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Specified stock size as an objective for the management of single stocks

by

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INTRODUCTION

The review of resource management, its objectives and implementation (Garrod Res. Doc 75/) outlines the developments in management in the ICNAF area which have prompted a re-evaluation of the maximum sustainable yield as the objective of management. Contributions by Pope (Res. Doc 75/) and Horwood (Res. Doc 75/) demonstrate theoretical reasons why Schaefer models may not be an appropriate means to identify the MSY of a conglomerate of fisheries in one area, or the level of fishing associated with it. Scientific advice in regard to regulation of fishing mortality thus falls between two stools; stock specific estimates of TACs set on an F_{max} related to the MSY PER RECRUIT may actually enable over-exploitation to take place because the stock specific data are not yet adequate to identify the level of F associated with the true MSY, yet overall limitation of a total resource complex will have effects which cannot be predicted and may still enable over-exploitation of certain stocks. Some improvement can be made by adopting more widespread use of management to maintain specified stock sizes following the concepts adopted for herring, and this contribution describes briefly the method and its advantages.

A review is therefore pertinent but it must be noted that scientific re-appraisal can only take account of technical problems. It cannot anticipate problems in the implementation of a regulation though the Commission may introduce some adjustment to the scientific advice as a matter of policy.

1. REGULATION OF STOCK SIZE AS AN ALTERNATIVE OBJECTIVE

The theoretical deterministic formulation postulated initially an equilibrium fishery having constant yield, fishing mortality and stock. That ideal was never intended as being realistic because fisheries are never in short-term equilibrium. When it became necessary to regulate the amount of fishing in the 1960s thought turned briefly to the notion of a constant physical yield (MSY) from a variable fishing mortality and stock and thence, through the need to adjust catch quotas and the attraction of a stable industry, to the notion of a variable catch (MSY per recruit) with a constant fishing mortality (F_{max}) from a variable stock. It is clear now that despite its theoretical elegance the MSY concept is no longer an adequate objective for management in all situations; it is difficult to estimate and it does not ensure that the stock cannot become over-exploited because the level of F at which a fishery induced reduction in recruitment occurs is not defined. Until the scientific uncertainties are resolved the FIRST responsibility of management is to maintain a stock size that will ensure continuity of the resource. That is, a variable catch and fishing mortality to maintain a constant stock. This is the primary purpose but it does not preclude other objectives if they lie within (above) that constraint, be it the MSY, MSY per recruit or a level of stock that will enhance industrial efficiency or cushion administrative difficulties.

Scientifically a regime based on minimum stock levels must:

i. identify the level of stock associated with the MSY, ie with a stock size already at a defined minimum that can generate recruitment at long-term average levels;

ii. identify stocks which have been depleted below the minimum level, ie stocks which will not return to the specified minimum at the existing level of fishing mortality through the normal variation in recruitment;

iii. specify management strategies that will maintain stocks in the first category or allow those in the second to recover.

2. ESTIMATION OF FISHING MORTALITY TO MAINTAIN SPECIFIED STOCK LEVEL

If a stock constraint is established for the age groups (j .. r) then the expected biomass of these age groups in year (x + 1) depends on the survival of fish from age groups (j-1, j ... r-1) in year (x). Expressing the average weight of fish at age a as W (a) and, if the stock constraint involves mature fish only, expressing the proportion mature at age a as M (a), then the biomass of the (spawning) stock (T (x + 1)) at the beginning of year x + 1 is given as:

* $\exp(-S(a) F(x) + M)$

$$T(x+1) = \sum_{a=j-1}^{r-1} W(a+1).M(a+1).N(a,x)/\exp(S(a)\,F(x) + M) \quad \ldots\ldots\ldots\ldots 1$$

where N (a, x) is the number of fish of age a at the beginning of year x, S (a) is the partial recruitment factor at age a and F (x) and M the usual mortality coefficients. The partial recruitment factor may vary over the age range but in considering the potential stock as a unit this may be simplified by assuming that all age groups concerned are subject to an average partial recruitment factor $\bar{S}$. Strictly the average partial recruitment factor would be weighted by the number of fish in each group but an approximate value for $\bar{S}$ would be given by:

$$\bar{S} = \sum_{a=j-1}^{r-1} S(a)/(r-j+1)$$

Thus from 1

$$\exp(\bar{S}.F(x) + M) = (\sum_{a=j-1}^{r-1} W(a+1)\,M(a+1)\,N(a,x))/T(x+1) \quad \ldots\ldots\ldots\ldots 2$$

and this can be solved for the value of F (x), which would just satisfy the stock constraint, as follows:

$$F(x) = -(M + \ln\{T(x+1)/\sum_{a=j-1}^{r-1} W(a+1).M(a+1)\,N(a,x)\})/\bar{S} \quad \ldots\ldots\ldots\ldots 3$$

Expression 3 gives an approximate estimate of the fishing mortality to be applied to a stock to ensure that a specified stock survives in the following year and hence the catch that could be taken in the current year. Such an approach remains subject to problems of data lag currently being encountered but, depending on the age range of the stock specified, it has the following advantages.

1. It addresses the real biological constraint on resource management and can be defined in terms of minimum spawning stock, or, if necessary, some minimum that would meet catch rate (economic) objectives.
2. It overcomes what is currently a major technical difficulty in defining F_{MSY} or F_{MAX} in a fishery where selection patterns may change.
3. Given an objective F set independent of the selection pattern the yield from partially recruited age groups can be manipulated in relation to a management strategy (see below).

