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Resource management, its objectives and implementation

by

D.J. Garrod
Ministry of Agriculture, Fisheries and Food
Fisheries Laboratory, Lowestoft, Suffolk, England

INTRODUCTION: CURRENT MANAGEMENT OBJECTIVES

Simply stated, a resource is either under-, fully- or over-exploited in relation to its potential biological productivity. The under-exploited stock is one where a further increase in exploitation will increase yield, the fully-exploited stock is one in which the level of exploitation will harvest the potential yield without endangering future catches and an over-exploited stock is one where exploitation has reduced the supply of young fish to the stock causing a shortfall on the potential yield. The fully-exploited stock is therefore fished to provide the maximum yield per recruit, which is at the same time the maximum sustainable yield (MSY), but the over-exploited stock has been fished at a level which, though it may give the maximum yield per recruit of fish in the stock, these recruits are declining in number and it will not give the maximum sustainable yield.

Fisheries management has developed from the desirability of conserving the resources and has defined its objectives in relation to the potential yield levels outlined above. There is an alternative view that the primary objective of management is not to preserve the resource and its yield but to optimize the economic performance of the fishing industries dependent on it. This is embodied in the concept of the maximum economic yield (MEY), which general studies have indicated will be located at a lower level of fishing than that giving the MSY, though this may depend on the breadth of economic implications taken into account. The same concept is

[1] All ICNAF documents will now be numbered to include the month (in Roman numerals) of the meeting at which they were presented.

incorporated in the notion of F_{OPT} which, formally, is the point at which the marginal cost of fishing and the marginal revenue are equal. It has been represented by $F_{0.1}$ where the marginal revenue is one tenth that of the fishery beginning on an unexploited stock but clearly there is a range of options here, none of which has unique merit.

There has been considerable controversy in recent years at the technical level on the relative merits of the MSY and MEY objectives. A part of this arises because although both are attractive theoretical concepts they are difficult to define as a practicable basis for management. The MSY of a stock cannot be located because of uncertainty regarding the stock and recruitment relationship and the MEY cannot be identified because of the complexity of economic factors, especially in an international fishery. The Convention initially defined the primary objective in terms of the MSY and, although the terms of reference have been broadened in recent years, the management measures so far adopted have retained the same rationale. It is in the development of practical management to meet this objective that difficulties have arisen which can best be seen in the context of the scientific advice on which they have been based and which have stimulated a further review of the MSY objective.

SCIENTIFIC ADVICE RELATED TO THE LEVEL OF EXPLOITATION

Recent scientific advice on under-fished stocks has been to control the rate of development of a fishery while the potential of the resource can be evaluated. Given the history of fishing in the ICNAF area in the 1960s the wisdom of such caution has been self-evident and this category will not be discussed further. Advice to distinguish between the fully- and over-exploited stocks has been far more critical because the two require different management actions. A fully-exploited stock can continue to be exploited at that level and, in practice within ICNAF, this has meant regulation of such stocks at a level of exploitation allowing the greatest amount of fishing (F_{max}) which will at the same time take the greatest catch without causing over-exploitation (MSY). Correction of over-exploitation requires a reduction in exploitation with a severity depending on the degree of depletion of the resource in question. Management decisions have therefore relied heavily on estimation of the MSY or the F_{max} at which that should be obtained.

Scientifically however there is technical uncertainty and a lack of biological criteria defining the stock and recruitment relationship which governs the distinction between a fully- and an over-exploited resource, and as a result it is seldom easy to identify a stock which has been depleted until the effect becomes very obvious. On the administrative side there are some doubts also owing to a lack of confidence in the adequacy of enforcement of Commission regulations and its effect on the efficiency of the regulations that are agreed. It is not possible to define the margin of error involved with either uncertainty and this, allied to the time lag in revision of management measures, allows the real possibility that regulations set at an MSY level will allow the degradation of a fully- to an over-exploited stock even within the regulated system. These doubts have intensified where poor recruitment has led to a natural reduction in stock abundance.

