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MANAGEMENT OF THE VICTORIAN SCALLOP FISHERIES: RETROSPECT AND PROSPECT

by

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INTRODUCTION

The use of a resource that is the property of no one in particular but everyone in general may lead to economic waste. An industry based on such a common property resource may use more inputs than the social optimum because the marginal social cost of production exceeds the marginal private cost. One way of improving resource allocation in these circumstances is for the government to intervene with measures which cause marginal costs to resemble marginal social costs. The theoretical features of this problem in marine fisheries have been well documented and will not be reviewed in this paper (Gordon, 1954; Scott, 1955; Turvey, 1964; Copes, 1972; Anderson, 1977). However, there has been relatively little empirical analysis directed at determining best operating conditions (for example, Crutchfield and Zellner, 1962; O'Rourke, 1971; Bell, 1972; Tomkins and Butlin, 1974), particularly for Australian fisheries.

In the early years of its comparatively short history the scallop fishery in Port Phillip Bay was open to all who wished to fish. However, with the rapid emergence of an "overfishing" problem the State government introduced a set of regulations to overcome the problem by reducing fishing effort. As a result the scallop industry in Victoria became one of the first "managed" fisheries in Australia - with restrictions on the entry of boats into the fishery being a major method of management. The newer fishery at Lakes Entrance has been managed in a similar way since its discovery. The purpose of this paper is to review the management of the scallop fisheries in an economic framework and, using the results of some bioeconomic models of the fisheries, to suggest a strategy for future management. The central hypothesis is that the amount of fishing effort used in the fisheries remains excessive.

THE VICTORIAN SCALLOP FISHERIES

THE BIOLOGY OF THE SCALLOP

The commercial scallop, Pecten alba (Tate), a bivalve mollusc of the family Pectinidae, is found throughout Port Phillip Bay (PPB) below about four fathoms. It also occurs over a large area of Bass Strait east of Wilson's Promontory, offshore from the town of Lakes Entrance (LE), and as far south as Tasmania at depths between ten and thirty fathoms. Scallops occur on various seabeds from fine silts to coarse grain sands, but are not found on reefs or weed beds. The two fisheries, PPB and LE, can be regarded as separate stocks. Because the LE fishery is in the open ocean its boundaries are less precise than the PPB fishery. The majority of the catch at LE is taken within a radius of about thirty miles from the port, although boats venture further south and east in favourable weather. The PPB stock can be regarded as a closed population whereas the fishable stock at LE may be several populations with an unknown degree of interaction.

The two shells of the scallop, one flat and the other dished, are hinged at one end. The main edible portion is the abductor muscle which controls feeding and movement. Feeding occurs by sieving water through a curtain-like mantle to obtain suitable-sized components of the plankton. Scallops move in a series of spurts by jetting water from between the shells in the area of the hinge. This limited ability to swim and the scallop's many well-developed eyes, which are capable of perceiving shapes as well as changes in light intensity, have led to the belief that individuals could swim away from an approaching dredge. This has not been substantiated by divers.

This species of scallop is an hermaphrodite. The gonad, which is attached to the abductor muscle, is creamy white at the testicular (proximal) end but pink to red at the ovarian (distal) end. The gonads of some scallops may be red throughout. Such gonads are made up entirely of ovarian tissue as a result of the scallop being infected by the trematode parasite Bucephalid cerceriae. Large numbers of these parasitic worms make the scallop sterile. Spawning first occurs in the second year of life. It appears to be induced by a sudden small rise in water temperature. The period of spawning in Port Phillip Bay occurs from August to November, whilst scallops in the Lakes Entrance fishery may commence spawning as early as June. During this period an individual scallop may spawn on a number of occasions. When the conditions are suitable, the scallop may spawn every two to eight minutes for three hours. Fertilisation of the eggs occurs externally after contact with the actively swimming sperm. The fertilised eggs at first sink to the sea bed and then go through a number of pelagic (floating at or near the sea surface) larval stages before permanently settling on the sea bed.

The settlement process, spatfall, occurs some six to eight weeks after fertilisation. As a consequence of tidal and current movements, which are especialy strong over the Lakes Entrance grounds, the area where spatfall occurs may be remote from the site of spawning. There is a large degree of variability in the number of scallops "recruited" to the stock. Sanders (1971) has suggested that this variability occurs irrespective of the existence and amount of exploitation.

The growth of individual scallops is rapid. A shell diameter of about 9 cm can be attained at an age of two and a half to three years. The growth rate of PPB scallops has been reported to be higher than those at Lakes Entrance, possibly because food supplies and water temperatures are more favourable. Natural mortality has been estimated to be between five and ten per cent per annum until the scallop is six years old, when mortality rises. The maximum age of scallops is about twelve years. Scallops seem to have only one predator, the eleven-armed spiny starfish Conscirasteria calameria.

The sole means of catching scallops commercially in Victoria is by dredging. A single dredge is towed from the stern of the boat by a wire cable. When this is fully retracted a self-tipping apparatus empties the contents on to a sorting table. The crew remove rubbish from the catch and pack the unopened scallops in sacks for transport to the processor. Scallop boats often work in dense packs whilst dredging grounds where the density of scallops is high. Crowding externalities manifest themselves in the form of snagged dredges, collisions, abusive language and the occasional fight.

HISTORY AND MANAGEMENT

The history of both fisheries is comparatively short. The Port Phillip Bay fishery began as a commercial operation in 1963 even though the presence of scallops had been determined by the state government authority for fisheries as early as 1957. Partly as a result of the near depletion of the D'Entrecasteaux Channel fishery in Tasmania, boat numbers increased rapidly in response to attractive catch rates and incomes (Sanders and Sturgess, 1968), until 1968 when 170 boats were fishing. Production peaked in 1967 when approximately 2,000,000 kg of edible flesh were taken; only the Georges Bank of North America produced more from a single fishery. This period of expansion was followed by a slump in catch rates. Catch rates dropped to such an extent that in April 1971 only four boats were fishing. Many fishermen chose either to leave their boats idle or to fish for other species. In June 1970 one fisherman discovered that a commercial scallop fishery existed in Bass Strait just offshore from Lakes Entrance. Within five months 68 boats were involved in this new fishery, most of them coming from the PPB fleet. This transfer of effort aided the regrowth of the scallop stock in PPB and the catch increased from 18,000 kg in 1970/71 to approximately 1,000,000 kg in 1972/73. Since the beginning of the LE fishery it has proved to be of similar importance to the PPB fishery.

Jurisdiction over marine fisheries in Victoria rests with the Fisheries and Wildlife Division (FWD), Ministry for Conservation. This body exerted little control over the PPB fishery in its first five years. The exception was the introduction in 1965 of a minimum size for scallops. Based on research into the growth rates and natural mortality of scallops the size selected (9.5 cm) was judged to provide the maximum yield of flesh from a given number of zero-age scallops entering the fishery.

In 1968 a licencing scheme, designed to limit further entry of fishermen, was introduced into the PPB fishery. This action was prompted by the steady decline in catch rates and the FWD felt that such a restrictive measure was necessary to ensure the long term viability of the fishery. A scallop licence is issued to a person for operation of a particular boat. Licences were offered to all fishermen actively fishing in the industry just before December 1967. Not all fishermen chose to accept this offer; a decision which was influenced by both the bleak short-term prospects for the fishery and the licence fee of $20 per foot of dredge width (about $160 per boat). Following the withdrawal of some fishermen in 1969 the number of licences stabilised around the 79 presently entitled to fish in PPB. The introduction of scallop licences was accompanied by a policy which restricted the width of the dredge according to the length of the boat. If fishermen replaced their boat with a larger one they were not permitted to increase the width of dredge. As a further control on effort fishermen were not permitted to operate outside the daylight hours of 5 a.m. and 5 p.m.

Soon after the Lakes Entrance fishery began the FWD initiated a licencing scheme for that fishery; this followed an amendment to the Victorian Fisheries Act (1968) made in September 1971. Because many of the boats in this fishery already held PPB licences their owners were given the option of taking out an all Victorian waters licence. As the name implies holders of this licence could participate in both the PPB and LE fisheries. Those fishermen whose previous scallop fishing had been restricted to the LE Grounds were offered licences applicable to that fishery only. Thus three types of Victorian scallop licences exist at the present time; namely, PPB only; all Victorian waters; LE only. Since 1971 the numbers of licences in these categories have remained static at 23, 56 and 34 respectively. From 1977 fishermen not "actively regularly and substantially" engaged in fishing are required to "show cause" why their licence should not be cancelled. To our knowledge no licences have been cancelled by this means. Scallop licences are not freely negotiable through a market. However, because the purchaser of a scallop boat is almost assured of obtaining endorsement of the licence, the price of the boat includes an amount for the acquisition of the licence.[1]

Fishermen of the LE fishery were prohibited from taking scallops less than 9.5 cm at the widest point. This regulation was introduced on the assumption that the growth parameters and natural mortality of scallops in the LE fishery were similar to those of the PPB scallop. Dredge width was tied to boat length by the same regulation as for PPB.

Since the introduction of scallop licences for the LE fishery in 1971, some regulations have been altered and new ones added according to the state of knowledge about the two fisheries and the abundance of scallops. The size limit on scallops caught at LE was removed in September 1976 and the size limit in PPB was lowered to 8.9 cm in June 1977. In December 1978 the latter size limit was also abolished. The major reasons for the abolition of size limits were the costs of sorting and measuring imposed on fishermen, the likely damage to undersized scallops returned to the water, and the cost of enforcing the minimum size.

The regulation under which the allowable width of dredge was proportional to boat length has been replaced with one which fixed a maximum size of dredge (3.36 m) for PPB and daily bag limits were imposed on both fisheries. Bag limits were first organized on a voluntary basis by the Scallop Fishermen's Association at Lakes Entrance. Subsequently, bag limits were legislated for both fisheries in 1976 because the FWD was concerned that voluntary arrangements would break down. When first introduced the bag limits were 15 bags per day in PPB and 25 bags per day in LE. These limits have been altered downwards for PPB and up and down for LE until they now stand at 10 bags per day and 50 bags per day respectively. Bag limits would appear to make redundant the control over fishing times and dredge width, but these regulations remain.

In December 1978, along with the abolition of size limits, a closed season was declared for the PPB fishery. On a trial basis the fishery was closed from December 20, 1978 until the first Monday in April 1979. During the open season the bag limits may be altered or fishing may be prohibited for some days each week, depending on the size of scallops being taken and their abundance. These regulations were used during the first open season when the northern half of the Bay was closed in October 1979 and fishing was limited to three days per week in the southern half. Prior to October many small scallops were taken by the PPB fleet which was augmented by a considerable number of all Victorian waters boats from LE. A summary of the regulations which applied to each fishery in December 1979 appears in table 1.

