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FURTHER RESULTS OF THE NORWEGIAN MAKCEREL INVESTIGATIONS

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INTRODUCTION

The Norwegian fisheries authorities have taken various steps to limit the fishing of mackerel in the northeastern North Sea due to heavy exploitation of the stock during the years 1967-1969. The conservation measures imposed on the fishery in 1970 and the biological basis of these measures, were described by Hamre (1970 b).

The present paper gives a brief account of the development in the mackerel fishery in 1970, and the effects of the restrictions imposed. Moreover, the paper deals with the investigation on the state of the stock in 1969-1970, and the exploitation policy which was recommended on the basis of the results.

THE MACKEREL FISHERY IN 1970

The total Norwegian catch of mackerel in 1970 amounted to 290,600 metric tons. Out of this 251,700 tons were used for meal and oil. About 90% of the catch was landed by purse seiners, and 10% by drifters and small crafts using hook and line.

According to the regulation, fishing for meal and oil was prohibited up to 1 August for the whole area east of 2^{o}W. This resulted in very low activity of the seiners on the traditional mackerel grounds during the winter and spring (Fig. 1). In late May some seiners operated on the Reef, but due to saturation of the market of mackerel for foodfish this fishery was stopped after only a few days.

In June the purse seine fleet moved to the Shetland area in search of herring. In late July schools of mackerel were found in the area west of Shetland. When the restricted area was opened on 1 August, a fishery for industrial purposes developed very quickly north of Shetland and between Shetland and the Viking Bank. For August a preliminary catch quota for reduction of 45,000 tons had been allotted, but this was filled the first week. From 7 to 13 August the whole area was closed for reduction purposes, but the northern part of the restricted area (north of $59^{O}N$) was again opened on 13 August. Few landings were, however, reported after that date (Table 2).

Due to reasons which will be discussed later, the catch taken north of $59^{O}N$ was excluded from the catch quota of the North Sea stock.

The area south of $59^{O}N$ was opened for the seiners on 31 August, and a catch quota of 180,000 tons was permitted to be used for meal and oil. The fishery for reduction was, however, closed on 7 November when some 15,000 tons of the quota remained to be filled. The early closure was due to an invasion of the strong 1969 yearclass to the grounds fished by the seiners. This fish was below the minimum legal size for reduction purposes (30 cm). Due to the situation in the market of mackerel for foodfish, the purse seine fishery was closed on 12 November and remained so for all purposes up to 12 July, 1971.

THE STATE OF THE STOCK

The size and exploitation of the mackerel stock fished by the Norwegian seiners are studied on the basis of catch statistics, age analysis and returns of tagged fish. The returns from three liberations of internally tagged fish are used to estimate recruitment and mortality rates, and applying these parametres to the catch statistics an estimate of the stock size is obtained.

Survival and recruitment

Tables 1 and 2 give the following basic data by week for the latter half of the years 1969 and 1970: the total catch (C_T), the catch used for reduction (C), returns of tags obtained from all reduction plants according to liberations (r), the corrected production of a selected group of plants (p) and the number of corresponding returns from that group (r′).

The selected test group includes 10 plants located on the southwest coast of Norway (Haugesund - Egersund). These plants are selected according to the estimated magnet efficiency of the plants and a statistical test of the variation in $(\frac{r}{p})$ when the plants received mackerel from the same fishing grounds. Factories having a) magnet efficiency above 50%, and b) random variation of $(\frac{r}{p})$ within a 95% confidence limit were accepted.

It appears that the latter condition excluded all factoris which had reported less than 20 tags in one season, even in cases when experimental tests of the magnet efficiency gave values of 80-85%. The reason for this must be that the factory workers pay less attention to appearing tags when tags are scarce. It may also be due to the fact that a single tag in a worker's pocket disappears more easily than a batch of tags. In general, it is found that a high frequency of tag reports does improve the homogenity of $(\frac{r}{p})$ and also the information on the prescribed reports following the tags.

The indices on r and r' refer to the liberations of tagged fish. Details of the liberations appear from the table below:

Liberation	Number tagged	Date	Tagging locality	Gear
1	1750	30 May 1969	$57^{\circ}38'$N $4^{\circ}35'$E	purse seine
2	4187	Jul-Aug 1969	$57^{\circ}15'$N - $58^{\circ}00'$N $5^{\circ}00'$E - $10^{\circ}00'$E	hook & line
3	3000	Jul-Aug 1970	$57^{\circ}30'$N 6°-8°E $58^{\circ}00'$N $4^{\circ}50'$E	hook & line

The tagging technique is described and discussed by Hamre (1970 b).

