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SIZE AND EXPLOITATION OF THE MACKEREL STOCK IN THE SKAGERAK AND THE NORTH-EASTERN NORTH SEA

by

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INTRODUCTION

Based on data form internal tagging of mackerel in 1969 the size of the stock available to the Norwegian purse seine fleet has been estimated to 850 000 tons (Hamre 1970). This estimate refers to the state of the stock on 20 September, 1969. From that date and up to the end of the year, 270 000 tons of mackerel were landed by the seiners. In addition the stock is further reduced due to other causes, so that the size of the stock at the end of 1969 may have been about 550 000 tons.

From 1967 to 1969 the total catch of mackerel in the North Sea and Skagerak amounted to 2 400 000 tons, and more than 90% of this has been taken by Norwegian seiners. Although the annual catch decreased slightly during this period, it seems obvious that the equilibrium state of catch and effort at the present level of fishing intensity will occure on a very low stock size level. It was thus felt that further uncontrolled fishing might cause serious effects on the mackerel stock. Various measures for controlling the fishery have therefore been considered together with their possible effects on the stock and yield.

Based on these studies the Norwegian fishery authorities have, on a national basis, taken steps to control the mackerel fishery in the Skagerak and North Sea. The aim of the present paper is to inform the Committee on the action taken, and give a brief account of the biological aspects of the stock conservation measures imposed on the fishery.

MEASURES OF CONSERVATION

The action so far taken applies to the mackerel fishery for meal and oil only, and is restricted to the North Sea stock within the area east of 2°W.

The regulation controls the total amount of fishing by a predetermined catch quota of mackerel used for reduction purposes. For 1970 this quota is set to 2 000 000 hl or about 180 000 tons.

The regulation is moreover intended to control the fishing mortality during the first half of the year. It is thus prohibited to fish mackerel for other purposes than human consumption and bait from 1 January until 1 August. The Director of Fishery is, however, authorized to grant dispensation from this general regulation in special cases. The North Sea areas south of 59°N has moreover been closed for fishing from 8 August to 30 August 1970.

In October 1969 the minimum legal size of mackerel was increased from 20 to 30 cm, with a 25% allowance of undersized fish in the catch (Hamre and Revheim, 1968).

Minimum legal size

The large proportion of immature fish in the winter landings in 1968 gave raise to a suggestion of a higher minimum size limit than the existing 20 cm limit. The quality of the landed mackerel was rather poor, and it was found that a raise in the limit to 30 cm might increase the sustained yield of the stock also in terms of weight (Hamre and Revheim, 1968).

In Figure 1 are shown three yield per recruit curves for mackerel recruiting the fished stock at lengths 26, 30 and 33 cm (l_c). Lower values than 26 cm may have no practical effect on the fishery. The used stock parametres are L_∞= 39 cm, W_∞= 550 g and K = 0.40, which refer to fish caught during summer and autumn (Castello and Hamre, 1969). The natural mortality rate M is set to 0.20 (Aasen 1969, Postuma 1969). The yield per recruit Y/R is in grams and refers to a recruitment lenght of 26 cm (Beverton and Holt, 1966).

As pointed out by Postuma (1969) the yield per recruit curve of mackerel is rather steep due to the rapid growth. The gain in yield per recruit by increased l_c is therefore rather insignificant unless for very high values of the fishing mortality (F).

A strong recruiting yearclass normally starts to appear in the purse seine catches during autumn when the fish are in their second year of life (average length 26 cm). The fish tend to school by size, but are often found in the same area as the adult stock, as is the case at present. The 1969 yearclass seems to be strong and has frequently been met by the seiners operating on the Reef this year. Several sets have also been released due to the new minimum legal size. In August the yearclass was most abundant in the south-eastern part of the North Sea. Due to this and other fishery policy matters the area south of 59° N was again closed for industrial fishing from 8 August to 30 August.

Without these restrictions considerable quantities might have been caught from this yearclass. With the present low size of the adult stock and the high fishing power of the fleet, an uncontrolled fishery on the recruits may have caused serious effects on the future spawning potential of the stock. Since the new legal size limit does not in any case reduce the possibility of obtaining a maximum yield per recruit, the limit was found justified to be applied to the mackerel fishery in general. As shown from Figure 1 an even higher limit will not reduce the yield per recruit. This is however not practical due to technical reasons.