AN EVALUATION OF THE MANAGEMENT POLICIES

LICENCING AND THE MANAGERS' OBJECTIVES

The set of arrangements by which the scallop fisheries are managed has evolved in a trial and error fashion to meet a complicated and imperfectly specified set of economic, social, and political objectives. Given the slow accumulation of knowledge about scallop populations and their interaction with the environment, including fishing, it is not surprising that there have been trials and changes. This section outlines some of the possible reasons why the managerial arrangements have taken their particular form; the reason why there has been complete reliance on regulations rather than market mechanisms is of notable interest. Related issues include the type of regulations used, and the nature of the rights they give fishermen. Of necessity, this involves speculation about the objectives of the participants in the managerial processes and the trade-offs between those objectives. Also, the form of the policies depends on the relative bargaining strengths of the participants. The observer can never know these relationships and objectives with certainty and our approach is to draw inference from statements made by the participants, and actions they have or have not taken.

The Fisheries Management Committee met first in 1976. This committee consists of representatives of fishermen in the various fisheries and the FWD. Its role is to advise the Minister and the Director of the FWD on management matters. This committee, the FWD and the politicians in government represent the major participants in the management process since 1976. Prior to that date fishermen were not involved directly in management.

The introduction of a limited number of scallop licences in 1968 was in accordance with the growing interest in the management of fishing effort during the 1960's, as the ideas of fisheries economists filtered through to biologically trained administrators (Sanders, 1967). In a paper to a national fisheries seminar, Sanders (1971) listed objectives for the management of scallop fisheries. This list provides an insight

Table 1. Regulations affecting the Port Phillip Bay and Lakes Entrance scallop fisheries (December 1979)

Regulation	Port Phillip Bay	Lakes Entrance
Boat licences	79:23 PPB only and 56 all Victorian waters.	90:34 LE only and 56 all Victorian waters.
Licence fee	$8.00/10 cm of dredge width.	$8.00/10 cm of dredge width.
Scallop size limit	None.	None.
Catch limit	10 bags/day.	50 bags/day.
Dredge width limits	Not greater than 3.36 m.	Related to boat length with maximum of 3.36 m.
Time limitation	5 a.m. to 5 p.m.	None.
Closed season	Mid-December to early April. Other closures as needed.	None.

into the managerial obligations as perceived by a senior member of the FWD. The objectives were:

* stability resulting from a level of exploitation which allows the production to be sustained and relatively constant,

* a satisfactory income for those engaged in the fishery, and

* a satisfactory quality and price to the consumer (p.10).

In the same paper Sanders summarized the philosophy of management as follows:

> The management of a fishery is the responsibility of both government and the persons engaged in the fishery. It is a responsibility which should at least be directed to the resource, to the industry and to the consumer (p.9).

Although the idea of sustained yield is clear the remaining objectives, with the repeated use of the word "satisfactory", might be regarded as principles without content. Or, taking a more lenient view of the philosophy behind them, they could be said to be consistent with the economic components of net social benefit (Copes, 1972). However, there is no specific mention of the idea of fishery rent or the economy-wide implications for resource use which follow from maximizing fishery rent. A responsibility directed "to the resource" is an unusual phrase but it seems to suggest that the preservation of the species is an objective of the managers. Sanders (1971) does mention "more sophisticated objectives" such as "sustained maximization of production, or maximization of profit". Without defining the profits to be maximized, he claims that these objectives "usually verge on the unrealistic and are unobtainable when put into practice" (p.9). Further evidence of the government's obligations, and an insight into the objectives implied by the licencing regulations, was given by the Chief Secretary at the time, Mr. Rylah, when introducing the relevant Bill:

> In considering whether or not further licences should be issued ... the Minister shall have regard to the welfare of the fishery concerned and of the persons engaged in the industry. This will allow the Minister to take into consideration such factors as the proper management of the fish stocks to ensure the continued productivity of the resources, the good of the persons engaged in the industry with particular reference to the man who carries out the harvesting and also to all other persons engaged in the various phases of the industry from the wharfside to the consumer. (Hansard, No.12, 1967, Parliamentary Debates)

Unfortunately, despite the creditable speed with which the FWD introduced this managerial innovation, the purpose of the licence limitation is ill-defined because what is meant by the "welfare of the fishery" or "the good of persons engaged" is not specified. In an earlier paper, Sanders (1967) acknowledged the existence of a relationship between fishing effort and fishermen's incomes stating that in an uncontrolled fishery "the economic end point ... is again a state of minimum profits" (p.3). Sanders maintained that the reason for regulating fishing was to achieve "optimum" fishing as defined by maintaining the profit margin at a desired level.

Because the "profits" remain undefined it is not clear whether the FWD was concerned about the business profits of fishermen or had in mind a social surplus (rent). Some subsequent statements were consistent with both interpretations. Fishermen's incomes will be influenced by the amount of the surplus (resource rent) which the state captures by various means and it appears that the FWD was particularly sensitive about these incomes; possibly because fishermen's incomes had decreased markedly by 1968 (Sanders, 1971, p.8). This concern with the welfare of fishermen prompted Sanders to observe that:

> licence limitation has the advantage...of facilitating control of fishermen's incomes. This in itself raises the problem of what this level should be. (Sanders, 1971, p.5)

In the event, the policy limiting the number of licences and the accompanying regulations restricting dredge width and the night-time closure of the fishery, were directed apparently at preventing expansion of effort. Although there was discussion within the FWD in 1967 that the number of licences might be adjusted by limited transferability and a "buy-back" scheme, specific mechanisms for reducing the number were absent from the legislation. In fact, it appears that the regulations affecting dredge width, boat replacement, and fishing time were not directed solely towards preventing expansion of effort. If these variables were not to be controlled, the resultant increase in the efficiency of fishing would require a reduction in the "optimal" number of licences.

> This trend could become progressive and could eventually lead to a very small efficient fleet. To overcome this problem, any system of licence limitation must incorporate restriction on the fishing power of the boats. (Sanders, 1967, p.4)

The pursuit of efficiency can only be considered a problem by those who see it as a price for the attainment of some other objectives. These other objectives remain unspecified but the fact that they existed was indicated by the judgement that any sudden reduction in the number of licences was "socially and politically undesirable" (Sanders, 1971, p.11). In the twelve years since licencing began, the only reduction in effort which took place through the number of licences was due to some fishermen declining a licence or voluntarily withdrawing in the first year of the scheme. The subsequent regulations (bag limits and a closed season) indicate that further reduction in effort was desirable. This was achieved by means other than reducing the number of licences, despite feeling within the Fisheries Management Committee that there were too many boats in the fisheries. Only recently has the FWD attempted to bring about any reduction in the number of licences. A fisherman who has not been "actively, regularly and substantially engaged" in the fishery for which he is licenced must "show cause" why his licence should not be cancelled. Like voluntary withdrawal this passive provision puts the onus on the fisherman. Also it could have the perverse effect of encouraging an increase in effort as part-timers protect their licences, as well as being a tedious and potentially costly scheme to administer. Judging by experience in the Canadian salmon fishery this provision is likely to have little effect in reducing the number of licences.

Further evidence of the policy makers' bias against actively reducing the number of boats is that when licence limitation was extended to the LE fishery soon after its commencement, an additional 25 boats from LE were issued with licences. Opinion in the FWD was that this action was justifiable because "these fishermen had a legitimate right to engage in this new fishery being established on their fishing grounds" (Sanders, 1971, p.12, emphasis added). It was not explained why these fishermen were attributed with some sort of ownership rights over these fishing grounds, theoretically a common property or state-owned resource. It appears from this and other actions that historical association with a fishery or port was judged by the FWD to give a fisherman preferential rights in limited-entry fisheries.

A similar expression of the belief in right of access by historical association may have led to the creation of the three types of licences - PPB only, LE only and all Victorian waters. To prevent the possibility of all licenced boats returning to PPB at some time in the future, it was decided that only those boats operating in the Bay just before the development of the LE fishery should be allowed to re-enter. This created special privileges for a group of fishermen whose major attribute appears to have been mobility. The 1979 experience in PPB suggests that total effort of the combined groups eligible to fish the Bay remains excessive. The fact that the FWD has considered it undesirable to create only two groups of fishermen, each confined to one fishery, adds support to the importance of historical access. The reasoning for not creating two fleets is the "inherent instability" of the scallop production at any one location and the objective of "satisfactory" level of income for fishermen. Because of the instability of production it is argued that confining fishermen to one ground or the other will cause income from scallops to become more unstable.

The pursuit of policies which have encouraged the greatest number of "legitimate" fishermen to continue operating in one or both fisheries for as long as they wish, could be said to be for the good of persons engaged in the industry. Offering licences to all fishermen and allowing all the acceptors to continue fishing allows them to fulfill the expectations on which their investments in the fishery were made. However, a significant number have since arranged the transfer of their licences to new entrants suggesting that this argument loses its force with the passage of time. Also, those policies may be consistent with unstated objectives such as preventing social dislocation, or maintaining regional employment opportunities in the individual's preferred job. However, there may be many ways of achieving ends such as these; indeed the ends themselves may be questioned. Unless the regulators clarify the extremely vague terms in the stated objectives, the least-cost ways of achieving the real objectives are left to chance. Until then, it will be recognized that the present policy is also consistent with another set of objectives which come under the umbrella of maximizing the number of minimally offended, voting producers. If the managers wish to pursue a regulatory approach it cannot be denied that deciding who is to leave the industry is difficult and the result likely to be unpopular. Licencing all fishermen, placing the onus on fishermen to withdraw or "show cause", and regulating effort by other means, tends to preserve the status quo and avoid these decisions. In a sense, preservation of the status quo may be consistent with idealized Paretian values; but those ideals may be misguided and impractical in these circumstances. To pursue this line of reasoning would lead into topics beyond the scope of this paper, namely, the emerging theories of regulation. However, Scott (1979) has suggested that these developments may find fruitful application in fisheries regulation and Sieper (1979) has argued their relevance to Australian primary industries.

BAG LIMITS AND THE CLOSED SEASON

The subsidiary regulations of daily bag limits and the closed season in PPB are also difficult to interpret in terms of the vaguely stated objectives. The closed season and area closures during the open season may impose hardship on the PPB only licence holders. Being unable to move to LE they are forced to other occupations during these times. Similarly the LE only boats will be disadvantaged to the extent that the all Victorian waters boats could fish LE during the PPB closures. It is possible that this measure may force the retirement of some PPB only boats, but there are less drastic ways of doing this. As long as the number of licenced boats which can operate in PPB remains unchanged, there seems to be no alternative to these measures; given the desire for regulation persists. Indeed, in these circumstances, it is not hard to foresee that more stringent regulation of fishing activity may be required to preserve the fishery. Even if the number of boats licenced for PPB were reduced, a closed season over all or part of the Bay may be needed for some years to allow the depleted stock of small scallops to grow and reproduce. Despite any race for scallops that may be encouraged by a closed season it may be justifiable as an emergency measure.