The right hand side columns of the Tables 1 and 2 show estimates of $(\frac{r'}{p})$ by week for the various liberations. The increase in $\frac{r'}{p}$ from week 30-36 to the week 37-46 in both years coincide with the area fished at the respective periods. In July-August the seiners were operating in the North Sea north of 59°N, but from September (week 37) and onward the fishery took place on the Reef west and south of Egersund (Fig. 1). The behaviour of the mackerel stock and the various factors affecting the data on the tag reports (Hamre 1970 a), indicate that random distribution of catch in relation to tagged fish can be expected during the latter periods. The data may therefore be used to estimate recruitment and survival of fish during the time between the two periods. Although the principles of the method used for obtaining these estimates have been described by previous workers (Jackson 1939, Baily 1951), an outline of the basic theory seems required for the understanding of the present application.

The change in population number (N) from time t_1 to t_2 may be formulated as follows:

$$N_2 = N_1 \cdot S + N_1 \cdot S \cdot R = N_1 \cdot S(1 + R) \qquad (1)$$

where N_1 and N_2 denote the number at time t_1 and t_2 respectively, S the coefficient of survival during the time interval $t_2 - t_1$ and R the coefficient of recruitment, measured as the fraction of recruits alive at the end of the considered period. Converting the equation to weight (P) by introducing the mean weight of fish at t_1 ($\bar{w}_1$) and t_2 ($\bar{w}_2$) we have:

$$P_2 = \frac{\bar{w}_2}{\bar{w}_1} \cdot P_1 \cdot S(1 + R) \qquad (2)$$

Two releases of tagged fish are considered, m_1 and m_2, one made at time t_1, the other at t_2 (or just prior to the time of sampling).

Two samples of the population are drawn, one at time t_1, the other at t_2. These samples may yield three groups of recoveries. The first sample may contain returns from m_1, which number is termed r_{11}, the first index referring to release number, the second index to the time of sampling. The second sample may contain returns from both releases which in a similar way are termed r_{12} and r_{22}.

The returns in the present case are obtained from the commercial catches used for meal and oil. Setting the ratios of tag returns/examined catch equal to their expectation, the following equations are obtained:

$$\frac{r_{11}}{e_1 \cdot C_1} = \frac{m_1 \cdot s_1}{P_1} \qquad (3)$$

$$\frac{r_{12}}{e_2 \cdot C_2} = \frac{m_1 \cdot s_1 \cdot S}{P_2} \tag{4}$$

$$\frac{r_{22}}{e_2 \cdot C_2} = \frac{m_2 \cdot s_2}{P_2} \tag{5}$$

where C is the catch used for meal and oil, e the corresponding efficiency coefficient of the plants (including all sources of loss of tags) during the respective sampling periods, s denotes the fraction of tagged fish surviving up to time t. When the time between release and sampling is short, s compensates for the tagging mortality mainly. It is assumed that during the period between the samples both tagged and untagged fish are subject to the same S. Sampling of the population in each case may be continued as long as no recruitment to the stock does occur.

From equations (4) and (5), and (2), (3) and (4) estimates of S and R are obtained respectively:

$$S = \frac{s_2}{s_1} \cdot \frac{m_2}{m_1} \cdot \frac{r_{12}}{r_{22}} \tag{6}$$

$$R = \frac{\bar{w}_1}{\bar{w}_2} \cdot \frac{e_2}{e_1} \cdot \frac{C_2}{C_1} \cdot \frac{r_{11}}{r_{12}} - 1 \tag{7}$$

The estimate of S is independent of the catch and consequently not influenced by the source of error of non-reported tags. It does include the tagging mortality, but if the tagged fish in both liberations have been subject to the same tagging mortality, this source of error is also omitted. The effect of shedding reduces r_{12} more than r_{22} which will result in an underestimate of the true value of S. In the present case this factor may, however, be neglected.

The estimate of R is independent of s but includes e, the correction factor for unreported recaptured tags. But if the fractions of unreported tags are the same for both samples, there is no effect of this factor on the recruitment estimate.

The catch and recovery data of Table 1 and 2 are grouped for application to the formulas (6) and (7). The chosen date for t_1 is 7 September, 1969 (first day of week 37), and t_2 is dated 6 September, 1970 (first day of week 37). The estimates will thus refer to one year. Since there is no sign of recruitment, neither in the ratio $\frac{r}{p}$ nor in the size distribution of the catch after that date for each of the years, the catch during the remaining season is co idered as one sample. The sum of catch and tag returns for the considered sampling periods appear from the bottom rows of the tables.