Control on the amount of fishing.

Another important conclusion which can be drawn from Figure 1 is that an increase in F above 0.4 will not increase the yield per recruit significantly. Increased fishing effort above this value may therefore result in a corresponding decrease in the catch per unit of effort only.

An equilibrium state of yield and stock size on a high level of fishing intensity has several well known disadvantages, such as reduced spawning potential, harvesting small sized fish, high cost of fishing etc. The introduction of a catch quota to reduce the fishing intensity is under the present conditions considered as the most important conservation measure imposed on the fishery. The aim of this is to limit the fishing effort so that F shall not exceed 0.4.

The necessity of an effective control on the amount of fishing was revealed from an evaluation of the stock strength and catch over the past 5 years. The figures of estimated stock strength appear from Table 1. The table shows the estimated strength of the yearclasses 1962 to 1966 in number at the beginning of each year for the age groups 2 years or more, the yearly catch by yearclasses and the corresponding F. At the bottom of the table the figures are summarized by year and converted to weight in the last row.

The stock strength by yearclasses prior to 1969 is back-calculated from the estimated stock strength at the end of 1969, the yearly Norwegian catches in 1966 to 1969 and the available data on the age composition of the catches. For these calculations the following equations have been used:

$$N_{t+1} = N_t \cdot e^{-z} \qquad (1)$$

$$C_t = E \cdot N_t(1 - e^{-z}) \qquad (2)$$

where N_t is the back-calculated number present at the beginning of the year t, N_{t+1} is the known number at the end of the year t and C_t is the catch in number during that year. $E = \frac{F}{F + M}$ is the rate of exploitation. Choosing M, z (and F) are read out of computed tables for the fraction:

$$\frac{e^{-z}}{E(1 - e^{-z})} = \frac{N_{t+1}}{C_t}$$

The z value inserted in (1) gives the estimate for N_t.

The chosen value for M includes the mortality rate due to other causes than Norwegian fishing. The mackerel catch by other nations during this period has been low compared to the Norwegian catch, but in order to include these catches also, M has been chosen equal to 0.25. From 1966 and backwards the yearclass strength is calculated by a fixed z = 0.3.

Although this method of back-calculation of stock strength is sensitive to errors in the basic data (errors accumulated with time) it is fair to conclude from Table 1 that the mackerel stock has been heavily fished in recent years, particularly in 1969. There is reason to assume that the estimated F value for 1969 of 0.80 should not be very far from the true value. The trend of increased F with decreasing stock strength indicates moreover that the natural balance between stock and fishing intensity has not yet been established. With further uncontrolled fishing the equilibrium stage between the stock strength and yield might therefore occur on an even higher level of fishing mortality than observed in 1969.

These findings caused grave concern about the future prospects of the mackerel fishery. It was commonly agreed that immediate action had to be taken in order to avoid further decimation of the stock. Various conservation measures were considered but the only practical way found for obtaining an effective control on the total amount of fishing was to limit the industrial fishery by a fixed quota for the year. In accordance with the view that the stock should not be subjected to a higher fishing mortality rate than 0.4, the Institute proposed that the total catch for 1970 should not exceed 200 000 tons unless a substancial recruitment to the adult stock was observed. Further tagging projects and catch analysis were suggested in order to give information about the latter problems.

Control on fishing mortality during winter and spring

As mentioned previously, the argument for increasing the legal size of mackerel was primarily to limit the winter catches. These catches contained a large proportion of immature fish of low quality for reduction. The condition factor and thus the ultimate weight of fish caught during winter and spring is moreover about 20% lower than that of the summer catch (Castello and Hamre, 1969).

Since the yield per recruit is proportional to the ultimate weight, the sustained yield based on winter catches will be reduced correspondingly.

The seasonal fluctuation in the condition factor is associated with seasonal fluctuation in the fat content of the fish. Figure 2 shows the percentage of fat in mackerel by months for the years 1968 and 1969. The data are obtained from Norges Makrellag's Yearbook 1969, and includes samples of all mackerel used for production of meal and oil.

Figure 2 shows a very rapid accumulation of fat during July, i.e. immediately after the fish have spawned. These data are essential for an economic assessment, because the first hand price on the product for reduction is directly related to the percentage of fat.

