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FISHERIES MANAGEMENT WITH PARTICULAR REFERENCE TO COMMERCIALLY EXPLOITED FISH STOCKS AROUND TASMANIA

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(with eight text-figures)

ABSTRACT

Multipurpose usage of the sea, including its major role as a source of high quality protein, demands the development and implementation of scientifically based management programmes. Technological advances in fishing have exaggerated the need for fisheries management based on stock assessment. A fish stock as a naturally renewable natural resource behaves generally in a manner susceptible to prediction by mathematical modelling. The work of Schaeffer and of Beverton and Holt is the basis of most currently used models. Economics play a major role in controlling commercial fisheries and fisheries managers must take both it and biological factors into account before intervening in a fishery to achieve stated objectives. Three Tasmanian fisheries are discussed in detail. A pot fishery for southern rock lobster is slightly over exploited and a reduction in the amount of effort seems to be required if production is to return to peak levels. A relatively new fishery for abalone based on collection by divers shows little sign of reaching maximum production although a previously steady increase in fished area now has ceased. The scallop fishery in D'Entrecasteaux Channel has collapsed and overfishing seems to have been a factor but other factors unrelated to fishing play some part.

INTRODUCTION

The sea is required for many purposes and is subjected to many forms of exploitation. Harvesting its fauna for human food is a traditional part of this exploitation which with a few notable exceptions has safely provided a continuous and naturally renewable source of animal protein constituting a very significant portion of the diet of much of the world's population. Current world production is 70 million metric tons, 45 per cent of world animal protein production. Ultimate production of protein from the sea might reach 100 million metric tons annually of the traditional species.

The valuable resource is characterised principally by its "common property" nature. The concept of the "freedom of the seas" dates at least from Grotius in 1608 and together with the "right" of the individual to exploit the resource is strongly defended within the fishing industry. It is often suggested that it is an "inalienable right" of the individual to exploit this community property.

This may have been morally correct and practically acceptable whilst exploitation methods remained primitive. Even so, legally it appears to have never been an unfettered "right" as the concept of conservation and the management of fish stocks is recorded in Egyptian, Greek and Roman literature. Now, there can be no doubt that stocks of fish subject to modern fishing techniques must be managed in order to both ensure their continuous existence and to maintain their productivity.

There is little doubt that, even amongst the varied interests gathered at a meeting such as this, there is widespread support for the "rational use of renewable resources". But the management required to achieve this objective has many phases such as, ensuring the provision of food or other naturally derived products, the maintenance of recreational opportunities and preservation for aesthetic or academic reasons. Sometimes these aspects conflict but the sea is large enough and diverse enough and sufficiently flexible to allow a satisfactory compromise to be achieved in most cases - providing, of course, that reason prevails during the negotiations. Here we are concerned with fisheries management defined broadly by Carlander (1969) as "everything done to maintain or improve fisheries resources and their utilisation".

Christie and Scott (1965) remind us that the steps that lie between fish in the water and fish products in the home are basically the same today as they were in the days of the earliest fishermen - fish must still be located, caught, transported and processed. The search is still of prime importance particularly for surface schooling fish. Hooks and nets remain the basis of catching, and the industry is still dependent on surface vessels.

However, particularly since World War II, rapid technological advances have made each fishery component many times more efficient. The search for fish has been revolutionised by the underwater sound systems developed for anti-submarine warfare, nets and ropes have been transformed by the production of a range of synthetic fibres and computers now design and control vessels and direct fleets to profitable areas.

This rapid progress in fishing efficiency has created a serious situation for fisheries management. The stage has now been reached where, at least on the international scene, fishing fleets can generate such a pulse of fishing effort that whenever a new resource is discovered it may become over-exploited before scientists can monitor the stock and suggest appropriate management measures. Fortunately, in near coastal waters where fisheries jurisdiction is established, strict controls can be introduced promptly and therefore the situation is not quite so critical. Of course in some cases inshore stocks have been subjected to a long history of inappropriate controls resulting in a diminished resource. Sometimes governments are unwilling to apply any controls for social or political reasons with the same inevitable result.

Ideally the exploitation of a fish stock should go hand in hand with the scientific investigations necessary to formulate the management measures which will achieve the goal of rational exploitation. Unfortunately in most cases investigations are not commenced until well after exploitation has started and often not until catch rates start to fall and the fishery appears to be in trouble. But it must be clearly understood that at the present stage of the development of fisheries science, precise stock assessment is not possible before fishing commences.