Daily bag limits are a simple control on output which is relatively cheap and easy to enforce. However, there are several problems associated with these limits. Firstly, as indicated into the managerial obligations as perceived by a senior member of the FWD. The objectives were:

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Unfortunately, despite the creditable speed with which the FWD introduced this managerial innovation, the purpose of the licence limitation is ill-defined because what is meant by the "welfare of the fishery" or "the good of persons engaged" is not specified. In an earlier paper, Sanders (1967) acknowledged the existence of a relationship between fishing effort and fishermen's incomes stating that in an uncontrolled fishery "the economic end point ... is again a state of minimum profits" (p.3). Sanders maintained that the reason for regulating fishing was to achieve "optimum" fishing as defined by maintaining the profit margin at a desired level.

Because the "profits" remain undefined it is not clear whether the FWD was concerned about the business profits of fishermen or had in mind a social surplus (rent). Some subsequent statements were consistent with both interpretations. Fishermen's incomes will be influenced by the amount of the surplus (resource rent) which the state captures by various means and it appears that the FWD was particularly sensitive about these incomes; possibly because fishermen's incomes had decreased markedly by 1968 (Sanders, 1971, p.8). This concern with the welfare of fishermen prompted Sanders to observe that:

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The pursuit of efficiency can only be considered a problem by those who see it as a price for the attainment of some other objectives. These other objectives remain unspecified but the fact that they existed was indicated by the judgement that any sudden reduction in the number of licences was "socially and politically undesirable" (Sanders, 1971, p.11). In the twelve years since licencing began, the only reduction in effort which took place through the number of licences was due to some fishermen declining a licence or voluntarily withdrawing in the first year of the scheme. The subsequent regulations (bag limits and a closed season) indicate that further reduction in effort was desirable. This was achieved by means other than reducing the number of licences, despite feeling within the Fisheries Management Committee that there were too many boats in the fisheries. Only recently has the FWD attempted to bring about any reduction in the number of licences. A fisherman who has not been "actively, regularly and substantially engaged" in the fishery for which he is licenced must "show cause" why his licence should not be cancelled. Like voluntary withdrawal this passive provision puts the onus on the fisherman. Also it could have the perverse effect of encouraging an increase in effort as part-timers protect their licences, as well as being a tedious and potentially costly scheme to administer. Judging by experience in the Canadian salmon fishery this provision is likely to have little effect in reducing the number of licences.

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A similar expression of the belief in right of access by historical association may have led to the creation of the three types of licences - PPB only, LE only and all Victorian waters. To prevent the possibility of all licenced boats returning to PPB at some time in the future, it was decided that only those boats operating in the Bay just before the development of the LE fishery should be allowed to re-enter. This created special privileges for a group of fishermen whose major attribute appears to have been mobility. The 1979 experience in PPB suggests that total effort of the combined groups eligible to fish the Bay remains excessive. The fact that the FWD has considered it undesirable to create only two groups of fishermen, each confined to one fishery, adds support to the importance of historical access. The reasoning for not creating two fleets is the "inherent instability" of the scallop production at any one location and the objective of "satisfactory" level of income for fishermen. Because of the instability of production it is argued that confining fishermen to one ground or the other will cause income from scallops to become more unstable.

The pursuit of policies which have encouraged the greatest number of "legitimate" fishermen to continue operating in one or both fisheries for as long as they wish, could be said to be for the good of persons engaged in the industry. Offering licences to all fishermen and allowing all the acceptors to continue fishing allows them to fulfill the expectations on which their investments in the fishery were made. However, a significant number have since arranged the transfer of their licences to new entrants suggesting that this argument loses its force with the passage of time. Also, those policies may be consistent with unstated objectives such as preventing social dislocation, or maintaining regional employment opportunities in the individual's preferred job. However, there may be many ways of achieving ends such as these; indeed the ends themselves may be questioned. Unless the regulators clarify the extremely vague terms in the stated objectives, the least-cost ways of achieving the real objectives are left to chance. Until then, it will be recognized that the present policy is also consistent with another set of objectives which come under the umbrella of maximizing the number of minimally offended, voting producers. If the managers wish to pursue a regulatory approach it cannot be denied that deciding who is to leave the industry is difficult and the result likely to be unpopular. Licencing all fishermen, placing the onus on fishermen to withdraw or "show cause", and regulating effort by other means, tends to preserve the status quo and avoid these decisions. In a sense, preservation of the status quo may be consistent with idealized Paretian values; but those ideals may be misguided and impractical in these circumstances. To pursue this line of reasoning would lead into topics beyond the scope of this paper, namely, the emerging theories of regulation. However, Scott (1979) has suggested that these developments may find fruitful application in fisheries regulation and Sieper (1979) has argued their relevance to Australian primary industries.

BAG LIMITS AND THE CLOSED SEASON

The subsidiary regulations of daily bag limits and the closed season in PPB are also difficult to interpret in terms of the vaguely stated objectives. The closed season and area closures during the open season may impose hardship on the PPB only licence holders. Being unable to move to LE they are forced to other occupations during these times. Similarly the LE only boats will be disadvantaged to the extent that the all Victorian waters boats could fish LE during the PPB closures. It is possible that this measure may force the retirement of some PPB only boats, but there are less drastic ways of doing this. As long as the number of licenced boats which can operate in PPB remains unchanged, there seems to be no alternative to these measures; given the desire for regulation persists. Indeed, in these circumstances, it is not hard to foresee that more stringent regulation of fishing activity may be required to preserve the fishery. Even if the number of boats licenced for PPB were reduced, a closed season over all or part of the Bay may be needed for some years to allow the depleted stock of small scallops to grow and reproduce. Despite any race for scallops that may be encouraged by a closed season it may be justifiable as an emergency measure.

Daily bag limits are a simple control on output which is relatively cheap and easy to enforce. However, there are several problems associated with these limits. Firstly, as indicated above, bag limits make redundant the controls on dredge width and fishing time. Therefore, costs are likely to be greater because some fishermen may operate more efficiently after 5.00 p.m. in PPB, and because the time required to take a given bag limit could be reduced with larger dredges. Secondly, daily quotas as opposed to annual quotas for every fisherman give only indirect control over total fishing effort and may result in higher costs. For every fisherman, a daily quota multiplied by the average number of fishing days corresponds to an annual quota. However, costs may be higher than with an annual quota because fishermen's choices about the distribution of their effort over the year are curtailed by a daily limit. Also, costs may be increased and control over total effort diminished, as fishermen take greater risks to increase the number of days they fish. These problems are exacerbated by the group of fishermen which is permitted to move between the two fisheries. As they do so daily quotas would need to alter to hold total effort within desired limits. Such variations in daily bag limits in turn create an additional source of uncertainty.

Thirdly, daily quotas were introduced first by the Scallop Fishermen's Association at Lakes Entrance as a means of influencing the price offered by processors. Bag limits have been altered since they became subject to regulation, no doubt after discussion in the Fisheries Management Committee. Therefore, the regulators might be seen to have assumed a price-influencing function in conjunction with producers. This function is not new to regulators in primary industries, nor is it inconsistent with the stated objective of satisfactory incomes for fishermen. However, it is a function that is not without conflict with the management of fishing effort and the consumer-oriented objective.

TRANSFERRING LICENCES

By various means it is possible for a retiring fisherman to transfer a licence to a new entrant to the fishery. As a result a de facto market in licences exists. During a survey (Belin, 1978, chapter 6) fishermen were asked to value their boats both with and without a licence. The implicit valuations of their licences averaged $2430, $3350 and $4750 for the PPB only, LE only, and all Victorian waters endorsements respectively. These figures suggest that the mobility permitted by the all Victorian waters licence enables the holders to capture rent from both fisheries and earn higher income - this was confirmed by the survey. Although it is not possible to make comparisons with published information from other fisheries these values seem low, possibly reflecting the relatively depressed state of the fisheries. Also, the values of the licences were low relative to the value of a boat at the time of the survey. Therefore boats appear to have significant value for uses other than scallop fishing.

Since their introduction the FWD has opposed a formal market for licences even though approval for "sales" is relatively easy to obtain. Some of the possible reasons for this stance were revealed at a seminar in October 1978 to discuss the sale of licences in limited entry fisheries (Sanders, 1978a, 1978b). Firstly, the sale of licences represents a windfall gain to the first generation of fishermen and imposes additional costs on the fishery. These costs are the interest payments on loans to purchase the licence, or the interest foregone on savings. While this is a cost to the individual, as it is to the purchaser of any asset, such a cost would not appear in a social cost-benefit analysis of saleable licences. From the viewpoint of the fishery there would be the offsetting gain in interest from the funds available to the seller; given a competitive capital market. Also, funds would be transferred to the purchase of fishing rights from other sectors of the economy if the gains were at least equal to the return of those funds elsewhere.

There are many examples (such as the 19th century squatter-graziers) to suggest that governments have not been persuaded by the windfall gain argument in the past. Also it is of doubtful relevance now; given that a de facto market exists on which many entrants have already traded. Also, as Sanders suggested, means such as higher fees could be used to reduce the value of licences; but these were seen "as administratively difficult and costly" (Sanders, 1978b, p.3).

Secondly, it was claimed that a market for licences would discriminate against entrants with the least ability to pay and does not necessarily give due priority to the most meritorious applicants. The common fear of monopoly control of fisheries is also evident in this reasoning. All types of rationing "discriminate" against somebody, therefore the force of this argument depends on the definition of merit. The FWD seems to believe that merit would be assessed best by a point score with high points for fishing experience, filial relationship to a fisherman, living near a port, and middle-age. This suggestion again stresses the importance of the belief in the right of access by association in the minds of the policy makers. Conversely, it can be argued that a market would encourage skilled entrepreneurs to enter the fisheries. Such people could engage skilled and experienced labour if required, and they would take this into account in determining the prices they could offer for a licence.

Other arguments against saleable licences included the possibility that some buyers would pay too much, either because of inflated expectations or because of non-monetary rewards from fishing as a way of life. The paternal attitude expressed in these reasons is obvious. It appears to stem from the major thread in Sanders' arguments, namely, the concern of the managers that fishermen earn an "acceptable" income. This objective of management sets fishermen apart from other members of the community and from producers of many other commodities. By preventing a formal market in licences (with the possibility of lower transaction costs than the informal market) which is separated from the boat market, the FWD is impeding one of the most powerful forces in producing "acceptable" incomes, namely, the mobility of resources in accordance with their opportunity costs. Also, we will argue that it is foregoing the opportunity to affect the number of licences in a non-regulatory fashion.