4. The specified stock can be established on the age groups for which the stock estimates are the most reliable and so release present advice on TACs (for many stocks) from crucial dependence on the strength of most recent year-classes. That is, the yield from these youngest age groups will be irrelevant to stock constraint for the following year. They will remain important to stock size in future years but, it follows from 3 that the required level of fishing mortality can be projected forward on known recruitment estimates and the TAC set to take into account anticipated stock trends in a meaningful way.

Table 1 illustrates application of the technique to data for the cod stock in Div 3NO. This is not a reassessment of that stock but based on data presented to STACRES coupled with the constraint that the spawning stock should not fall below 15 per cent of the estimates for the unexploited stock. Given the assumptions it indicates the need for a reduction in catches in 1976 through 1978 to maintain the stock constraint. The catch figures represent the upper limit of what could be caught but alternative strategies to accept lower catches in the immediate future could be evaluated in the same way.

It has to be noted that the approach outlined is obviously only applicable to stocks where analytical data are available; it requires a stock constraint, and the use of the constraint will give most advantage where it applies to age groups almost fully recruited to the fishery. If the constraint were based on the mature fish of a stock which matures at a very early age then the numerical benefit of the method may be small though the advantages in management strategy will remain if the arguments put forward earlier are accepted.

3. THE STOCK CONSTRAINT

The estimation described above is applicable to any stock of specified age groups but, considering that the need to adopt this approach has arisen because of uncertainty regarding stock and recruitment relationships in order to meet the biological concern of resource management, it should be applied to the potential spawning stock. The possible form of the stock and recruitment relationship has been discussed very extensively in recent years and it suffices to say here that the optimum stock level has not yet been convincingly demonstrated in any set of data for marine fish resources so far presented. Given the need for a limit this leaves only two options:

i. to examine the spawning stocks of exploited resources to identify the proportionate reduction in spawning stock from the unexploited stock condition which is believed not to have had a deleterious effect on recruitment;

ii. to identify in historic data a spawning stock size known to have generated an adequate level of recruitment.

With regard to the first option there are stocks which have been depleted to 10% of the unexploited level ca so that a 15% constraint could be agreed bearing in mind that density dependent increase in growth rate of the exploited stock would imply that the real reduction in spawning stock would be less. However it is doubtful whether an approximation of this form could claim widespread support and it is open to challenge for many resources where the density dependent component of mortality regulating yearclass size is very small. The most acceptable approach must be to adopt a demonstrably adequate spawning stock level or, if a constraint based on economic criteria is intended, then a stock level which can be seen to be adequate for the purpose defined.

4. SUMMARY

This contribution proposes an alternative management objective based on a stock constraint. This is seen as an essential development in the scientific advice in the single species context needed to overcome the uncertainty surrounding the 'stock and recruitment' issue. It has a wider implication to the implementation of management policy because, if adopted, both catch and fishing mortality would be expected to vary.

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Table 1. Illustrative Calculation of Possible Catches based on Stock Constraint

Based on Cod Div. 3NO, M = 0.2

(A) PARAMETER

Age	W (a) [1]	Mat^n M(a) [2]	Partial Selection S(a) [1]	$\overline{WM}$ W(a).M(a)	$\overline{WM}_{x+1}$ W(a+1) M(a+1)	Unexpld Stock $P_N \times 10^6$ N(a,v)
3	.50		.20		.05	100
4	1.07	.05	.50	.05	.43	82
5	1.71	.25	.70	.43	1.48	67
6	2.97	.50	1.00	1.48	2.81	55
7	3.75	.75	1.00	2.81	5.00	45
8	5.00	1.00	1.00	5.00	6.00	37
9	6.00	1.00	1.00	6.00	6.90	30
10	6.90	1.00	1.00	6.90	7.80	) 45

(a) Biomass of unexploited stock $T_{(v)}$ = 916k ton
Constraint $T_{(x)}$ @ .15$T_{(v)}$ = 135k ton

(b) $\dfrac{r-(j-1)}{\sum_{j-1}^{r-1} S(a)} = 1.25 = \dfrac{1}{\bar{S}}$

(B) PROJECTION

	1973 [1]	1975 [1] PN	1975 F	1976 PN	1976 F	1977 PN	1977 F	1978 PN	1978 F
3	118	92	.14	(100)	.12	(100)	.08	(100)	.14
4	86	60	.35	65.5	.30	(72.6)	.21	(75.6)	.35
5	25	57	.50	34.6	.43	39.8	.29	(48.2)	.50
6	9	34	.70	28.3	.60	18.4	.42	24.4	.70
7	2	9	.70	13.8	.60	12.7	.42	9.9	.70
8	2	3.3	.70	3.7	.60	6.2	.42	6.8	.70
9	1	.8	.70	1.3	.60	1.7	.42	1.7	.70
10	1	.8	.70	.3	.60	.6	.42	.9	.70
T(x)	57	130		127		129		139	
$\sum_{a=j-1}^{r-1}$ W(a+1)M(a+1)N(a,x)		286.9		266.4		232.7		286.5	
$\bar{S}$ F(x)		.55		.48		.34		.55	
F(x)		.69		.60		.42		.69	
Y_w (tons)			70k		56k		41k		70k

1 Summ. Doc 75/4

2 Pinhorn A. 1969: Fishery and Biology of Atlantic cod (Gadus morhua) off the southwest coast of Newfoundland. J.Fish. Res. Brd. Canada 26(12): 3133-3164.

NB Recalculation of Yw/R using partial recruitment indication F values derived here are less than F_{MSY}