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REPORT OF THE NORWEGIAN - EEC JOINT SCIENTIFIC SUB-GROUP ON THE DISTRIBUTION OF SHARED FISH STOCKS IN THE NORTH SEA

12 - 15 June 1979, Bergen

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REPORT OF THE NORWEGIAN-EEC JOINT SCIENTIFIC SUB-GROUP ON DISTRIBUTION OF SHARED FISH STOCKS IN THE NORTH SEA

1. Introduction

At the meeting of the EEC/Norway Joint Working Group on the Distribution of the North Sea Joint Stocks, held in Bergen on the 12-15 February 1979, a sub-group of scientists from the two parties concerned was set up to prepare a report on the data from which the allocations of joint stocks to the fisheries zones of the two parties in ICES Sub-area IV might be based. The factors which this scientific sub-group were asked to take into account in preparing their report were:
1) The distribution of eggs and larvae; 2) the distribution of juvenile fish; 3) the distribution of the adult stock based on survey data; 4) the distribution of commercial landings; 6) spawning areas; 7) the exploitation rate and management measures. The sub-group was asked to report on cod, haddock, whiting, saithe, plaice, herring and mackerel.

After a brief discussion, during the Bergen meeting mentioned above regarding sources of relevant data, and their acceptability in this context, the scientists of the two parties initially worked independently on extracting and preparing the relevant data and preparing draft reports. Subsequently they met in Bergen on the 12-15 June to agree a joint report based on these drafts. A list of participants is given in Annex 1.

The Liaison Committee of ICES, acting on a request from NEAFC, prepared a report on the distribution of shared stocks in the North Sea which dealt, amongst others, with the same species as those enumerated above and which took into account very similar criteria (Anon. 1978). The EEC/Norwegian Scientific Sub-Group relied quite heavily on this report; the one which they now present differs from it chiefly in that new data, which have become available since the ICES report was prepared, have also been utilised.

The Scientific Sub-Group would wish to draw attention to the fact that the data available in relation to some of these criteria, and particularly for some of the species considered, are rather inadequate to permit precise allocations to be made to the zones of the two parties. To do so survey data would be required which covered all relevant areas in the North Sea at approximately the same time and using the same sampling gear. For most purposes the surveys which most closely meet these requirements are those organised by ICES on an international cooperative basis, with restricted objectives. To extend such surveys to cover all the criteria and species enumerated in the terms of reference given above would require an impracticable input of scientific resources. More international co-ordinated surveys, for example at other times of year would, however, be of great value not only in this context but also for other scientific purposes.

It should be appreciated that for several of the species dealt with in this report the population in the North Sea (Sub-area IV) has considerable interchange with populations in adjacent areas, for example with IIIa and IIa. In these cases, however, this has not been taken into account in the estimates made, which have been strictly confired to Sub-area IV. This may have introduced some element of unreality to the estimates given.

It is also the case that for some stages of the life-cycle of some of the species there is no satisfactory way of conducting such surveys because of peculiarities of their distribution and behaviour It must also be stressed that landing data from the commercial fisheries are not available, for some of the countries which took a large proportion of the total landings, on a sufficiently detailed areal breakdown to permit the total annual commercial landings to be allocated with any great precision between zones. Even if a precise area beakdown of landing data was available this would not necessarily provide a good index of the distribution of the exploitable stock. The landings taken in a zone are determined not only by the stock within that zone, but also by its availability to capture and by the amount of fishing effort expended in taking it. The two latter factors can vary widely between zones. Despite these limitations in the data available the estimates based on different criteria given in this report for several species are rather close when, on our knowledge of the biology of these species, this would be expected. Similarly where, from the biology of the species concerned, the criteria would be expected to provide different estimates these broadly vary in the direction expected. This gives greater credence to the results than would be justified by the individual estimates in the light of the inadequacies of the available data.

The Scientific Sub-Group would wish to point out that where the various criteria give very different estimates of the distribution between zones for the same species there is no objective scientific method of giving weighting to these criteria to attain an overall estimate. The importance of weighting factors increases where criteria give radically different estimates. These are largely confined to the highly migratory pelagic species-herring and mackerel. In these cases we know of no way in which one can weight the fact that adult herring, for example, used to overwinter in the Norwegian zone but had their major distribution during the remainder of the year, and in other stages of the life-cycle within the EEC zone, to obtain an objective single value for allocation to zones.

It should also be stressed that, once an allocation to zones is arrived at it may not be the most efficient way of exploiting the resources to take these allocations entirely within the zones to which they apply. Any such restriction on the distribution of fishing may result, because of differences in age distribution or in seasonal distribution between zones, in the total yield which can be taken being less than would be possible with a more flexible system.

Most of the estimates of the proportions within zones given in this report are based on estimates of abundance within ICES statistical squares over whatever period adequate data are available. These were then summed for squares which are completely contained within one zone; in cases where the dividing line between zones cut a square the value for that square was proportioned between the two zones in proportion to the relative areas of it within the zones. The values used for proportioning purposes in these cases are given in Figure 1. In estimating the mean proportional distributions between zones in cases where more than one survey was available the individual annual estimates were calculated and a straight arithmetic mean estimated. To avoid having to many illustrations in the report mean values for each statistical square have been calculated and plotted on a single chart. If one then calculates from the values given on these charts the proportions in the two zones one will be estimating a mean value which is weighted by the abundance of the year classes. This will give a differnt value from the straight arithmetic mean given in the text and one which we consider is less representative of the value required for this purpose.