If exploitation of a new resource is under consideration the best steps that can be taken are:

(1) Resource surveying - resulting in preliminary management recommendations.
(2) Fishery monitoring during the development phase allowing continuous modification of the preliminary controls.
(3) Stock assessment of the established fishery providing the basis for a long term management regime.

Although only rough assessment and general control are possible early in the development of a fishery this is normally enough to restrict over-exploitation and unnecessary restraints should be avoided. If development is initially rapid interim precautionary measures should be used to control the situation even though they may of necessity be somewhat arbitrary.

STOCK ASSESSMENT - BASIS FOR MANAGEMENT

Any industry based on a renewable natural resource must have information on stock size and its behaviour, particularly under the stress of exploitation.

In an unexploited fish stock natural mortality tends to balance additions to the population and, apart from short-term natural fluctuations which are sometimes severe, the stock tends to remain fairly constant. So, changes can be described by -

$$S_2 - S_1 = (G + R) - M \quad (1)$$

where S = stock size, (at time 1 and time 2); G = growth; R = recruitment; M = natural mortality.

When exploitation commences, a second negative component "fishing mortality" (F)(principally the catch) is added so equation (1) becomes

$$S_2 - S_1 = (G + R) - (M + F) \quad (2)$$

It can be easily seen that, even with this new mortality component added, the yield from the fishery can be sustained if the catch and the natural mortality balance recruitment and growth. This is one of the earliest mathematical models developed for fisheries by Russell (1931). Its use has been theoretical rather than practical.

To describe the behaviour of fish stocks more adequately, further models have been produced; perhaps the two best known being those of Schaeffer (1954) and Beverton and Holt (1957). Since this work in the 1950s these models have been modified and expanded to describe and predict the behaviour of a wide range of exploited fish stocks. The Schaeffer model treats the fish population as a simple mass of fish and assumes that the population will increase if it is at a lower level than that which the ecosystem will sustain - its rate of increase will be some function of the population size, P, i.e.

$$\frac{dP}{dt} = f\ (P) \quad (3)$$

If a catch is taken from the stock then the actual change in population during a unit interval of time will be

$$P = f(P) - C \quad (4)$$

The catch during the year is also a function of the size of the population and the amount of activity expended to take the catch - this activity is called the "fishing effort" E

$$C = \emptyset\ (P.E.) \quad (5)$$

If the catch equals the rate of increase then the population remains the same - the <u>steady state condition</u> from (3)

$$C = f\ (P) \quad (6)$$

To apply the model in practice we need to have some expression for f(P) bearing in mind that if the population is zero it cannot increase and at its maximum it will stop increasing. Data from experimental populations and actual fisheries indicate that a good approximation is the quadratic.

$$fP = aP(P_{max} - P) \quad (7)$$

or the yield C_s on a sustained basis

$$C_s = aP(P_{max} - P) \quad (8)$$

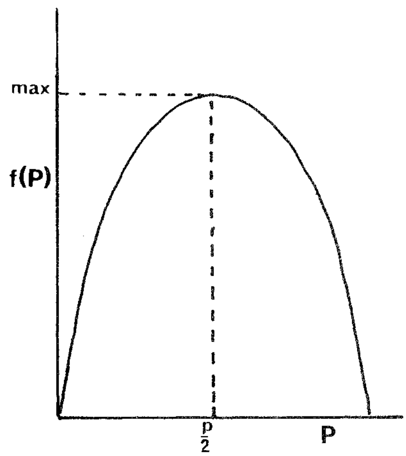

FIG. 26. - Rate of increase in population at varying population levels (after Schaeffer).

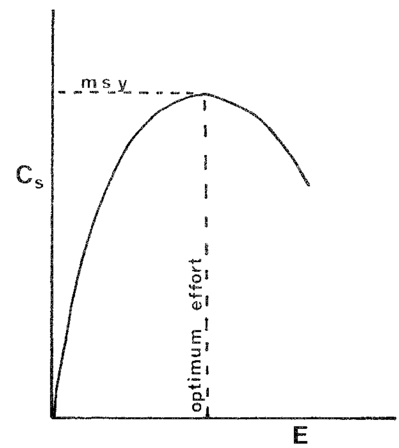

FIG. 27. - The theoretical relationship between the steady state catch and fishing effort (after Schaeffer).