The data form liberation 2 and 3 are used to estimate S. In both liberations the fish were tagged and released in the same area by the same personell using the same equipment and tagging technique. The same survival rate ($s_2 = s_3$) is therefore expected. The basic formula of S may thus be written :

$$S = \frac{m_3}{m_2} \cdot \frac{r_{22}}{r_{32}} \qquad (8)$$

A small correction in m_2 is, however, justified due to fishing prior to t_1. The correction is done by subtracting the quantity:

$$\sum C_T \cdot \frac{\sum r_2}{e_1 \cdot \sum C} = \frac{18 \cdot 145}{0.47 \cdot 142} = 39$$

where the figures of Table 1 are summared over the weeks 33-36 (for the calculation of e_1 see equation (10).

The maximum likelihood estimate of S is thus:

$$S = \frac{3000}{4187 - 39} \cdot \frac{192}{440} = 0.315$$

Approximate variance of S is according to Bailey (1951), by the use of his small sample estimate of S:

$$V(s) = S^2 - \frac{m_3^2 \cdot r_{22}(r_{22} - 1)}{m_2^2 (r_{32} + 1)(r_{32} + 2)} = 0.000739$$

Confidence limits to S are:

$$S \pm \frac{2\sqrt{V(S)}}{\sqrt{r_{32}}} = 0.315 \pm 0.003$$

Since the recruitment coefficient is independent of m and s, the returns from liberations 1 and 2 can be added in the formula of R:

$$R = \frac{\bar{w}_1}{\bar{w}_2} \cdot \frac{e_2}{e_1} \cdot \frac{C_2}{C_1} \cdot \frac{(r_{11} + r_{21})}{(r_{12} + r_{22})} - 1 \qquad (9)$$

The ratio $\frac{e_2}{e_1}$ may not equal 1, because effort was made in 1970 to improve the magnet efficiency of the plants. Estimates of e for the two periods under study are, however, available from the investigated group of factories assuming equality of the ratios:

$$\frac{\Sigma r}{e \cdot \Sigma C} = \frac{\Sigma r'}{\Sigma p} \qquad (10)$$

The figures are summed over the respective sampling periods. This formula gives the following estimates of e:

$$e_1 = \frac{659 \cdot 106.600}{495 \cdot 304.049} = 0.467$$

$$e_2 = \frac{670 \cdot 55.531}{396 \cdot 170.502} = 0.551$$

The mean individual weight of mackerel in the 1969 sample (w_1) was 503 grams, and in the 1970 sample (w_2) 424 grams.

Inserting the values of the respective figures in (9):

$$R = \frac{503 \cdot 0.551 \cdot 170.502 \cdot 659}{424 \cdot 0.467 \cdot 304.049 \cdot 230} - 1 = 1.25$$

The estimates of S and R applied to (1) gives:

$$N_2 = N_1 \cdot 0.315(1 + 1.25) = N_1 \cdot 0.71$$

Thus, during the period 7 September, 1969 to 6 September, 1970, the strength of the mackerel population in number of individuals available to the Norwegian purse seiners was reduced with 29%. In weight the reduction, according to (2), was 40%:

$$P_2 = P_1 \cdot \frac{424}{503} \cdot 0.315(1 + 1.25) = P_1 \cdot 0.60$$

Estimates of N and P in absolute terms can now be considered on the basis of the catch records.

<u>Size and composition of the catch</u>

From 7 September, 1969 to 6 September, 1970 the total catch of mackerel landed by Norwegian crafts amounted to 420,100 tons. 334,400 tons were landed from the area south of 59°N (Fig. 1), 85,700 tons from the Shetland area. The latter catch was landed during week 30-36 in 1970.

The age analysis of the catches shows that the Shetland area was inhabited by the older age-groups of mackerel whereas the recruiting yearclass during this period occurred in the southern area (Table 3). If the mackerel from Shetland originated from the North Sea, the proportion of tags in the catches from the two areas should be equal. This was not the case (Table 2) and the low proportion of returns from the Shetland catch could only be explained by an assumed contribution of fish originating from other areas. The catches used for meal and oil prior to week 37 in 1970 were therefore excluded from the allowed quota of the North Sea stock.

