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International Council for the Exploration of the Sea

C.M. 1971/H:28
Pelagic Fish (Northern) Committee

Report On the North Sea Herring Assessment Working Group Meetings

Charlottenlund, 14-19 June and 1-5 Sept. 1971.

I. Terms of Reference and Participation.

At its Ninth Meeting in May 1971, NEAFC passed the following resolution:

> "In view of the Commission's interest in the possibility of regulating the North Sea herring fishery by means of catch quotas, the ICES North Sea Herring Assessment Working Group is asked to review the present status of the North Sea herring stocks and to advise on the following questions:
>
> 1) What alternative schemes of total catch limits should be set in order to allow recovery of the stock to a satisfactory level within a reasonable period of time?
>
> 2) Are differential quotas by season, region and category necessary to achieve effective conservation; if so, what form might the take?
>
> 3) Is the 4°W Meridian the appropriate north-western boundary for the quota area?
>
> It is noted that all the catch, fishing effort and biological data for the period ending 31st December 1970 must be made available before the Group can carry out the above study, and that it is desirable that as many data for the year 1971 as possible, should also be made available".

A request for a meeting of the North Sea Herring Assessment Working Group was foreseen at the ICES Statutory Meeting in 1970, and the week 14.-19. June 1971 was reserved for the purpose (C.Res.1970/2:9). At this meeting, however, the Working Group felt that for reasons set out below it could not yet offer answers to the questions referred to it by NEAFC and it was decided that another meeting should be held at the 1-5. September 1971.

Both meetings were held at ICES's headquarter, Charlottenlund and were attended by the following members

Mr. H. Ackefors	Sweden	Both meetings
Mr. A.C. Burd	U.K.	" "
Mr. H. Lassen	Denmark	Second meeting
Mr. A. Maucorps	France	" "
Mr. K. Popp Madsen	Denmark	Both meetings
Mr. K.H.Posthuma	Netherlands	" "
Mr. A. Saville	U.K.	" "
Dr. A. Schumacher	Germany	" "
Mr. O.J. Østvedt	Norway	" "
Mr.J.Møller Christensen	Secretary to the Liaison Committee.	

The absence of the members from Poland and U.S.S.R. was noted with regret.

II. The Material.

The present meetings continued the work of earlier meetings held in January 1969 and in December 1969. A report (Doc.C.M. 1970/H:6) on these meetings was presented to the Liaison Committee at ICES Statutory Meeting in 1970 and a revised version is in press (Coop.Res.Rep., Ser. A. No. 26). This report contained an extensive compilation of data, mainly from the period 1960-1968 and is a necessary background paper to the present report, in which only additional or revised data are given.

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As on earlier occasions the Assessment Group had to spend a disproportionate amount of its allotted time on arranging the data in suitable form. Major fisheries are still uncovered by detailed catch statistics and are in some cases not even referable to the gross statistical areas usedby ICES. Equally serious deficencies characterize the biological data where such basic information as age distributions and numbers caught per unit of weight are lacking for entire areas or fisheries representing thousands of tons.

The working Group noted with regret that the strong recommendation set out in the former report concerning the need for more comprehensive data had not led to any noteworthy improvement.

The deficencies in the data available introduce an uncertainty in the conclusions drawn, which must necessarily affect the possible quota levels.

III. The Resent Development in the Fisheries.

III a). Landings.

The general decline in total catch from the North Sea and Skagerrak since the peak year of 1965 continued in 1969 and 1970 (Table 1). The total catch in 1970 of 618 000 tons was 24 % below the average catch level in the period 1955-64 prior to the heavy expansion of the fisheries, and 38 % lower than the catch in 1968.

While 1969 showed a general decrease in catch in most subareas the development in 1970 showed a quite different pattern. The main decline took place in Skagerrak and the north-eastern North Sea, while a substantial increase took place in the north-western and central North Sea areas. As shown in Table 2 the recorded catch in the north-eastern North Sea went down by 86 % from 1969. It must be noted, however, that the allocations to North Sea subareas of Danish, Faroese, Icelandic and Swedish catches are based on a limited sampling of detailed statistics in one Danish harbour. Though the actual figures are bound to be uncertain, the independent picture from the Norwegian catch distribution supports the general development as described above.

The few preliminary figures available for the first four months of 1971 (table 3) indicate a distribution of catches similar to that of 1970.

III b). Catch per Unit Effort.

For the period 1955-1971 catches per unit effort are given in table 4 for trawl and drift-net fisheries in the North Sea. The data are in fact the data published and commented upon in the last Report of the North Sea Herring Assessment Working Group with the addition of the data available for 1969-1971.

In general a slight increase took place in 1969, most markedly in the Southern area, followed by a decline in 1970 to what in most areas appear to be the lowest levels on record.

III c). Effort

Estimates of effort for the period 1955-71 are given in Table 5 for the north-western, north-eastern, central and southern North Sea and the Bløden area. These data are arrived at by dividing the total catch in an area by the catch per unit effort in that area. As discussed in the 1970 Report of the North Sea Herring Assessment Working Group, the method is only reliable when the catch per unit effort of an area is estimated from fisheries taking the major part of the total catch in that area. Difficulties in this respect were experienced in the areas of the northern North Sea, and the effort estimates of the north-western and north-eastern North Sea are, therefore, to be considered with reservation.

For the Skagerrak no effort estimates could be made due to lack of data.

The 1970 figures indicate an increase over the 1969 values in most areas.

III d). Catch composition.

The total catches from the North Sea in 1969 and 1970 continued at the lower catch levels of 1967 and 1968. The data of catch in number show a reduction of the catches of juvenile herring (0 and 1 rings) in the north-eastern North Sea with a reduction of catch from that area in 1969 and a great reduction in 1970.

The catch from the north-west continued at the high rate of recent years, but again with about the same numbers of juvenile herring in these catches.

In the central North Sea the catch for consumption declined further and the proportion of 1-ringers increased in both years. Large increases took place in the catches of herring from this area for industrial purposes, the numbers caught in 1969 and 1970 increasing by about 1.7 times over the catch of 1968.

The catch in Area IV c increased somewhat in 1969 and 1970 with the improved recruitment to the southern area.

It is in the Skagerrak area that the most alarming changes have taken place. In this area the fishery has become dependent on 0-group fish, if the samples of herring from which the age compositions are based, can be taken as representative of the fishery. However, these data must be treated with caution, as it is not clear whether the proportions of herring reported in the mixed catches are entirely reliable.

IV. Total Catch limits.

Essentially any fishery regulation is directed towards a control of the fishing mortality either in an entire fish stock or in components thereof (e.g. juveniles).

The main task of the Working Group was therefore to estimate the parameters of fishing mortality, natural mortality and stock size from past time data and to establish a basis for prognoses of the future development of the herring stocks.

IV a) Natural Mortality.

Following the method described by Agger, Boëtius and Lassen (1971) a computor analysis using a Least Square Estimation of the total North Sea catch data for the period 1955-1968 was made which gave an estimate of natural mortality $M = 0.0859 \pm 0.0087$ on adult herring. The value of M derived by this method is similar to that calculated by Postuma (1963) for Southern North Sea herring.