The final disadvantage of saleable licences given by Sanders (1978a) is that such a system would be difficult to revoke. Except to serve the political purposes of the Minister or his advisors, it is difficult to conjure-up circumstances in which a return to an administrative system would be warranted. A government may be tempted to do so if over-concern with incomes produced very high prices for licences, or if an undesirable concentration of ownership developed. In these circumstances, however, to revoke the market would be like amputating a toe at the neck.

In more fundamental terms it is possible that the government is concerned that saleability would alter the bundle of property rights embodied in a scallop licence. The present arrangement involves a partial transfer of rights to the individual under a tenure-like arrangement, with the rent being the annual licence fee. Saleability would alter the bundle of property rights more towards individual ownership. It is not hard to imagine that a government might be uncomfortable about being seen to vest ownership of a community resource in individuals - particularly when open access existed in living memory. There are, of course, many precedents for similar changes in property rights and governments always have the ability to stake the community's claim through appropriate fees and covenants - as every house-owner knows. As an aside, it is interesting to speculate if this is the reason why governments are often averse to markets which appear to "trade in paper". The rights given by the paper are often well established but the "property" is not so clear cut, for example, broadcasting and taxi licences. After all, buying and selling tangible property like land is just "trading in paper" - the title.

We have outlined some of the weaknesses in these arguments against a formal market in licences. The weakneses are amplified by the fact that the FWD has been unable or unwilling to prevent the informal market. The advantages of saleable licences have been discussed elsewhere (Anderson, 1977) and we need not repeat those arguments here; suffice it to say that we see no reasons why those advantages should not apply to the scallop fisheries. With Crutchfield we believe that:

> Efficiency in use, continuity of operation and ease of administration are eloquent arguments for relatively free and costless transferability of limited fishing rights. The price they will come to carry is both an economic barometer and an allocative device that no amount of government administrative effort could match (Crutchfield, 1979, p.745).

Rather than continue to debate the question of saleability the managers would be served better to debate the form and extent of the rights to be offered. A clear definition of the bundle of rights is necessary if buyers and sellers are to place their valuations on a licence. Also the nature of the rights will affect the costs to the managers and fishermen of policing and enforcing those rights. Similarly they will affect the cost of making a transaction. If, for example, licences were in perpetuity it is possible to envisage the need for some form of title and the involvement of the legal profession in conveying titles. Long-term or perpetual rights have the administrative advantage of reducing the number of issuings compared to short-term licences. As well, they would provide their owners with more certainty in managing their financial portfolio. Other important questions to be debated include:

* are licences to be offered to fishermen for the operation of a particular boat, and if so, what are to be the provisions for replacing the boat?

* is the set of rights to be leasable as well as saleable?

* what is to be the nature of inter-generation transfers, that is, is the licence to form part of an estate which can be willed and subject to death duties?

Judged by their beliefs and previous actions the managers may be disposed to restrict the potential buyers of licences to "legitimate" fishermen. Such a stipulation could have unfortunate consequences in terms of the economy's allocation of resources, including managerial skill and innovation in the scallop industry.

This section has reviewed the stated objectives of the managers. Broadly, the approach of the managers has been to leave the number of boats unaltered and to affect total effort by controlling the effort per boat. We have speculated about some possible motives for these strategies. If informed public discussion of the management of these fisheries is to proceed the managers must accept the responsibility of clarifying their vague objectives. This is particularly important now because some of the decisions which must be made, such as the type of property rights to be vested in fishermen, may set the future course of history for these and other fisheries.

BIOECONOMIC MODELS OF THE SCALLOP FISHERIES

INPUTS AND OUTPUTS

In the mainstream of present theories of commercial fishing, the yield (catch) of the fishery depends upon the inputs man uses to go fishing and the growth and reproductive characteristics of the stock of fish. Following the conventional Schaefer-type of logistic analysis, growth of the stock of fish is assumed to be a function of its mass (Schaefer, 1954 and 1957). In an unchanging environment with limited food supply a stock which is not fished will grow to some maximum size. When the catch taken from such a stock is greater (less) than the natural growth the mass of the stock will decrease (increase). The <u>sustainable yield</u> for a given size of stock is achieved when the catch equals the natural growth. This yield is sustainable because the same quantity of inputs (effort) applied to the stock in subsequent periods will produce the same catch. If effort changes, catch and population will change until a new sustainable yield is attained at a new equilibrium stock.

The sustainable yield curve can be viewed as the long-term production function of the fishery. It shows the quantities of fish which can be obtained on a continuing basis at various quantities of effort. Each point on the curve implies that a different size of stock is in equilibrium at that particular quantity of effort. The sustainable yield curve resulting from this model is bell-shaped over some or all of its range, indicating that a given sustainable yield can be obtained from two amounts of effort and two equilibrium sizes of stock. The mathematical and biological details of this and other models of fisheries have been discussed by Clark (1976) and Anderson (1977). In the absence of published information on growth, mortality, spawning, and the recruitment of young scallops, it was not possible to estimate stock production models for each fishery in the manner of Beverton and Holt (1957). Consequently, this study uses the type of sustainable yield-effort model outlined above.

It was mentioned earlier that there is some evidence that the size of the scallop populations may vary irrespective of the amount of fishing effort. This type of situation could arise if the growth of the population is more dependent on environmental stimuli than on the size of last year's population. Other circumstances in which the conventional model may not be appropriate are when the proportional growth rate of the species increases over some range of population size, or if there is a minimum size below which the population is not viable (Clark, 1976, Ch.1). Lack-of-fit of the conventional model may be indicative of these other hypotheses.

A major difficulty in estimating yield curves from observations of catch and fishing effort is that the actual catches in a given period are unlikely to be sustainable catches for the observed quantities of effort; particularly if there are considerable changes in fishing effort between periods. Because the scallop fisheries have been in operation for only a small number of years, it was not possible to use the methods devised by Schaefer (1957) and Gulland (1968) for modifying observed data to approximate steady state conditions. Rather than assume that actual catches are sustainable, as was done in a previous study (Belin, 1978), the approach used was to estimate by non-linear regression the parameters of various population-growth-effort models with different forms of the growth function. These models were then used to predict sustainable yield curves.

The definition and measurement of fishing effort is one of the major problems in fisheries economics. In common with most analyses of fisheries to date, we have by-passed this problem and adopted a one-dimensional proxy for the bewildering array of substitutable inputs which are capable of affecting the catch and population of a fishery in a given way. Such inputs include vessel length, tonnage, engine type and power, gear type and size, hull configuration and navigational equipment, to name but a few. We believe this approach is consistent with the overall state of biological knowledge about scallop fisheries and the accuracy of the information on which the models are based. However, it is recognized that a single proxy for a multi-dimensional phenomenon makes it difficult to suggest effective controls on effort (Wilen, 1979). A common procedure to obtain an appropriate proxy is to use the biologists' definition of effort, namely, the product of the fishing power of the gear multiplied by the time (or number of operations) for which the gear is used (Turvey, 1964; Tomkins and Butlin, 1975). Fishing power is the product of the area of influence of the gear in a single operation and the efficiency of the gear (Sanders and Morgan, 1976). The indicator of effort used in this study is in accord with this procedure. We have used the unit of effort known by the FWD as "effort A". This unit is defined as the number of hauls multiplied by dredge width and divided by one hundred. Effort measured in this unit has been collected by the FWD from records supplied by the fleet since the beginning of the fisheries. Because it attempts to measure the area swept by the dredges, effort A accounts for some of the differences in fishing power between scallop vessels. Indicators of effort which are more easily measured, such as hours fished or number of hauls, do not have this advantage.

The objective of the economic analysis was to find the quantities of effort and catch which maximize resource rent. In this simple form of static analysis resource rent was defined as the total revenue earned by the fishery (price times yield) minus the total social cost. Maximum resource rent occurs when marginal revenue equals marginal cost. It was assumed that the Victorian scallop fisheries face a perfectly elastic demand schedule for the following reasons. Firstly, there are many substitutes for scallops including oysters, lobsters, prawns, mussels and the more expensive cuts of meat. Secondly, Victoria produces around 60 per cent of Australian production and prices generally are determined on the world market. To test the sensitivity of the results three prices are used: $2.50/kg, $3.00/kg and $3.50/kg. At the present time the price is about $3.30/kg. It was considered that available data do not permit more refined analysis using less elastic demand, other objectives (Copes, 1972), and incorporating time (Clark, 1976). The objective of maximizing resource rent may be implied within the managers' set of objectives. Except for sustainable yield their other objectives cannot be quantified.

THE COST OF FISHING EFFORT

Debate exists as to the shape of the cost of effort curve for a marine fishery. Some writers assume that all inputs which comprise fishing effort are in perfectly elastic supply. In this case the cost of effort curve for the fishery would be linear and it would pass through the origin (Gordon, 1954; Tomkins and

Butlin, 1975). Other writers argue that the function should have a steadily increasing slope because ever-increasing rewards will be needed to lure away and retain labour and capital from alternative employment (Turvey, 1964; Copes, 1970). While the logic of this argument is appealing, to estimate such functions for the Victorian scallop fisheries would require detailed knowledge of the changes in the alternative earnings of labour and capital which may be attracted to the fishery, a task beyond our ingenuity. Griffin, Lacewell and Nichols (1976) have argued the case for a cost of effort function which exhibits a decreasing slope because fishermen's total costs contain some costs proportional to catch and some costs proportional to effort. Therefore, the function relating total cost to effort will reflect partially the curvature of the yield function, although the above arguments about the effort proportional component are still relevant. In their study of the Gulf of Mexico shrimp fishery, Griffin et al. found that the results obtained from using a model which differentiated between these two types of costs were different from those obtained using a linear model. However, these differences depend on the inclusion of catch proportional costs which are independent of the price of fish. It can be shown that if the only catch proportional costs incurred are those that are proportional to the value of the catch, the optimal catch predicted by the "proportional" cost model does not differ from that of the linear model (Belin, 1978, p.129). Because scallop fishermen incur "catch proportional" costs which depend on the value of the catch only (crew costs),[2] a linear cost of effort function was used. This may be written:

(1) $$TC_i = zE_i$$

where TC is the total cost of fishing in year i, E is the efort in year i and z is a constant. To estimate z a survey of scallop fishermen was conducted.

Because the number of holders of Victorian scallop licence is 113 it was considered feasible to attempt to interview them all. After accounting for those fishermen who did not fish during the survey period (29), were untraceable (24), who did not wish to particpate in the survey (29), or were unable to supply useful information (4), records for 27 boats were obtained. We attempted to obtain cost and income information from the interviewees for the three financial years 1973/74, 1974/75 and 1975/76. However not all of the 27 surveyed boats fished in every one of these years so that the number of boat-year observations totalled only fifty-two. Of these only 42 could be used to estimate unit costs of effort because ten observations were for boats which fished at both localities in the one year. This left 32 observations for the PPB fishery and 10 for the LE fishery.