In fisheries the population level is not usually directly measurable and the catch per unit effort U is used as an index to the population : the constant of proportionality is called the catchability coefficient.

$$P = \frac{1}{q} U \qquad (9)$$

Substituting in (8)

$$C_s = a \frac{1}{q} U \left(\frac{1}{q} U_{max} - \frac{1}{q} U\right) \qquad (10)$$

$$\left(\text{let } \frac{a}{q^2} = b\right)$$

$$C_s = bU(U_{max} - U) \qquad (11)$$

$$\text{or } E = b\,(U_{max} - U) \qquad \text{since } Cs/U = E$$

$$\text{therefore } U = U_{max} - \frac{1}{b} E \qquad (12)$$

$$\text{and } Cs = U_{max} E - \frac{1}{b} E^2 \qquad (13)$$

Therefore, in the steady state catch per unit of effort (U) and effort (E) are linearly related (equation 12) and catch is a parabolic function of effort (equation 13).

The exact slope of the curve depends on the initial assumptions made and later modifications of the Schaeffer model suggest that the right hand side of the curve which will be seen to be critical from a management viewpoint is probably flatter in most cases than predicted by the simple model. In practical terms this means that the decline of fisheries subjected to "overfishing" is slower.

Contrasting with these approaches, Beverton and Holt (1957) developed the earlier Russell philosophy and formulated a series of equations to relate yield to growth parameters, and to instantaneous rates of fishing and natural mortalities. These parameters may be measurable by appropriate scientific research on the fish stocks.

Whichever approaches are utilised to determine effects of fishing on stocks further factors have importance in the formulation of appropriate management regimes. These are chiefly economic and social.

BIOECONOMIC FACTORS IN MANAGEMENT

Without Government intervention commercial fisheries are controlled as much by the economics of fishing as by the biological status of the stock. It is therefore essential that when seeking to manage the exploitation process economic considerations be taken into account and if possible a bioeconomic model developed. The importance of economics is readily seen when one considers that the "laissez - faire" or "non-management" approach to fisheries control was the prevailing view in most countries until recently and is still more common that the "interventionist" philosophy.

The justification for "non management" is that in a commercial fishery, fishing will cease before the stock is reduced to a "critical level". This has now been shown to rest on doubtful assumptions and ignores the economic well being of the industry - a valid responsibility of the fisheries manager.

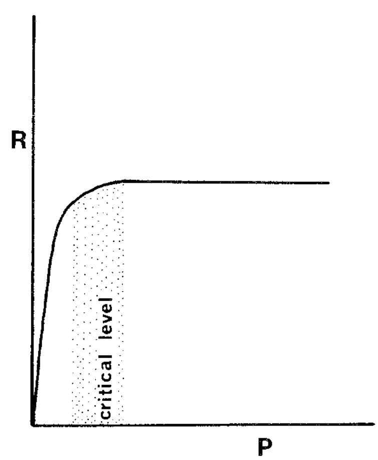

FIG. 28. - Stock and recruitment relationship. Recruitment is independent of population size except at low levels.

There now seems to be evidence that the assumption for practical purposes of independence between the size of a stock of fish and recruitment is not always valid. Whilst it seems likely that most stocks do behave in practice as though recruitment was independent, like the relationship in figure 28 some, particularly those in which the individuals have a low fecundity such as some elasmobranchs, show a more dependent relationship.

In addition it is now possible that large highly effective fleets can overshoot the critical level of stock size and reach the area shown on the extreme left of figure 28 before economic forces reduce fishing effort.

The economic health of the industry based on a particular stock hinges on the relationship between catch, fishing effort, the value of the catch and the cost of the effort.

Figure 29 describes the theoretical relationship where catch and its value increase along the line OA' with increasing effort. The rate of increase of catch slows until it ceases at B' when the maximum sustainable yield is being taken and thereafter yields decline. Assuming constant costs and prices, the cost of fishing effort is shown by the line OC' and OD' (total costs being higher than running costs by the allowance for capital). The area enclosed by the catch effort curve and cost effort line represents the net revenue from the fishery and at the effort level A net revenue A'E is a maximum - the corresponding catch level is the maximum net economic worth of the fishery and is the economic objective of fisheries management.