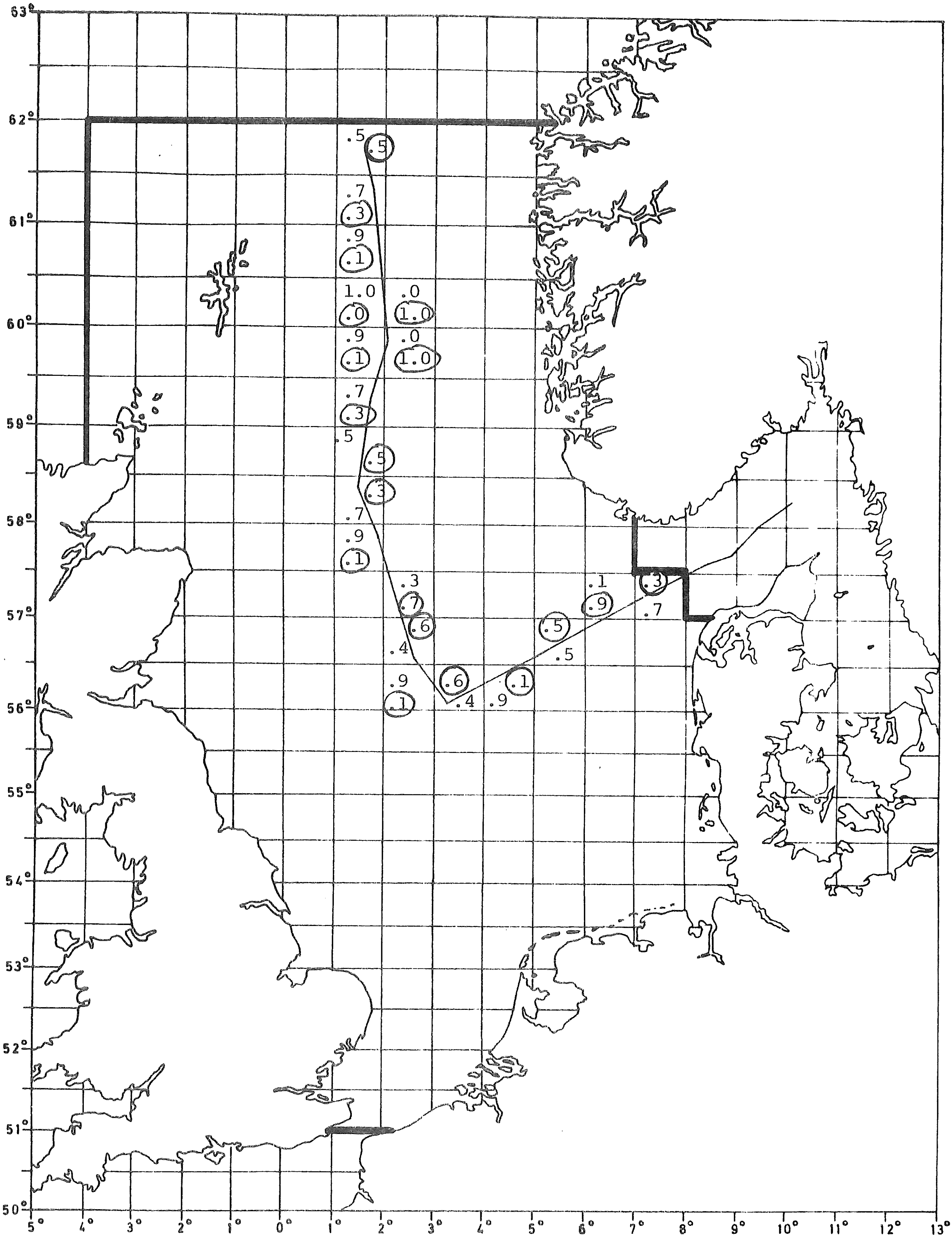

Fig. 1. Values used in portitioning squares cut by the dividing line between zones, N to EEC, (N) to Norway, and boundaries of ICES Sub-area IV.

2.

Cod

1. Distribution of Eggs and Larvae

Information on the distribution of cod eggs was summarised in a chart by the ICES North Sea Roundfish Working Group (Anon, 1977). This chart is reproduced as Figure 1. Cod eggs are widespread over the greater part of the North Sea, with some well-defined areas of higher density corresponding to major spawning areas. As indicated on the chart a fairly large proportion of the area is inadequately surveyed.

The data used in the preparation of Figure 1 are taken from a number of sources and are not always comparable. Consequently it has not been possible to prepare a quantitative plot and this, in addition to the problems created by the unsurveyed areas, means that it is not possible to estimate the proportion of the total egg production in each of the two zones. However, Figure 1 probably gives a reasonable impression of the relative importance of the two zones in terms of egg production.

2. Distribution of Juveniles: 0- and 1-group

0-group

Results of ICES International 0-group surveys have been summarised for the years 1974-78 and the average numbers of cod per statistical rectangle are plotted in Figure 2. From the results of these surveys the percentages in the Norwegian zones and EEC zones of the North Sea are as follows -

Year	Percentage	
	Norwegian Zone	EEC Zone
1974	32.5	67.5
1975	28.7	71.3
1976	38.8	61.2
1977	27.2	72.8
1978	27.1	72.9
Average	30.9	69.1

The surveys have covered a large part of the North Sea but unsampled areas include the Norwegian coastal zone and the Southern Bight. As there are important spawning areas in the Southern Bight the omission of this area from the surveys is likely to result in an underestimate of the proportion in the EEC zone.

1-group

Data on the distribution of 1-group in the North Sea are available from the reports of the ICES International Young Herring Surveys. The data from the five most recent surveys (1974-78) are summarised in Figure 3 as average numbers per hour fishing in each square. Blank squares indicate unsampled areas. The proportions in the two zones are as follows:

Year	Percentage	
	Norwegian Zone	EEC Zone
1974	26.2	73.8
1975	0.8	99.2
1976	5.5	94.5
1977	6.5	93.5
1978	11.7	88.3
Average	10.1	89.9

3. Distribution of adult fish - Research surveys

Catches of cod of age-group 2 are available from the ICES Young Herring Surveys. Data for the five most recent surveys are summarised in Figure 4 as average numbers per hour fishing in each square.

Year	Percentage	
	Norwegian Zone	EEC Zone
1974	16.5	83.5
1975	15.3	84.7
1976	7.7	92.3
1977	20.8	79.2
1978	11.0	89.0
Average	14.3	85.7

Similar data for age-groups 3 and older are given in Figure 5. For these age-groups the proportions in each zone are as follows:

Year	Percentage	
	Norwegian Zone	EEC Zone
1974	14.2	85.8
1975	14.1	85.9
1976	13.1	86.9
1977	24.2	75.8
1978	16.6	83.4
Average	16.4	83.6

A calculation of the percentage in each zone based on the biomass of age-groups 2 and older for the years 1976-78 gave an estimate of 14% in the Norwegian zone which does not differ significantly from the percentages based on numbers of fish given above.

4. Distribution of adult fish - Commercial landings data

National estimates of the proportions of landings taken in the Norwegian and EEC zones were submitted to the ICES North Sea Roundfish Working Group at its 1977 meeting. These data were subsequently published by ICES (Anon. 1978). Data for England and Wales were not available at that time. The previously published data have been updated by the addition of data for England and Wales and the revised tables are given below:

Table A Percentages of Sub-area IV cod landings coming from the Norwegian zone of the North Sea[x)]

Country	Percentage
Belgium	< 5
Denmark[1)]	25
France	0.5
Germany, Fed. Rep.[2)]	6
Netherlands	1-5
Norway[3)]	80
Poland[2)]	30
UK (England)[4)]	7

Table A cont.

UK (Scotland)[4]	27
USSR	N.A.

1) Based on 1975 data

2) Approximate figures for 1970-73

3) Average figures 1972-76

4) Averages for 1974 and 1975

N.A. Not available

Table B 1975 cod landings from Sub-area IV allocated to the Norwegian zone and the EEC zone on the basis of the percentages in Table 1A

Country	Tons	
	Norwegian Zone	EEC Zone
Belgium[1]	189	7 377
Denmark	11 586	34 758
France	43	8 624
Germany, F.R.	987	15 470
Netherlands[2]	582	22 681
Norway	2 214	553
Poland	897	2 094
UK (England)	2 353	31 262
UK (Scotland)	10 073	27 235
Total	28 870	150 054
Percentage	16	84
Remainder unallocated	8 714	

1) Assuming 2.5% in the Norwegian zone (see Table A)

2) Using the midpoint of the range of values in Table A for the percentage in the Norwegian zone.

The data in Table A differ somewhat in the time period to which they relate. To calculate an overall percentage for each zone the percentages for each country in each zone have been applied to that country's North Sea landings in 1975. The resultant quantities have been summed for each zone and expressed as percentages of the overall total (Table B). The data apply to a period before the extension of coastal state jurisdiction when there was freedom to fish over the whole area up to the 12 n m limit. The data relate to landings only and do not make any allowance for quantities which may have been discarded. However for cod the quantities discarded are relatively small. From the data provided the overall percentage taken from the Norwegian zone was 16% with 84% coming from the EEC zone. This is in good agreement with the estimate in Section 3.

5. Migrations

There is known to be some migration between the North Sea and the English Channel. Also there is likely to be a certain amount of diffusion across the northern boundaries of the North Sea. However, in relation to the total quantity of cod in the North Sea the amount of interchange with adjacent areas is small.

Within the North Sea the adult cod undertake limited migrations. Results of tagging experiments were summarised by the ICES Roundfish Working Group (Anon. 1971). Scottish experiments have been done mainly in waters close to the Scottish coast and there was little evidence of migration away from the area of liberation. Experiments on the Norwegian west coast showed the same features. In the main part of the North Sea the pattern appears to be one of concentration in winter on to the main spawning grounds and dispersion over a wider area in summer. Examples of this are illustrated diagramatically in Figure 6 which shows the approximate extent of the summer distribution of cod associated with three important spawning areas in the central and southern North Sea. It is not possible to evaluate quantitatively how the migration patterns may influence the seasonal distribution between zones.

6. Spawning areas

Cod spawning is widespread over most of the North Sea area. A number of the main spawning grounds can be defined, but in addition to these there are numerous lesser spawning grounds, the positions and relative importance of which cannot be defined in any detail. The chart (Fig. 1) of the distribution of cod eggs probably gives as good an indication of the distribution of cod spawning grounds as is available at present. It is not possible to assess the proportion of cod which spawn in each zone.