Some of the reasons for non-participation require further comment. When licence holders live at localities around the perimeter of Port Phillip Bay or at Lakes Entrance, and their occupation involves movement, it becomes a difficult task to make contact with them. The fact that many boats changed hands during the survey years and that many of the previous owners had changed addresses exacerbated this problem. Included in the group which did not wish to participate were licence holders/skippers who showed no interest; those who felt that the survey was an invasion of privacy; and those who insisted that individual boat records were hidden in the aggregate costs of a larger firm and hence unobtainable. Although a Greek language interpreter was used on some occasions during the PPB part of the survey, language difficulties frequently prevented a successful interview. Apparently some people thought the interviewer was a taxation investigator. This attitude was hard to overcome resulting in further unsuccessful interviews. Twenty-nine people stated that they did not fish for scallops during the survey years. Some of these were probably exaggerating to avoid the formality of continuing with the interview. Finally, there was the small number of cases (4) where the interviews themselves were successful but the financial records were too confused by frequent changes of ownership to be useful.

There is a possibility that bias may have arisen as a result of the low number of successful interviews, particularly because of the relatively low number of interviews (for all the above reasons) with licence holders/skippers of Greek origin. Using the loose criterion of counting the names on the licence forms which seemed Greek, the proportion of Greek fishermen in the population was about 35 per cent, or twice the frequency in the survey. There is, however, no evidence to suggest that Greek fishermen, untraceable fishermen, or unco-operative fishermen operate differently from the remainder of the fleet. Nevertheless, the cost figures derived from the survey must be treated cautiously. Where necessary the sensitivity of the results to changes in the cost of effort is investigated.

To obtain a total cost for each boat-year observation it was necessary to make an allowance for the opportunity costs of labour and capital. The capital values of boats and equipment were the depreciated values of replacement costs measured in 1975/76 dollars. Depreciation schedules were estimated using the straight line method and the average life expectancies of the various types of equipment. The opportunity cost of capital was assumed to be 10 per cent per annum. Where a skipper was employed the payment made for his services was used for the opportunity cost of labour and management, otherwise $8,828 p.a. was used. This figure was the average annual earnings per employed male unit in Australia during 1975/76 (Australian Bureau of Statistics, 1976). To express all costs in 1975/76 dollars various indices of the aggregate Index of Prices paid by farmers (Bureau of Agricultural Economics) were used.[3]

Records of the effort expended by each boat were obtained from the FWD. Using these data it was possible to estimate the unit cost of effort for each fishery by adding all costs incurred by the sample fleet and dividing by the aggregate amount of effort. These estimates were $56.20 per unit of effort A for the PPB fishery and $111.70 per unit of effort A for the LE fishery.

The twofold difference in these units costs is attributable to higher costs in the LE group for the following items - crew payment, food for the crew, insurance, fuel and oil, repairs and maintenance and depreciation. Because crew costs are proportional to catch this item of cost is higher for the LE group because of higher catches. Greater insurance protection is used because of the possibility of losing a vessel in the rough conditions of Bass Strait and because of the dangers in traversing the sandbar at the entrance to the Gippsland Lakes. The greater size of the vessels in the LE group compared with the PPB group (13.1 m and 11.4 m respectively), longer travelling times, and ocean conditions help to explain the higher costs for fuel and oil, repairs and maintenance and depreciation.[4]

YIELD-EFFORT FUNCTIONS AND OPTIMAL EFFORT

Methods and Data

The basic assumption used to obtain sustainable yield curves was that catch is a function of population and effort, that is,

$$Q_i = g(x_i, E_i) \tag{2}$$

where x_i is the population at the beginning of month i, Q_i is the catch, and E_i is the total effort used in month i. The simplest form, and that usually suggested, for equation (2) is:

$$g(x_i, E_i) = x_i q E_i \tag{3}$$

where q is the constant of proportionality or the "catchability coefficient" (Clark, 1976, p.14). If the time between observations of Q and E is sufficiently large the population may change, causing (3) to predict unrealistically high catches when effort is high. A comparison of equation (3) with the exponential relationship $g(x_i, E_i) = x_i\ (1 - \exp(-qE_i))$ indicated that constant catchability was a reasonable assumption for the range of effort observed in the monthly data.

The change in the population each month was predicted using an hypothesised growth function and the current month's catch:

$$x_{i+1} = x_i - Q_i + f(x_i) \tag{4}$$

where f(x) is the hypothesised growth function. This difference equation is the discrete time analogue of the differential equation which describes the underlying process of growth and fishing in continuous time. Three forms of the growth function were used:

$$\text{Model 1:} \quad f(x) = xr(1 - x/K) \tag{5}$$

$$\text{Model 2:} \quad f(x) = nx^{m+1} - sx^2 \tag{6}$$

(7) Model 3: $f(x) = r(1 - x/K)$

Model 1 is the usual logistic growth function and model 2 is the generalized form of the von Bertalanffy growth function. Model 2 reduces to model 1 when $m = 0$. For all forms of the growth functions the population existing prior to fishing (x^*) can be predicted by solving the equation $f(x^*) = 0$, $x^* > 0$.

The first two models predict low net growth for populations which are either small or close to the maximum. Maximum growth, corresponding to the maximum sustainable yield, falls somewhere between these extremes. The assumptions which produce these effects are that growth is slow at low populations due to a shortage of breeding stock and due to a depletion of resources, such as food supply, at high populations. If $-1.0 \leqslant m < 0$ in model 2, the net growth does not decline to zero as population falls but approaches an asymptote. This implies that the population is able to regrow to a given size in a given period regardless of the reduction of initial size (Pella and Tomlinson, 1969).

When performing the regression with model 2 the estimate of "m" was found to be less than -1.0 (see below), resulting in a sustainable yield curve which is unbounded, that is, a maximum sustainable yield does not exist. While this is unsastisfactory for predictions of maximum sustainable yield, the curve is reasonable in the region of the observed data and so may provide useful information for management. This problem with model 2 and the intractable behaviour of the estimating equation (see appendix) suggested model 3. The important biological characteristic of model 3 is that the carrying capacity of the environment, expressed by K, is the only regulator on growth. As the population approaches K, growth approaches zero; growth approaches a maximum (r, the maximum sustainable yield) as the population approaches zero. Thus, the sustainable yield curve is asymptotic and the model predicts that fishing cannot exterminate the population although it may be greatly reduced in size. A nonlinear version of model 3, namely

$f(x) = r[1 + (x/K)(m-1) + x^2m/K^2]$, was also tested. All meaningful values of "m" were found to be consistent with the observations, thus "m" could not be determined.

The data used in the analysis were the monthly totals of catch (flesh weight) and effort A from the beginning of each fishery to June 1977. These data were obtained from FWD records which are compiled from fishermen's returns. For ease of presentation, table 2 and figures 1 and 2 show the annual aggregates of catch and effort for each fishery. The early years of PPB show the harvesting of a previously unexploited stock with rapidly increasing quantities of effort. The marked decline in catch per unit of effort during those years indicates that the population was being depleted, and that the observed catches were far from sustainable.

Catch throughout the life of the fishery was predicted by up-dating the estimate of the population each month using equation (4). In this process catch was predicted from the old population and the growth by f(x). The parameters of the growth function were estimated by regressing the predicted catches against the actual catches. This non-linear regression was carried out on Melbourne University's Cyber computer using the Fletcher-Powell subroutine of the International Mathematical and Statistical Library. The vector of parameters (β) and x* for each of the growth functions are:

Model 1: $\beta = (q,r,K)$, $x^* = K$

Table 2. Catch and effort data for the Victorian scallop fisheries

Observ'n number	Year	Catch (kg)	Effort A	Catch/Effort A
Port Phillip Bay fishery				
1	63/64	727 826	7 989	91.1
2	64/65	1 370 064	19 391	70.7
3	65/66	1 744 398	34 875	50.0
4	66/67	2 008 856	65 085	30.9
5	67/68	1 916 821	114 406	16.8
6	68/69	679 270	71 116	9.6
7	69/70	286 143	48 864	5.9
8	70/71	18 406	3 140	5.9
9	71/72	138 980	8 029	17.3
10	72/73	977 390	30 140	32.4
11	73/74	813 932	34 044	23.9
12	74/75	219 288	14 874	14.7
13	75/76	78 027	5 064	15.4
14	76/77	330 191	19 244	17.2
Lakes Entrance fishery				
1	70/71	640 797	21 635	29.6
2	71/72	1 015 882	30 935	32.8
3	72/73	906 063	18 546	48.9
4	73/74	294 366	7 487	39.3
5	74/75	341 752	11 578	29.5
6	75/76	663 897	17 966	37.0
7	76/77	230 575	5 960	38.7

Model 2: $\beta = (q,s,n,m)$, $x^* = (s/n)^{1/(m-1)}$

Model 3: $\beta = (q,r,K)$, $x^* = K$

Examination of the series of residuals for all models indicated strong autocorrelation (between 0.8 and 0.9) which would invalidate the assumptions underlying the determination of confidence intervals (appendix). To correct for this autocorrelation the variables were transformed by constructing a new series of residuals (v_i) using the relationship $v_i = u_i - \hat{\rho} u_{i-1}$, where u_i is the residual in month i and $\hat{\rho}$ is the estimated correlation coefficient. Each model was fitted again with this transformation to estimate the parameters and the confidence intervals. This procedure for correcting autocorrelations may be subject to bias and the results cannot be guaranteed. However, we believe that some confidence is restored because there was little difference between the estimated parameters in the two stages, the confidence intervals with the transformed variables were more conservative, and the autocorrelation in the transformed residuals was reduced to between 0.1 and 0.2.