Table 2 shows, however, that a certain fraction of the mackerel near Shetland does originate from the North Sea. Twenty tags from liberation 1 and 2 were reported during the considered period, 19 of these from plants with low magnet efficiency. (Most of the Shetland catch was produced by plants located north of Haugesund, and up to 1970 the main effort to improve the magnet efficiency of plants had been concentrated on the plants located further south.) An approximate estimate of this fraction may be obtained by assuming that tagged and untagged fish from the North Sea stock have migrated to the Shetland area in the same proportion as they occured on the Reef during autumn 1969. Then the following relation must exist:

$$\frac{19}{e' \cdot C_S} = \frac{\sum(r_1 + r_2)}{e_1 \cdot \sum C} \qquad (11)$$

where r and C are summed over the weeks 37-46 in 1969 (Table 1). C_S is the catch from the Shetland area which originated from the North Sea stock. e' denotes the magnet efficiency coefficient of the plants which have produced the bulk of the landings from Shetland in 1970.

Since there is no reason to assume that the value of e' has changed during July-October 1970, an estimate of e' is obtained by refering to the period when these plants received mackerel from the same ground as the test group, i.e. the weeks 37-45 in 1970. During this period equality of the following ratios is expected:

$$\frac{\sum (r - r_1')}{e' \cdot \sum (C - C_p)} = \frac{\sum r'}{p} \qquad (12)$$

where C_p denotes the weekly production of the test group. $\sum C_p$ for the considered period amounted to 66,873 tons.

Inserting the respective table readings and solving (12) with respect to e' we have:

$$e' = \frac{(670 - 396) \cdot 55.531}{396 \cdot (170.502 - 66.873)} = 0.371$$

An estimate of C_S is now obtained according to (11):

$$C_S = \frac{19 \cdot 0.467 \cdot 304}{659 \cdot 0.371} = 11.0$$

C_S is given in thousand tons. This is 13.2% of the Shetland catch used for meal and oil. An additional catch of 5,000 tons was used for foodfish. The estimated total contribution from the North Sea stock fished in the Shetland area in 1970 is thus some 11,700 tons.

The landings of mackerel by yearclasses from the various areas during the period under study are given in Table 3. The sum of the catch from the North Sea and the 13.2% of the Shetland catch is regarded as the total Norwegian catch of mackerel removed from the North Sea stock during the period 7 September, 1969 to 6 September, 1970 (column T).

Size and composition of the stock

Using samples drawn from the purse seine catches as representative for the stock, the age composition is determined and given in Table 4. The data refer s to the previously considered sampling periods of the respective years.

The table shows that the recruitment takes place in the age groups 1 to 4. This is in accordance with the observations made by Postuma (1970). Assuming no substantial recruitment to yearclasses older than the 1966 yearclass after September 1969, the contribution of the yearclasses 1965 and older to the total catch from the North Sea stock in 1970 may be used to estimate N_1 and N_2 in absolute terms:

$$E \cdot 0.62 \cdot N_1(1 - S) = 422.559 \qquad (13)$$

E is the rate of exploitation which is determined by the survival S and the mortality due to other causes than the Norwegian fishery. It is here assumed that all the available age groups are fished with the same rate.

Details on size and composition of catches from other nations which might have exploited the North Sea mackerel stock during the considered period are not yet available. With regard to the older age groups their catches are, however, considered to be very low compared to the Norwegian catch.

Postuma (1970) estimated the total instantaneous mortality rate during the years 1959-1966 to be 0.28. The fishing mortality during this period was low and Postuma considered this estimate to refer mainly to the natural mortality. The mortality rate caused by the fishing activity of other nations than Norway, does not seem to have changed substantially up to the time of the present study. The total mortality rate due to other causes than Norwegian fishing is therefore considered very close to 0.25 (instantaneous terms). The corresponding value of E is 0.783.

The estimated stock strength in million of individuals (N_1) and in thousand tons (P_1) referring to 7 September, 1969 are according to (13) :

$N_1 = 2105$, $P_1 = 1058$

The corresponding estimates of N_2 and P_2 are obtained from (4) and (5):

$N_2 = 1492$, $P_2 = 632$

The number recruited (R') during the time between the estimates are:

$R' = N_1 \cdot S \cdot R = 829$

The estimated stock strength (N) by yearclasses is outlined in Table 4. The 1970 catch after 6. September amounted to 184,686 tons (Table 2).

DISCUSSION

Since the sample variance of S is very small, the discussion is confined to the sources of error which may bias the estimate of N according to equation (13).

The estimates of P_1 and P_2 my be used to check the survival of the tagging (s):

$$\frac{s_2 \cdot m_2}{P_1} = \frac{\sum r'_2}{\sum p}$$

$$\frac{s_3 \cdot m_3}{P_2} = \frac{\sum r'_3}{\sum p}$$

where r and p are summed over the respective sampling periods.

