International Council for the
Exploration of the Sea

C.M. 1963
Herring Committee
No. 117 (H)

Fishing effort and mortality of North Sea herring

by

J.J. Zijlstra and K.H. Postuma
Netherlands Institute for Fishery Investigations
IJmuiden, Netherlands

Introduction

In the last few years the serious state of many North Sea herring fisheries has caused much concern, which led to a recommendation at the I.C.E.S. meeting in 1960 to set up a Working Group to investigate the possible causes of the decline in the herring fisheries with special reference to the effect of fishing. From the reports of the Working Group (1961, 1962) it appears that no firm conclusions could be reached, owing presumably to the complex situation in the North Sea herring tribe.

There are arguments that the North Sea herring is not a homogeneous stock, but consists of possibly three main populations, which are found isolated in certain periods of the year (for instance in spawning time), but mix on the feeding grounds in summer in proportions, which may vary from area to area and from year to year.

To make an appraisal of the effect of fishing on any of these stocks, estimates of the total catch of and the effort exerted on that stock are needed, which means that the catch in the "mixed" fisheries has to be split up in components, derived from the three populations.

The main concern of the Working Group has been this separation of the "mixed" catches, in an attempt to estimate the total catch of herring, belonging to one of the populations, the Southern Bight herring. However, in spite of the great quantity of material used, which consisted of data of all countries with herring fisheries in the North Sea, no justified split of the "mixed" catches was considered to be possible, which made an appraisal of the effect of fishing on the Southern Bight stock unattainable.

The experiences of the Working Group thus prove that it is extremely difficult to estimate the effect of fishing on the three herring populations separately. For this reason, an attempt has been made in this paper to arrive at an estimate of the total effort, exerted on North Sea herring, irrespective of populations. By comparing these effort data with mortality rates measured in some important herring fisheries in the North Sea, it was anticipated that this study might contribute to an appraisal of the effect of fishing on North Sea herring.

I. Estimates of fishing effort

To obtain an estimate of the total fishing effort, exerted on North Sea herring, data on the total catch of these herring and on the catch per unit of effort in the fisheries are required.

Total catch

Data on the herring catches in the North Sea are given for a long serie of years in the Bulletin Statistiques of the I.C.E.S. It has been assumed, that the figures of the catch of adult North Sea herring can be obtained by subtracting from the total North Sea catch the Norwegian and Danish catches, as the bulk of the catch of these countries is presumably either Atlanto-Scandian herring (Norway) or immature herring (Denmark). Figures of the total catch, thus obtained, are shown in fig. 1a for the periods 1925-1938 and 1946-1960.

Catch per unit of effort

A difficulty in determining an index of the catch per unit of effort for the North Sea herring fisheries is that the total catches of fig. 1a represent the yield of a variety of herring fisheries, fishing in different regions of the North Sea, in different seasons and presumably on different components of North Sea herring. It seems therefore unlikely that the catch per unit of effort of any single herring fishery will give a proper estimate of the abundance of the North Sea herring.

Therefore, data on the catch per unit of effort of fisheries in the northern, central and southern North Sea were combined, with the intention to get a fair representation of the main North Sea fisheries.

The only long series of data on catch per effort which were available were those of four fisheries: in the northern North Sea German trawl (Schubert, 1961) and Scottish driftnet (Parrish and Craig, 1961), in the central North Sea: German trawl (Schubert, 1961) and in the southern North Sea English driftnet (Cushing, 1961).

The data on the catch per unit of effort of these four fisheries are shown in fig. 2.

Before pooling the catches per unit of effort of the four fisheries, each set of figures was first converted to the same average level, taking the data of the German trawl fishery in the northern North Sea as a standard. This was done by multiplying each figure of a fishery with the factor

$$\frac{\Sigma \text{ c/f German trawl fishery in the northern North Sea.}}{\Sigma \text{ c/f other fishery}}$$

Then, after averaging the German and Scottish data for the norhtern North Sea, the straight, unweighted mean of the converted catches per unit of effort of the northern, central and southern North Sea was calculated.

The value thus obtained, was taken as an index of the catch per unit of effort of the North Sea fisheries.

A closer examination of the four sets of c/f figures led to another estimate of the overall index of abundance.

There is a discrepancy between the German and Scottish data in the northern North Sea in the postwar period (see fig. 2), the German c/f declining, the Scottish c/f increasing.