These specific uncertainties relate to the management of individual stocks but in the practice of management other difficulties have arisen because fisheries are seldom based on single stocks but on a complex of resources of varying interest to the different countries. In particular in mixed fisheries the present framework of catch regulations may lead to incompatibility between TACs on species caught together so that it is not possible to achieve the TAC of each one simultaneously. There is also scientific concern regarding the biological interaction between the separate resources.

Taken together these various factors have called in question the value of TACs set in relation to the MSY of individual stocks and led to the suggestion that a new objective should be adopted to reduce exploitation to a generally lower level in order to alleviate the biological risk and, by increasing stock size, confer the economic benefits associated with it.

There are two specific suggestions defining the alternative objective. These are (a) to establish the TAC of individual stocks on the basis of a stock constraint, (b) to consider the resource complex in particular areas as a whole and adopt either catch or fishing effort regulations which would pertain to the whole. There is also the additional possibility of combining the various modes of regulation.

The formulation of catch regulations based on designated stock sizes is described by Garrod (Res.Doc. 75/IX/124). Its primary advantage lies in overcoming technical difficulties in defining the MSY when the stock and recruitment relationship is not known. Other advantages may arise in developing a management strategy to restore stocks that have been depleted.

Management objectives based on general production models have been discussed at previous meetings and consideration of the effect of biological and fishery interactions in defining the MSY, or the effort associated with it, is developed further by Pope (Res.Docs. 75/IX/126, 75/IX/127) and Horwood (Res.Doc. 75/IX/125). These studies show that, in the case of pronounced biological interaction where one resource may increase to replace another which is heavily fished, then the overall MSY of the resource complex may only be achieved by a very specific mixture of fisheries aimed at the different species and that outside these limits the species composition of the complex, and catches, will be very dependent on the level of fishing mortality applied though the overall total catch may be fairly stable. In an analogous way, if there are no biological interactions then the attainment of the MSY will depend on the species preferences of the fisheries involved and, if these vary with species abundance, then the yield may be stable over a range of levels of fishing though this may not be the theoretical MSY of the resource.

Theoretical consideration of two interacting fisheries again indicates that the overall MSY will be associated with a particular species composition and its achievement will depend on the fisheries exploiting the complex being matched to that 'optimal' species composition.

These various lines of evidence indicate that the general production models do not necessarily indicate the MSY of a complex, but possibly only the MSY of fisheries having had the species preferences observed during development of the fishery. In the event of the total level of exploitation being regulated by an overall catch or effort regulation the 'true' MSY is only likely to be achieved by a very 'mixed', i.e. indiscriminate, fishery. It is also apparent that the level of catch may remain fairly stable over a wide range of levels of exploitation though there is a progressive change in species composition. This is important because species will continue to vary in their economic importance and so there is the possibility of gradual degradation of the total resource towards species which were initially of least value.

In practical terms this means that the general production models do not necessarily indicate the catch or effort to be associated with the MSY, particularly if the analysis excludes some part of the resource complex. It also suggests that the same total yield could be obtained over a range of levels of exploitation. Thus a single overall catch regulation might not achieve the MSY and it would not protect particular stocks but would allow shift in the species composition, possibly in an adverse way. Equally a single overall effort regulation might not achieve the MSY but it would tend to fix the species composition of the resource in a particular way. If the resource complex and all its component interactions were sufficiently understood an array of individual catch regulations should, in principle, achieve the Commission objectives in respect of yield. Since these are not fully understood it is necessary to protect the individual species so far as possible, using stock constraints where necessary, and to augment this by an overall regulation which provides a 'cushion' against unknown interactions and preserve a satisfactory resource configuration.