In earlier assessments a value of natural mortality of 0.2 has been used when considering the effect of fishing on North Sea adult herring stocks. Estimates of population size by the Cohort Analysis have been made using this value for the total North Sea catched from 1947-1970 and also for the combined catches of adult and juvenile herring from divisions IV b, IV c and VII de.

The Cohort Analysis technique is dependent to a great extent on the reliability of the value of natural mortality used. The effect of using the different value of M are discussed in the appropriate sections.

IV b) Fishing Mortality.

The table below gives the mean values of F obtained from the Cohort analysis on the adult stocks for the total North Sea for both estimates of M, and the F values for the catches of areas IV b and IV c combined. The effect of the lower value of M is to increase the fishing mortality by about 20 %. There is a close correlation between the two estimates which can be represented by the equation:

$$F_{M.1} = 1.14 \; F_{M.2} + 0.068$$

Estimates of Adult Fisheries Mortality.

Method	Cohort Analysis				Least Square	
Region	IV b IV c VII de	Total North Sea		IV b IV c VII de	Total North Sea		
Year M	0.2	0.2	Year M	0.2	0.2	0.0859	Mean stand. dev.
1947	0.09	0.12	1958	0.93	0.40	0.65	± 0.03
1948	0.14	0.13	1959	0.95	0.50	0.67	± 0.06
1949	0.17	0.17	1960	0.69	0.27	0.39	± 0.01
1950	0.19	0.16	1961	0.67	0.30	0.46	± 0.02
1951	0.31	0.19	1962	1.34	0.39	0.59	± 0.03
1952	0.32	0.23	1963	0.83	0.16	0.17	± 0.03
1953	0.43	0.25	1964	0.99	0.25	0.31	± 0.01
1954	0.69	0.36	1965	1.25	0.61	0.76	± 0.02
1955	0.61	0.31	1966	0.67	0.59	0.72	± 0.03
1956	0.61	0.33	1967	1.16	0.73	0.85	± 0.04
1957	0.75	0.39	1968	1.00	0.94	1.09	± 0.16

Because of the inherent character of the Cohort analysis the mortality estimates for 1969 and 1970 cannot be considered of comparable accuracy and are excluded from this table.

The data for the total North Sea show a steady increase in F up to 1960 followed by a decrease to about 1965 which is associated with the expansion of the fishery in the northern North Sea. The effect of the increase in catch from these previously relatively lightly fished areas is to create an apparant increase in total North Sea stock resulting in a lower value of F. Subsequent to 1967 the total North Sea mortalities increased to their highest levels.

In areas IV b and IV c are situated the majority of spawning places of the North Sea stocks. The fishingmortalities for the adult herring indicate a continious increase in exploitation up to 1959 and thereafter the mortalities have remained at a high level.

The Cohort analysis included the catches of immature herring as 0, 1 and 2 ringers. In the calculations of fishing mortality and stock size a constant in natural mortality was used throughout the life span. This was considered less objectionable than trying to make changes in this value on hypothetical grounds.

The table below gives the fishing mortality estimates for juvenile herring using M = 0.2 for the total North Sea catches and those for area IV b and IV c.

Estimates of Fishing Mortality on Juvenile Herring

Year	IV b IV c VII de M=0.2	Total M=0.2	Year	IV b IV c VII de M=0.2	Total M=0.2	Year	IV b IV c VII de M=0.2	Total M=0.2
1947	0.01	0.02	1955	0.32	0.21	1963	0.47	0.17
1948	0.01	0.01	1956	0.44	0.26	1964	0.55	0.21
1949	0.02	0.02	1957	0.24	0.11	1965	0.71	0.34
1950	0.03	0.03	1958	0.44	0.22	1966	0.50	0.33
1951	0.09	0.05	1959	0.50	0.29	1967	0.54	0.22
1952	0.23	0.10	1960	0.54	0.30	1968	0.28	0.18
1953	0.41	0.11	1961	0.54	0.15			
1954	0.29	0.15	1962	0.30	0.10			

The increase in F in both series corresponds in time with the commencement of the Bløden young herring fishery. The F values for 1957 and 1958 in both series are not inconsistent with mortality calculated from the Bløden tagging experiment.

A comparison was made between the total mortality estimates derived from the Cohort and Least Squares analyses and estimates of mean total mortality for the North Sea obtained by weighting the mortalities obtained from catch per effort estimates of the individual stocks by estimates of the relative size of the stocks obtained from larval production figures.

The regression equations obtained from these comparisons were:

$$Y_c = 0.5035X + 0.3464$$

$$Y_{L.S} = 0.5636X + 0.3464 \quad \text{where}$$

Y_c = mortality estimate from Cohort analysis

$Y_{l.S}$ = " " " least squares analysis

X = monthly estimate from catch per unit effort data.

From these equations the mortality values for Cohort and Least Square analyses in 1969 and 1970 can be estimated from the available estimates from catch per unit effort.

These are:	Cohort analysis	Least squares
1969	1.304	1.202
1970	0.718	0.679

IV c) Stock Size.

The table below gives the stock sizes of adult and juvenile herring from the Cohort analysis using M = 0.2.

Estimated Stock Size in Number (x 10^{-9}) M = 0.2

	IV b + IV c			Total North Sea		
Year	Juv.	Adult	Total	Juv.	Adult	Total
1947	23.4	41.0	64.4	17.1	22.4	39.5
1948	20.7	37.2	57.9	14.4	22.8	37.2
1949	14.6	35.2	49.8	9.9	21.7	31.6
1950	18.1	29.6	47.7	9.7	18.7	28.4
1951	20.2	23.3	43.5	11.7	13.2	24.9
1952	21.2	20.6	41.8	9.0	11.9	20.9
1953	20.5	21.0	41.5	5.9	12.3	18.2
1954	21.7	16.8	38.5	11.0	6.6	17.6
1955	18.5	17.1	35.6	12.0	4.1	16.1
1956	14.9	13.9	28.8	9.9	4.2	14.1
1957	37.5	11.9	49.4	18.8	3.4	22.2
1958	29.2	9.1	38.3	17.0	1.5	18.5
1959	21.8	14.0	35.8	13.1	3.7	16.8
1960	11.4	12.5	23.9	7.1	3.0	10.1
1961	24.3	11.2	35.5	10.0	3.2	13.2
1962	23.7	7.9	31.6	8.1	1.5	9.6
1963	22.3	10.1	32.4	8.6	2.5	11.1
1964	23.0	12.7	35.7	8.8	1.9	10.7
1965	16.0	11.7	27.7	6.2	1.0	7.2
1966	14.0	8.9	22.9	3.8	1.5	5.3
1967	15.8	6.1	21.9	5.3	0.9	6.2
1968	27.5	4.1	31.6	8.7	0.6	9.3

The adult stock was defined as all fish older than 3 years of age plus the stock of 3 yearsold excluding those taken in the Bløden fishery and the North eastern North Sea.

The stock size for the period 1955-1968 were also calculated for the total North Sea data using M = 0.1. The two estimates of stock are closely correlated and taking the estimates of recruitment at 3 years of age the following equation allows conversion of stock at M = 0.2 to stock at M = 0.1.

$$R_{M.1} = 0.409\ R_{M.2} - 0.1$$

From this it can be seen that the stock sizes are considerably lower using M = 0.1.