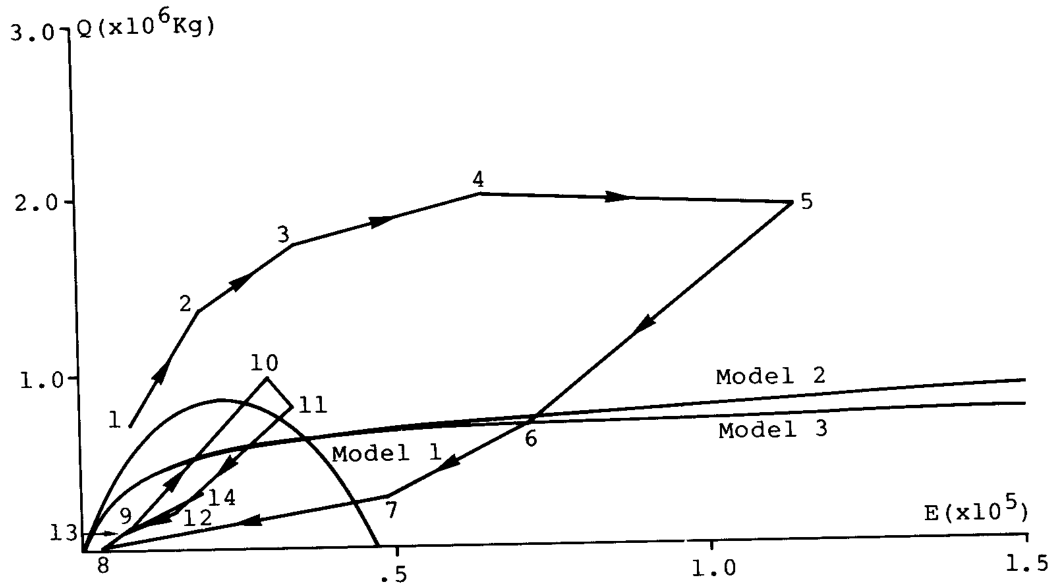

Figure 1 : PPB Catch and effort by year, and the estimated sustainable yield curves.

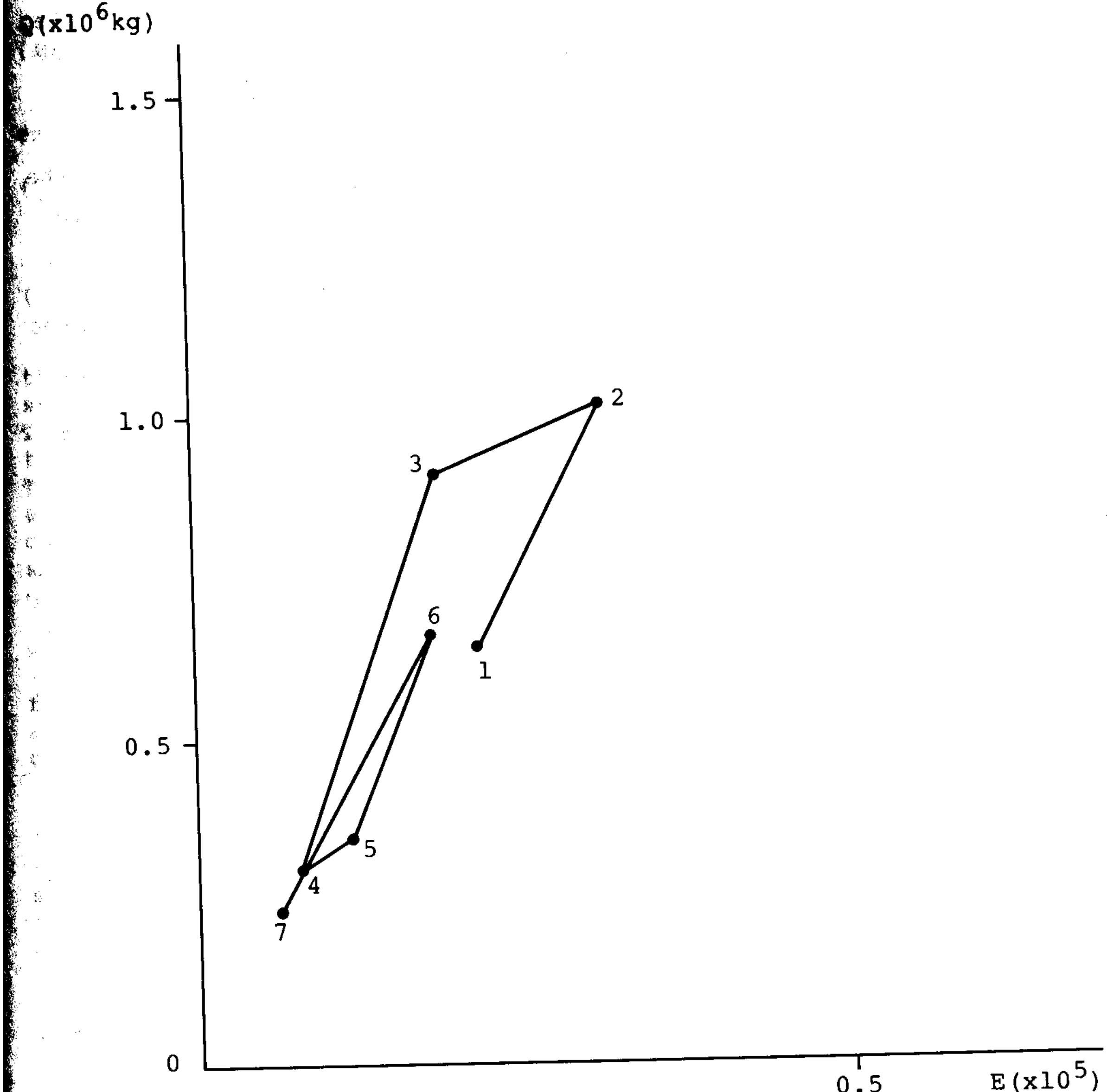

Figure 2 : LE catch and effort by year

Using the estimated parameters of the growth functions the sustainable yield curves were obtained by setting population change to zero and postulating a constant effort. This amounts to finding a size of population for which the rate of growth equals the rate of catch. Population is eliminated using equation (3) to give a yield-effort curve $Q = Q(E)$. For example, with model 1:

(8) $\qquad rx(1-x/K) = Q = xqE$

For $x \neq 0$, this can be re-written as:

(9) $\qquad r(1 - x/K) = qE$

Re-arranging gives:

(10) $\qquad x = K(1 - qE/r)$

Therefore:

(11) $\qquad Q = Q(E) = K(qE)(1 - qE/r)$

Equation (11) is a quadratic in qE. This quantity can be thought of as the proportion of the population caught. The sustainable yield curve has a maximum value of $Q = rK/4$ at $E = 1/2q$. Model 2 allows only numerical solution but the same mathematics apply.

Port Phillip Bay Fishery

The estimated parameters for <u>model 1</u> were:

$K = 6.268 \times 10^6$ $\quad(5.290 \times 10^6$ to $7.293 \times 10^6)$

$q = 1.161 \times 10^{-5}$ $\quad(0.950 \times 10^{-5}$ to $1.395 \times 10^{-5})$

$r = 0.046$ $\quad(0.035$ to $0.058)$

where the figures in parentheses are the 95 per cent confidence intervals for the parameters. To give an indication of the goodness of fit the standard error of the regression equation was computed. This figure is the standard deviation of the actual observations of catch from the predicted values and can be interpreted as an average error in predicting Q from the regression equation. The standard error of the regression for model 1 was 0.417×10^6 kg.

The sustainable yield curve resulting from model 1 is shown in figure 1. The maximum sustainable yield is 0.8586×10^6 kg per year (0.7196×10^6 to 0.9836×10^6) at 0.2360×10^5 units of effort A per year (0.2010×10^5 to 0.2786×10^5). Combining this sustainable yield curve with the cost of effort function (equation 1) permits determination of the maximum resource rent and the corresponding quantities of catch and effort. Resource rent (RR) may be written:

(12) $$RR = P.Q(E) - zE$$

where P is the price per kg of scallop flesh.

Maximum resource rent occurs when:

(13) $$Q'(E) = z/P$$

For model 1 the solution to equation (13) can be found explicitly as:

(14) $$Q'(E) = (-2K/r)(qE)(1-qE) + Kq(1-qE) = z/P$$

On re-arrangement equation (14) yields:

(15) $$qE = (2/r + 1 - ((2/r-1)^2 + (8z/P)/(rqK))^{1/2}) / (4/r)$$

The results obtained when equation (15) is solved for E, and the corresponding values of catch (Q) and resource rent (RR), are set out in table 3 for a range of prices and costs of effort. The width of the confidence intervals for E* and Q* indicate that these quantities are not highly predictable with this model. Therefore, the results suggest that "fine-tuning" in the allocation of effort to this fishery is not possible using past catch and effort data and a logistic model. However, there are some interesting features of the results. Firstly, the optimal quantities for the variables of interest are relatively insensitive to changes in price and cost over the indicated ranges. For example, for a cost of \$56.20/unit effort a 40 per cent increase in price (\$2.50 to \$3.50) gives a 13 per cent change in E* and a five per cent change in Q*. Similarly, for a price of \$3.50/kg, a 33 per cent increase in cost (\$56.20 to \$75.00) gives a 10 per cent change in E* and a four per cent change in Q*.

Secondly, using the average effort A per boat since the beginning of this fishery (494 units), it is possible to gain a rough estimate of "optimal" number of boats. The boat numbers shown in table 3 have been calculated at E* for each cell in the table. At all combinations of price and cost the boat numbers are markedly below the number presently entitled to fish PPB, namely 79. This remains true after allowing for the confidence intervals around the E* values. The highest upper-limit to the confidence intervals on effort occurs at a price of \$3.50/kg and a cost of \$56.20/unit effort, this value (0.2107×10^5) would suggest about 43 boats. Since the time of the survey, costs (noticeably fuel) have risen and price has been around \$3.50. Therefore, taking \$75.00/unit effort and \$3.50/kg as indicative of present conditions, model 1 suggests that the "optimal" number of boats lies between 29 and 38, with the best estimate being about 34.

The estimated parameters for <u>model 2</u> were:

$q = 1.186 \times 10^{-5}$ $(9.621 \times 10^{-6}$ to $1.435 \times 10^{-5})$

$s = 6.203 \times 10^{-10}$ $(3.636 \times 10^{-10}$ to $1.102 \times 10^{-9})$

Table 3. Best operating conditions: Port Phillip Bay Model 1

Cost of effort ($/unit A)	Price ($/kg) 2.50	3.00	3.50
56.20	E^* = 0.1631 (0.1412 to 0.1848) Q^* = 0.7766 (0.6377 to 0.9064) RR^*= 1.0249 B = 33	E^* = 0.1752 (0.1506 to 0.1998) Q^* = 0.8017 (0.6632 to 0.9296) RR^*= 1.4205 B = 35	E^* = 0.1840 (0.1580 to 0.2107) Q^* = 0.8168 (0.6784 to 0.9438) RR^*= 1.8247 B = 37
65.00	E^* = 0.1517 (0.1299 to 0.1711) Q^* = 0.7489 (0.6090 to 0.8809) RR^*= 0.8862 B = 31	E^* = 0.1657 (0.1424 to 0.1879) Q^* = 0.7825 (0.6437 to 0.9118) RR^*= 1.2705 B = 34	E^* = 0.1758 (0.1511 to 0.2004) Q^* = 0.8027 (0.6642 to 0.9305) RR^*= 1.6668 B = 36
75.00	E^* = 0.1387 (0.1182 to 0.1564) Q^* = 0.7127 (0.5704 to 0.8479) RR^*= 0.7415 B = 28	E^* = 0.1549 (0.1330 to 0.1750) Q^* = 0.7572 (0.6176 to 0.8885) RR^*= 1.1099 B = 31	E^* = 0.1666 (0.1430 to 0.1889) Q^* = 0.7842 (0.6454 to 0.9132) RR^*= 1.4952 B = 34

* Indicates optimal quantities. Units are: E(effort $A \times 10^5$), Q($kg \times 10^6$), RR($\$ \times 10^6$), B(boats), RR is evaluated to E^*Q^*; B is an approximation of E^*. The figures in parentheses are the 95 per cent confidence intervals.

