to be related to the expected economic life of the vessel, although it would also depend on other factors which cannot be incorporated in the model, such as age of operator, family considerations and levels of debt).

The Model Results

Long run results

The results of the long run simulations are summarised in Table 2. Full results and sensitivity analyses are given by Haynes and Pascoe (1988). As the current fleet consists of 246 active boats holding about 106 000 active Class A units, the results suggest that some 53 boats would need to leave the fishery to reach even the long run open access equilibrium; more would have to leave for rents to be generated. These results are in agreement with the beliefs that, at present, the fishery is being overfished, and that rents are accruing only to a few operators and not to the fleet as a whole. Profits would be maximised with an effort little more than a quarter of the long run equilibrium effort applied under open access.

In the long run policy simulations, boats and Class A units could leave the fishery only through either the forfeiture provisions of the boat replacement policy or by being purchased through the Voluntary Adjustment Scheme. The other policies - gear restrictions and seasonal closures - are aimed at reducing effective effort through impeding catching efficiency and access to the resource, respectively. The limited entry policy was not simulated, since it is known from experience to have been ineffective. From Table 2, it can be seen that gear restrictions resulted in a reduction in effort in the fishery, but did not result in the attainment of any rents. This was because the increase in fishing costs due to the reduced catching efficiency offset the benefits that could accrue from the reduced effort. Closures did not result in any substantial changes from the simulation with only the boat replacement policy. Rents appeared only in the simulations involving the Voluntary Adjustment Scheme, and this was the only policy that caused the numbers of boats and of Class A units to fall below those of the open-access simulation. That the scheme would successfully reduce the number of Class A units to the target level (70 000) was in fact an assumption of this simulation, not a result; the cost to the operators of doing so was neglected.

TABLE 2

Results of the Long Run Simulations

Regime	Boats	Class A units	Effort(a)	Catch	Rent
	No.	'000	'000	kt	$m
Open access	192	92	385	10.1	0
Single ownership(b)	78	36	101	6.3	38
<u>Management</u>					
Boat replacement policy	217	103	353	9.9	0
Gear restrictions(c)	225	105	254	9.0	0
Seasonal closures(c)	217	103	345	9.9	0
Voluntary Adjustment Scheme(c)	147	70	356	10.0	5
All above management policies	147	70	258	9.1	5

(a) Effective hours, adjusted for fishing powers of each of 12 groups of boats. (b) Profit maximisation; for all other regimes, the objective is effort maximisation. (c) Combined with boat replacement policy.

A series of long run simulations was also run with different combinations of the policies, and regression analysis was used to determine the effects of each policy on the selected variables. From Table 3, it can be seen that the boat replacement policy results in more boats and Class A units remaining in the fishery than would occur in its absence, regardless of which other policies are in force. Gear restrictions reduce both catch and effort, while reduction of the fishing season has no detectable effect. Again, by assumption, the Voluntary Adjustment Scheme reduces numbers of Class A units and hence of boats; it again has positive (though small) effect on rents.

TABLE 3

Overall Effect of Policies on the Selected Variables

Variable	Boat replacement policy	Gear restrictions	Seasonal closures	Voluntary Adjustment Scheme	$\bar{R}^2$
Boat numbers	+			-	0.83
Class A units	+			-	0.93
Catch		-			0.71
Effort		-			0.72
Rent	+			+	0.35

+, statistically significant positive effect; -, significant negative effect; elsewhere, no statistically significant effects.

Since none of these policies appear likely to produce substantial long term rents, are there any alternatives that might do so? One possibility is the imposition of a levy on effort related to the operating costs incurred. This levy base, because it relates directly to the cost of effort, should result in less effort and a lower level of catch. An effort levy of 24 per cent was found, through the use of the model, to provide the same level of industry profitability as simulation indicated for the current policies ($5m), while releasing operators from many of the present constraints. Such a levy could be collected through the normal taxation system (via a percentage charge on tax-deductible fishing costs) with little additional cost to either industry or government.

Short run results

The short run analysis comprised a series of simulations, each with a new policy added into the previous policy mix. It was assumed that, in the short term, fishing would continue as long as the gross margin (revenue minus variable costs) remained positive. Each simulation was for a single year, given the 1985-86 fleet structure as the starting point. Note that, since the limited entry policy has been in force for about ten years, it would not be expected to produce further short term results, and thus provides a basis for comparison with the other policies, all of which have been introduced or greatly modified since 1985. The policies modelled were those actually introduced. The incremental effects of the current policies on output, effort and gross margins in the first year are shown in Table 4.

It can be seen that the effect on the key variables of imposing the boat replacement policy on the limited entry regime is negligible. This is due to there being sufficient inactive Class A and Class B units in the fishery to meet the requirements of the forfeiture provisions as boats are replaced. The slight increase in gross margin is the result of such replacement, and is not affected by the boat replacement policy.