Taking the estimates of adult stock for the period 1947-1968 a decline of ten times is seen. The decline for the limited Southern and Central North Sea area is considerably greater.

IV d). Stock-Recruitment Relationship.

Using the estimates of each age group of the adult stock for the total North Sea summarized in the previous section the spawning potential of the stock was calculated from fecundity data on northern North Sea herring.

Fecundity per age group (From Baxter)

Rings	2	3	4	5	>5
No of eggs ($\times 10^{-3}$)	45	67	87	96	101

Spawning Potential

(Number of Adult Females x Mean Number of Eggs per Age Group x 10^{-12})

Year	Sp.pot.	Year	Sp.pot.	Year	Sp.pot.
1947	1677	1955	589	1963	334
1948	1510	1956	513	1964	453
1949	1370	1957	434	1965	480
1950	1167	1958	345	1966	344
1951	964	1959	429	1967	242
1952	833	1960	426	1968	157
1953	777	1961	414	1969	126
1954	631	1962	322		

A plot of recruitment estimates as 0-ringers from the Cohort analysis on the spawning potential of the parent stocks indicated a rather constant level of recruitment. This level was at about 8 x 10^9 with rather great variability in recent years.

IV e) Growth Parameters and Yield Curves.

To calculate the total yield it is necessary to have a method of converting numbers of fish at different ages to weights. The most convenient form in which to do this is by using the parameters of the Bertalanffy growth equation. These parameters were calculated for each of the subareas of the North Sea (IV a, IV b and IV c) using data of mean weight at age in each month over the period 1955-1970. Because of the large seasonal differences in weight at age it is necessary to take weight in the same season in each year. For area IV a the period chosen was June-September, for area IV b July-October, and for area IV c October-January.

The calculated growth parameters showed only minor differences between these three areas, and therefore it appeared legitimate to calculate parameters applicable to the total North Sea. These were: $W_\infty = 271.09 \pm 2.0$ $K = 0.377 \pm 0.04$ and $T_o = -1.526 \pm 0.43$. From these new mean weights at age were calculated for use in subsequent computations particularely in those concerned with forecasting future yields at different levels of fishing mortality.

Yield per recruit curves were calculated, using the Beverton and Holt model, at three levels of natural mortality (M) and over a range of fishing mortalities (F) from 0.0 to 0.9 utilizing the Bertalanffy parameters given above. These curves are given in Fig. 2. If M is 0.1 the calculated maximum yield per recruit is taken at an F of 0.35, if M is 0.15 at an F of 0.40 and if M is 0.2 at an F of 0.50.

Figure 3 shows the catch of adult fish in numbers in area IV b and IV c plotted against the fishing mortality rate calculated for that year by the Cohort analysis using a natural mortality rate of 0.2. The curve has a maximum at an F of about 0.3. This is in reasonable agreement with the maxima calculated from the yield recruit curves in view of the fact that (a) the latter were calculated as yields in weight not in number and (b) with fishing on the stock from an age of 1 year and not solely as adult fish.

IV f) Prognoses for Different Levels of Fishing Mortality.

The basis of the forecast is a recruitment calculation. It has not been possible to demonstrate a stock-recruitment relationship and it has been taken that recruitment varies about an average of recruits per year: 8×10^9. Thus no account is made for the possibility of a decrease in the number of recruits caused by very small spawning potentials. The computation of stock in weight from stock in number is made by means of the Berthalanffy equation with the parameters given in section IV d.

As the starting point of the calculation the age composition of 1/1-1972 was established by applying a fishing mortality of 0.7 for adult and 0.2 for juveniles (0 and 1 ringers) together with a natural mortality of 0.1 for all ages, see section IV a to the catch in numbers per age in 1970. The age composition arrived at per 1st Jan. 1972 was:

	Winterrings									
Stock in numbers x10^{-9}	0	1	2	3	4	5	6	7	8	9
	8 x)	5.9 x)	2.8	0.84	0.37	0.054	0.021	0.026	0.004	0.004

x) The yearclasses 1970 and 71 was both taken as being of average strength: 8×10^9 0-group recruits.

This gives a stocksize in weight of 1.0 mill tons.

The catches and stocksizes were then calculated for a 5 year period together with the biomass of stock in weight and in numbers. The results are given in table 8.

The effect of a stock-recruitment relationship was investigated but due to very large scatter in the original data little confidence could be placed in the results.

V. Differential Catch Quotas.

Differential quotas will in principle allow higher catches to be taken in a fishery than with an overall quota. The more detailed a catch quota system is the bigger is the possibility of steering the fishing effort towards those levels of fishing mortality which in different periods, stages or areas may allow the maximum catch to be taken.

Differential regulatory measures were discussed in the former report by the Working Group. All these meassures were aimed at increasing recruitment or reducing mortality in the adult stocks or a combination of both. Differentiation of catch quota by region, season and category will be discussed.

V a). By Region.

An overall quota in the North Sea could be divided between certain areas of the North Sea. The purpose of this measure would be the protection of specific components of the North Sea herring.

For the purposes of the assessment the North Sea catches have been reported in four major regions of the North Sea and separately the catches of juvenile fish in the central North Sea. Taking the areas separately it was impossible to analyse the data satisfactorely using the Cohort analysis.

Consequently no estimate could be made of the effects on changes in fishing mortality within these areas which would follow the application of a catch restriction.

An analysis was made using the catch data for the central and southern North Sea combined. The results of this Cohort analysis suggest that this larger area might be regarded as a management unit. It does not necessarily mean that in the remaining North Sea area a management programm would be feasable.

V b). By season.

As the quality and the weight of the herring changes during its annual cycle some gain could be achieved by restricting the catches to the period of big fat content and weight.

An analysis of the available data on weight per month per age-group showed a 30 % decrease in mean weight over all age groups between mid summer and the first quarter of the year.

During the first four months of the year about 20 % of the yearly catch is landed. If no fishing were to take place during this period, these fishes could be caught in the remainder of the year with a 80 % increase in weight. This would result in a 6 % increase in weight of the total catch without any increase in fishing mortality.

V c). Quotas by Categories.

The only practicable differentiation of quotas by categories is that between juveniles (0 and 1 group) and adults. In table 8 predictions of catch and of stock in number and weight are given for various estimates of fishing mortalities on juveniles and adults. The table is derived be the method of section IV f. The present effect of the juvenile fishery on the Bløden is best illustrated by the prediction using the bottom set of fishing mortalities (.5 - .0) where it is seen

that an annual catch of about 100,000 tons would be expected from the juvenile fishery alone.

VI. North-Western Boundary of the Quota Area.

The area to the west of Shetland has been fished by the Scottish fleet in the early part of the Shetland herring season for many years, but the proportion of the total Scottish catch taken in that areas was, until 1965, comparatively small averaging less than 10 %. Since 1965 this proportion has increased considerably and in the 1968, 1969 and 1970 seasons other countries fishing in the north-western North Sea have also taken an increasing proportion of their catches from west of Shetland. In 1970 the fishery to the west of Shetland extended further west than in previous years and appreciable catches were taken west of 4°W - the western boundary of the ICES North Sea statistical area IV a.