At effort level B the maximum quantity (usually weight) of fish is being harvested and this is probably the most common objective of the manager - the maximum sustainable yield.

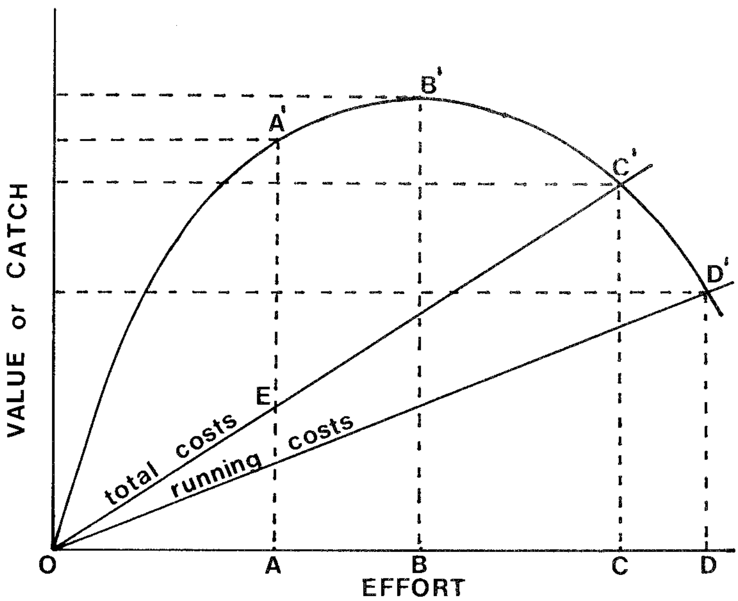

FIG. 29. - Total revenues, costs and sustainable yields with respect to effort (after Christie and Scott).

At effort level C total costs equal total value - theoretically the fishery is making no net economic contribution to the overall economy. Here the fishery operates on a subsistence basis which is a result of non-management but can often be caused by design in conditions of severe unemployment.

At level D the value of the catch is only covering running costs - the quality and efficiency of the fleet declines. Government subsidies may be paid or at least be actively sought.

Of course this situation is complicated by changing costs and returns and by natural variation around the catch effort curve. Fisheries managers have a number of methods available to them to control fishing effort and therefore maintain the fishery at a given point or to move the fishery in either direction along the curve. However the number of viable alternatives is controlled by the degree to which the management agency has legal jurisdiction over the resource.

STOCK ASSESSMENT OF TASMANIAN FISHERIES

As can be seen from the foregoing section stock assessment depends on accurate measurement of catch and effort or catch per unit effort of each fishery extending over a reasonable time period.

Catch figures are usually readily available though sometimes of questionable accuracy and often not sufficiently segregated geographically. In Tasmania reliable effort figures are not available for the years before 1963 and even now doubts still exist about the chosen effort units in some fisheries. Where no effort measurements are available it is possible to calculate a figure if reliable catch rates, i.e. catch per unit effort can be obtained. As fisheries research vessels are of very recent origin in Australia the only other available source of this information is the log books of commercial fishing boats, preferably groups of boats.

It is interesting to note that early in the history of Tasmania quantative fisheries information was collected; however, very little remains of what records were maintained before World War II.

Economic data on Tasmanian fisheries is very limited indeed. Smith and Fergusson

(1969) comprehensively surveyed the rock lobster fishery in 1964-65. A further study on this fishery and the abalone fishery is in progress.

Rock Lobster

The fishery for Southern Rock Lobster is the most significant component of the State's fishing industry and has been so for many years. It has been managed since last century and strict controls have been necessary in recent years. Winstanley (1972) reviewed the history of the fishery and the data in figure 28 come largely from that paper. Annual catches are recorded as far back as 1888 and some indication of effort from 1926. The currently used unit of effort is the potlift - when a standard lobster pot is set and hauled once. But as a reasonable first approximation total annual fishing effort can be assumed to be proportional to the number of vessels fishing in that year and as this figure is known for over 40 years this data series has been used to assess the stock.