7. Exploitation and management

North Sea cod are heavily exploited by human comsumption fisheries but, compared with haddock and whiting, the quantities discarded or taken as by-catch in industrial fisheries are relatively small. However numbers discarded may be higher when an abundant yearclass recruits. The trend in landings in recent years is shown in Figure 7A. In most years landings have been about 200 000 tons with higher values in years following the recruitment of abundant year-classes. Recruitment (Fig. 7B) has been very variable, but the year-classes of 1969, 1970 and 1976 have been particularly abundant. Spawning stock biomass (Fig. 7C) increased in the late 1960s reaching a peak in 1969-70. Since then the trend has been downwards to a level similar to that in the mid-1960s, but this trend is expected to reverse when the 1976 year class recruits to the adult stock in 1980. A yield-per-recruit curve is plotted in Figure 7D. This is based on the exploitation pattern in 1978 used as the basis of assessments in the 1979 ICES Working Group[x)]. This Group estimated the present (1978) level of F to be 0.74 (on age-groups subject to maximum exploitation) which is in excess of the F_{max} of 0.25.

x) This report has not yet been approved by the International Council for the Exploration of the Sea; it has therefore the status of an internal document and does not represent advice given on behalf of the Council.

However extrapolation on a yield-per-recruit curve from the present position to the F_{max} position may be unrealistic as it is by no means certain that the stock biomass could increase to the level predicted from yield-per-recruit considerations.

Current mesh regulations have little effect on the management of the cod stock as the optimum mesh size for cod is much larger than would be acceptable for many other species. Small increases in mesh size, e.g. from 70/75 mm to 90 mm would be expected to have an insignificant effect on cod. In recent years the main regulatory measures have been by attempting to restrict catches by quota regulation within agreed Total Allowable Catches. Fishing mortality was at its highest in 1971-73 (F = 0.97) but in recent years appears to have reduced to about 0.7.

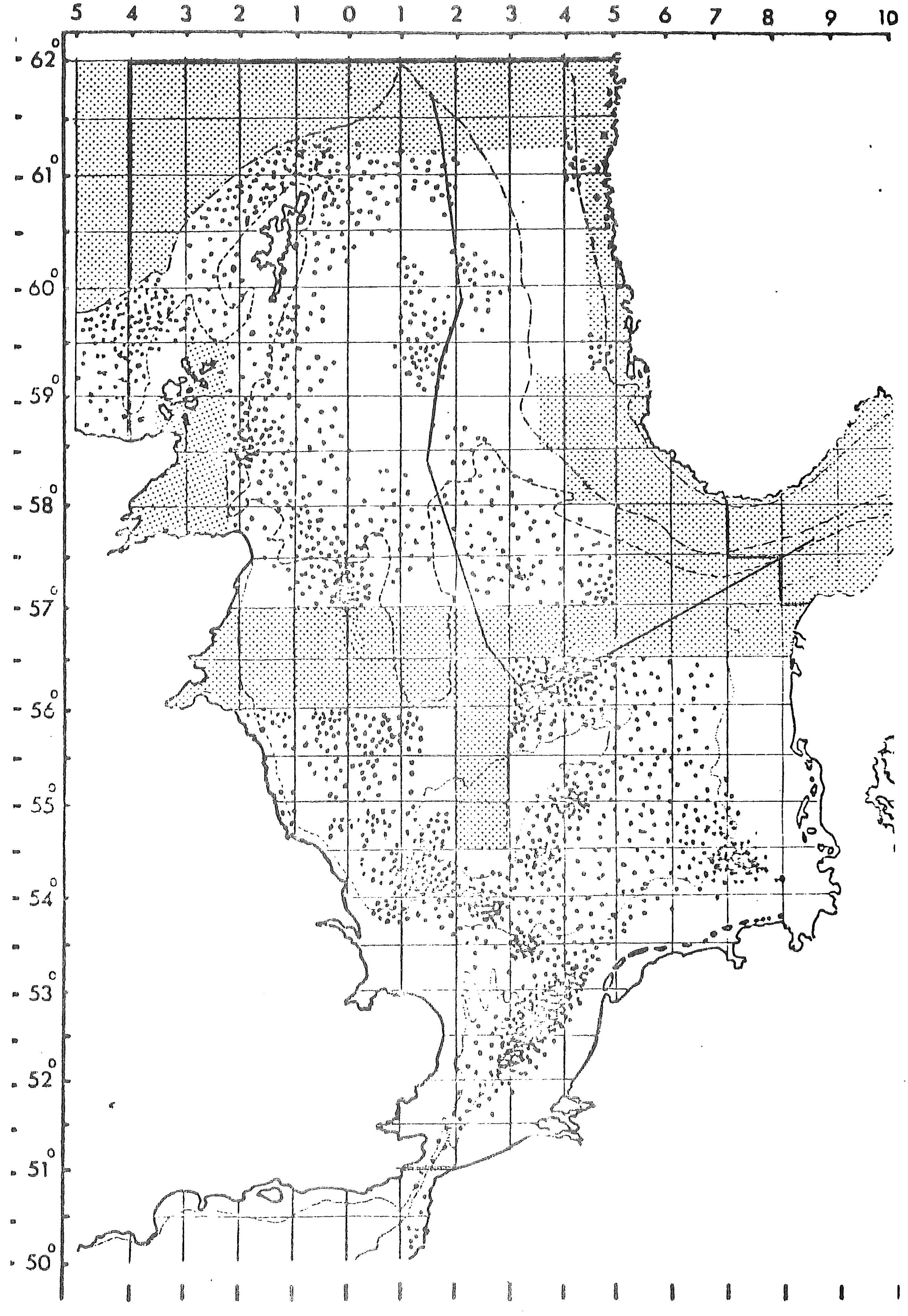

Fig. 1. Spatial distribution of cod eggs in the North Sea according to information after 1945 (shaded area not surveyed). Source: ICES C.M.1977/F:8, Appendix.