Inserting the respective table readings (Tables 1 and 2):

$$s_2 = \frac{416 \cdot 1058}{4148 \cdot 106.6} = 0.995$$

$$s_3 = \frac{265 \cdot 632}{3000 \cdot 55.6} = 1.004$$

Although much attention has been paid to improve the tagging technique, 100% survival of the tagged fish can not be expected. The calculated s_2 and s_3 are assumed to be too high, a result of a slight overestimate of the stock size. There are two main factors which may possibly overestimate N and the corresponding P:

a) an overestimate of the mortality rate due to other causes than the Norwegian fishery, and

b) interchange of individuals with other stocks.

With regard to (a) no further data are available to check this stipulated mortality. Based on the results given by Postuma (1970) this parametre was chosen equal to 0.25 (instantaneous terms). The value seems reasonable, and if 0.20 is taken as a lower limit, N, P and s are reduced with approximately 6%.

It has previously been shown that interchange of individuals between mackerel stocks occurs (Bolster 1969, Zijlstra and Postuma 1968). The catches from the Shetland area in 1970, contained only a minor part of mackerel from the orth Sea stock, and consequently the Shetland fishery has exploited other populations.

Mixing of stocks in the Shetland area is confirmed by the results of the 1971 investigations. 4,400 mackerel was tagged and released in an area southwest of Irland in May 1971, and so far 36 tags have been recovered. These tags were from catches taken in the Shetland area during July-August 1971. From the same catches (170,000 tons) were recovered 78 tags from liberations 1, 2 and 3. A preliminary calculation similar to that of equation (11) shows a contribution to the catch from the North Sea stock of about 30%.

The area around Shetland appears to be a boundary between two stocks, the one spawning in the North Sea and that spawning south of Irland. The area is inhabited by the older age groups of both stocks (Fig. 2), and mixing may therefore be limited to these groups only.

An analysis of the effect of interchange of individuals with the Irish stock on the estimates of N is complicated. The problem depends on circumstances relating to the balance between emigration and immigration. It may, however, be stated that immigration to the North Sea stock tends to underestimate N, whereas emigration acts in the opposite way. Since the estimate of N is regarded as an overestimate of the true value, further consideration may be limited to the effect on N caused by possible emigration.

If a fraction of the North Sea stock which inhabited the Shetland area during the summer 1970 did not return to the southern grounds in the North Sea, this would be recorded in S as an additional natural mortality of fish. However, since the majority of fish in these schools belong to the older groups, the survival coefficient of these groups (S') will become smaller than the estimated average of S. An indication of an overestimate in S when applied to the older age groups occurs from the data in Table 4:

$$S' = \frac{N_2'}{N_1'} = \frac{358}{1305} = 0.274$$

This estimate of S' depends, however, on the accuracy of the age readings and is also biased by the possible error introduced in S.

The indication of a lower survival rate in the older age groups may either be due to a higher fishing mortality rate or emigration, the former being less likely. If this possible error was corrected for in equation (13), it would in both cases result in a lower estimated value of N_1.

CONSERVATION MEASURES IN 1971

The conservation measures imposed on the Norwegian mackerel fishery in 1971 are based on the same principles as in 1970 (Hamre 1970 b). Primarily, the aim of the regulation is to limit the fishing effort to an annual fishing mortality of 35%. This is practised by an annual catch quota for meal and oil. Based on the present findings on the state of the stock, a preliminary catch quota of 135,000 tons was allotted for 1971. The quota was applied to the area east of 2°W (Fig. 1). It was, however, presupposed that possible landings from the Shetland area should be included according to the proportional contribution by the North Sea stock.

The fishery has further been regulated by prohibiting purse seining for mackerel in the restricted area up to 12 July, 1971. At that date the area was opened for purse seining for foodfish, whereas permission to land mackerel for reduction purposes was only given for the area north of 59°N. The restriction on the area south of 59°N was kept in force in order to protect the strong recruiting yearclass 1969 which is coming up in the Skagerak and southeastern North Sea (Fig. 2). According to a recent decision, the area south of 59°N may be kept closed for fishing for reduction purposes throughout the year.

As described previously the catch taken around Shetland this year contained a minor portion of fish from the North Sea stock (about 30%). It was thus found justified to raise the quota for reduction purposes to 225,000 tons, the new quota being applied to the area north of 59°N only. According to the latest catch records available, some 50,000 tons of the quota remains to be filled.

SUMMARY

1. The paper deals with (a) size and composition of the mackerel stock in the Skagerak and northeastern North Sea, and (b) regulation measures imposed on the fishery.