A restriction on the winter and spring fishery was thus justified both with regard to the maximum obtainable yield in weight and particularly in value. The restriction on the fishery in the pre-spawning period will moreover increase the average spawning potential of the stock and thus the probability of recruitment. Finally the cost of fishing mackerel with purse seine in autumn is considerably less than in winter and early spring because the fish avoid the winter cooled surface water and thus frequently break the nets. It was therefore recommended that the season for industrial fishery should not be opened before 1 August . In autumn 1969 the Norwegian purse seiners landed 450 000 tons of mackerel. According to the stock size estimate this was about 50% of the available stock. It was thus found likely that the fleet would be able to fill the fixed quota within the limited season.

SUSTAINED YIELD

Postuma (1970) has reported the catch per unit of effort of the Dutch trawl fishery on mackerel over the past 10 years. The fishery is carried out during April-May and covers the same area as fished by the Norwegian seiners. His indices of stock abundance as catch in tons per 100 hours fishing of a standard trawler is compared to corresponding stock size estimates in million tons (from Table 1). Fig. 3

From 1966 and onward the two independent sets of stock abundance estimates agree closely. Postuma has reported (personal communication) that the Dutch mackerel fishery in 1970 was rather poor, and it has even been difficult to obtain samples from the trawlers.

In 1964 and 1965 the catch per unit of effort indices are somewhat lower than the back-calculated values. This might, however, be explained as low availability of the strong 1962 yearclass to the trawl fishery before 1966. As shown by the age composition of the Dutch trawl catches, the 1962 yearclass is represented, in number, by 15 and 12% for the years 1964 and 1965 respectively. On the basis of the age composition given in Table 1 these figures would have been 34 and 33% respectively, provided the yearclass was fully recruited to the catchable stock.

Since the two estimates of stock strength agree closely it seems fair to place confidence in the back-calculated stocks in Table 1. Some general conclusions on size and exploitation of the stock in recent years can therefore be drawn.

Before the purse seiners started to fish the mackerel in the North Sea in 1965, the adult stock may have fluctuated in size between three and four million tons related to the strength of the recruiting yearclasses. According to Postuma (1969) the stock size in the late fifties may have been somewhat higher due to the very strong yearclasses 1955 and 1958 (c/f = 19). The total catch in the North Sea prior to 1965 did not exceed 100 000 tons or about 2-3% of the adult stock. This means that before the purse seine fishery started the mackerel stock in the North Sea was extremely underexploited and would have given a much larger sustained yield if more intensively fished.

A preliminary estimate of the maximum sustained annual yield which might be expected from this fish resource, amounts to some 400 000 metric tons. The estimate is based on the calculated average strength of recruitment at 2 years of age, of the yearclasses 1962 to 1966 (underlined figures in Table 1). This average strength of recruitment is 1910 million recruits. If the stock is harvested as previously suggested (F = 0.4, bulk of catch taken during autumn) the yield per recruit is estimated to 210 grams (Figure 1). Since this estimate also refers to recruits at 2 years of age, the two figures are directly multiplyable, giving 400 000 tons.

Five yearclasses may not be considered adequat to estimate mean recruitment to the adult stock when the strength of the yearclasses may vary in proportion 1:12. The estimate is however, found reasonable because it includes a pattern of yearclass strength which seems to be quite normal for the stock. Postuma assumed that the recruitment to the stock in the fifties was better than in recent years. This might be true, but it is a fact that the strong 1962 yearclass has not yielded the same proportion to the Dutch trawl fishery as it has to the Norwegian catch. This has no doubt biased the relative recruitment strength estimated from the Dutch fishery.

The estimated sustained yield presumes moreover, that the reduced stock size level due to increased $\bar{F}$ does not influence the recruitment, The balance between stock strength, fishing mortality and recruitment under the said conditions ($\bar{F}$ = 0.4, recruitment 1900 million individuals) will occur at an average stock size level of some 1.1 million tons, or about the same size as the spawning stock in 1969. Whether this will be adequat to secure maximum recruitment in the furture is still an open question.

SUMMARY

1. The present paper deals with conservation measures recently imposed on the Norwegian mackerel fishery for meal and oil in the Skagerak and the North Sea, and their expected effects on the stock.