The trend in the German data is similar to that in the figures in the areas central and south and correspond well with c/f data of Belgian and Dutch trawl fisheries in the northern area, available for the postwar period.

A possible explanation for the aberrant figures of the driftnet fisheries in the north western North Sea in the postwar period is offered by the observation, that the character of the main part of these fisheries (Buchan pre-spawning fisheries) has changed from a fishery on adult herring to a recruit-fishery in the early fifties. (Parrish and Craigh, 1961). This would make the Scottish data less suitable to indicate changes in abundance of the herring in the northern area.

Therefore, a second index of an average mean catch per unit of effort of the North Sea fisheries was obtained, by omitting the Scottish data in the estimate of c/f for the northern area.

The two sets of average c/f figures for the North Sea calculated with and without the Scottish data are pictured in fig. 1b.

Effort estimates

From the data on total catch and the two sets of average c/f figures two estimates have been computed of the total effort exerted on North Sea herring, which are shown in fig. 1c.

Both sets of effort estimates show principally the same. In the prewar period 1925-1938 the effect was rather steady at approximately 100,000 units. However, in the postwar period, the effort increased, from about 60,000 to about 130,000 units (c/f data with Scottish data = fs) or 160,000 units (c/f data without Scottish data = f)

From 1946-1949 the effort increased rapidly, followed by a period of slow increase from 1949-1954. Then again a steep increase in effort is indicated between 1954 and 1956, which levelled off again in the period 1956-1960. It is important to note that according to the calculations, the effort in the period 1955-1960 was 30-60% higher than the steady effort level in the prewar period.

II. Mortality rates

The procedure to obtain an overall estimate of Z for North Sea herring was the same as followed in the c/f appraisal. Estimates of Z were collected for fisheries in the northern, the central and the southern North Sea and were then combined by taking a straight, unweighted average.

Estimates of Z for the periods 1925-1938 and from 1946-1960 were available from the Scottish fishery (1930-1938 and 1948-1960), (Parrish and Craig, 1961)

and from the East-Anglia fishery (Cushing, 1961), but not for the trawl fisheries in the northern and central North Sea. For the latter fisheries the estimates had to be calculated. Data on age-distributions of herring were available from German, Belgian and Dutch sources. By combining these data per year and raising them with combined abundance figures from the same fisheries, estimates of abundance per age-group were obtained for the period 1925-1936 and 1946-1961, from which estimates of Z could be calculated.

The estimates of Z thus obtained were not uniformly calculated, owing partly to different methods used in the various investigations and partly to differences in the age of recruitment between pre- and postwar material. In general Z was calculated from the abundance of fish over three years old in one year and the abundance of fish over four years old in the next year ($Z_{3/4}$).

Table 1 summarizes the Z-values and the average "North Sea" Z obtained in the years between 1925-1938 and 1946-1960.

As the annual estimates of Z fluctuate widely, data grouped in five years periods are given in table 2.

Period	Area south	Area central	Area north	Average
1925 - 1930	0.63 (5)	0.44 (5)	0.15 (5)	0.41
1930 - 1935	0.55 (5)	0.48 (5)	0.64 (5)	0.56
1935 - 1938	0.45 (3)	-	0.63 (4)	0.54
1946 - 1950	0.57 (4)	0.25 (4)	0.48 (4)	0.44
1950 - 1955	0.71 (5)	0.46 (5)	0.42 (5)	0.53
1955 - 1960	1.01 (5)	0.57 (5)	0.71 (5)	0.76

Table 2. Mortality rates (Z), as averages of five years periods, in the northern, central and southern North Sea, together with the average Z of the three areas. Between brackets: number of estimates.

The data on the average "North Sea" Z show more or less the same pattern as found for the effort data. Although widely fluctuating in the prewar period, the values of Z do not show any particular trend, whereas a definite trend is apparent in the postwar period, when the average Z values are increasing. Besides, in all four fisheries the highest Z values are found between 1955 and 1961.

III. Relationship between effort and mortality

With the methods used to estimate f and Z no high degree of exactness can be expected, which will certainly affect any calculations made about the relationship between the two sets of estimates. Especially the regression of Z on f must be considered with much care.and can hardly be expected to give much valuable information.

Still, the correlation between Z and f appears to be highly significant. In the calculation of the correlation coefficients the mortality values were related to the average effort in the two years between which the estimate of Z was made. For instanse, Z 1925/1926 was related to $\frac{f\ 1925 + f\ 1926}{2}$. This was done, because presumably part of the effort, related to Z, was exerted in one year and part in the next year.