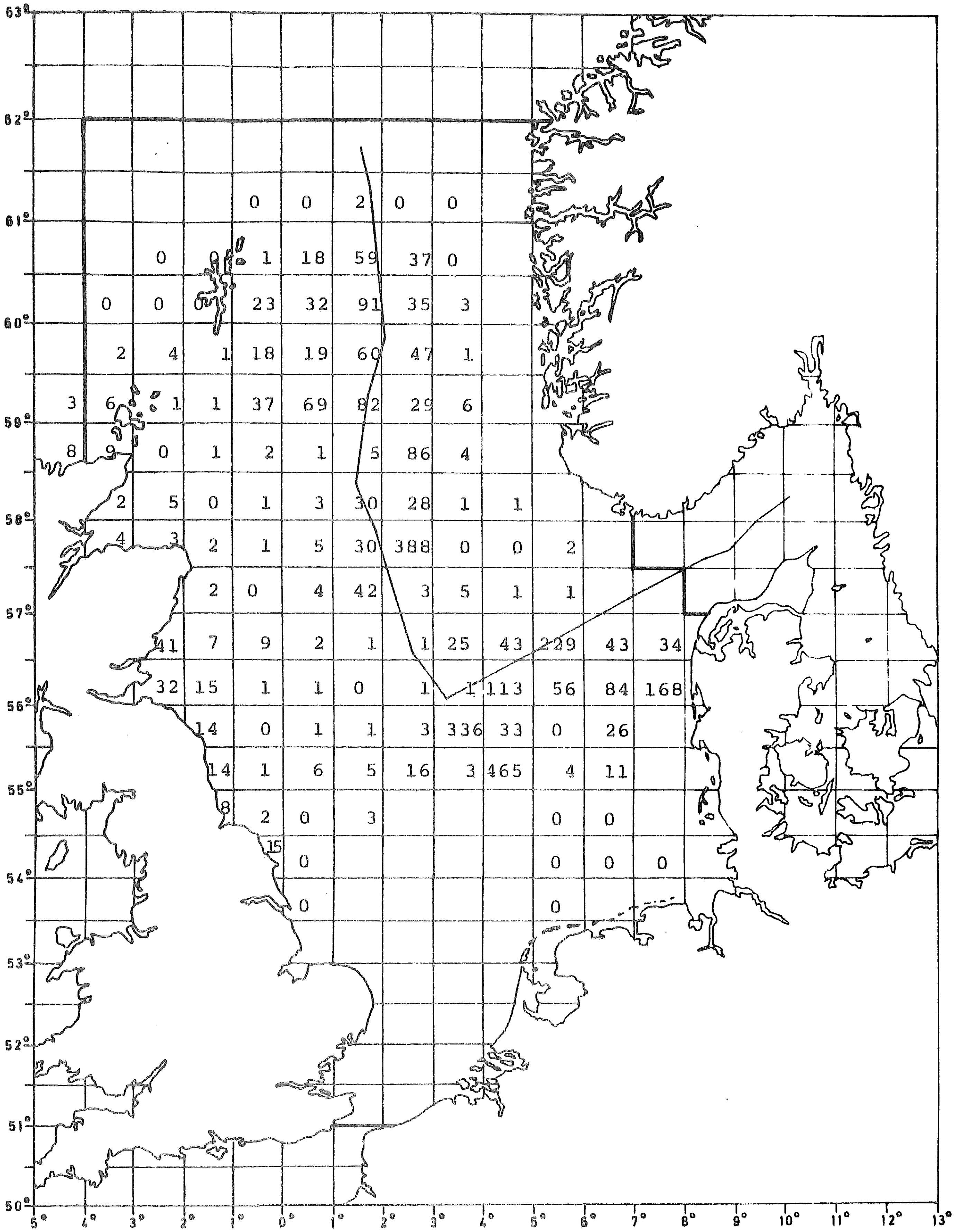

Fig. 2. Cod 0-group. Mean number per hour, 1974 - 1978.

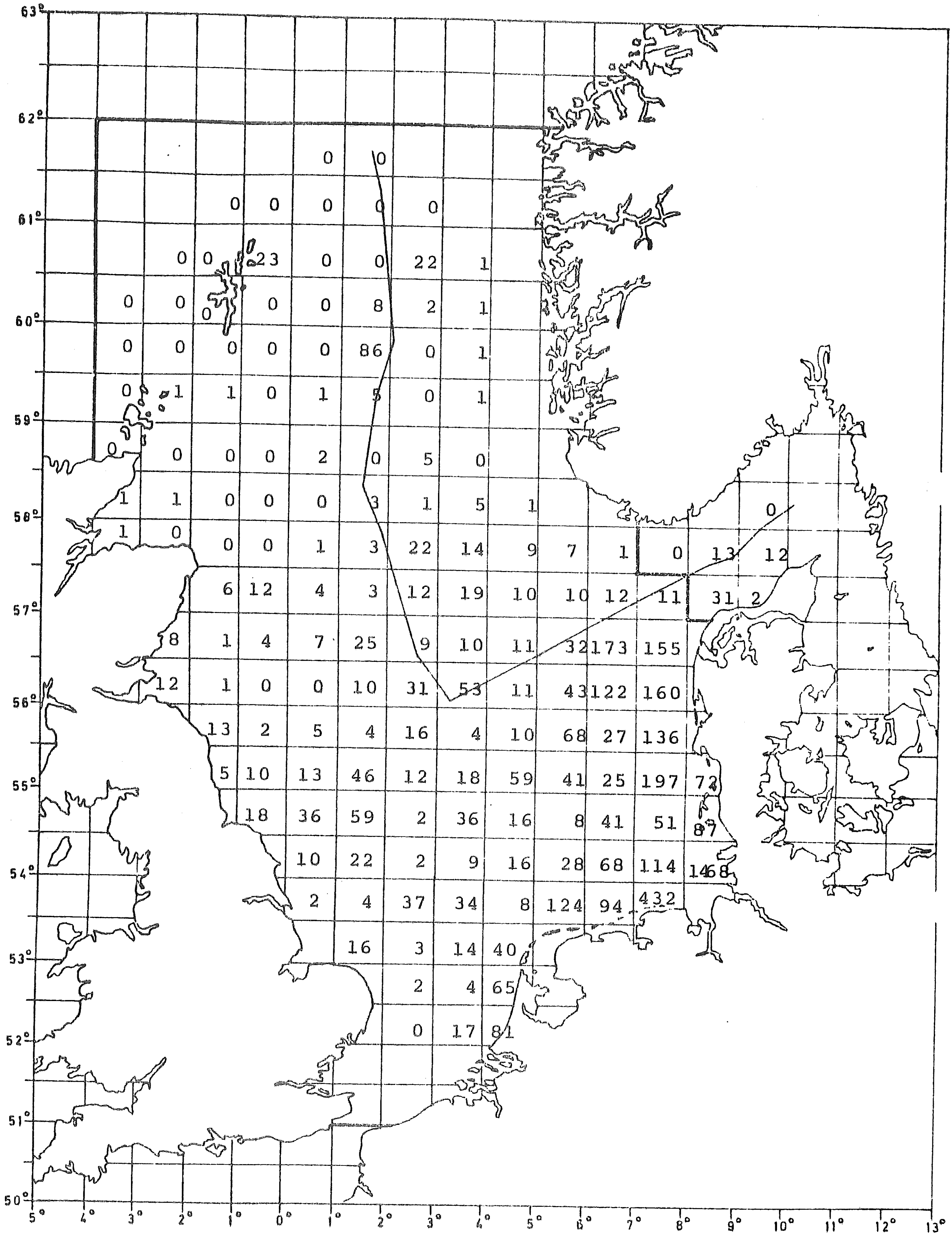

Fig. 3. Cod 1-group. Mean number per hour, 1974 - 1978.