2. The fishery is controlled by a predetermined annual catch quota with the aim of limiting the instantaneous fishing mortality to 0.4 (Figure 1). The quota to meal and oil for 1970 is set to 180 000 tons.

3. In order to increase the value of the catch the season January - July is closed for industrial fishing (Figure 2).

4. A minimum legal size of 30 cm is applied to the meal and oil fishery in general.

5. With these regulation measures in force it is expected that the stock at equilibrium may yield a sustained annual catch of some 400 000 tons.

REFERENCES

Beverton, R. J.H. and S. J. Holt. 1966. Manual of Methods for Fish Stock Assessment Part II - Tables of Yield Functions. FAO Fish. tech. Pap. 38 Rev. 1: 1-67.

Castello, J. P. and J. Hamre. 1969. Age and Growth of Mackerel from Skagerak and the Northern North Sea. Coun. Meet. int. Explor. Sea. H:7 1-6. 4 tabl. 3 fig. Mimeo .

Hamre, J. and A. Revheim. 1968. Abrief statement on the present state of the Norwegian mackerel fishery. Coun. Meet. int. Explor. Sea. H:24 1-4 Mimeo.

Hamre, J. 1970. Internal Tagging Experiments of Mackerel in the Skagerak and the North-Eastern North Sea. Coun. Meet. int. Explor. Sea. H:25 1-7. 3 tabl. 2 fig. Mimeo .

Postuma, K. H. 1969. On the mackerel in the north-eastern North Sea. Coun. Meet. int. Explor. Sea. H:21 1-8. 5 fig. Mimeo

Postuma, K. H. 1970. On the abundance of Mackerel in the northern and north-eastern North Sea in the years 1959-1969. In press.

Aasen, O. 1969. A Method of estimating Mortality in Fish Stocks. Coun. Meet. int. Explor. Sea. H: 8 1-8. 4 fig. Mimeo .

Table 1. Estimated stock strength in number (N), catch in number (C) and corresponding fishing mortality rate (F) by yearclasses and years. The figure P at the bottom of the table shows the Σ N and Σ C converted to weight in 1000 tons.

	1 Jan. 1970	1969		1 Jan. 1969	1968		1 Jan. 1968	1967		1 Jan. 1967	1966		1 Jan. 1966	1 Jan. 1965	1 Jan. 1964
Year-class	N	C	F	N	C	F	N	C	F	N	C	F	N	N	N
1967	(72)	64	(0.58)	(165)	88										
1966	306	395	0.75	830	765	0.59	1920								
1965	199	256	0.76	546	245	0.34	986	207	0.18	1515					
1964	51	114	1.07	191	146	0.51	408	143	0.27	686	60	0.08	956		
1963	23	27	0.70	59	52	0.57	134	35	0.21	212	15	0.06	289	390	
1962	199	285	0.81	576	303	0.38	1082	455	0.31	1895	206	0.08	2635	3550	4790
Older	204	334	0.88	632	605	0.60	1481	1268	0.56	3330	795	0.19	5170	6990	9420
Σ	1054	1475	0.80	2999	2204	0.50	6011	2108	0.37	7638	1076	0.14	9050	10930	14210
P	550	683		1130	779		1885	867		2780	484		3450	3920	4300