VI a). Catch statistics.

The catches taken by the Scottish and Norwegian fleets from the north-western North Sea and that part of the Faroese, Icelandic and Swedish catches landed in Denmark from this area in 1970 are given in Table 9 by months. These have been subidivided into three areas: west of 4°W, from 4°W to the west coasts of Shetland and Orkney, and to the east of Shetland and Orkney. In 1970 91 % of the Norwegian catch from the Shetland area was taken from the grounds to the west of Shetland and 60 % of the Scottish catch came from this area. Of the Icelandic, Faroese and Swedish catches landed in Denmark only about 20 % of the north-western North Sea catch came from these western grounds but it is possible that this is an underestimate of the true proportion in that catches from these western grounds were more likely to be landed in Faroes or Scottish ports than in Denmark.

The distribution of these landings by months in the three areas are of interest in showing that the fishery, and so presumably the fish, moved eastwards from the more westerly grounds as the season progressed. This was also the pattern of the Scottish fishery in the Shetland area in earlier years.

VI b). Age composition.

Evidence as to whether the fleet continues to fish the same stock as the fishery moves eastwards in somewhat inadequate. The age compositions of the catches of the Scottish and Norwegian fleets in the three areas used for the catch statistics are given in Table 9. These are in substantial agreement in showing that in all three areas the catches were predominantly composed of 3 and 4 years old fish. The higher proportion of 3 years old fish in the east Shetland area probably is a reflection of the fact that most of the age sampling in that area was done in August, when the proportion of younger fish is generally higher. The scarcity of fish older than 4 years in the catches from all three areas makes it appear unlikely that an appreciable component of the population in any of these areas is derived from the Minch stocks. These stocks still have a high proportion of older fish in the population.

VI c). Meristic characters.

The data available on the meristic characters of the herring populations in this area are given in Table 9 . The fish caught to the east and to the west of Shetland have very similar vertebral and keeled scale counts. However, Minch and east Shetland fish show identical values for these characters so that they are of no value in clarifying whether the fish caught west of Shetland belong to one or other of these stocks, or are a mixture of the two. The mean l_1 data given in Table 9 show that in this character there is no significant difference between the east and west Shetland herring but that both have significantly higher values than fish from the Minch.

VII. Discussion.

In the previous report particular attention was drawn to the sequential nature of the changes of catch, catch per effort, larval production and mortality by fishing area in the North Sea. The reduction in the southern area of the adult stock was followed somewhat later in the central North Sea and finally in more recent years in the northern North Sea. It was noted that the decline in total catch since 1965 had not been as rapid as had been expected from the reduction in catches of adult herring and it was concluded that the real state of the North Sea stock was masked by the increased exploitation of immature herring, both juvenile and pre- first time spawners, and by the shift of the fishery into more northern areas.

These conclusions have been further strengthened by the evidence of the fisheries in 1969 and 1970. The North Sea catch was reduced to about 550 000 tons in both years, of which about 66 % was taken from the northern North Sea. In 1970 the catch in the north-western area alone accounted for 60 % of the North Sea catch. This catch was mostly taken west of Orkney and Shetland, an area never exploited to this degree in previous years.

The extension of the fishery into new areas has made the task of assessing the present state of the stock (in order to arrive at a recommended conservation measure) even more difficult than before.
The present assessment of the North Sea herring stock is based almost solely on data on catch in numbers per year and per age group. The quality of this material is very uneven from area to area and from one fishery to another.

The most comprehensive set of data, available back to 1947, derives from the fisheries in the central and southern North Sea (area IV b and IV c). The consistency of age and catch data from the Northern North Sea is rapidly decreasing from west towards east. For the large fisheries in later years in Skagerrak data are so poor that they had to be excluded from the analysis all together.

It is not clear to what extent the exclusion of the Skagerrak area affects the analysis carried out. On the assumption, that the herring in Skagerrak is partly or wholly also exploited in the fisheries in the North Sea proper, then the effect of the Skagerrak fisheries will be measured within the values of fishing mortalities obtained from the total North Sea data.

The vital parameter in assessing the effect of fishing on a stock is a reliable estimate of the natural mortality: M. Hitherto a value of M = 0.2 has been used in herring assessment. There has been evidence, however, that this value was too high and the Working Group undertook a mathematical analysis of catch data from 1955-1968 which gave of value of M = 0.08 ± 10 %.

A comparison was made of stock estimates and fishing mortalies derived from analyses using both values of M. Close correlations exists between the two estimates, the lower M giving fishing mortalities about 20 % higher and stock values about 60 % lower than using M = 0.2.

A series of the results from Cohort analysis using M = 0.2 was available covering the years 1947-70. Because of lack of time it was not possible to repeat these using the value of M = 0.1 but because of the proportionality between the two estimates they are valid for interpretations in the present context.

One question asked of the Working Group concerned the effectiveness on conservation of differential quotas for different regions of the North Sea. The catch data were grouped in Skagerrak and four subareas of the North Sea. In order to regard an area as a management unit the Working Group had to demonstrate that the stock composition within the area would predictably respond to changes in fishing effort within the area.

Cohort analysis and Least Square analyses of data from separate subareas broke down for areas IV a NE and IV a NW and the results for the central and southern areas were considered too unreliable

to be used.

Estimates of fishing mortalities and stock size were consequently confined to data representing larger areas i.e. total North Sea less Skagerrak and the central and southern areas combined.

The fishing mortality over the period 1947-68 (Text table, section IV b) shows similar values for southern and total North Sea up to 1951. At this time most of the fishery was concentrated in the south. The two sets of values diverge subsequently as fishing in the northern North Sea begin to increase its effect on hitherto lightly fished stocks.

The comparatively low values of F for the total North Sea about 1963-64 are associated with the large expansion of effort in the north-eastern North Sea on the strong 1960 yearclass. This affects the Cohort analysis as if added recruitment to adult age groups took place and results in underestimation of F.

Since 1965 the two estimates converge as all areas and stocks are under exploitation. The very high values of F for 1967 and 1968 compare well with those obtained from catch, effort and age data from the fisheries.

Estimates of fishing mortality on juveniles were also obtained by the Cohort analysis (section IV b) by assuming a M = 0.2 for the 1 and 2 years old fish. Estimates based on central and southern North Sea data give higher values of F compared with those derived from the total North Sea.

The values obtained from the southern data may be overestimated as the young herring catches, comprising all three herring stocks, are related to adult catches mainly taken from two of these. It is noted, however, that all estimates from 1957 and 1958 are of the same order as those derived from the Bløden tagging experiment (15-20 %).

The stock size estimates and the fishing mortalities obtained from the Cohort analysis are only representative of the areas and stocks which are contributing a major part of the catches. The northern area has only been heavily exploited since 1963-64 since which date it has provided a major part of total catch. Thus the stock size estimates and the fishing mortalities from Cohort analysis for the total North Sea largely reflect conditions in areas IV b and IV c prior to that period. In 1963-64 and subsequent years they largely reflect the conditions in area IV a. Thus the low values of F for the total North Sea in 1963-64 are merely a reflection of the shift in the area exploited by the fishery and it is only in the most recent years that the F values given by the Cohort analysis are really representative of the fishing mortality to which the total North Sea stock of herring is subjected.