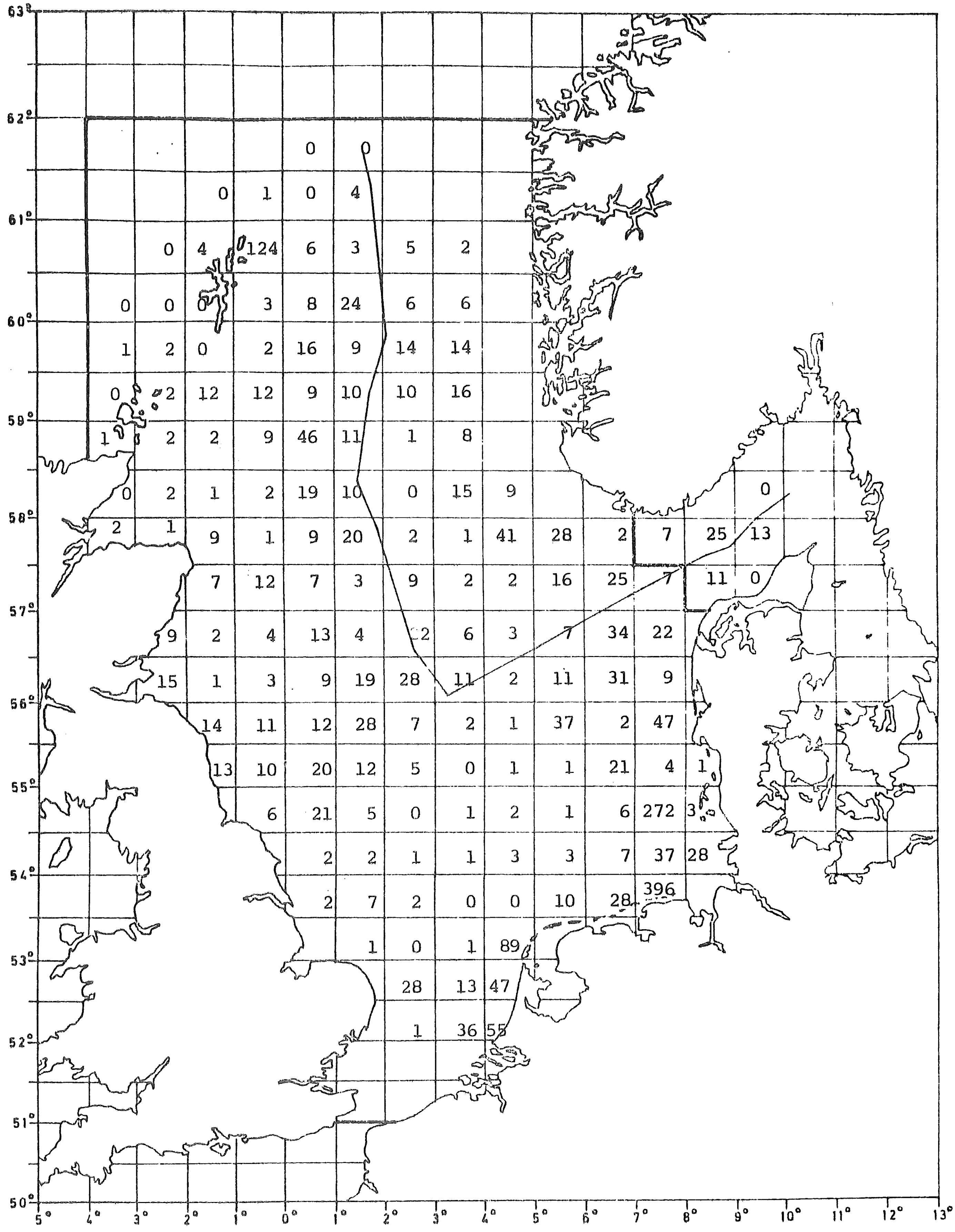

Fig. 4. Cod 2-group. Mean number per hour, 1974 - 1978.

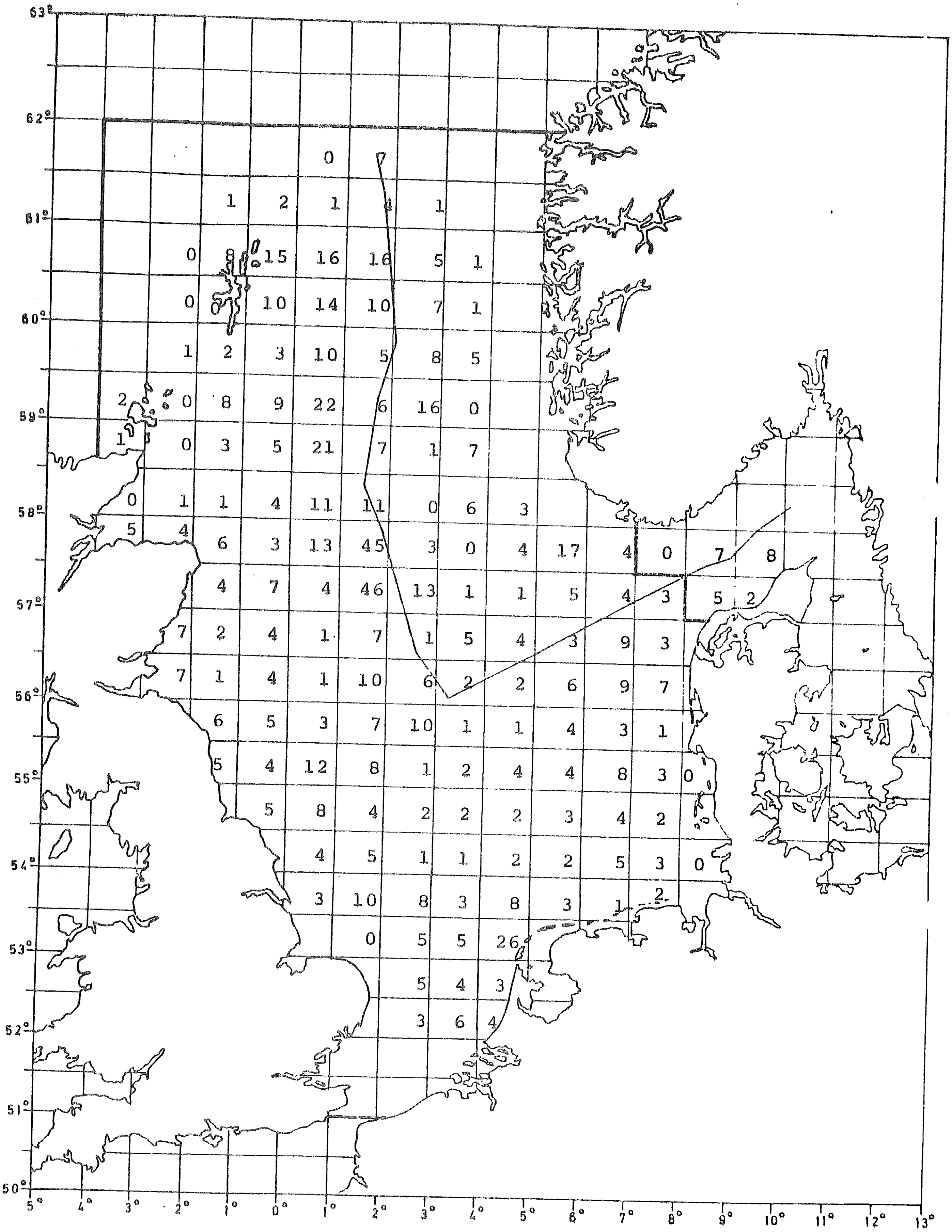

Fig 5. Cod 3+-group. Mean number per hour, 1974 - 1978.