Thus, the correlation coefficient and the regression equation were computed, for both sets of effort data (fs = including Scottish c/f data and f = without Scottish data).

Both correlations proved to be significantly differnnt from zero ($p = 0.01$), indicating that fishing had a measurable effect. The correlation coefficients were:

$r = 0.45$ (fs) ($p \lesssim 0.01$)

$r = 0.48$ (f) ($p \lesssim 0.01$)

The equations, describing the relationship between fs - Z and f - Z were:

$Z = 0{,}000.0075\ fs - 0.29$

$Z = 0{,}000.0051\ f - 0.04$

It is obvious, from an inspection of the effort data shown in fig. 1c, that the prewar data do not contribute very substantially to the relationship found between f and Z, because f in that period was more or less constant. Therefore, the Z-f relationship has been calculated apart for the pre- and postwar period.

For the prewar period no relationship between f and Z could be detected, both correlation coefficients being not significantly different from zero.

For the postwar period (1946-1960), when a fair range of effort values was available, again a highly significant correlation between f and Z was found, with r being:

$r = 0.64$ ($0.01\ p\ 0.001$) (fs)

$r = 0.71$ ($p = 0.001$) (f)

and equations:

$Z = 0.000{,}0082\ fs - 0.36$

$Z = 0.000{,}0060\ f - 0.15$

The regression equations are not very different from the ones calculated for the whole material.

In the relationship between f and Z there are two points of special importance:

1. The fairly high degree of co-variance between the two estimates, which is most easily interpreted as an indication that fishing has a measurable effect on the total mortality of the North Sea herring.
2. The negative values found for M, the natural mortality, in all four equations, which, of course, cannot be correct.

Discussion

There are two main conclusions in this study on fishing effort and mortality rates of the North Sea herring.

a. The effort exerted on the North Sea herring has apparently increased more or less continuously in the postwar period, reaching a considerably higher level in the years between 1955-1960 than in the prewar period. Whether this increase in effort was equally distributed over the three (hypothetical) stocks or over the three areas north, central and south, seems doubtful, but has not been investigated.

b. In the period of expanding fishery an increase in the apparent mortality rate took place, so that the highest effort estimate coincided with the highest Z value in the period 1955-1960. In that period the mortality rates reached a peak value in each of the northern-, the central- and in the southern North Sea fisheries.

An important question concerning this study is in how far the method used here is valid and free of bias.

It seems fairly certain that the North Sea herring tribe is not a homogeneous population, but consist of possibly three sub-populations, with different migration routes, mortality rates, growth patterns and, possibly differences in the effort exerted in the stocks. (Postuma and Zijlstra, 1958, Zijlstra, 1958, Zijlstra, 1961).

Although this inhomogeneity of the North Sea herring has been recognized and accounted for by averaging abundance and mortality estimates from the northern, central and southern North Sea, so that estimates of each of the three stocks are probably incorporated in the "average" North Sea estimate, the methods used may introduce errors and may contain pitfalls.

By giving the estimates of the three areas the same weight, variations and trends in the relative importance of the herring stocks in the three areas in the course of the period investigated have been neglected. In a future study this could be amended, partly by weighing the estimates of each area, for instance by the total catch in the area, if these are known.

However, this objection is in this particular case partly met by the fact that both catch per effort and mortality rates in the three areas show a similar trend in the most important period 1946-1960.

Therefore, it seems not very likely, that the postwar trend in the effort and in the average mortality estimates will greatly change by applying more refined methods.

It is unreasonable to expect that with the methods used the regression equations found give a very accurate description of the actual relationship between f and Z, as has been said before.

It is possible that the negative values found for M are due to the inexactness of the method. However, the negative M values could easily be explained if the actual increase in effort in the postwar period has been

more important than expressed in our figures, due to a gradual increase of the efficiency of the fisheries, which was not fully accounted for in the c/f data.

It is the impression that such an underestimate of the effort in recent years could very well have occurred. Therefore, there is no reason to assume that the negative M values invalidate the other conclusions of this study.

Summary

Effort and mortality estimates from North Sea herring in the period 1925-1960 were determined by averaging abundance and mortality estimates from the northern, central and southern North Sea.

The fishing effort, exerted on North Sea herring, was found to increase consistently in the postwar period 1946-1960, whereas it was fairly constant in the pre-war years. In the years 1955-1960 the effort level was considerably higher than in the prewar period 1925-1938.