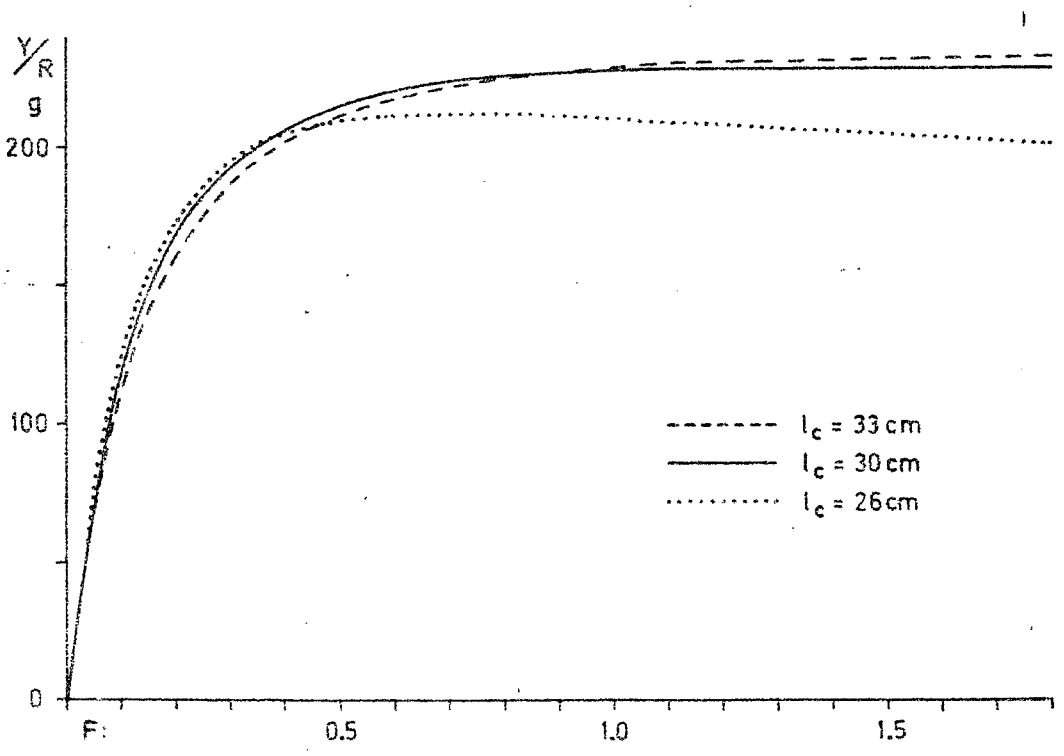

Fig. 1. Yield per recruit of mackerel (Y/R) as a function of the instantaneous fishing mortality coefficient (F) for various values of mean recruitment length (l_c). The estimates of Y/R refer to recruitment at 26 cm (2 years of age).

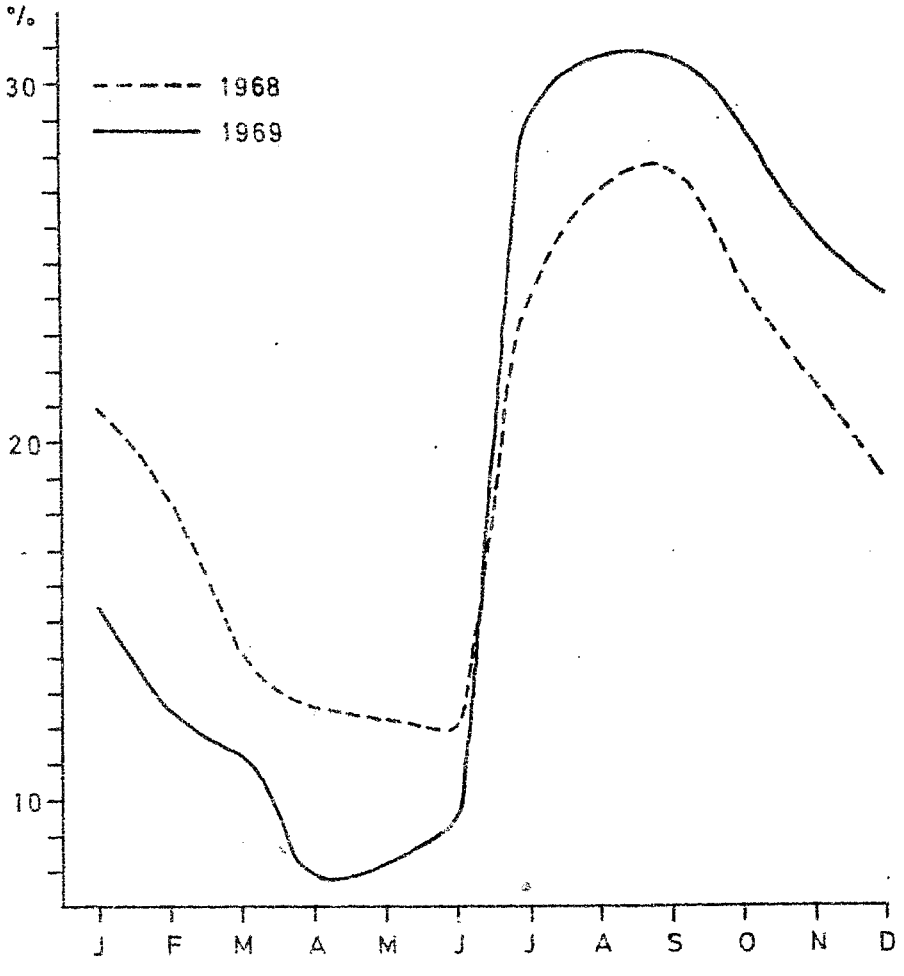

Fig. 2. Percentage of fat in mackerel by months.

