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A yield per recruit function for Subarea 1 cod

by

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Introduction

At its 1968 meeting the Subcommittee for Assessments prepared a review of the state of the fisheries in the ICNAF area, and, with regard to Subarea 1 cod, it was concluded that this stock is 'demonstrably overexploited' /Redbook, part I, p. 30, 1968/. This conclusion was drawn from assessments summarized under Appendix 1, Annex 1 /p.44 of that Redbook/ which were based on a constant parameter model using the parameters listed /M = 0.2/ and assuming 'knife-edge' recruitment at specified levels 1_c/L . Taking the threshold 1_c = 35 cm indicated that yield per recruit would increase with up to 60 per cent reduction in fishing mortality /F/: the alternative calculation using 1_c 45 cm suggested that the level of F in 1965/66 /= 0.6/ was close to the optimum for the mesh size in use. In no case was the stock underexploited and the present situation was considered to lie within the range given. An alternative empirical analysis of the catch statistics for Subarea 1 cod also indicated the level of fishing to be close to the optimum and hence conformed more closely to the rigorous assessment using 1_c = 45 cm /Garrod 1968/.

At its mid-term meeting in London in January 1969 the Sub-Committee made provisional estimates of the catch quotas that should be set to achieve specified reductions in fishing mortality in 1969, though these were not related to stipulated managment objectives. These quotas were based on calculations prepared by one of us /Horsted 1969/. The form of these calculations provided further information on the pattern of recruitment to this fishery, and so permits the assumption of 'knife-edge' selection to be replaced by variation of fishing mortality with age. A yield per recruit curve has therefore been re-calculated to include this extra information in order to confirm the earlier conclusions of the Subcommittee.

<u>The estimation of partial recruitment values</u>

The working paper referred to calculated the numerical abundance of each age-group at the beginning of each year using a defined value of F for all age-groups and years. For each age-group estimates were made in two ways:

/i/ as the survivors from the stock in year x;

/ii/ as the number of fish at the beginning of year x + 1 necessary to generate the catch observed in that year.

The difference between these estimates represents the number of <u>new</u> recruits /immigrants ?/ entering the age-group x + 1, and the ratio between this and the number in the stock of a year-class at the beginning of year x measures these new recruits as a proportion of the previous stock of that year-class. These proportions are shown for pairs of age-groups in Table 1.

The ratio for age-groups 9/8 is negative in all cases and could be interpreted in terms of emigration of older fish /to East Greenland and Iceland/ or in terms of the variance of the estimates of mortality. It seems reasonable to assume from the ratios of 8/7 that recruitment is complete in the eighth year and from this the proportion of total recruitment can be computed for earlier ages. Thus, for example, if the ratio of new recruits at 8 /${}_rN_8$/ to the stock of 7-year-olds /N_7/, ${}_rN_8/N_7 = 0.104$, and ${}_rN_8 + N_7 = 100$, then $N_7 + 0.104\ N_7 = 100$ and $N_7 = 0.906$. The estimated proportions of the total year class recruited at each age-group are shown in Table 2, the value for 3-year-olds having been interpolated from the illustration of these results in Figure 1. They are underestimates to the extent that ${}_rN_x$ has not been corrected for natural mortality during the year prior to recruitment.

The original derivation of these stock estimates from a constant value of F for all age-groups within one year implies that all members of each age-group are equally available to the fishery. The new recruits must therefore be immigrating into the area of the fishery. However, by definition, population models should consider a 'unit stock' which would initially contain all potential recruits to the fishery, but at varying degrees of availability. That means that the size of a year-class is determined before recruitment, and its recruitment over a range of ages is expressed in variations of the catchability coefficient giving a proportion of F_{max}, the fishing mortality to which fully recruited age-groups are exposed. This approach to partial recruitment has been checked /Garrod, unpublished/ by calculating variations of F with age from the same original catch data using Gulland's modification of the 'virtual population' technique /Gulland 1965/. The estimates so derived are compared with those estimated by assuming immigration of new recruits in Table 2.

In effect this comparison does no more than check the accuracy of the arithmetic, but it does illistrate the dual interpretation of the same figures, neither of which can be incorporated in the constant parameter model. Note however that 50 per cent recruitment occurs at about five years of age, corresponding to an l_c 50-60 cm. This seems absurdly high in terms of the size of fish caught : one would expect all cod over 50 cm to be available to all gears. However, we are considering variations of F with age and this is not only a function of size, but also of the concentration of fleets on particular parts of the stock. Thus, if immature and mature cod are intermingled in the autumn they will be subject to the same F in that part of the year; but, if fleets concetrate on prespawning or spawning aggregations of mature fish earlier in the year, one may suspect these older fish to suffer a higher mortality irrespective of their size in relation to a particular type of gear. The effectively high l_c may therefore not be unrealistic.

<u>Results</u>

These estimates of fishing mortality, varied with age, have been incorporated in a population model which gives the variation in yield per recruit illustrated in Figure 2. Taking the level of fishing mortality to have remained at F = 0.6, the same as in 1965/66 /the most recent years for which estimates are available at the time of writing/, this calculation suggests that the upper limit of recruitment l_c = 45 cm used in the 1968 assessment was the more nearly correct. It appears that the the level F = 0.6 is close to that giving the maximum sustained yield: it is equally true that some reduction in effect would not have an appreciable effect on the total yield, except for the immediate losses in the years immediately following regulations. The connotation that could attach to the phrase 'demonstrably overexploited' does seem to overestate the situation in this fishery as it was in 1966, especially since no evidence has been presented to show that fishing may have had a significant effect upon recruitment in this stock.

References.