$n = 3.463 \times 10^{6}$ $(1.192 \times 10^{4}$ to $1.747 \times 10^{7})$

$m = -1.295$ $(-1.422$ to $-0.903)$

where the figures in parentheses are the 95 per cent confidence intervals. The standard error of the regression for model 2 was 0.318×10^{6} kg. Although the error of prediction is lower with this model than with model 1, the behaviour of the sustainable yield curve ($m < -1.0$) suggests that it is not a satisfactory model for this fishery. Table 4 shows the optimal quantities of effort and catch at the selected costs and prices. These figures are shown without confidence intervals because of the behaviour of the estimating equation (appendix). The confidence intervals for a price of \$3.50/kg and a cost of \$75.00/unit effort were investigated in detail by the searching procedure and found to be 0.0565×10^{5} to 0.1277×10^{5} for effort ($E^* = 0.0843 \times 10^{5}$) and 0.2363×10^{6} to 0.6110×10^{6} for catch ($Q^* = 0.3740 \times 10^{6}$).

The slope and position of the sustainable yield curve (figure 1) produce smaller quantities for optimal effort and catch than model 1. Thus, for example, the number of boats indicated by model 2 for the highest cost and highest price is between 12 and 22 with the best estimate being 17.

The estimated parameters for <u>model 3</u> were:

$K = 7.270 \times 10^{6}$ $(6.411 \times 10^{6}$ to $8.341 \times 10^{6})$

$q = 1.188 \times 10^{-5}$ $(9.821 \times 10^{-6}$ to $1.451 \times 10^{-5})$

$r = 6.524 \times 10^{4}$ $(5.025 \times 10^{4}$ to $8.144 \times 10^{4})$

The standard error of the regression was 0.0315×10^{6}. This represents an improvement of 25 percent compared with model 1 which has the same number of parameters. Model 3 has about the same standard error as model 2 but fewer parameters. The sustainable yield curve on an annual basis is shown in figure 1; the maximum sustainable yield is 0.7829×10^{6} kg (0.603×10^{6} to 0.977×10^{6}). The optimal quantities of effort and catch (table 5), like those of model 2, are about one-half of those suggested by model 1. For example, the number of boats indicated by model 3 for the highest price and highest cost is between 14 and 23, with the best estimate being 18. The nature of the sustainable yield curve for model 3 gives slightly greater sensitivity of optimal effort to changes in the cost-price ratio than model 1.

Lakes Entrance Fishery

The catch and effort data for LE are such that it is not possible to obtain sensible estimates of the sustainable yield curve. Experimentation with the models used for PPB produced maximum sustainable yields and economic optima which were so large that the degree of extrapolation from the data points makes

Table 4. Best operating conditions: Port Phillip Bay Model 2

Cost of effort ($/unit A)	Price ($/kg) 2.50	3.00	3.50
56.20	E* = 0.0805 Q* = 0.3658 RR*= 0.4619 B = 16	E* = 0.0955 Q* = 0.3965 RR*= 0.6526 B = 19	E* = 0.1098 Q* = 0.4212 RR*= 0.8573 B = 22
65.00	E* = 0.0697 Q* = 0.3395 RR*= 0.3958 B = 14	E* = 0.0834 Q* = 0.3721 RR*= 0.5741 B = 17	E* = 0.0963 Q* = 0.3979 RR*= 0.7668 B = 19
75.00	E* = 0.0598 Q* = 0.3120 RR*= 0.3314 B = 12	E* = 0.0725 Q* = 0.3468 RR*= 0.4965 B = 15	E* = 0.0843 Q* = 0.3740 RR*= 0.6769 B = 17

* Indicates optimal quantities. Units are: E(effort $A\times10^5$), Q($kg\times10^6$), RR($\$\times10^6$), B(boats), RR is evaluated to E*Q*; B is an approximation to E*.

Table 5. Best operating conditions: Port Phillip Bay Model 3

Cost of Effort ($/unit A)	Price ($/kg) 2.50	3.00	3.50
56.20	E* = 0.0870 (0.0670 to 0.1085) Q* = 0.3834 (0.2933 to 0.4782) RR*= 0.4694 B = 18	E* = 0.1040 (0.0799 to 0.1300) Q* = 0.4182 (0.3208 to 0.5204) RR*= 0.6702 B = 21	E* = 0.1196 (0.0918 to 0.1499) Q* = 0.4453 (0.3419 to 0.5536) RR*= 0.8866 B = 24
65.00	E* = 0.0746 (0.0574 to 0.0928) Q* = 0.3533 (0.2693 to 0.4418) RR*= 0.3986 B = 15	E* = 0.0903 (0.0695 to 0.1127) Q* = 0.3907 (0.2990 to 0.4870) RR*= 0.5851 B = 18	E* = 0.1048 (0.0806 to 0.1310) Q* = 0.4199 (0.3221 to 0.5224) RR*= 0.7882 B = 21
75.00	E* = 0.0632 (0.0486 to 0.0784) Q* = 0.3215 (0.2437 to 0.4040) RR*= 0.3300 B = 13	E* = 0.0778 (0.0600 to 0.0966) Q* = 0.3617 (0.2760 to 0.4519) RR*= 0.5013 B = 16	E* = 0.0913 (0.0703 to 0.1140) Q* = 0.3929 (0.3007 to 0.4896) RR*= 0.6901 B = 18

* Indicates optimal quantities. Units are: E(effort $Ax10^5$), Q($kgx10^6$), RR($\$x10^6$), B(boats), RR is evaluated to E*Q*; B is an approximation of E*. The figures in parentheses are the 95 per cent confidence intervals.

them highly uncertain. The confidence intervals around these estimates were so wide that they could not be computed. There are several possible reasons for these results. Firstly, there are relatively few observations with which to work. Secondly, the range of observations is relatively small, reflecting the controls which have been operating on this fishery since it commenced. Thirdly, there is a set of reasons for believing that the assumptions of the models do not apply to this fishery in aggregate. Principal amongst these is that the LE fishery is dispersed over a wide area. It is possible that these grounds are not based on a distinct self-sustaining unit but represent separate populations. If this were true then those populations would need to be modelled separately, but models like those used for PPB would not be appropriate if there were significant migration between those populations (Pella and Tomlinson, 1969, pp.425-427).

Summary and Implications

The results of all three models support the hypothesis that the amount of fishing effort which can be expended in PPB remains excessive. While the confidence intervals attached to the estimates of catch and effort for all models strengthen this support they also indicate that "fine tuning" of the fishery may not be possible with static models which rely on catch and effort data alone. A serious problem for the managers is that the optimal quantities of catch and effort are far more sensitive to the form of the growth function than to changes in the cost-price ratio. This is evident when the results of model 1 are compared to those of models 2 and 3. Even though models 1 and 3 have different postulates about the growth of the population it is difficult to choose between them on a priori grounds. Model 1 has the comfort of convention while model 3 may be consistent with the scallop's method of reproduction and the observation that recruitment is variable. In the event, when the standard error of regression was used as the criterion, model 3 best fitted the data. These results indicate the importance of biological information which will help to discriminate between these models or suggest better ones.

The hypothesis of excess effort in the LE fishery can be neither confirmed nor rejected. A previous study by one of us (Belin 1978) argued that effort was excessive. However, in retrospect the assumptions of that analysis seem unrealistic. To the extent that separate populations are contained within the LE fishery, a more detailed analysis of catch and effort data by fishing area may be useful.

A MANAGEMENT STRATEGY FOR THE FUTURE

In this section we do not consider all the possible methods of managing the fisheries. The authorities have chosen to limit entry by licencing boats as a means of controlling fishing effort. Although this policy is relatively blunt and would need to be accompanied by some restrictions on the effort of individual boats, fishermen have come to accept it and, presumably, base their expectations on it continuing. As a result, radical departures from this scheme, such as an output tax or annual output quotas for individuals may be resisted by fishermen. Also major policy changes would require a cost-benefit analysis of the change-over. Such an analysis is beyond the scope of this paper, and except in the broadest qualitative sense may be beyond the limits of the available data. Indeed, the change-over costs would need to include the cost of obtaining appropriate data to implement any new policies, along with the costs of educating fishermen and the public, and differences in administration and enforcement costs. In the case of an output tax and two fishing grounds the cost of obtaining sufficiently accurate data, and developing models with superior predictive power to those discussed here, may be high relative to the other responsibilities of FWD and the small size of the scallop industry. Output taxes and quotas may be costly to enforce because of the relatively large number of processors and the proximity of a state border to the LE fishery. For these reasons we confine our attention to some modifications of the existing policy.

The major conclusion which emerged from our analysis is that the amount of effort which could be expended in PPB is in excess of that which maximizes resource rent. Our calculations with model 1 suggested that about 34 boats (less than half the present number) would be best in terms of that objective, and model 3 suggested about 18 boats. The following discussion uses the "conservative" result of model 1 by way of example. Implementation of our strategy will take time and this will allow further research on the population dynamics of the scallop. In the event that further reductions in effort are indicated by superior models (say, model 3) no structural change is required in the proposed policy.

If the number of boats operating in PPB were reduced to 34 the effect on resource rent at LE of the remaining 79 licenced boats is not known with similar confidence. Nevertheless there is evidence to suggest that the two fisheries have different capacities to produce rent and, therefore, ought to be managed separately. This cannot be achieved while the three types of licence exist.

In 1976 the Fisheries Management Committee suggested a solution to the problem of the three types of licences. All licences were to be converted to the all Victorian waters type. Every year a licencing panel would allocate boats to each fishery according to the owners' preferences. The numbers allocated to the fisheries would depend upon the results of annual surveys of the fishing grounds and up-to-date statistical information on catches and incomes. In the likely event that more fishermen preferred one fishery than the number the panel would permit, allocation would take place on the "relative merit" of fishermen. Merit would be assessed by a point score with high points for a place of residence near the preferred fishery, a long period of fishing on the preferred ground, and length of time the fisherman had held a scallop licence. The allocation made by this process would be reviewed mid-way through each year and altered if necessary. For unknown reasons this proposal, which again emphasises the philosophy of historical access and preserving the status quo, has not been implemented. Beside appearing to need considerable administration, the proposal left unresolved the question of the total quantity of fishing effort for both fisheries. Although this proposal involved only one type of licence it would have led to separate management because any movement between the fisheries was under the control of the administrators.