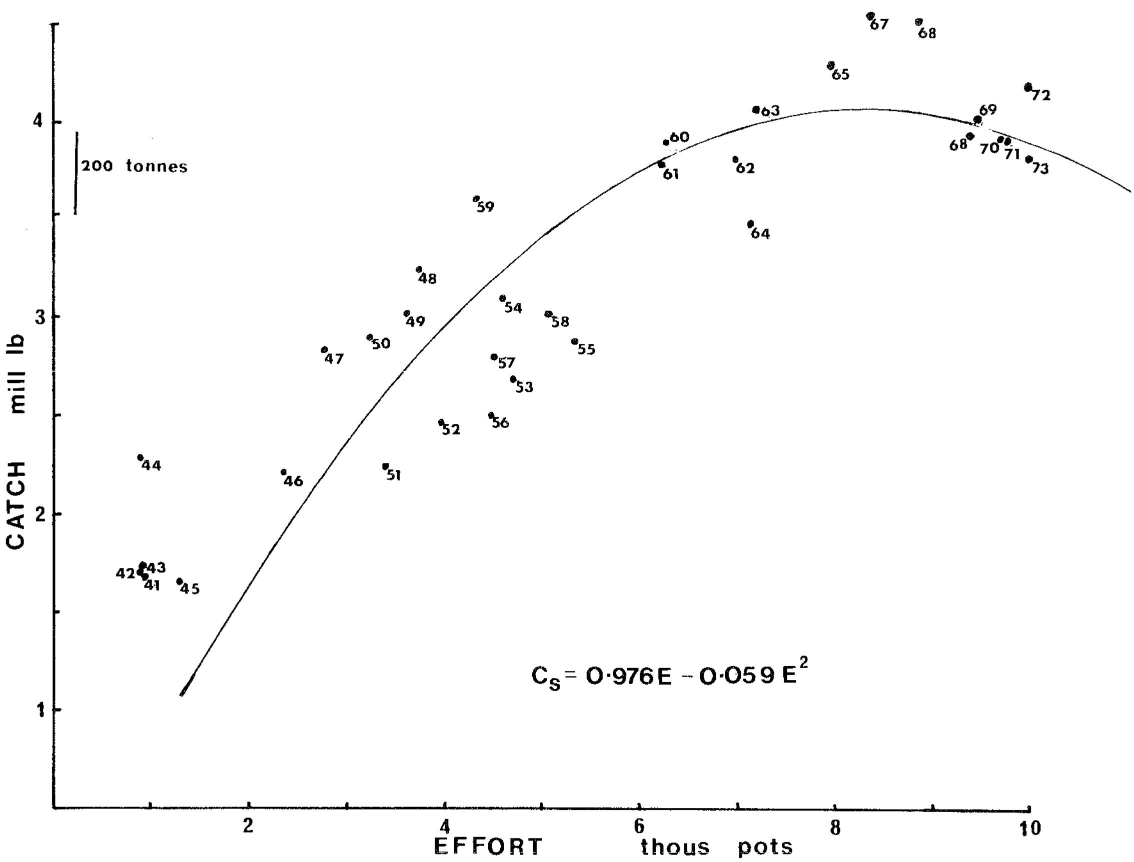

FIG. 30. - Catch and effort for the Tasmanian southern rock lobster fishery 1941 - 1973. Catch is expressed as millions of pounds landed weight and effort as thousands of lobster pots used each year.

The curve in figure 30 is computed by Bradbury (in preparation) using the method of Schaeffer and reveals that in this fishery the effort already exceeds the optimum under conditions currently applying. Any increase in fishing effort must be expected to decrease the yield unless other controlling factors, such as the age of first capture, can be favourably adjusted.

Abalone

Commercial harvesting of these marine snails commenced in Tasmania late in 1964. Previously there had been isolated insignificant trials but in practical terms this is one of the few examples of a fishery that has been studied and closely monitored from the virgin condition.

It is also unusual in that the fisherman is also the fishing gear and he can observe most of the fish population.

Figure 30 shows that annual levels of fishing effort continued to increase until the late 1960s and was matched by almost proportional increases in catch. However when effort reached 38,000 diving hours per year and appeared likely to go much higher the Government intervened to hold it near that level by limiting entry to the fishery until a better assessment could be made.