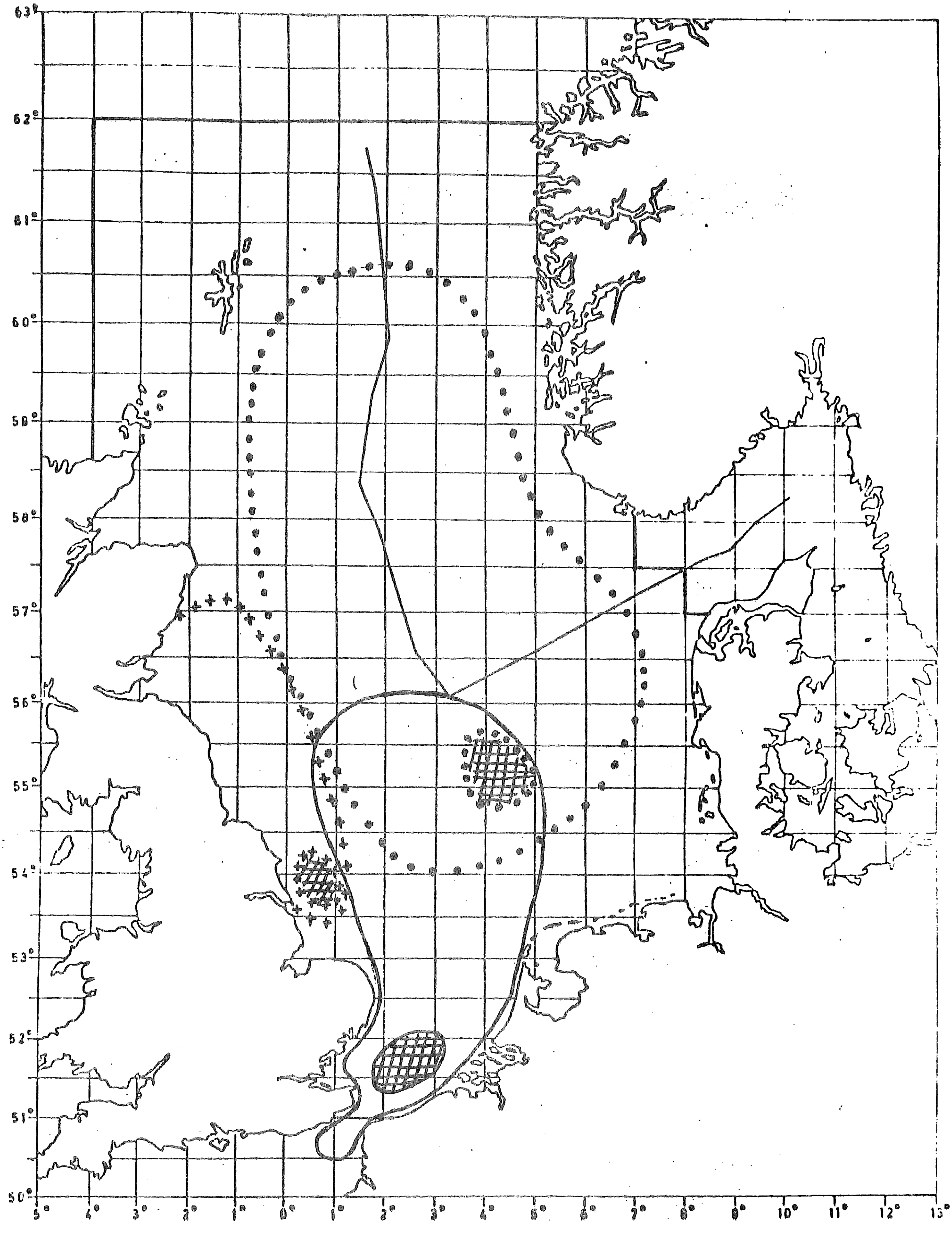

Fig. 6. North Sea cod. Approximate summer distribution of cod associated with three important spawning areas.

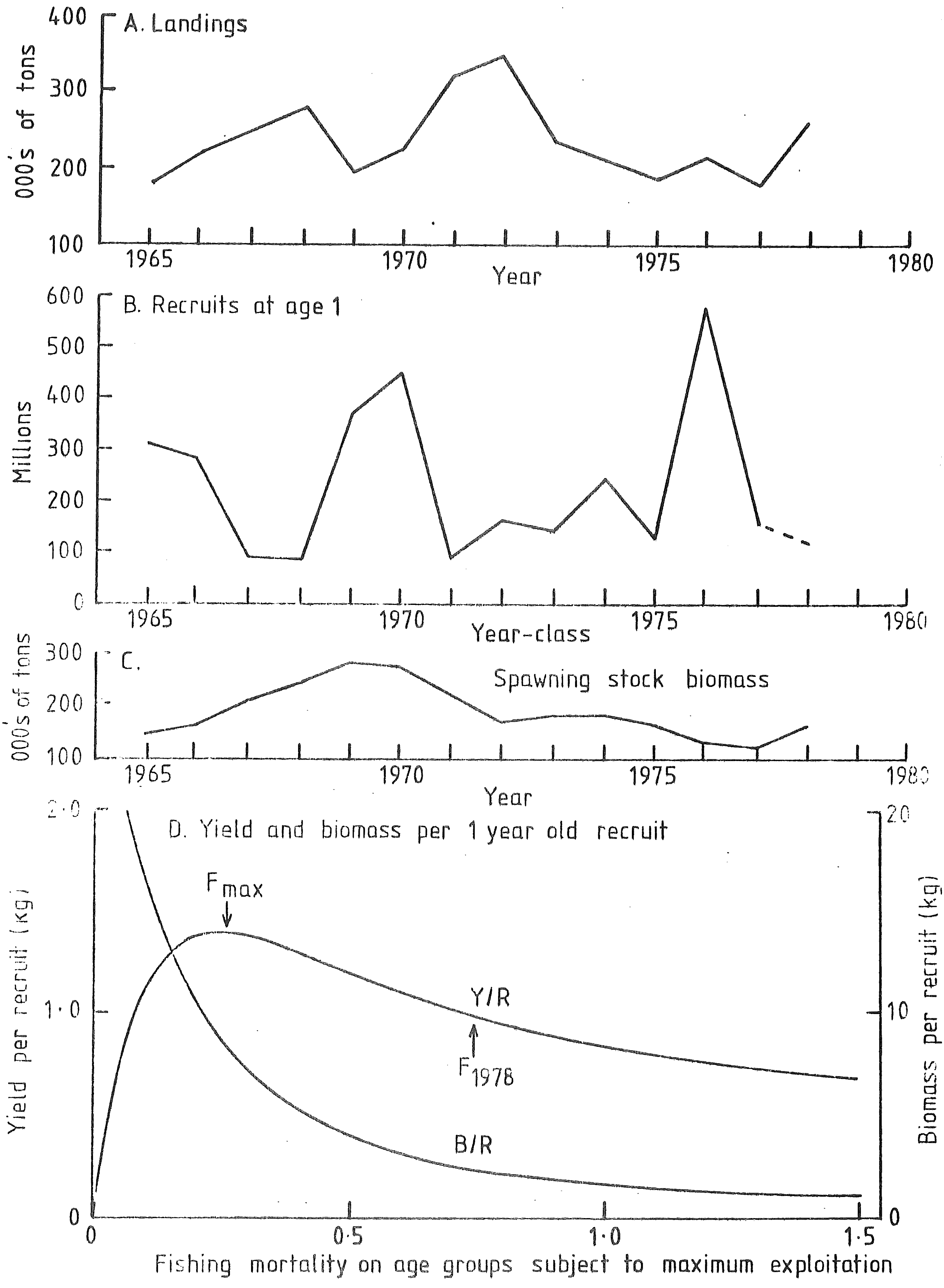

Fig. 7. Population parameters for cod.

3. Haddock

1. Distribution of eggs and larvae.

Information in the literature on the quantitative distribution of the biomasses of eggs and of larvae is very scanty. Early contributions sometimes indicate the numbers caught per haul, but the grid of stations is usually too wide to give a reasonable coverage of the pertinent area. It is also questionable whether these early works are representative of the present situation. There are some indications that the distribution of the haddock in the North Sea has been more northerly in the more recent decades.

The best presentation of the distribution of eggs and young larvae is probably that produced by Saville (1959), shown in Figures 1 - 6. These indicate an appreciable variation from one year to another though certain features in the distributional pattern appear to be rather stable. There are usually very few eggs and larvae in the area east of 3^{o}E, and north of 58^{o}N; while a concentration south-west of Egersund in Norway is found in some years, corresponding to the concentration of immatures off the entrance to Skagerrak apparent in the charts of distribution of 0- and I-groups (Figs. 7 - 9).

It is not possible to estimate precisely the proportion of the total egg production within zones from Figures 1 - 6. On the assumption of an equal distribution within the contour lines shown, and counting the number of squares covered, a very crude estimate may be that 10 - 15% of the plankton stages are found in the Norwegian zone.

2. Distribution of juveniles - 0- and I-group.

0-group

Mean catch per hour fishing per statistical square are obtained from the International 0-group Gadoid Surveys which have been carried out for a number of years. Figure 8 shows the mean numbers for the whole of the period from 1974 - 1978. The proportions calculated for each single year give the following estimates:

Year	Percentage	
	Norwegian zone	EEC zone
1974	32.7	67.3
1975	19.3	80.7
1976	48.4	51.6
1977	16.3	83.7
1978	19.4	80.6
Mean	27.2	72.8

Soviet surveys covering almost the total North Sea area (Fig. 7) give an estimate of 33.5% 0-group in numbers found in the Norwegian zone as a mean over the period 1973 - 1976. This is in good agreement with the IOGS estimate above.

I-group

Mean catch in numbers of I-group haddock from the International Young Herring Surveys are shown for the period 1974 - 1978 in Figure 9. The variation from one year to another is appreciable, as shown below:

Year	Percentage	
	Norwegian zone	EEC zone
1974	24.1	75.9
1975	21.9	78.1
1976	25.6	74.6
1977	36.0	64.0
1978	40.1	59.9
Mean	29.5	70.5

3. Distribution of adult fish - Research surveys.

Figures 10 - 11 show the distribution of 2-and 3-group fish respectively giving mean catches for the whole of the period 1974 - 1978.