Our proposal to achieve separate management without the need for administrative allocation is:

* to create two classes of licence - PPB only and LE only,

* to allow existing fishermen free choice of their permanent fishery,

* to make licences freely tradeable,

* to create a "buy-back" authority with the power to purchase and dissolve licences in each fishery.

This strategy, which is a small adjustment in current practice, formalizes the de facto market in licences and offers the means to affect the long-term quantity of effort in each fishery without complete reliance on regulatory devices, such as daily quotas and closed seasons.

In the first instance, the holders of all Victorian waters licences would be permitted to choose the fishery in which they were to remain. In fact, given that few of the two resident groups would be likely to change, there is no reason why this choice could be not be extended to all fishermen. Allowing fishermen to choose their fishery probably will mean that more than the optimal number would choose PPB - hence the buy-back authority. This arrangement seems more equitable than allocating 34 boats to that fishery by a merit system. An alternative approach might be to auction 34 licences to an audience of all licenced fishermen. In this case the offer prices of successful bidders would be influenced by their expectations of the additional rent to be earned by the smaller number of boats. Given the imperfect knowledge of the fisheries this alternative may reduce the flexibility of the managers in future years. The more gradual approach suggested above permits the market, including the authority, and the managers' researchers to accumulate and utilize additional information. Any subsequent movement of fishermen between the fisheries would require the purchase of a licence for that fishery on the open market. Given that the de facto market in licences has not given rise to monopoly control there appears to be no reason to prevent the acquisition of more than one licence either within or between fisheries.

Making licences transferable would formally acknowledge that the first generation of licenced fishermen have been given their perception of the capitalized rent of the fishery for the given amount of licenced effort. However, as mentioned earlier, the relatively small amounts of money involved and the existence of the informal market make this an insignificant problem. When fishermen made their choice of fishery and the market began to operate it is likely that the value of the licences will alter. The extent of this alteration is difficult to predict but a likely result is that the value of PPB licences would rise and the value of LE licences would fall. As a result some fishermen, particularly those who had previously purchased all Victorian water licences, may feel aggrieved. Two reasons suggest that this problem need not be taken too seriously. Firstly, the amounts of money involved are likely to be small. Secondly, it is possible that, on average, holders of the all Victorian waters licences are the more efficient fishermen (Belin, 1978, chapter 6). Therefore, they may be more likely to remain in their chosen fishery and benefit as a result of the activities of the buy-back authority. In any case, changes in policy are one of the inevitable risks associated with the purchase of any asset.

Vigorous activity by the buy-back authority in PPB offers the facility to reduce the total effort in the fisheries. Because boats and licences would be tradeable separately the authority would need only to trade in licences. This seems feasible in this industry because the value of the boat was high relative to the value of a licence at the time of the survey. Since the survey licence values have increased but the same relationship with boat values exists. Therefore, in the short-term at least, scallop fishermen selling their licences should have little difficulty in disposing of their boat if they wish to do so. Scallop boats are not highly specialized in their design; in fact, older boats were converted from use in other fisheries. Similarly there was no evidence from the survey to suggest that the majority of fishermen are locked into the scallop fisheries because they lack skills which could give them occupational mobility. Some worked in other fisheries as well as scallops, many had trade skills, and some had businesses of which scallop fishing was a part.

The analysis of price in a licence market with a small number of potential sellers, an unknown number of potential buyers and one large buyer (whose purchases alter the available supply and affect the income streams of all participants) remains an intriguing matter for further research. There does, however, seem good reason to suspect that the operation of the authority will be made easier by freely saleable licences compared to the situation where the authority was the sole potential buyer. Similarly, the tactics of the authority in the timing, size and means of announcing its bids, and the amount of information it should reveal about the fisheries and its own intentions, are not immediately obvious. The effects of these variables on the operation of the market through time are researchable topics. There seems to be no set of possible answers to these questions which negates the idea of a market with a supply-influencing agent. Neither is it necessary to await definite answers before creating the market, indeed the answers may be expected only by studying the market in operation.

As the number of boats was reduced the remaining fishermen in each fishery would benefit from a greater share of the increasing rent. For example, the results of model 1 for PPB with a price of $3.50/kg, a cost of $75.00/unit effort and 34 boats, suggest that the average rent per boat would be about $44,000 per year. As this number of boats was approached there would be a considerable burden on the coffers of the authority. Also, in terms of income distribution, scallop fishermen would be seen to be privileged at the community's expense. These are good reasons for suggesting that remaining fishermen pay higher licence fees as the number of licences is reduced and that this intention be announced at the start of the programme. In the final analysis any changes in licence fees will be the result of a value judgement by the managers. By that judgement will be affected not only the rent acquired by the state, but also the prices of licences, and the wealth and income of scallop fishermen. Licence fees are levied according to the width of the dredge. Given that it would be impossible to police a fee based on the number of hauls and dredge width (both components of "effort A"), continuing to levy a fee on the latter component of fishing power is a sensible, although not necessarily a "best" approach. Manipulation of this fee may permit some rationalization of the controls on the effort of boats. For example, a sliding scale of fees in relation to dredge width may permit technical advance in dredge design which is prevented by the present limitation on dredges greater than 3.36 m in width. By itself, a policy of higher fees for dredges greater than this limit would encourage longer fishing hours and more hauls. Therefore the night-time embargo on fishing would need to continue. In the long term a reduction in the number of boats and such a change in the structure of fees could reduce, if not eliminate, the need for bag limits and closed seasons.

The far greater uncertainty about the response of sustainable yield to effort in the LE fishery suggests that the buy-back authority may be less vigorous in that fishery than in PPB. The licence values determined by the market, more detailed analysis of the catch-effort data by fishing area, and time will help it to formulate strategies for that fishery.

The managers' concern for the "satisfactory" incomes of fishermen will require careful scrutiny under separate management. If the managers were to be concerned about the distribution of income between the two fisheries, licence fees would be an important variable, given different capacities of the fisheries to generate rent. The only way to guarantee equality of incomes and to maximise the community's benefit would be for the managers to extract all the rent through unequal fees. If some rent were to be left to fishermen then all could be extracted and redistributed between the fisheries in some appropriate form, or licence fees could be manipulated further.

CONCLUDING COMMENTS

The choice of a management regime for a fishery will depend upon the objectives of the managers. This paper has reviewed the stated objectives of the managers of the scallop fisheries and found them to be difficult to interpret. The policy which has resulted from these objectives has emphasised control of the fleet's effort with little attempt to influence the size of the fleet.

The Fisheries Management Committee indicated that a reduction in the number of licenced scallop boats might be desirable (Fisheries Management Committee, 1977). However, their conviction that scallop populations are inherently unstable has prevented them from specifying any "right" number. Our study has confirmed that scallop production and populations are difficult to predict. However, using maximum resource rent as an objective, our study appears to confirm the managers' suspicion that there are too many boats - at least in the Port Phillip Bay fishery. As an upper limit it has been suggested the appropriate number lies between 29 and 38 with our best estimate being 34. No such recommendations can be made for the Lakes Entrance fishery at this stage.

Our suggestion for a means of achieving this reduction is based on separate management of the fisheries, saleable licences and an authority to buy and dissolve licences. This proposal would formalize the <u>de facto</u> market for licences and allow a reduction of effort in the long-term.

Although some controls on the effort per boat would need to continue this proposal may allow the set of controls to be reduced. By adjusting the licence fees resource rent may be distributed between government and fishermen as desired.

"Satisfactory incomes" seems to be one of the important objectives put forward by the managers. The meaning of this objective remains unclear and from a purely economic point of view it may be inappropriate to be concerned with ensuring "satisfactory incomes" for fishermen. Our proposals would leave unchanged the managers' options in relation to this objective.

NOTES

1. "Transfers" of licences must be approved by the Director of the FWD and in most cases approval is obtained. Technically, a "new" licence is issued to the purchaser of the boat. Most sales of boats are probably conditional on such approval being obtained.

2. In many fisheries, including the scallop fisheries, most crews are paid a share of the value of the catch.

3. In Australia there are no indices available which reflect movements in the prices paid by fishermen. It seems reasonable to believe that there is a close correlation between price movements in fishing and farming.

4. The average net incomes were $7,707 for the PPB group, $3,525 for the LE group and $8,605 for the group which fished both locations. After deducting allowances for the operator's labour and management the average percentage rates of return on capital were -0.5, -13.6 and +1.4 respectively. These rates of return are much less than those reported by Sanders and Sturgess (1968) for the PPB scallop fishery in 1964/65. Sanders and Sturgess reported their results for the following boat classes; under 36 feet, 36-40 feet, 41-45 feet and over 45 feet and the percentage rates of return were 24, 12, 27 and 11 respectively. These attractive rates of return explain why boat numbers rose rapidly in the first five years of the fishery. Conversely, the low rate of return for the PPB fishery from 1973/74 to 1975/76 helps to explain why the number of boats fishing was always less than the total number of eligibe boats. For further details of the costs and incomes of the surveyed fishermen see Belin (1978, Chapter 6).

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APPENDIX

The confidence intervals for the parameter estimates were obtained by extending standard procedures. This extension produces as asympotically exact confidence region for the parameters.

The basis of the procedure is that SSD (β) - SSD $(\hat{\beta})$ is distributed asympototically as $\sigma^2 \chi_p^2$, where β is the true parameter vector, $\hat{\beta}$ is the estimated vector, and p is the number of parameters (Shaw and Griffiths, 1979). If σ^2 is estimated by:

$$SSD(\hat{\beta})/(N-p),$$

where N is the number of years, then:

$$((SSD(\beta) - SSD(\hat{\beta}))/p) / (SSD(\hat{\beta})/(N-p))$$

is distributed approximately as $F_{p,N-p}$, thus defining a region of values of β for which the null hypothesis is accepted.

The confidence limits for a function of the parameters are given by the extreme values taken by the function over this region. The maximum and minimum of a function $P(\beta)$ are constrained extrema and were found by the algorithm of Nelder and Mead (1964) using a "soft" penalty function, namely:

$$5(SSD(\beta) \times \text{magnitude (gradient } P(\beta))) / \text{magnitude(gradient } SSD(\beta))$$

A step function was used for the confidence intervals on the parameters. There was evidence that the lower end of the confidence intervals for model 2 were approximate due to the existence of multiple local minima. This problem was overcome by searching the local minima using the final simplex as a guide to the constraint surface. This technique was found to be successful but very time consuming. For this reason only one set of confidence intervals was produced for the results of model 2. Models 1 and 3 did not have these computational problems.