The estimates of the mortality rates showed a similar pattern as the effort estimates and the highest values of Z were found in the years between 1955-1960.

A highly significant correlation was found between the effort and mortality data of North Sea herring.

References:

Cushing, D.H. - The Effect of Fishing on the Downs Stock of Herring in the North Sea.
Cons. Intern. Expl. Mer, Paper Herring Symposium, C.M. 1961, no. 25 (mimeo).

Erdmann, W. - Der deutsche Trawlheringsfang 1934.
Der Fischmarkt NF 3, 3, 60-74, 1935.

Erdmann, W. - Der deutsche Schleppnetzheringsfang 1935.
Ibid 4, 3, 60-81, 1936.

Erdmann, W. - Der deutsche Schleppnetzheringsfang 1936.
Ibid 5, 3, 61-88, 1937.

Erdmann, W. - Der deutsche Schleppnetzheringsfang 1937.
Ibid 6, 3, 72-83, 1938.

Gilis, Ch. - Observaties over de volle haringconcentraties in het noordelijke en centrale gebied van de Noordzee in de jaren 1946-1947 en 1948.
Zeewetenschappelijk Instituut Oostende, 1-45.

Gilis, Ch. - Observaties over de visserij en de biologie van de volle haringconcentraties uitgebaat door de belgische haring-treilers in 1949.
Zeewetenschappelijk Instituut Oostende, 1-27, 1950.

Gilis, Ch. - Voortgezette observaties over de visserij en de biologie van de jaarlijkse haringconcentraties door de belgische haringtreilers in de Noordzee uitgebaat, A. volle haringconcentraties, 1950; B. IJle haringconcentraties 1950-1951.
Ibid, 1-40.

Gilis, Ch. - Voortgezette observaties over de visserij en de biologie van de jaarlijkse haringconcentraties door de belgische haringtreilers in de Noordzee uitgebaat, A. volle haringconcentraties 1951; B. IJle haringconcentraties 1951-1952.
Ibid, 1-36.

Gilis, Ch. - Waarnemingen over de A. volle haringconcentraties 1952 I. Noordzee, II Smallsdiepte; B. IJle haringconcentra-ties 1952-1953, door de Belgische treilers uitgebaat.
Ibid, 1-44, 1953.

Gilis, Ch. - Waarnemingen over de concentraties A. van de volle haring 1953, B. van de ijle haring 1953-1954 door de belgische trawlers in de Noordzee uitgebaat.
Ibid, 1-46, 1954.

Gilis, Ch. - De haringcampagne gedurende de periode juli 1954 - februari 1955.
Ibid, 1-51, 1955.

Gilis, Ch. - De haringcampagne gedurende de periode juli 1955 - februari 1956.
Ibid, 1-36, 1956.

Lissner, H. - Die deutsche Trawlheringssaison 1929.
Der Fischerbote 22, 4, 57-62, 1930.

Lissner, H. - Die deutsche Trawlheringssaison 1930.
Ibid, 23, 3, 29-36, 1931.

Lissner, H. - Die deutsche Trawlheringssaison 1931.
Ibid, 24, 5, 77-81, 1932.

Lissner, H. - Die deutsche Schleppnetzfischerei auf Heringe 1932.
Der Fischmarkt, NF 1, 4, 119-123, 1933.

Parrish, B.B. and Craig, R.E. - The herring of the N.W. North Sea - Postwar changes in the stock fished by Scottish drifters.
Cons. Intern. Expl. Mer, Paper Herring Symposium, C.M. 1961, no. 23.

Postuma, K.H. and Zijlstra, J.J. - On the Distinction between Herring Races in the autumn and winterspawning Herring of the Southern North Sea and English Channel by means of otoliths and an application of this Method in Tracing the Offspring of the Races along the Continental Coast of the North Sea.
Cons. Intern. Expl. Mer, Rapp. Proc. Verb., 143 (2), 130, 1958.

Schubert, K. - Survey of the German Commercial Herring Fisheries and the Biological Conditions of the Stocks.
Cons. Intern. Expl. Mer, Ann. Biol., XII, 1955, 185-193, 1957.

Schubert, K. - Survey of the German Commercial Herring Fisheries and the Biological Conditions of the Stocks.
Cons. Intern. Expl. Mer, Ann.Biol.,XIII, 1956, 192-197, 1958.