As the Cohort analyses only can be applied to yearclasses which have some history of fishing as adults, the stock size estimates gets increasingly unreliable after 1967.

For both area-estimates a dramatic decline of adult stock is apparant (text table, section IV c) while the juvenile stock values appear far more stable.

From the Cohort Analysis comparing catch on effort, and from the yield curved as catch per recruit it would appear that the maximum sustainable yield from the total North Sea would be achieved at a F of about 0.3 for stock over all age groups. Various estimates have been made of the various catch expectations using differential fishing mortalities for the juvenile and adult parts of the stock.

VIII Conclusion.

In the former report of the North Sea Herring Assessment Working Group it was concluded that under normal environmental conditions the steady yield of the population of North Sea autumn spawning herring would be about 700-800 thousand tons of adult and juvenile herring.

At the present meeting the Working Group found that the catch figures for 1969 and 1970 despite a further extension of the fishery to the west of Shetland had declined to a level below that of the possible maximum sustainable yield. Based on the stock in 1968 the Working Group suggested a limitation of catch to 500,000 tons to obtain a reduction in fishing mortality of 50 %. In 1970 the catch was 23 % above this limit with no apparent reduction of fishing mortality from that of 1968.

The main object of the present meeting was to advise on the three questions set out in Section I of this Report:

1) The Working Group could not establish a stock-recruitment relationship with the data available and had to adopt the assumption of constant recruitment at an average level.

   The Working Group used the catch figures of 1970 as a basis for calculating future catch levels and stock levels for different values of fishing mortality.

   Under the assumptions made the Working Group found that at the present fishing intensity both catch and stock would continue to decrease. The Working Group concluded that an over all catch limit set at about 300,000 tons could achieve a reduction of about 50 % of the fishing mortality on the total North Sea stock. At this level of fishing mortality held constantly for about 4 years an increase in annual catch of 50 % could be allowed.

   These prognoses take no account of future yearclasses deviating markedly from the average recruit strength. This can only be done by yearly adjustments based on estimate of yearclass strength of 1 and 2 years old herring, and will require a far higher data sampling standard than the present.

2) The Working Group examined regional management units and concluded that though there might be a possibility of regarding the region south of 57°30' n.lat. as such it did not mean that the area north of 57°30' could so be considered. In view of this it was thought that with the data available regional quotas could not be established with any predictable effect.

   For this latter reason the Group could not propose any conservation by seasons alone. It was noted, however, that for an equal number of fish killed the yield in weight could be increased by about 6 % if the fishing was limited to be the second half of the year.

   The effect of setting different fishing mortalities on juvenile and adult components of the stock are given in table 8. The table also shows the predicted catches at average recruitment which would result from the choice of fishing mortality restrictions by category.

   Because of the inherent inaccuracies in the data and the possible effects of omission of the Skagerak catches the confidence limits on all estimates are very wide, perhaps of the order of ± 50 %.

3) On the basis of the available data it is not possible to state categorically where the western boundary of the North Sea herring stocks should be drawn. This question can only be answered with complete confidence by mounting a major herring tagging experiment in this area.

It is recommended that the 4°W be maintained until more adequate data are available.

IX. References.

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Table 1. Total catch in metric tons from the North Sea and Skagerrak.

Year	North-West IV a	North-East IV a	Central IV b	South IV c+VIId,e	Bløden IV b	Total North Sea	Skagerrak[x)] IIIa	Total North Sea & Skagerrak
1955	287 792	67 426	170 339	168 400	112 500	806 457	89 000	895 457
1956	194 486	79 100	163 909	134 000	103 700	675 195	82 000	757 195
1957	209 018	97 333	150 661	122 700	103 200	682 912	90 500	773 412
1958	164 678	98 186	156 101	92 600	158 900	670 465	131 000	801 465
1959	259 577	144 196	147 098	77 200	156 400	784 421	139 000	923 421
1960	101 144	263 979	166 306	64 880	99 922	696 231	75 820	772 051
1961	60 950	274 786	168 881	98 182	93 849	696 648	85 291	781 939
1962	37 578	291 786	143 300	54 746	100 375	627 785	104 246	732 031
1963	73 108	301 326	228 209	45 726	67 717	716 086	163 228	879 314
1964	66 052	444 029	187 878	56 572	116 626	871 157	309 804	1 180 958
1965	298 345	580 767	132 865	21 777	135 009	1 168 763	256 742	1 425 505
1966	278 613	424 035	114 075	11 623	67 237	895 583	144 655	1 040 238
1967	117 312	373 663	107 929	11 446	85 249	695 599	279 744	975 343
1968	286 681	256 750	57 757	9 610	106 897	717 695	280 036	997 731
1969	213 138	148 061	40 034	24 322	121 220	546 775	113 279	660 054
1970	312 585	21 262	111 706	27 086	74 831	547 747	70 527	617 997

1955-1959 Data for the North-west, North-east and Central based on data of Cushing and Bridger (1966), added to North-east was the Swedish catch from region IV a (Bulletin Statistique).

1955-1959 Data of the southern area and Bløden from Cooperative Research Report, series B, 1965. Annex: Table 11 and Table 12.

1960-1968 All the data from the revised herring assessment Group Report 1970.

x) - Data from Bulletin Statistique excluding Danish catches in Kattegat for 1955-59.

Table 2 - Herring catches, North Sea and Skagerrak

1969-70	1969 Skagerrak III a	1969 North Sea North East IV a E	1969 North Sea North West IV a W	1969 North Sea Central IV b	1969 North Sea South + English Channel IV c + VII d.e.	1969 Total	1970 Skagerrak III a	1970 North Sea North East IV a E	1970 North Sea North West IV a W	1970 North Sea Central IV b	1970 North Sea South + English Channel IV c + VII d.e.	1970 Total
Belgium [1), 3)]		32	68[4)]	[1)]	367	468		50	750[4)]			1 200
Denmark [2), 2)]	57 965	55 550	11 360	113 350	0	238 225	30 107	1 800	61 423	70.108	400	163 438
Faroe Isl. [1),2)]		12 805	27 835[4)]			40 640		5 898	40 884[5)]	11 623		58 405
France [2)]		278	605[4)]	3 362	11 062	15 307		48	818[4)]	2 433	8 183	11 482
Germany F.R. [2), 2)]		16	448	11 428	906	12 798		10	177[4)]	6 405	558	7 150
Iceland [2)]		6 300	13 697[4)]			19 997	6 453	1 220	20 587[4)]	1 144		29 404
Netherlands [1), 2) - 1), 2)]		2 084	474	16 542	10 669	29 769		281	177	28 815	16 945	46 218
Norway [2), 2)]	13 957	15 618	99 316	4		128 895	7 037	3 331	146 397	27 613		184 378
Poland [1), 2)]		166	362[4)]	8 077	616	9 221		123	2 069[4)]	2 836	29	5 057
Sweden [5), 5)]	41 357	26 035	6 765	309		74 466	26 930	5 560	4 470	24 640		61 600
UK(Engl.) [1), 1)]				5 964	702	6 666				8 731	971	9.702
UK(Scot.) [2), 2)]		9 785	10 051	2 217		22 053		1 929	17 767	2 189		21 885
U.S.S.R. [1), 1)]		19 392	42 157[4)]			61 549		1 012	17 066[4)]			18 078
Total	113 279	148 061	213 138	161 254	24 322	660 054	70 527	21 262	312 585	186 537	27 086	617 997