Assessment is complicated by both a steady increase in fished area and the presence of small pockets of virgin stock densities within the fishing blocks. However taking zone 2 only (Tasman Island to Port Davey) these problems are minimised and figure 31 shows some evidence of a slowing of the rate of increase in catch per unit increase in effort. These data together with analyses of length frequencies in the commercial catch indicate that at least, in some areas, the sustainable yield of the area is being approached.

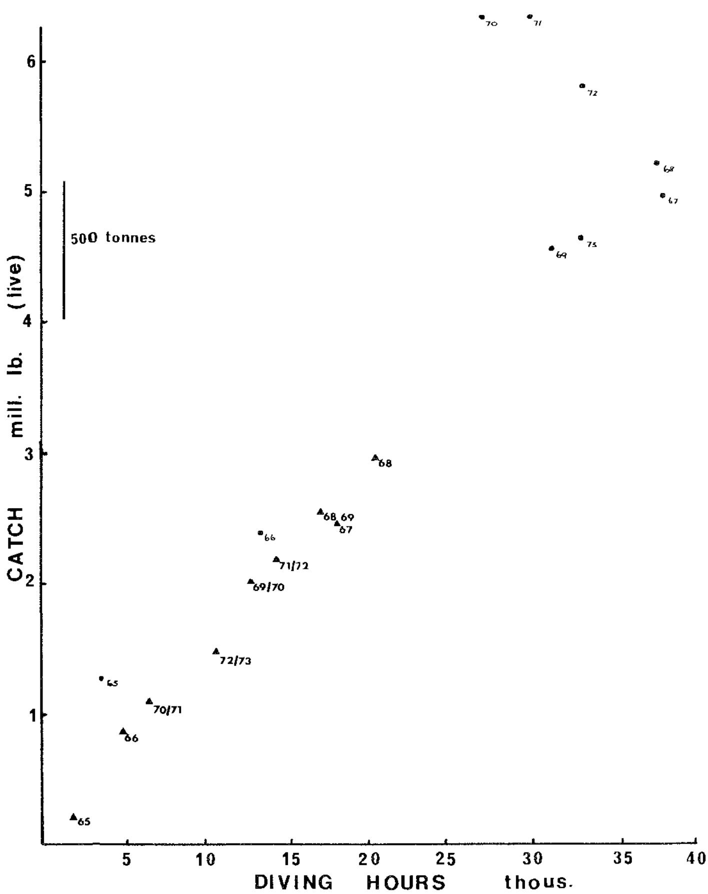

FIG. 31. - (a) Catch and effort in Tasmanian abalone fishery 1965 - 1973. Catch expressed as millions of pounds live weight and effort as thousands of diving hours (circular symbols)
(b) as above but for zone 2 only (triangular symbols).

Scallops

There is certainly no fishery in the State and probably no other Tasmanian natural resource that has for so long been a topic of public controversy as the scallops. Its fluctuations have been the subject of parliamentary committees of enquiry, public debate and continuous discussion in the press. The basic cause of the population fluctuations is the scallop's highly variable, and as yet unpredictable, recruitment. The combination of high fecundity and apparent sensitivity of the recruitment process to environmental conditions, results in years of high recruitment interspersed with years of low and often negligible spatfall. Thus we have a population behaviour pattern perhaps more akin to that of plague insects such as locusts than fish, where a possibly complex combination of favourable biological and environmental factors is required for a successful mass spatfall. Therefore there is some support for the hypothesis that the "normal or average" population density of scallops in most areas is very low almost certainly below that necessary to sustain a commercial fishery in the usual way and fishing only takes place in "abnormally high" population densities which are by definition discontinuous.