2. During the period 7 September, 1969 until 6 September, 1970 the North Sea stock has been reduced with 29% in number and 40% in weight. The survival coefficient is estimated to 0.315, corresponding to a fishing mortality of 66%. The stock size at the latter date is estimated to 1492 million individuals or 632 thousand tons. The recruitment during the period is estimated to 829 million individuals.

3. The Norwegian mackerel fishery for meal and oil is restricted to the area north of 59°N (Fig. 1). The quota for this area after 12 July, 1971 is 225,000 tons.

REFERENCES

Bailey, N.J.J. 1951. On estimating the size of mobile populations from recapture data. Biometrika, 38:293-306.

Bolster, G.C. 1969. English Mackerel Tagging Experiments 1962-67. Coun. Meet.int.Comm.Explor.Sea. H:32, 1-7. Mimeo.

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

Hamre, J. 1970. Size and Exploitation of the Mackerel Stock in the Skagerak and the North-Eastern North Sea. Coun. Meet.int.Comm.Explor.Sea. H:26 1-5.1 tabl.3fig Mimeo.

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

Zijlstra, J.J. and K.H. Postuma. 1968. Netherlands Mackerel Fishery in the North Sea in 1966. Annls.biol.23:195-197.

Table 1. Catch (in tons) and tag returns (in number) by weeks in 1969. X denotes undated recoveries. For further explanation see text.

Week no.	C_T	C	r_1	r_2	p	r_1'	r_2'	$\frac{r_1'}{p}$	$\frac{r_2'}{p}$
30	25.142	24.475			2.727				
31	1.468	0.893	1		0.066	1		15.15	
32	9.584	8.823	2		1.819	2		1.10	
33	30.054	29.378	3	4	14.426	3	3	0.21	0.21
34	34.624	34.050	10	3	10.508	9	3	0.86	0.29
35	31.884	31.237	12	7	14.782	8	5	0.54	0.34
36	48.283	47.596	6	4	11.333	6	2	0.53	0.18
37	48.623	47.621	19	58	21.041	14	41	0.67	1.95
38	9.176	7.654	11	17	2.917	8	14	2.74	4.80
39	11.093	10.479	3	16	6.225	3	16	0.48	2.57
40	61.718	60.539	12	45	17.104	9	39	0.53	2.28
41	59.490	58.057	21	128	24.987	16	107	0.64	4.28
42	62.184	60.628	14	83	15.574	12	65	0.77	4.17
43	57.040	55.839	24	137	17.088	15	103	0.88	6.03
44	0.086		7	41	0.105	1	8	9.52	76.19
45	4.367	3.232	1	22	1.448	1	21	0.69	14.50
46	0.246				0.111		2		18.02
X			11	57					
Σ	495.062	480.501	157	622	162.261	108	429	0.67	2.64
Σ(37-46)	314.023	304.049	112	547	106.600	79	416	0.74	3.90

Table 2. Catch (in tons) and tag returns (in number) by weeks in 1970. X denotes undated recoveries. For further in explanation see text.

Week no.	C_T	C	r_1	r_2	r_3	p	r_1'	r_2'	r_3'	$\frac{r_1'}{p}$	$\frac{r_2'}{p}$	$\frac{r_3'}{p}$
30	2.729	0.602		3		0.375						
31	17.090	14.563				2.576						
32	57.131	54.294	1	4		7.841						
33	5.623	4.261		2		0.238						
34	5.686	3.191	1	3		0.135						
35	5.810	3.710	1	3	2	0.190		1			5.26	
36	0.287			1								
37	2.249	1.196				0.090						
38	57.487	55.012	8	34	67	15.601	2	14	36	0.13	0.90	2.31
39	4.947	4.138	3	13	30	1.994	2	11	21	1.00	5.52	10.53
40	3.218	2.353	1	4	7	0.680		3	6		4.41	8.82
41	0.155			4	14			1				
42	83.814	79.718	20	89	178	24.742	12	48	111	0.49	1.94	4.49
43	27.701	25.270	6	48	142	12.237	3	29	86	0.25	2.37	7.03
44	0.271				2				1			
45	4.844	2.815				0.187	1	5	4	5.35	26.74	21.39
X			1	10	9							
Σ	279.042	251.123	42	218	451	66.886	20	112	265	0.30	1.67	3.96
Σ(37-45)	184.686	170.502	38	192	440	55.531	20	111	265	0.36	2.00	4.77

Table 3. Norwegian mackerel catches in tons (C_T) and million individuals (n) by yearclasses, areas and seasons. A denotes total catch form the area north of 59°N in 1970. T denotes the sum for the three first columns. For further explanation see text.