Estimates of 2-group and of older fish for separate years show the range of variation:

Year	Percentage			
	2-group		3+-group	
	Norwegian zone	EEC zone	Norwegian zone	EEC zone
1974	17.8	82.2	8.8	91.2
1975	16.6	83.4	13.1	86.9
1976	16.6	83.4	17.4	82.6
1977	27.7	72.3	13.6	86.4
1978	38.7	61.3	20.8	79.2
Mean	23.5	76.5	14.7	85.3

4. Distribution of adult fish - commercial landings data.

Percentages of sub-area IV landings reported from the Norwegian zone by various countries are shown below:

Country	% from Norweg. zone	Based on
Belgium	< 5	
Denmark	28.5	Average 1974-76
France	1.2	
F.R.G.	26	Approx. fig. for 1970-73
Netherlands	10-25	
Norway	60	Average figure 1972-76
Poland	30	Approx. fig. for 1970-73
U.K. (Engl.)	8	Averages for 1974 and
U.K. (Scotl.)	24	1975
USSR	N.A.	

The splits shown above were made from rectangle and other data provided by ICES's working group members. Applied to nominal landings in 1975 from the North Sea an overall estimate of the percentage taken in the Norwegian zone can be arrived at:

Country	From Norwegian zone (in tons)	From EEC zone (in tons)
Belgium	55	2 154
Denmark	9 385	23 545
France	56	4 590
F.R.G.	623	1 773
Netherlands	323	1 578
Norway	6 103	4 068
Poland	446	1 039
U.K. (Engl.)	920	10 579
U.K. (Scotl.)	15 525	49 161
Total	33 436	98 487
In %	25.3	74.7

5. Migrations.

Tagging experiments on haddock have not been done on a wide enough scale to provide useful information on migration between zones.

The distributional pattern at age, as shown in the figures, indicates a wider distribution of the younger age-groups and a tendency for the adult fish to concentrate more in the north-western North Sea. In relation to the Norwegian zone this is shown by the estimates given in the different sections above:

0-group	27-33%	in Norwegian zone
I-group	30%	in Norwegian zone
2-group	24%	in Norwegian zone
3-group	15%	in Norwegian zone.

6. Spawning areas.

In this case recent contributions are also scarce. Thompson (1928) depicted the spawning areas in the North Sea as shown in Figure 12, based on a six years analysis of mature fish in commercial landings. Because of the more northerly distribution of the North Sea haddock, which seems to have taken place since these early investigations, the main spawning area in the North Sea, at present, is probably confined to the northern half of that shown in Figure 12. This is corroborated by Saville (1959), who showed (Figs. 1 - 6) that, though eggs were found within the major part of the area defined by Thompson over a longer period of years, only a minor part of it could actually be nominated as spawning area in any single year from the distribution of eggs.

The main features appear to be a concentration of spawning products, in all years investigated, along the eastern parts of the Shetlands and the Orkneys; in some years along the banks bordering the western edge of the Norwegian Deeps; and a smaller patch of eggs has often been recorded off the approaches to Skagerrak.

The main feature in defining spawning grounds east and west respectively of the dividing line between the Norwegian and the EEC management zones is perhaps the total absence of eggs and young larvae east of 3^{o}E, this is over the Norwegian Deeps.

7. Exploitation and management.

The landings of haddock are shown in Table 1 for the years 1968-1978. The very high landing figures in the mid-1960s, and throughout most of the 1970s, are mainly due to a major increase in recruitment in that period. Before 1964 the stock biomass of haddock $\geq$ 2-group in the North Sea was at the level of approximately 100 000 tons until the extremely good year-class of 1962 was born. This year-class resulted in an increase in biomass to over 500 000 tons. By the time this biomass had decreased to 300 000 tons the even richer yearclass of 1967 was born. The resulting biomass in 1969 reached nearly 1 million tons. In 1974 another good yearclass was born on the basis of a stock biomass of c. 300 000 tons of 2-group and older.

Table 1. Landings of haddock from the North Sea 1968 - 78.

1968	139 775 tons
1969	639 195 "
1970	671 833 "
1971	258 220 "
1972	213 556 "
1973	196 079 "
1974	193 429 "
1975	174 163 "
1976	204 603 "
1977	150 678 "
1978	89 794 "

The present stock is estimated at approximately 200 000 tons. This is twice the stock size prior to the early 1960s and in the middle of the range which produced the outstanding year-classes. It may be concluded that the North Sea haddock stock does not suffer from so-called recruitment overfishing.

The most recent estimate of fishing mortality, would indicate that about 2/3 of the exploited stock is removed annually. This means that the age range in the exploited stock is comparatively small and that the "buffering" capacity of the population against large variations in yearclass strength, and thereby in landings is relatively low.

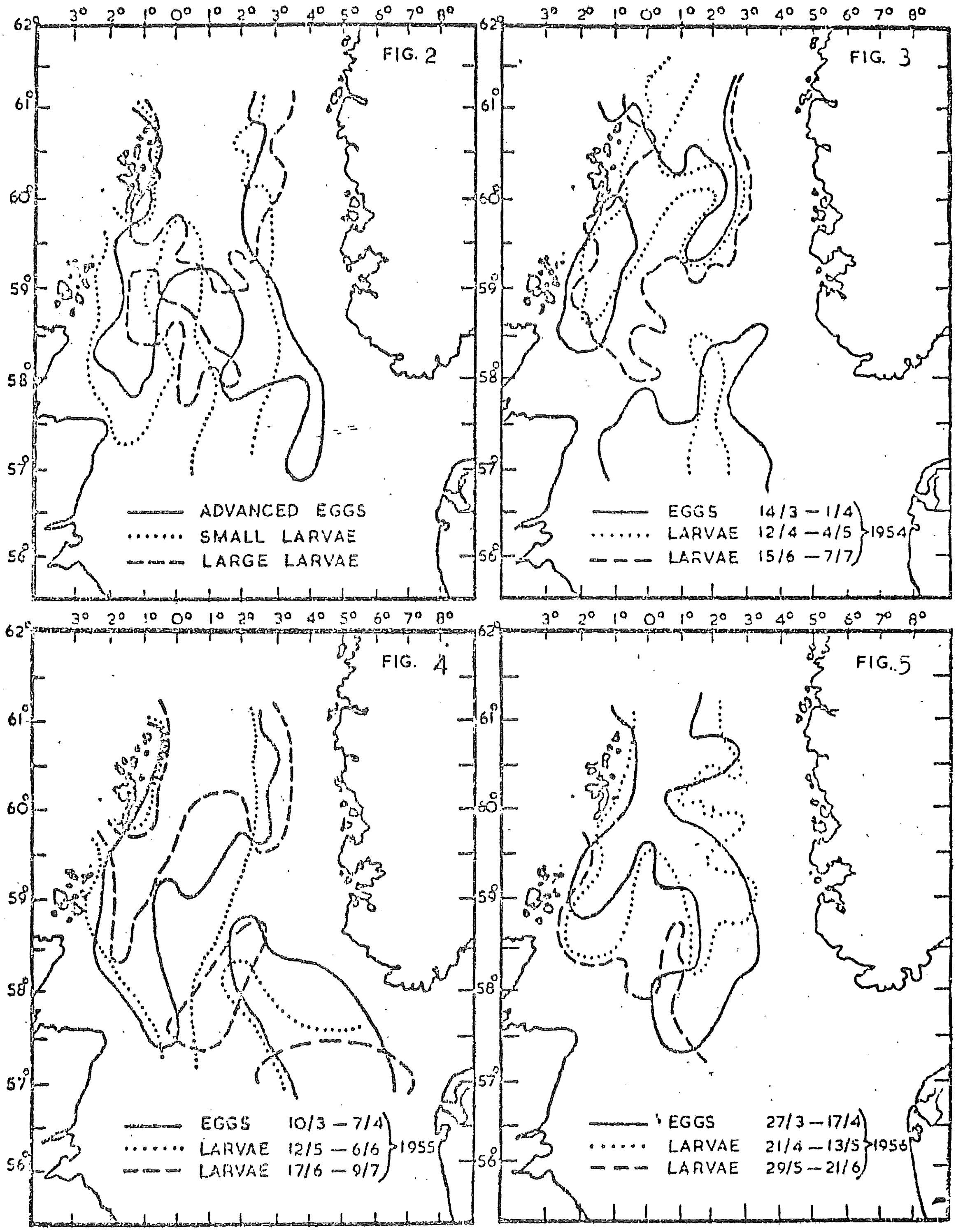

Fig. 1 Distribution of Haddock Eggs and Larvæ over all cruises in northern North Sea, 1952-1957.
Fig. 2 Distribution of Haddock Eggs and Larvæ on successive cruises in northern North Sea, in 1954.
Fig. 3 Distribution of Haddock Eggs and Larvæ on successive cruises in nothern North Sea in 1955.
Fig. 4 Distribution of Haddock Eggs and Larvæ on successive cruises in northern North Sea in 1956.