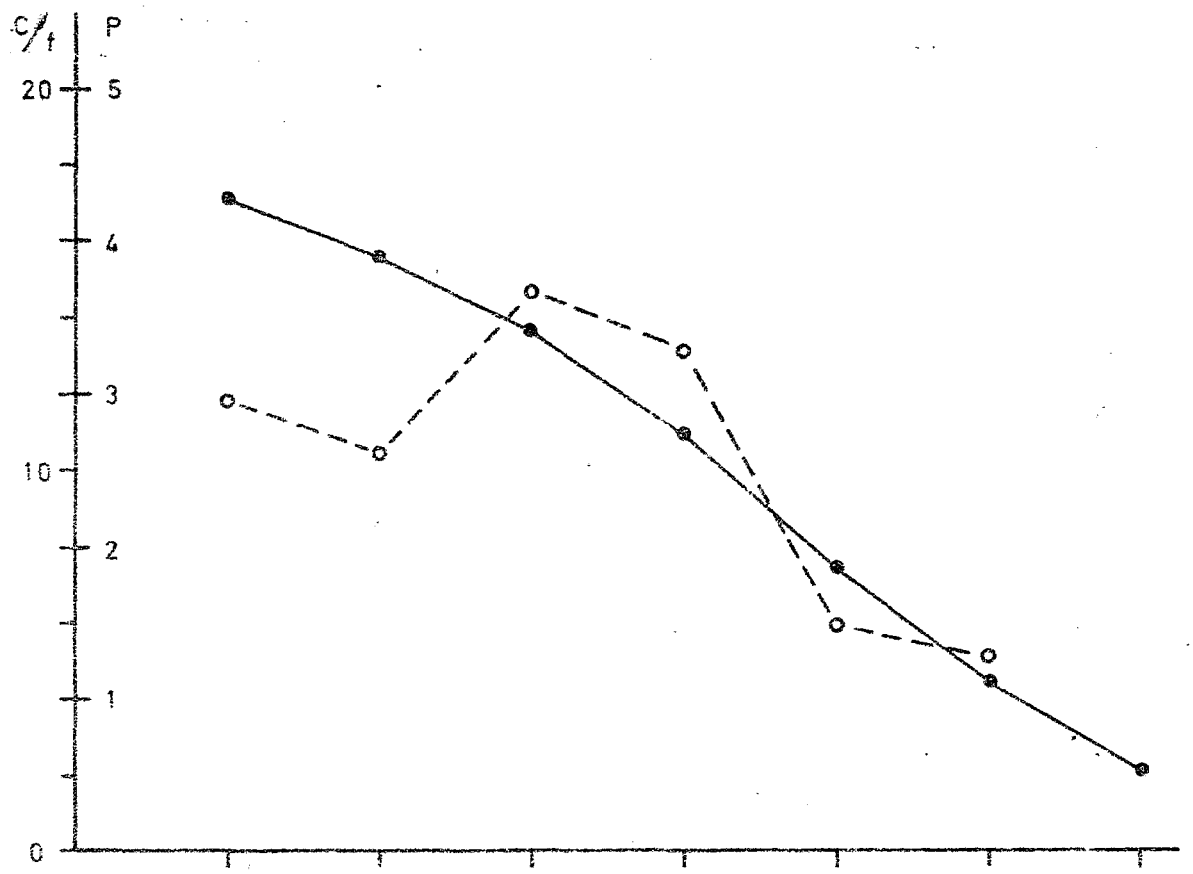

Fig. 3. Stock abundance of mackerel by years in the north eastern North Sea. The broken curve shows the catch per unit of effort (C/f) in tons per 100 hours fishing of a Dutch standard trawler. The solid curve shows the stock estimates in million tons appearing from Table 1.