THE IMPLEMENTATION OF COMMISSION REGULATIONS

The foregoing discussion identifies the regulatory requirements in relation to any level of exploitation that might form the objective of the Commission. If the objective remained the MSY, or some strategy associated with it, then both single species and overall regulations would be desirable. If the Commission adopted an objective more explicitly related to economic considerations this would be examined in relation to the potential level of catch and effort involved and would again require both types of regulation if the objective were to be achieved. But whatever the objective or complexity of the resource array to which it is applied, the management strategy must be implemented by either catch or effort regulations. The choice between these options has not yet been resolved, perhaps because the solution resides in a 'package' of regulations appropriate to each area rather than in one or the other as a generally 'best' approach. The relative merits have been considered by STACRES and STACREM (Table 1 of Special Meeting of Experts on Effort Limitation, Woods Hole, 1973 - 1973 Meeting Proceedings, p. 77) and discussion since that time has helped to focus attention on the main areas of difference. These concern

(i) scientific aspects arising from the statistical reliability of estimates associated with each type of regulation (which bear on (ii)),

(ii) administrative aspects concerning the ease of allocation of a regulation and its enforcement, and

(iii) sovereignty - the degree to which an international organization should influence directly the economic performance of a national industry by control of both catch (earnings) and effort (cost).

Two particular administrative aspects of catch quota regulations do feed-back to influence the scientific area, the monitoring and reporting of the catch statistics and the effects of discarding at sea. These might be offset by adjustment of a catch regulation as a 'cushion' but this must be held entirely separate from the scientific advice and undertaken as a specific aspect of Commission policy.

This review is concerned only with the scientific merits of the two modes of regulation. These fall into three categories

A the estimation of stock size in relation to Commission objectives,

B the precision with which that objective can be achieved,

C the influence of scientific precision on the ease of allocation of the regulation.

Each of these categories should be considered in relation to both single species and an overall regulation of a resource complex.

A The estimation of stock size in relation to Commission objectives

(i) Single species

The comparison between the existing stock size and some desired stock size provides the basis for every resource management strategy. Sources of uncertainty in estimates of the existing stock size have been discussed; they arise from deficiencies in analytical techniques, bias and random error in sampling, and in the estimation of parameters. These have the same influence on both modes of implementation and need not be discussed further,except to observe that they blur the precision that can be expected of any management procedure.

(ii) Resource complex

It follows from the previous discussion that an overall regulation cannot be regarded as a precise measure: its need arises because the information is not sufficient to specify the size of all individual stocks precisely. The level of such a regulation is deduced from relationships between observed catch and effort. Errors in estimation of overall stock size may arise through failure of the fishery to exploit the total available resources but, as with the consideration of the effect of such errors on individual stock regulation, the errors will affect subsequent catch or effort regulations to a similar extent.

B The precision of a regulation

(i) Single species

Most recent studies have concentrated on the statistical precision of forecast estimates of the level of catch or effort for achieving the objective. Given a specified stock size of fully recruited age groups and the level of fishing mortality aimed at, the estimate of a catch quota will be most heavily influenced by the error in numbers of young fish entering the fishery,and effort regulations will be influenced by year to year, or within year, variations in the effectiveness (catchability) of the unit of effort. Previous analyses of these errors suggest that in both cases the level of exploitation achieved by a regulation will have a coefficient of variation ± 20-30 per cent of the intended level of the regulation (Pope and Garrod 1975).

(ii) Resource complex

The multi-species fishery situation introduces additional error in the precision of the single species regulation, or of a single overall regulation, through the influence of undetected biological or fishery interactions between the component resources. In the context of catch regulations the overall TAC will in general be less than the aggregate of the individual species TACs because of the by-catch problem in a mixed fishery. It is unlikely that the allocation for all species caught together will be fulfilled at the same time, so that the actual catch (leading to the overall TAC) should be conditioned by fishing ceasing when the TAC of one or other of the species in a mixed fishery has been taken.

In the context of an overall effort regulation the directivity of fishing to the individual species could be expected to vary with short-term variations in abundance and species preference leading to changes in the catchability coefficient used as a basis for the regulation and hence in its efficiency.