	South of 59°N Week 37-52 1969		South of 59°N Week 1-36 1970		North of 59°N 13.2% of A		T		A	
Year-class	C_T	n	C_T	n	C_T	n	C_T	n	C_T	n
1969			0.423	1.567			0.423	1.567		
1968	5.233	21.805	3.270	10.548	0.195	0.813	8.698	33.166	3.359	9.079
1967	16.063	41.183	2.183	5.900	0.599	1.535	18.845	48.623	3.404	7.566
1966	73.265	174.442	4.703	12.376	2.730	6.500	80.698	193.318	12.564	26.733
1965	54.658	113.872	2.674	6.684	2.037	4.243	59.369	124.799	15.771	29.760
1964	16.281	29.074	0.557	1.358	0.607	1.083	17.445	31.515	8.614	14.123
1963	6.796	13.325	0.299	0.574	0.253	0.497	7.348	14.396	7.691	12.610
older	141.709	230.165	6.291	13.107	5.281	8.576	153.281	251.849	34.296	50.440
Σ	314.005	623.872	20.400	52.114	11.702	23.247	346.107	699.233	85.699	150.311
1966-1969	94.561	237.435	10.579	30.391	3.524	8.848	108.664	276.674	19.327	43.378
1965& older	219.444	386.437	9.821	21.723	8.178	14.399	237.443	422.559	66.372	106.933

Table 4. Size (N) and age composition (%) of the mackerel stock in 1969 and 1970. For further explanation see text.

	1969		1970			
Yearclass	%	N_1	%	N_2	$N_1 \cdot S$	$N_2 - (N_1 \cdot S)$
1969			14.4	214.8		214.8
1968	3.5	73.7	20.8	310.3	23.2	287.1
1967	6.6	138.9	10.5	156.7	43.8	112.9
1966	27.9	587.3	30.3	452.1	185.0	267.1
1965	18.3	385.2	9.6	143.2	121.3	21.9
1964	4.7	98.9	1.8	26.9	31.2	- 4.3
1963	2.1	44.2			13.9	-13.9
older	36.9	776.7	12.6	188.0	244.7	-56.7
1966 - 69	38.0	799.9	76.0	1133.9	252.0	881.9
1965 & older	62.0	1305.1	24.0	358.1	411.1	-53.0

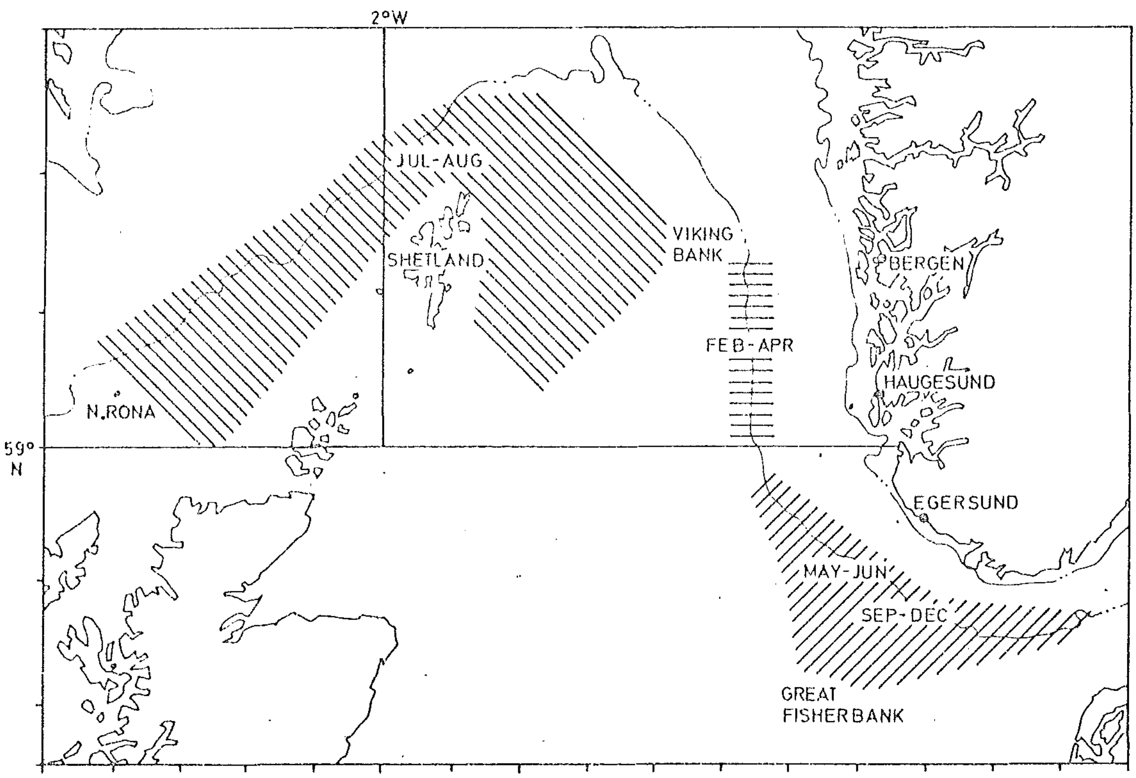

Figure 1. Fishing areas for Norwegian purse seiners by season.