1) - Bulletin Statistique
2) - National Statistics
3) - Estimated
4) - Proportion in IV a E and W estimated on the basis of landings reported separately
5) - National Statistics, split by area estimated on the basis of Danish effort statistics

Table 3 Herring catches, North Sea and Skagerrak

January - April 1971

	Skagerrak IIIa	North Sea NE IVa E	North Sea NW IVa W	North Sea Central IVb	North Sea South + Engl. Channel IVc + VIId, e	Total
Denmark	5 560	0	17 620	50 120	0	73 300
Faroe Islands x)	0	143	8 298	0	0	8 441
France						500
Germany Fed. Rep.						0
Iceland x)	0	0	2 371	0	0	2 371
Netherlands	0	60	100	140	5 700	6 000
Norway	0	1089	856	2	0	1 947
Poland						0
Sweden x)	866	0	1 829	660	0	3 355

x) Faroese, Icelandic and Swedish catches only comprise landings in Danish harbours.

Table 4. Catch per unit effort, in drift-net and trawl fisheries in the southern, central, north-east and north-western North Sea.

Years	North-West		North-East			Central		South		Bløden
	Drift[1]	Trawl[2]	Drift[3]	Trawl[4]	Trawl[5]	Drift[6]	Trawl[7]	Drift[8]	Trawl[9]	Trawl[10]
1955	5.2	44.0	?	9.8	1.5	3.1	56.0	3.4	104	-
1956	3.9	23.7	?	13.9	3.6	3.1	46.0	4.3	88	-
1957	3.6	47.6	4.8	7.0	3.3	2.8	80.0	3.6	78	-
1958	4.1	27.1	3.1	13.3	4.3	2.6	27.0	2.7	81	1.94
1959	4.0	52.9	3.8	8.6	3.9	2.4	66.7	2.2	150	1.74
1960	3.2	29.6	3.4	12.9	2.7	2.3	25.1	3.4	113	1.22
1961	4.2	23.9	3.3	6.6	1.8	1.9	42.0	3.2	169	1.22
1962	3.7	18.8	1.8	4.1	2.0	1.9	24.8	2.7	56	1.94
1963	3.9	21.7	1.2	7.2	3.6	5.2	42.3	2.2	50	1.16
1964	3.4	25.4	2.5	9.5	3.4	2.6	38.3	3.8	57	1.78
1965	3.4	19.9	3.0	5.1	2.5	3.2	30.7	1.8	60	1.46
1966	4.3	14.7	2.8	2.9	1.6	3.2	37.5	1.4	-	0.98
1967	4.7	8.4	1.8	1.0	1.0	1.2	25.8	1.4	-	1.35
1968	3.8	1.1	1.6	1.5	1.0	0.6	18.7	0.3	43	1.64
1969	4.8	3.1	0.1	2.5	-	2.0	21.1	-	86	1.22
1970	2.6	2.2	-	0.3	-	-	22.7	0.9	49	1.07
1971	-	-	-	-	-	-	-	-	-	1.34[x]

1) Scottish catch per arrival in May-September (tons).

2) Netherlands catch per 100 hours fishing by a standard (500 BHP) trawler in July-September (tons.

3) Polish catch per shot in April-July (tons).

4) Netherlands catch per 100 hours fishing by a standard trawler in January-April (tons).

5) German logger trawl, catch per day (only catches with 60% herring)

6) Netherlands catch per shot (tons)(May-September)

7) Netherlands catch per 100 hours fishing by a standard trawler (tons) August-October.

8) U.K. catch per shot (tons) (October-December)

9) Netherlands catch per 100 hours fishing of a standard trawler (tons) November-December.

10) Danish catch per hour (tons) in the immature herring fishery in the Bløden area.

x) provisional

Table .5. Effort estimates, obtained by dividing the total catch in an area by the catches per unit effort of drift-net and trawl fisheries in that area.

Years	North-West		North-East			Central		South		Bløden
	Drift[1] Scottish	Trawl[2] Dutch	Drift[3] Polish	Trawl[4] Dutch	Trawl[5] German	Drift[6] Dutch	Trawl[7] Dutch	Drift[8] English	Trawl[9] Dutch	Trawl[10] Danish
1955	57.6	6.9	-	6.9	44.9	54.9	3.0	54.3	161.9	-
1956	49.7	8.2	-	5.7	22.0	52.9	3.6	31.2	152.3	-
1957	58.1	4.4	20.3	13.9	29.4	53.8	1.9	34.1	153.4	-
1958	40.2	6.1	31.7	7.4	22.8	60.3	5.8	34.3	114.3	81.9
1959	64.9	4.9	38.4	16.8	37.0	61.3	2.2	35.9	51.5	89.9
1960	31.6	3.4	77.6	20.5	97.8	72.3	6.6	19.1	57.4	81.9
1961	14.5	2.6	83.3	41.6	152.6	88.9	4.0	30.7	58.1	76.9
1962	10.2	2.0	162.1	71.2	145.9	75.4	5.8	20.3	97.8	51.7
1963	18.7	3.4	251.1	41.9	83.7	43.8	5.4	20.8	91.5	58.4
1964	19.4	2.6	177.6	46.3	130.6	73.3	4.9	14.9	99.2	65.5
1965	87.7	15.0	193.6	113.9	232.3	41.5	4.3	12.1	36.2	92.5
1966	64.7	19.0	151.4	146.2	265.0	35.6	3.0	8.3	-	68.6
1967	25.0	14.0	207.6	373.7	373.7	89.9	4.2	8.2	-	63.1
1968	75.4	260.6	160.5	171.2	256.8	96.6	3.1	-	22.3	65.2
1969	44.4	68.8	-	59.2	-	20.0	1.9	-	28.3	99.4
1970	120.2	142.1	-	70.8	-	-	4.9	-	55.2	69.9
1971	-	-	-	-	-	-	-	-	-	38.0[x]

1) Arrivals (x 1000).

2) Fishing hours (x 100.000)

3) Shots (x 1000)

4) Fishing hours (x 100.000)

5) Days fishing (x 1000)

6) Shots (x 1000)

7) Fishing hours (x 100.000)

8) Shots (x 1000)

9) Fishing hours (x 1000)

10) Fishing hours (x 1000)

x) provisional

Table 6 North Sea Catch in Millions of Fish by age.