As with errors in stock size, the errors involved in projecting the present effect of fishing to their presumed effect in two years time are impossibly difficult to quantify: they may be very specific to each species complex and vary with time within it. As before, the only conclusion that can be drawn is that the errors will reduce the precision with which any resource can be regulated. The studies do not point unequivocally in favour of one method or the other.

C The influence of scientific precision on the allocation of a regulation

(i) Catch regulation

The purpose of the regulation as defined here is to maintain the stock at a determined level by permitting the harvest of a specified quantity of fish. The regulation of catch is therefore a direct approach to the objective in a quantity which, although subject to errors in its estimation in relation to the objective, once it is determined can be allocated directly.

(ii) Effort regulation

A fishing effort regulation seeks to control the catch by harvesting a proportion of the stock and this proportion is not necessarily constant. Its allocation depends on the assumption that a given unit of fishing activity will harvest a constant proportion of the stock so that, once the proportion is determined, the number of units of effort is defined. This necessitates conversion of a derived fishing mortality to a quantity of fishing by a standard unit and its reconversion to national units. In all methods so far proposed this derivation depends at some point on the comparison between catches over time of different vessels,and therefore the system incorporates some aspect of the historic performance of a vessel in terms of catch overlaid by the influence of vessel efficiency. The system is vulnerable to differences in the basic information that would invalidate the comparisons between vessels, e.g. species composition of catches, and it is particularly liable to error in the essential predictive sense if the constraint of regulation leads to the modification of fishing patterns.

The numerical difficulties referred to above have so far created a serious obstacle to allocation of effort quotas. The alternative possibility of reducing fishing effort by a proportional change in the existing fishing activity of each nation can overcome the implicit problem of equity at the time of regulation but since it would certainly differ between national fleets any subsequent trend in efficiency could be expected to generate difficulty of a comparable nature.

(iii) Combined catch and effort regulations

One of the options for management includes combined catch and effort regulation. This presents a particular problem because, just as the catch regulation of a mixed fishery requires compatibility between species quotas, combined catch and effort regulations require compatibility between the two regulations whether they be in respect of single or mixed fisheries.

The chances of the two regulatory limits being reached at the same time can be examined in two stages, the errors involved in establishing the two regulations and those involved with its implementation. The first phase depends as before on the estimation of the size of the stock to be regulated. If fishing mortality is over-estimated, in general the resource and potential catch will be underestimated and vice versa. The second stage is accessible in that the match of an effort to a catch regulation would require some prediction of the expected catch per unit fishing activity of a standard vessel and the likely success of realizing that average can be seen in the variance of fishing performance of existing fishing operations. An analysis of the performance of three tonnage categories each containing 40 English trawlers fishing at Iceland in 1969-71 indicated a standard deviation in performance between vessels within categories of ± 20 per cent. The standard deviation of smaller vessel groups will be substantially higher and, in the limit of one vessel taking a very small quota, the error would approximate and be analogous to that recorded in groundfish survey estimates of stock abundance. If the survey represents a single trip then the variance of this sample estimate on the actual stock abundance would be analogous to a single commercial trip achieving a performance corresponding to the true (predicted) stock abundance. The 95 per cent confidence limit on groundfish survey estimates of abundance (as catch per haul) is of the order ± 40 per cent, i.e. nearly half or double the true value. Whilst the comparison between commercial operations and groundfish survey is not exact, it does illustrate the possibility that for the commercial fleet of a nation taking a very small catch allowance or a vessel with a specific allocation, there would be a real chance that either the catch per unit fishing activity is underestimated by 50 per cent so the catch allowance is taken by half the expected fishing, or it is overestimated by 100 per cent so the catch is only half taken up by the time the effort quota is exhausted. That is, given the need to predict compatible values a country with a small allowance might find it catches either all of its catch allowance and bears the 'cost' of underutilized fishing capacity, or catches half the allowance. As the number of 'samples' involved in a national fishery increased so the realized catch per unit activity would more closely approach the expected catch per unit, subject always to the accuracy of the initial prediction.