Schubert, K. - Survey of the German Commercial Herring Fisheries and the Biological Conditions of the Stocks.
Cons. Intern. Expl. Mer, Ann.Biol. XIV, 1957, 169-174, 1959.

Schubert, K. - Survey of the German Commercial Herring Fisheries and the Biological Conditions of the Stocks.
Cons. Intern. Expl. Mer, Ann.Biol. XV, 1958, 141-156, 1960.

Schubert, K. - Survey of the German Commercial Herring Fisheries and the Biological Conditions of the Stocks.
Cons. Intern. Expl. Mer, Ann. Biol. XVI, 1959, 192-206, 1961.

Schubert, K. - Survey of the German Commercial Herring Fisheries.
Cons.Intern.Expl.Mer, Ann.Biol.XVII, 1960, 188-205, 1962.

Schubert, K. - The Development of the Effort in the German Trawl Herring Fishery.
Cons. Intern. Expl. Mer, Paper Herring Symposium, C.M. 1961, no. 4 (mimeo).

Zijlstra, J.J. - On the "Herring Races" spawning in the southern North Sea and English Channel. (Preliminary report)
Cons.Inntern.Expl.Mer, Rapp. Proc.Verb., 143 (2), p. 134, 1958.

Zijlstra, J.J. - On the Recruitment Mechanism in the North Sea Herring.
Cons.Intern.Expl.Mer, Paper Herring Symposium, C.M. 1961, no. 29 (mimeo).

Year	Z_1	Z_2	Z_{3a}	Z_{3b}	Z_3	Z
1925/1926	0.87	0.05	-0.23	-	-0.23	0.23
1926/1927	1.14	0.34	0.53	-	0.53	0.67
1927/1928	0.27	0.53	0.11	-	0.11	0.30
1928/1929	0.26	-0.19	-0.17	-	-0.17	-0.03
1929/1930	0.61	1.47	0.52	-	0.52	0.87
1930/1931	0.70	0.55	0.68	0.61	0.64	0.63
1931/1932	0.74	0.85	0.22	1.14	0.68	0.76
1932/1933	0.42	0.51	0.91	1.11	1.01	0.65
1933/1934	0.24	0.51	0.91	-0.06	0.43	0.39
1934/1935	0.65	-0.02	0.28	0.60	0.44	0.36
1935/1936	0.12	0.00	0.29	0.51	0.40	0.17
1936/1937	0.70	-	-	0.30	0.30	0.50
1937/1938	0.54	-	-	0.19	0.19	0.37
1938/1939	-	-	-	1.51	1.51	-
1946/1947	0.65	0.35	0.69	-	0.69	0.56
1947/1948	0.08	0.15	0.37	-	0.37	0.20
1948/1949	1.04	0.22	-0.19	0.99	0.40	0.55
1949/1950	0.50	0.29	0.99	0.00	0.49	0.43
1950/1951	0.55	0.26	-0.20	0.21	0.00	0.27
1951/1952	0.52	0.47	-0.12	-0.01	-0.06	0.31
1952/1953	1.01	0.50	0.54	0.92	0.73	0.75
1953/1954	0.27	0.44	0.85	0.56	0.71	0.47
1954/1955	1.22	0.62	0.82	0.63	0.73	0.86
1955/1956	0.86	0.78	0.94	0.33	0.64	0.76
1956/1957	1.81	0.23	-0.27	0.51	0.12	0.72
1957/1958	1.00	0.36	0.82	0.15	0.49	0.62
1958/1959	0.77	0.82	0.83	1.83	1.33	0.97
1959/1960	0.60	0.68	1.25	0.80	1.03	0.77
1960/1961	1.27	0.57	0.37	-	0.37	0.74

Table 1. Mortality estimates.