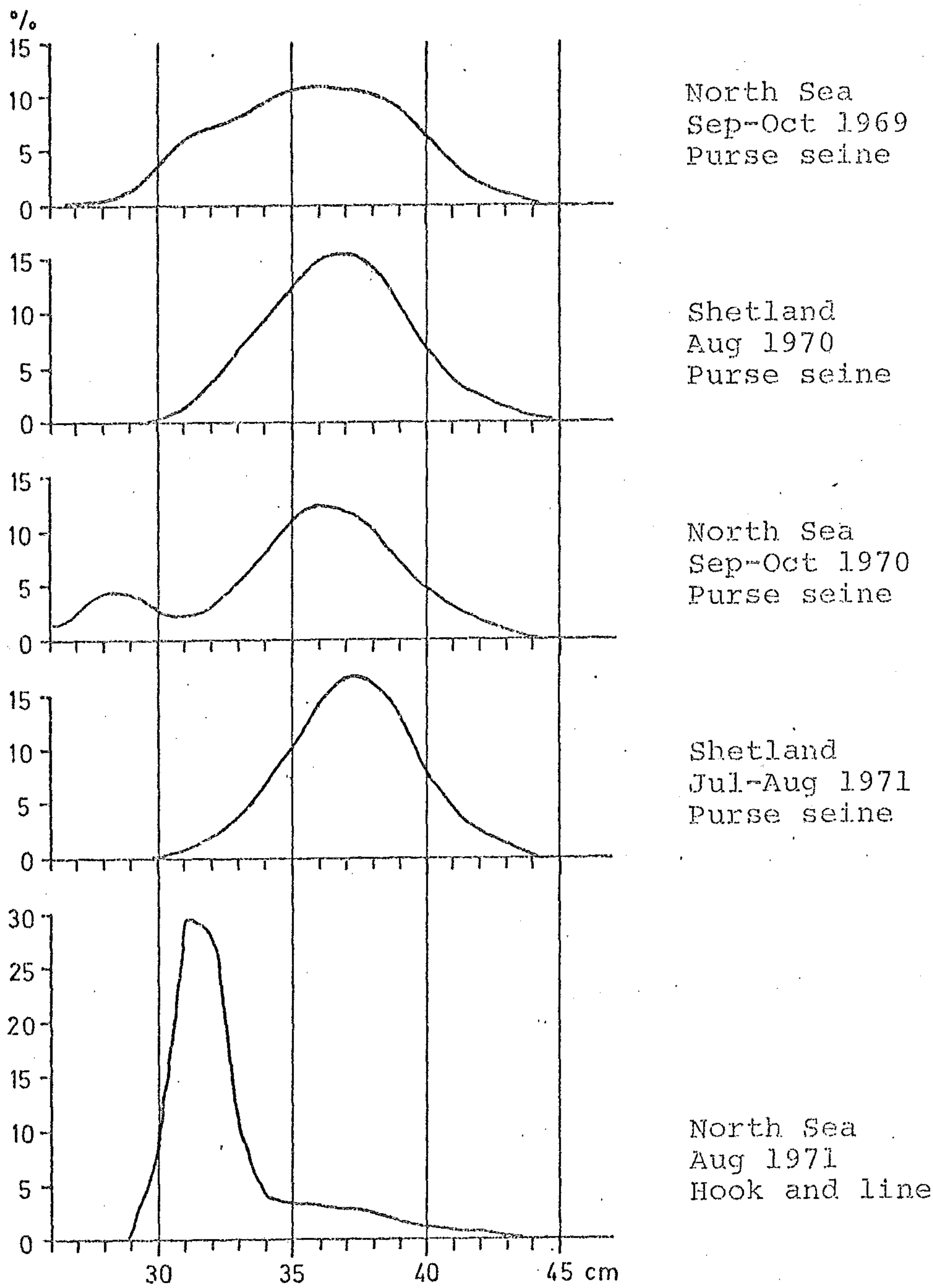

Fig. 2. Length frequency distribution (%) of mackerel by season and area.