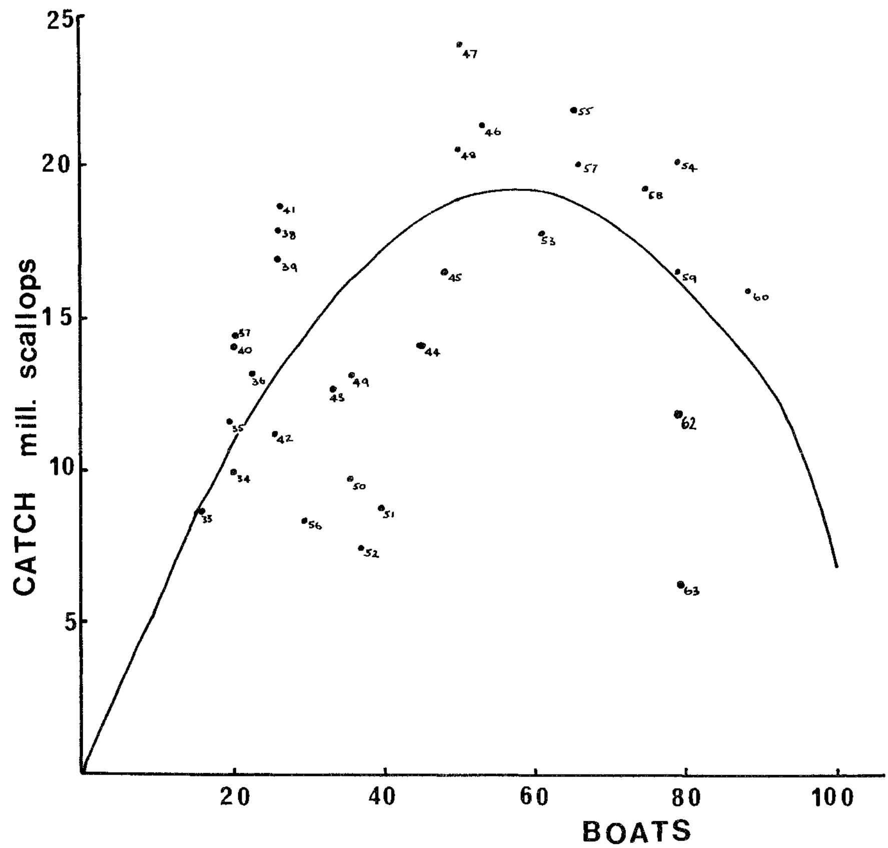

FIG. 32. - Catch and effort for scallop fishery in D'Entrecasteaux Channel 1934 - 1963. The effort unit is the number of boats fishing each year. During this period there was some variation in the species composition of the catch and in the prescribed length of the fishing season. Catch is expressed as number of scallops landed. The curve, drawn from the Schaeffer model $Cs = 6.58 \times 10^5 E - 5.73 \times 10^3 E^2$, indicates a maximum sustainable yield of 19 million scallops at the effort level of 58 boats.

But some areas do regularly sustain high population densities and this no doubt was the case in D'Entrecasteaux Channel. Figure 32 shows the variations and decline of production in this area and the other significant scallop areas. Some of the fluctuations are explainable in terms of variation in fishing methods and species interaction however most are due to recruitment variations.

Figure 32 reveals that effort in the Channel increased steadily through the 1950s until it reached a peak in 1961 resulting in peak production followed by a dramatic and seemingly permanent collapse. However although the catch and effort curve superficially seems to point to overfishing in the classical sense there were known to be other important factors operating. For example over the 50 years from 1920 to 1970 scallops have slowly but steadily "retreated" from the Derwent Estuary above Hobart southwards down the Estuary and then down the Channel. This retreat can be readily correlated with increasing population and industrialisation in the Hobart area and so with pollution of the Derwent and surrounding waters. Some of these pollutants being released into the Estuary are known to be toxic to scallops.