(Z_1) = East Anglian fishery

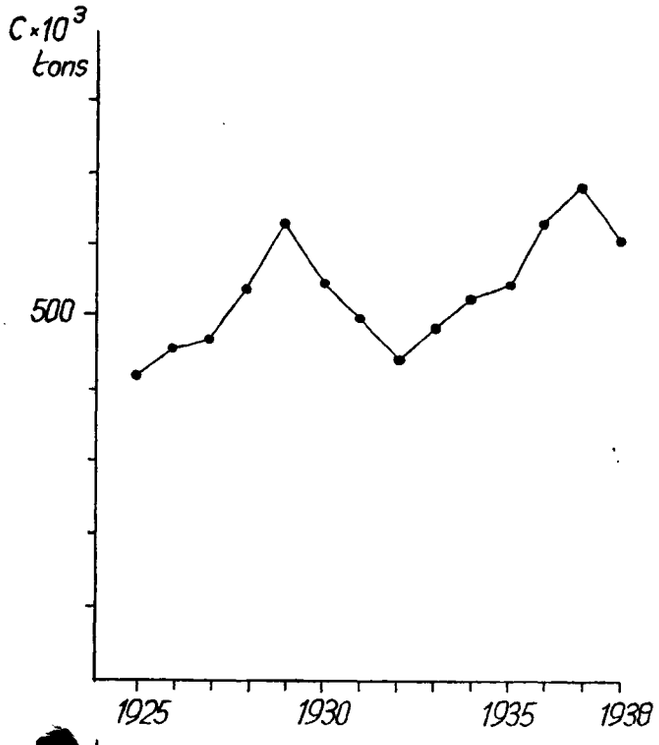
(Z_2) = Dogger fishery

(Z_{3a}) = Fladen fishery

(Z_{3b}) = Scottish driftnet fishery

$$(Z_3) = \frac{Z_{3a} + Z_{3b}}{2}$$

$$(Z) = \frac{Z_1 + Z_2 + Z_3}{3}$$



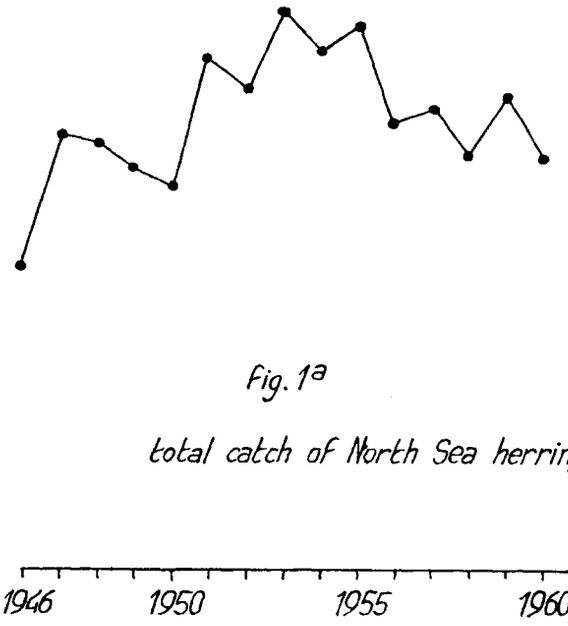
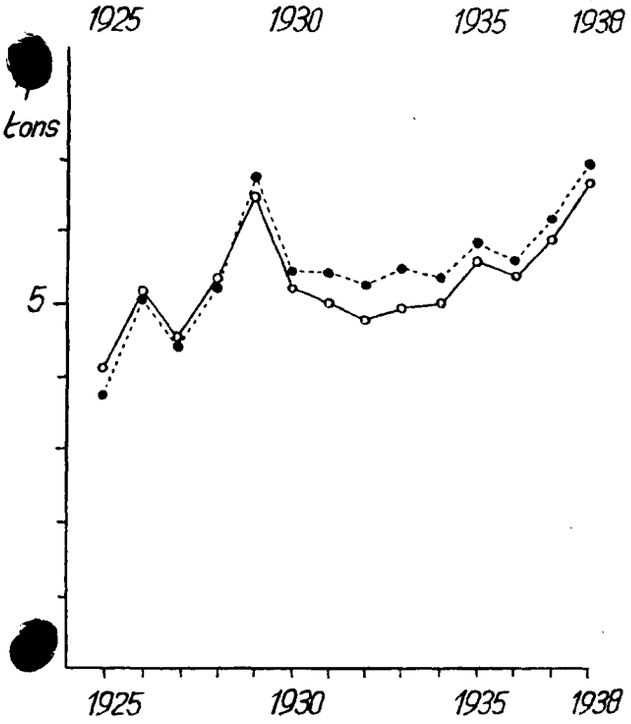