Year	Area	AGE IN WINTER RINGS										
		0	1	2	3	4	5	6	7	8	>8	Total
1955	IVaW		4.2	697.6	385.8	144.9	149.0	138.6	28.1	42.4	41.1	1631.7
	IVaE	0.1	20.2	125.3	82.4	54.6	20.1	16.0	23.2	12.6	14.2	368.7
	IVb		87.1	610.8	216.5	108.8	84.7	39.9	30.2	16.9	10.9	1205.8
	IVbYH	164.2	1960.6	162.2	25.5							2312.5
	IVc			335.3	321.5	170.8	82.8	37.1	38.2	37.1	39.3	1062.1
	Tns	164.3	2072.1	1931.2	1031.7	479.1	336.6	231.6	119.7	109.0	105.5	6580.8
1956	IVaW		0.6	248.7	543.5	214.2	89.9	62.8	42.3	30.6	41.0	1273.6
	IVaE			15.6	148.9	98.7	45.2	55.1	11.9	8.6	27.6	411.6
	IVb		22.5	607.9	341.7	92.7	33.1	39.7	29.1	49.0	106.0	1321.7
	IVbYH	95.9	1667.7	432.5	33.4							2229.5
	IVc		6.0	555.3	153.7	110.1	80.3	36.7	20.8	15.9	12.9	991.7
	Tns	95.9	1696.8	1860.0	1221.2	515.7	248.5	194.3	104.1	104.1	187.5	6228.1
1957	IVaW			216.5	287.5	261.4	195.7	84.4	43.8	39.0	69.6	1197.9
	IVaE			19.6	37.4	124.8	51.0	70.8	63.8	37.5	24.8	429.7
	IVb		14.1	421.9	143.3	219.0	70.7	37.3	30.3	20.2	53.5	921.3
	IVbYH	278.7	1461.1	400.6	37.0							2177.4
	IVc		7.4	585.3	231.0	38.7	26.7	14.7	9.2	2.8	5.5	1010.3
	Tns	278.7	1482.6	1643.9	736.2	643.9	344.1	207.2	147.1	99.5	153.4	5736.6
1958	IVaW 1°		29.9	41.8	326.8	139.7	233.3	81.4	41.9	27.1	19.3	941.2
	IVaE 2°			43.5	247.8	64.3	85.5	28.5	17.1	9.3	22.9	518.9
	IVb		218.5	413.0	207.6	59.0	125.6	25.1	7.6	7.6	28.4	1092.4
	IVbYH	97.1	4028.7	265.0	26.5							4417.3
	IVc		1.7	266.1	190.6	58.9	16.7	11.7	6.7	1.7	1.7	555.8
	Tns	97.1	4278.8	1029.4	999.3	321.9	461.1	146.7	73.3	45.7	72.3	7525.6
1959	IVaW 2°		13.5	1488.9	128.1	173.6	74.8	99.8	46.5	23.0	26.0	2074.2
	IVaE 2°			182.5	78.7	210.0	115.9	111.2	60.5	52.1	163.1	974.0
	IVb		85.1	929.5	140.1	60.2	24.9	34.0	9.2	5.2	24.9	1313.1
	IVbYH		1500.2	1847.9	61.4							3409.5
	IVc		10.6	485.1	79.2	53.5	17.8	4.0	3.3	2.0	4.6	660.1
	Tns		1609.4	4933.9	487.5	497.3	233.4	249.0	119.5	82.3	218.6	8430.9

Table 7 North Sea Catch in Millions of Fish by Age

A G E

W i n t e r R i n g s

		0	1	2	3	4	5	6	7	8	>8	Σ	t	No/kg
1969	IVa W of 2°E	-	101.1	736.2	109.4	52.4	103.9	17.2	14.7	10.3	4.5	1149.7	213 138	5.39
	IVa E of 2°E	-	128.2	559.3	136.0	61.9	66.9	29.3	27.4	16.9	20.4	1046.3	148 061	7.1
	IVb adult	-	44.8	154.6	29.1	13.5	18.1	3.0	0.2	0.2	-	263.5	40 034	6.58
	IVb young	112.0	2223.7	271.1	13.0	-	-	-	-	-	-	2619.8	121 220	21.611
	IVc	-	5.5	161.8	8.8	5.3	1.9	0.4	0.4	-	0.2	184.3	24 322	7.578
	Total NS	112.0	2503.3	1883.0	296.3	133.1	190.8	49.9	42.7	27.4	52.5	5263.6	546 775	9.24
1970	IVa W of 2°E	-	13.0	930.9	695.3	98.7	39.4	49.3	5.7	10.0	4.0	1846.3	312 585	5.91
	IVa E of 2°E	-	32.6	68.7	23.5	9.6	5.4	4.1	1.2	1.2	8.1	154.4	21 262	6.79
	IVb adult	-	27.7	203.5	63.4	9.3	3.3	6.6	0.9	0.4	-	315.1	46 686	6.75
	IVb young	898.1	1118.7	718.1	17.6	2.2	0.6	-	-	-	-	2755.3	139 851	19.701
	IVc	-	4.2	81.6	83.8	5.4	1.6	1.0	0.1	0.4	0.1	178.2	27 086	6.58
	Total NS	898.1	1196.2	2002.8	883.6	125.2	50.3	61.0	7.9	12.0	12.2	5249.3	547 470	9.59

Table 8. Prediction of Catch and Stock Weight as Functions of Fishing Mortality for M = 0.1 (see Section IV f).

F Juvenile	F Adult	Year	Catch Quota (1000 tons)	Stock at the end of the year Number x 10^{-6}	Weight (1000 t)
0	0	1972	0	16331	1642
		1973	0	22016	2535
		1974	0	27160	3501
		1975	0	31811	4484
0	0.3	1972	217	13975	1335
		1973	316	16606	1733
		1974	396	18370	2055
		1975	456	19552	2301
0	0.7	1972	284	11754	1045
		1973	332	12520	1145
		1974	359	12864	1202
		1975	374	13019	1233
0.2	0.3	1972	282	12663	1252
		1973	357	14415	1555
		1974	415	15589	1790
		1975	458	16375	1964
0.2	0.7	1972	348	10442	963
		1973	366	10618	999
		1974	375	10698	1017
		1975	379	10733	1025
0.5	0.7	1972	388	8906	866
		1973	370	8392	828
		1974	356	8161	800
		1975	348	8057	783
0.5	0	1972	104	13483	1463
		1973	104	16591	2077
		1974	104	19402	2696
		1975	104	21944	3296

Table 9 a. Distribution of catches in the Shetland area in 1970 by Scotland, Norway, Iceland [x], Faroes [x] and Sweden [x].

Month	West of 4° W	Between 40°W and Orkney and Shetland	East of Orkney and Shetland
April	-	340	911
May	-	4 211	3 872
June	8 017	72 712	650
July	14 565	59 915	9 177
Aug.	5 523	8 957	4 370
Sept.	-	801	7 073
Oct.	-	131	7 138
Novbr.	-	-	6 431
Decbr.	-	-	332
Total	28 105	147 067	39 954