CONCLUSIONS

Given the large number of potential errors in the system it is clear that management of resources cannot be exact but some conclusions are possible.

The regulatory options are:

(i)	Individual species catch quotas	(single resource, single measure)
(ii)	Individual species effort quotas	(" " " ")
(iii)	Multi-species catch quotas	(complex resource, single measure)
(iv)	Multi-species effort quotas	(" " " ")
(v)	Multi-species catch and effort quotas	(" " dual measure)
(vi)	Individual species catch plus multi-species effort quotas	(mixed regulation)
(vii)	Individual species catch plus multi-species catch quotas	(" ")

Species differ in their value to different countries and the degree of conservation required varies. Accepting the argument previously put forward that management action must discriminate to the species level,it is essential that the fishing activity be directed. The effects of not directing the fishery in this way are illustrated by Pope (Res.Docs. 75/IX/126 and 75/IX/127) and except in rare instances this cannot be achieved through an effort regulation, so that,where necessary,individual species must be protected by catch quotas. The second option is therefore barely feasible and the one advantage hitherto maintained for effort regulation in this context, i.e. the advantages of a constant level of fish mortality (investment), disappears if the need for stock constraints is accepted, because it implies that both catch and fishing mortality regulations should be adjusted. Options (iii)-(v) are inappropriate for the same reasons; in practice they do not afford the individual species the protection it may need, or, looked at another way, they allow sequential depletion of preferred species within the overall limit.

Experience has also shown that the individual species catch quota system by itself is not sufficient in a mixed fishery. All fisheries are to some degree mixed so the choice narrows to (vi) and (vii) where, in a special case, if mixing were not significant the multi-species catch quota would be the aggregate of the individual species quotas.

Then the real choice is whether the degree of mixing justifies an overall resource quota and if so whether it should be framed in terms of catch or effort. The contributions by Pope (Res.Docs. 75/IX/126, 75/IX/127) and Horwood (Res.Doc. 75/IX/125) show that general production analyses do not necessarily indicate the MSY of a resource complex or the fishing effort associated with it, particularly if the analysis excludes some part of the resource complex. The relationships may be parabolic, but only one of a family of parabolic curves expressing possible relationships depending on species preferences. Thus, an overall catch regulation might not achieve the MSY and would allow a shift in species composition and conversely, whilst it also may not achieve the MSY, an overall effort regualtion would tend to fix the species composition of the complex. There may be other circumstances where the potential yield is fairly stable over a range of levels of fishing effort as the species composition shifts and, indeed, this could be one interpretation of the Newfoundland fishery if the yield from the recently developed capelin fishery were included.

Our overall conclusion is that the MSY concept has led to the possibility of over-exploitation within the existing regulatory system. In principle this could be overcome by stock constraints,and species catch regulations remain necessary to direct the various fisheries,but the data are not adequate to give comprehensive protection so that an overall limit on the fishery is desirable in all sea areas. The application of such a limit either as catch or as fishing effort has consequences which cannot be predicted in detail and it is therefore more of a convenient method of limiting the fishery rather than a genuine measure of resource management. The advantages of the overall catch limit lie in the negotiation of allocations and avoidance of the inequities that will be associated with fishing effort control due either to trends in fishing efficiency or incompatibility with species catch allocations; it would be extremely difficult to match the effort allocation to the catch allocation with any confidence or equity of both regulations for all countries.

The association between that regulation and the individual species catch allocations would be fortuitous, emphasizing the convenience rather than resource orientated justification for the chosen level of the overall regulation. It would appear therefore that so far as the biological objectives of management are concerned. and given adequate enforcement, neither overall catch nor effort regulation has an indisputable advantage, but the former has fewer disadvantages and retains a greater possibility of weighting for the undesirable mixed species fishery content of national fisheries.

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