Fig. 1ª

total catch of North Sea herring



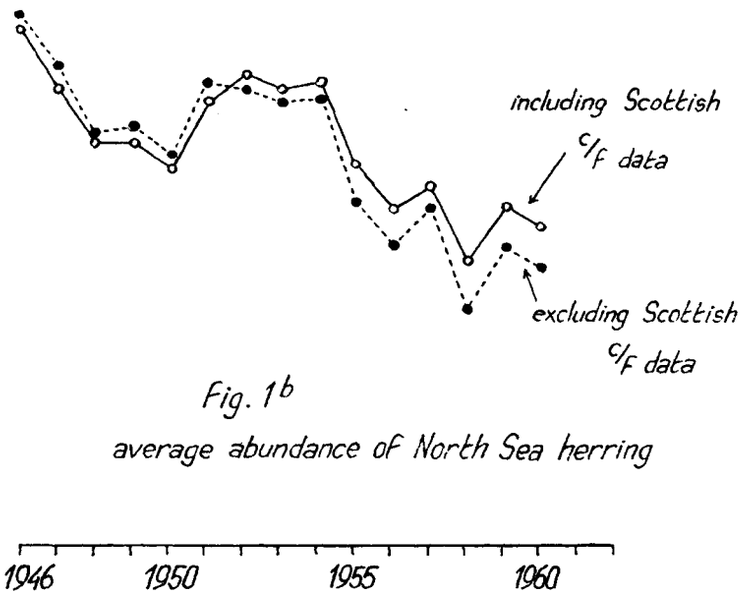
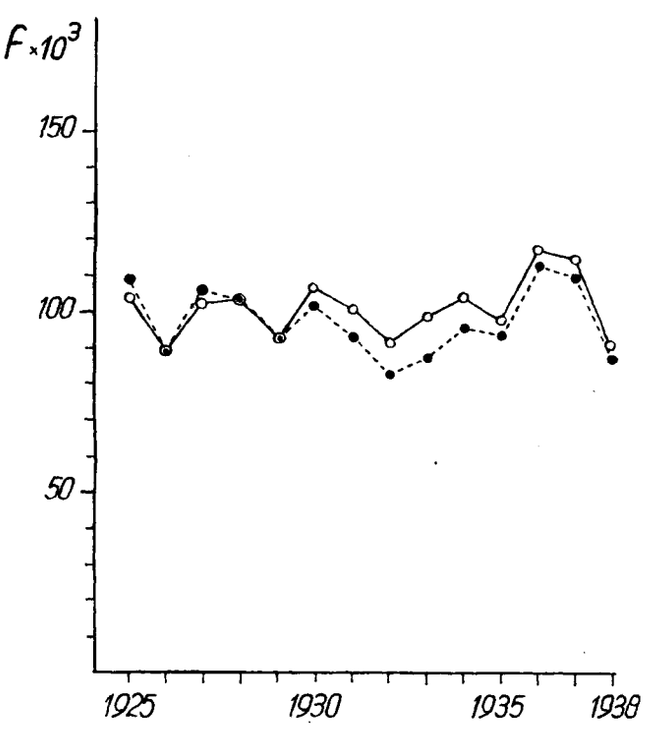