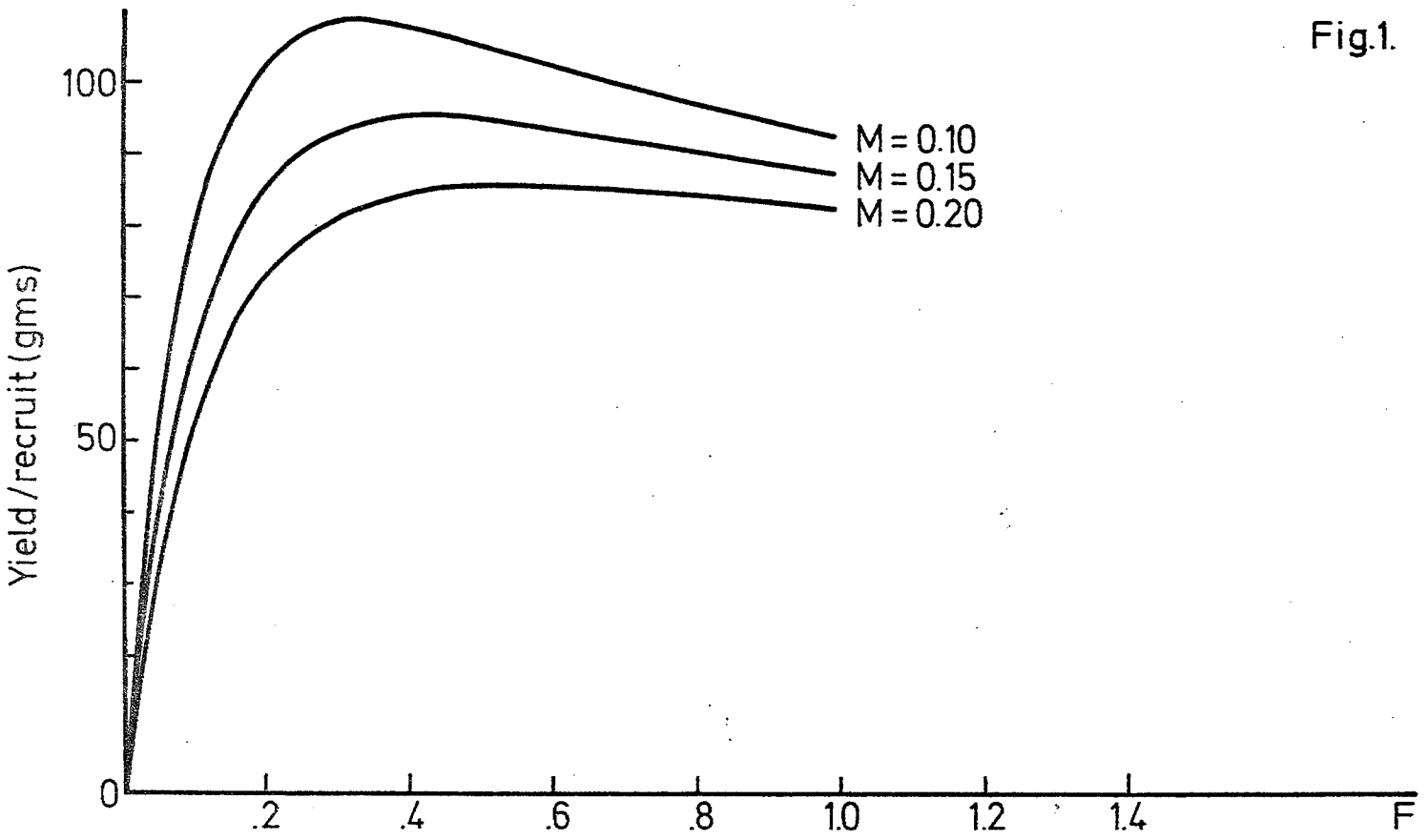
Table 9 b. Percentage age compositions (Norwegian + Scottish data) in three areas of Shetland fishery in June-August 1970.

Area	Winter Rings								
	2	3	4	5	6	7	8	>8	n
West of 4°W	41.2	43.3	4.3	3.5	6.0	0.6	1.0	0.2	840
4°W-west-east of Orkney and Shetland	54.5	31.2	5.0	1.1	3.4	0.7	0.8	0.7	1 564
East of Orkney and Shetland	79.9	15.5	2.0	0.4	1.0	0.5	0.4	0.5	2 017

Table 9 c. Mean V_s, K_2 & l_1 characters of herring samples from West Shetland, East Shetland and Minch grounds.

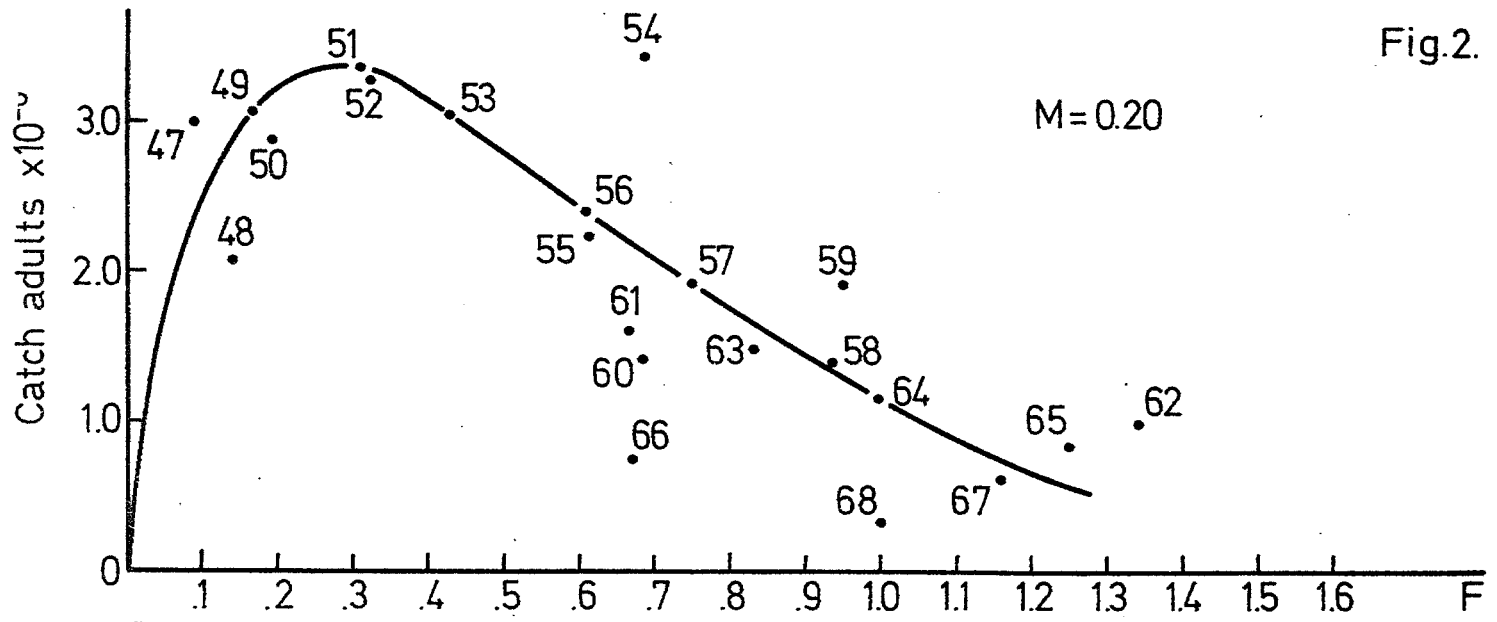
West Shetland			East Shetland			Minch		
V_s	K_2	l_1	V_s	K_2	l_1	V_s	K_2	l_1
56.53	14.14	15.11	56.51	14.19	14.93	56.51	14.19	13.86

Fig.1.



Yeild curves with different values of natural mortality

Fig.2.



Catch of adults in areas IVb and IVc on fishing mortality.