Garrod, D.J., 1968. 'Schaefor-type' assessments of catch/effort in North Atlantic cod stocks. ICNAF Res. Doc. 68/51 /mimeo/.

Gulland, J.A., 1965. Estimation of mortality rates. Annex to ICES C.M. 1965, Doc. No. 3 /mimeo/.

Horsted, Sv. A., 1969. On the possibility of assessing stock size and catch quota for Subarea 1 cod. ICNAF Res. Doc. /mimeo/.

ICNAF, 1968. Redbook, Part I.

Table 1 New recruits per age-group as a proportion of the stock of the preceding age-group

Year-class	Calendar year					Mean	Age-groups in ratio
	1963	1964	1965	1966	1967		
1954	x						
1955	0.265	x					
1956	0.205	0.029	x				
1957	0.045	0.000	0.130	x			
1958	1.747	0.201	0.030	0.000	x	x	9/8
1959		0.590	0.190	0.264	0.095	0.104	8/7
1960			0.647	0.267	0.180	0.136	7/6
1961				0.532	0.638	0.268	6/5
1962					3.241	1.351	5/4

Negative ratios $_rN_{x+1}/N_x$ for age-groups 9/8 denoted x, and negative ratios for other age-groups are assumed to be zero.

Table 2 Estimates of recruitment to the exploited stock

Age	Partial recruitment (fishable proportion of each age-group)	Variation of F_{max} owing to partial recruitment
3	0.160	+
4	0.267	0.31
5	0.628	0.60
6	0.797	0.76
7	0.906	0.74
8	1.000	1.00

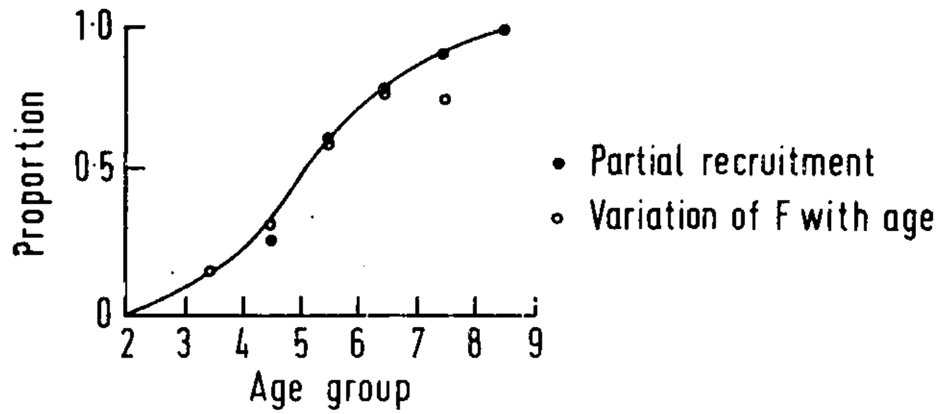

Figure 1 Variations in recruitment on fishing mortality with age.

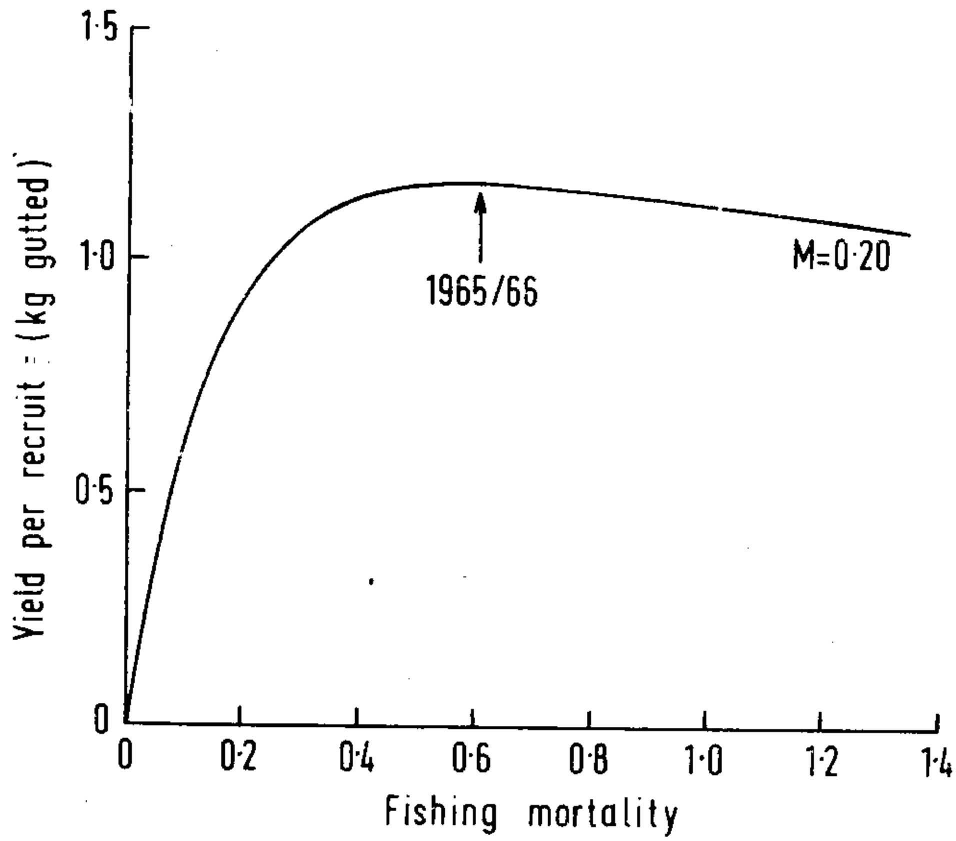

Figure 2 Yield per recruit curve for Subarea 1 cod.