The reduction of the fishing season likewise has no effect on either catch or effort, as the existing capacity of the fleet is more than sufficient to take the catch in the shorter time. The policy does, however, result in a change in the mix of boats, which in turn results in a higher gross margin. (If the delay in harvesting results in larger prawns on average being caught, then the resulting higher prawn prices will further increase the gross margin).

The addition of gear restrictions has a major effect on effort and gross margin and a lesser effect on catch. It was assumed that the restrictions would result in a 20 per cent reduction in fishing power over the season. Catch falls by about 6 per cent. Although effective hours decline due to the decreased fishing power of the fleet, nominal hours increase, resulting in increased costs and hence a fall in the gross margin.

The addition of the Voluntary Adjustment Scheme to the other policies has little effect on the levels of catch or effective effort. Assuming that the funds available to the scheme can be used entirely to purchase Class A and Class B units, approximately 14 boats and 8 000 Class A units disappear from the fishery. Although the gross margin, before levies, would increase, subtraction of the levy which finances the scheme results in a decline in gross margin.

TABLE 4

Results of Short Run Simulations for First Year

Policy	Boats	Class A units	Effort(a)	Catch	Gross margin
	No.	'000	'000 ha	kt	$m
Limited entry	246	114.6	441	10.1	25.7
plus boat replacement policy	246	113.7	441	10.1	26.9
plus seasonal closures	246	113.3	441	10.1	29.8
plus gear restrictions	246	113.2	366	9.5	19.4
plus Voluntary Adjustment Sc'	232	105.4	353	9.4	16.7(b)

(a) Effective hours, adjusted for fishing power. (b) Net of the cost of the levy ($3.9m)

Discussion and Conclusions

The model is predicated on certain cost and sale price assumptions and on the catch-effort relationships, and implicitly on the assumption of constant catching technology. Costs and technology, of course, can and will change, while further biological research will no doubt expand our knowledge of stock levels, recruitment and the effect of fishing effort. Management decisions, however, must be made on the basis of existing information, and the model incorporates what is known about the fishery at present.

One measure of the success of management is the extent to which it results in rent being generated in the fishery: an open-access fishery generates no rent. The model results indicate that the maximum rent that can be obtained from the fishery under the assumed conditions is about $38m. If the Voluntary Adjustment scheme is able to reduce the number of Class A units to the target level, then rents of only $5m are likely. On the basis of the past performance of the scheme, and the prices asked for Class A units, this could take many years and require far more than the funds currently being raised by the levy. Further, from the operator's standpoint, even the present $16 000 average levy per boat is not a worthwhile investment (assuming a discount rate of 20 per cent, as used by Hagan and Henry (1986) for valuing southern bluefin tuna quotas), unless the scheme provides annual returns of $40 000 per boat five years hence and operators have at least a ten-year time horizon. As returns are not likely to be of this order, and a five-year time horizon is more realistic (Hagan and Henry) the investment appears unattractive.

The ability of management to produce rents in the fishery, and the rate of growth of those rents, will depend on the rate of adjustment as well as on the removal of physical capacity through the buy- back scheme. The results suggest, however, that the financial penalty to operators replacing boats (that is, the cost of purchasing a Class B unit and the required number of Class A units) inhibits adjustment and hence retards the generation of rents. The boat replacement policy and the Voluntary Adjustment Scheme will also be affected by the ease with which boats can be taken out of the fishery. Inability of operators to enter alternative fisheries, or difficulty in selling boats, will reduce the willingness of operators to sell their endorsements, either to the buy-back scheme or to other operators.

In the model, both closures and gear restrictions proved ineffective in generating rents in the long term, and gear restrictions imposed additional short term costs on the operators. The short term model analysis, however, excluded the effect of these measures on the size of prawns and the consequent increase in returns to the operator. The short term analysis also excluded the effect of increases in prawn stocks in subsequent years that might arise from the policies. On the other hand, in the longer term, improved technology could offset the gear restrictions, countering any positive effects on the prawn stock.

The alternative policy discussed earlier - the effort levy based on total costs - offers some prospects of real economic gains. The effort levy has the attraction of being flexible and administratively simple, and it could eliminate most of the other regulations.

The results presented in this paper are only the first step in the use of the model. Further development of the model is already under way, for the more detailed analysis of alternative management options. The existence of the model - and the knowledge of its potential uses - should encourage those involved in the industry to provide further specific input. Ultimately, the model is expected to be easily usable by management, and its value will increase the greater is that input. The model is to form the basis of further applied economic analysis of the northern prawn fishery such as monitoring surveys, as well as analyses of alternative policies. It is also likely that similar exercises will be requested for other fisheries.

This model is only one example of the wide range of analysis undertaken at the Bureau. It does, however, demonstrate the gains that can be achieved through public research on the management of a public resource.

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