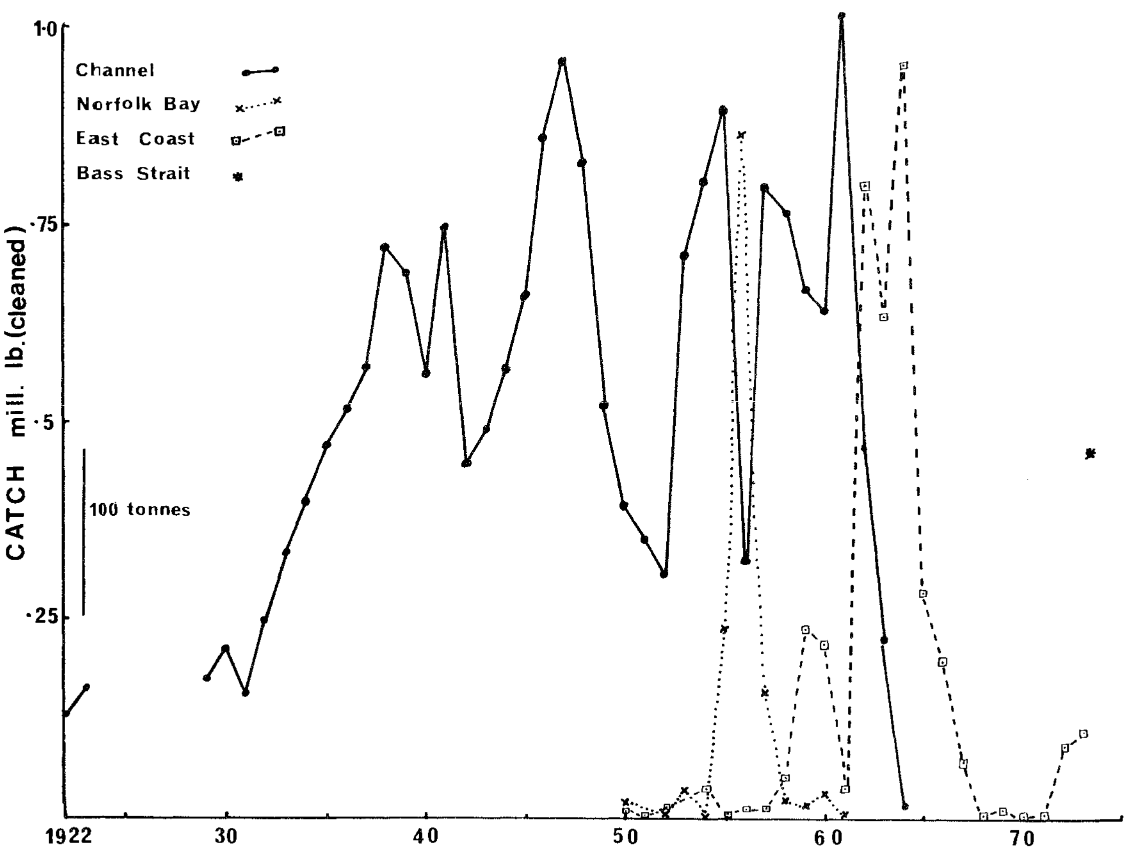

FIG. 33. - Annual landings of scallops in Tasmania for the main fished areas.

The sea floor in D'Entrecasteaux Channel seems now to be noticeably different to that referred to by earlier investigators and the inferred change no doubt had an effect on the benthic fauna. There is little evidence to support the popular view that dredging with the "sputnik" dredge significantly contributed to the decline, in fact C.S.I.R.O. investigations (Olsen unpublished) including underwater films seems to refute the argument. On the other hand current work by Dix (in preparation) on scallop spawning and larva indicate the apparent marked sensitivity of scallop eggs and larvae to minor changes in water quality.

Other Species

Catch and effort data on other species are not adequate for meaningful stock assessment at least at present. An investigation, principally being carried out by the Fisheries Division of the Victorian Department of Conservation for the whole of south-eastern Australia, is underway into the population dynamics of the edible shark species but the problem is complicated by the fishery's multi-specied nature. Heavy fishing on a stock with apparently limited recruitment potential can quickly result in over-fishing.

The snoek fishery has not varied greatly in recent years and fluctuations seem to be unrelated to fishing pressures.

A small fishery for Australian Salmon is part of the larger southern Australian industry and local exploitation is not significant in the total concept.

The beginning of a purse seine fishery for jack mackerel this year has afforded another opportunity to commence stock monitoring at the start of a fishery. The stock is large, possibly migratory and the fish occur in schools during at least part of their life - all these factors pose problems for the stock assessor.

CONCLUSIONS

Active fisheries management is essential to achieve the goal of rational exploitation of the State's marine resources. This goal has a number of components some of which may be potentially in conflict. To formulate an appropriate regime to control the commercial fishery reliable stock assessment and complementary economic information necessary to cope with the modern fishing industry is essential. In Tasmania most of the available pre-requisites for adequate management are now available - fisheries jurisdiction is accepted, adequate statistics are being collected and appropriate models and people to operate them are now available. Further biological and economic information is required to complete the management foundation. What is perhaps more important is that the management agency - the State Government - has shown a readiness to implement and subsequently modify management regimes. The well being of the State's marine resources for commercial or other purposes can only be ensured by active management based on factual stock assessment.

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