Fig. 1ᵇ

average abundance of North Sea herring



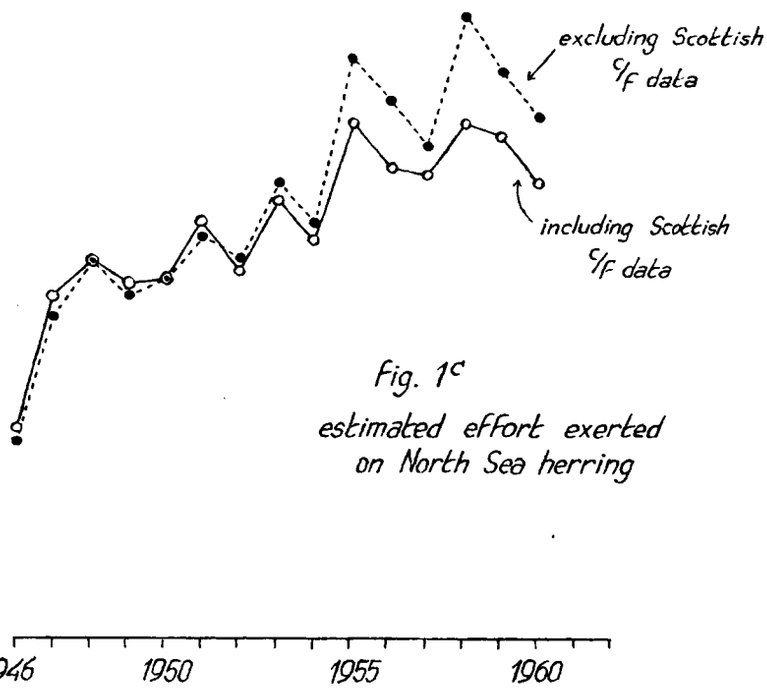


Fig. 1ᶜ

estimated effort exerted on North Sea herring

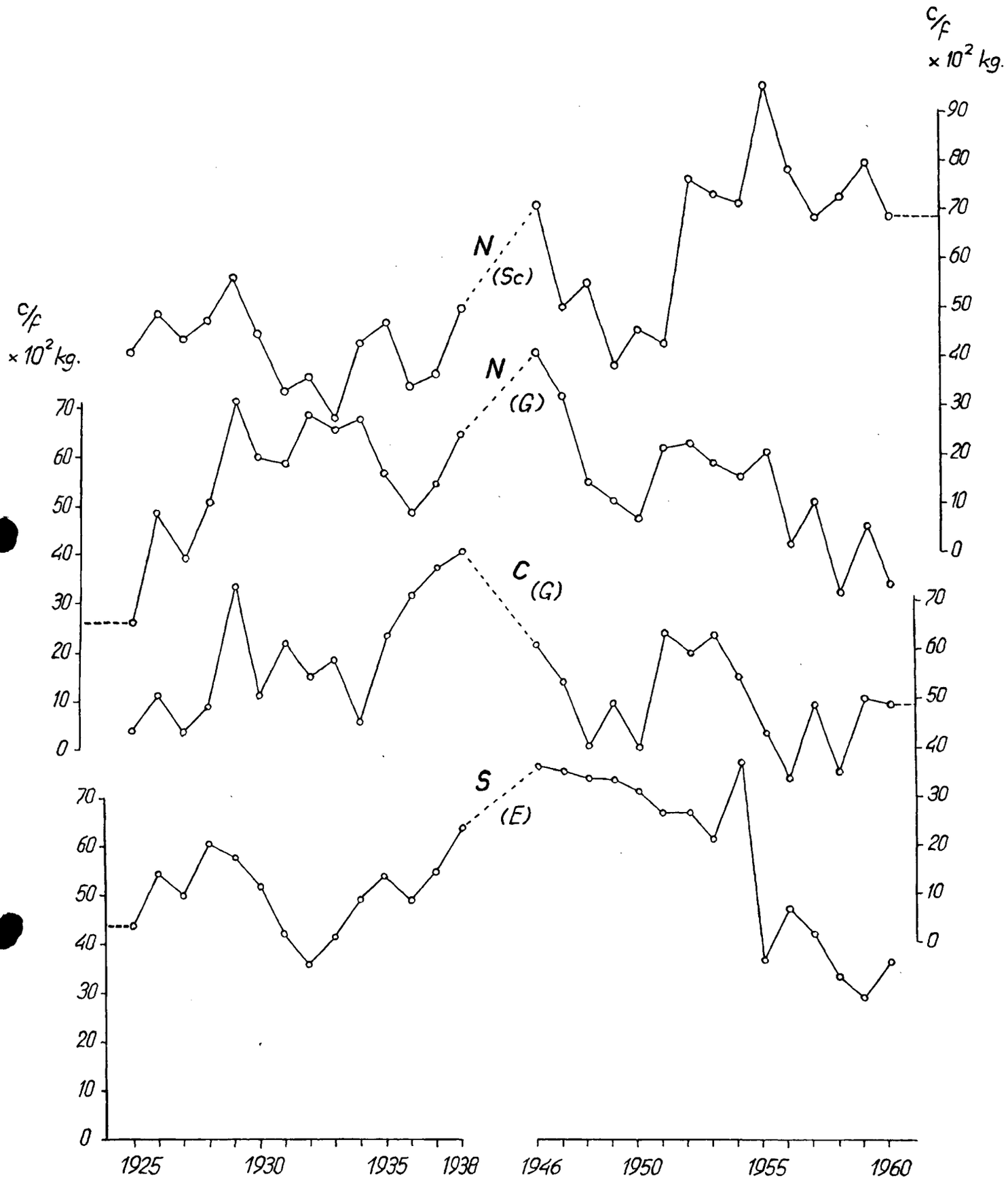


Fig. 2

Catch per effort in:

$N_{(Sc)}$	Northern North Sea, Scottish driftnet fishery
$N_{(G)}$	" " " , German trawl fishery
$C_{(G)}$	Central " " , " " "
$S_{(E)}$	Southern " " , English driftnet fishery