(after Saville 1959)

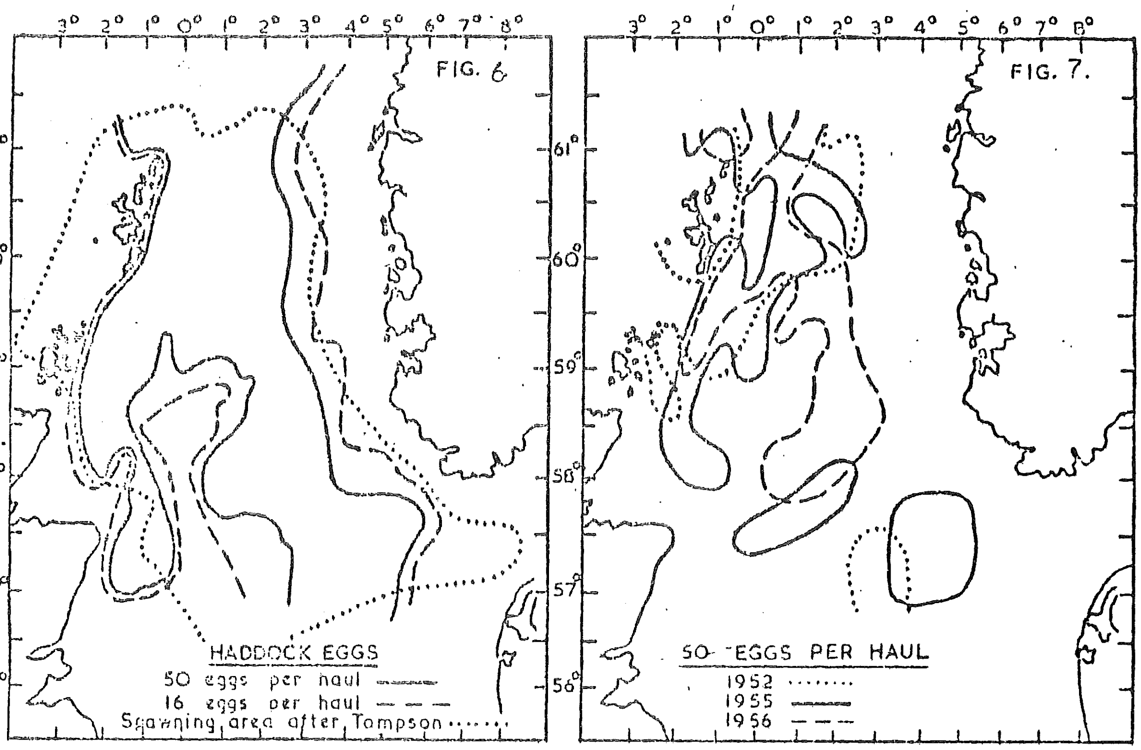

Fig. 5. Haddock Spawning Area in northern North Sea, 1952-1957.
Fig. 6. Haddock Spawning Areas in northern North Sea in individual years.

(Saville 1959)

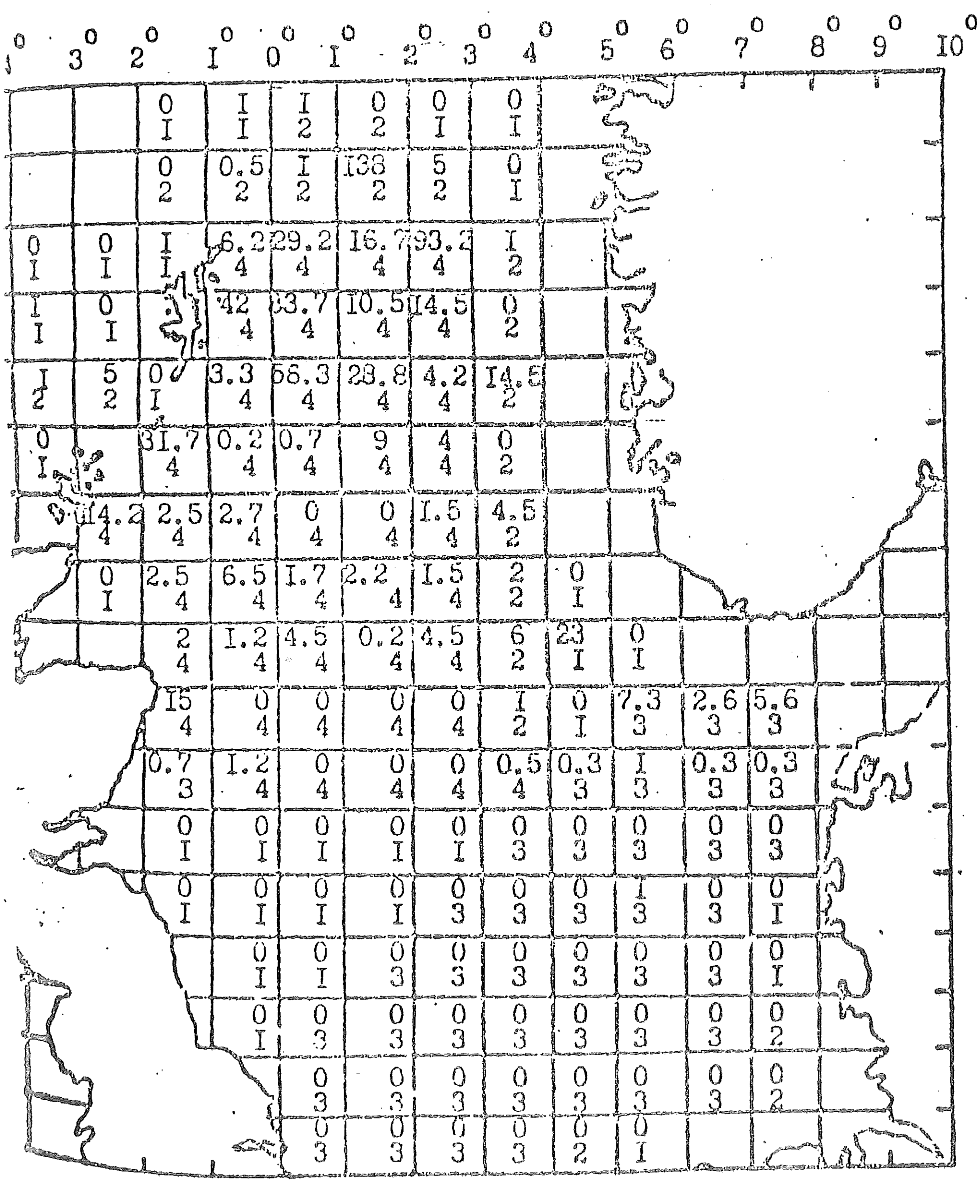

Fig. 7 . Mean number of O-group haddock per standard haul , 1973-76 (Upper figure) and numbers of hauls (lower figure). (Malkov 1977)

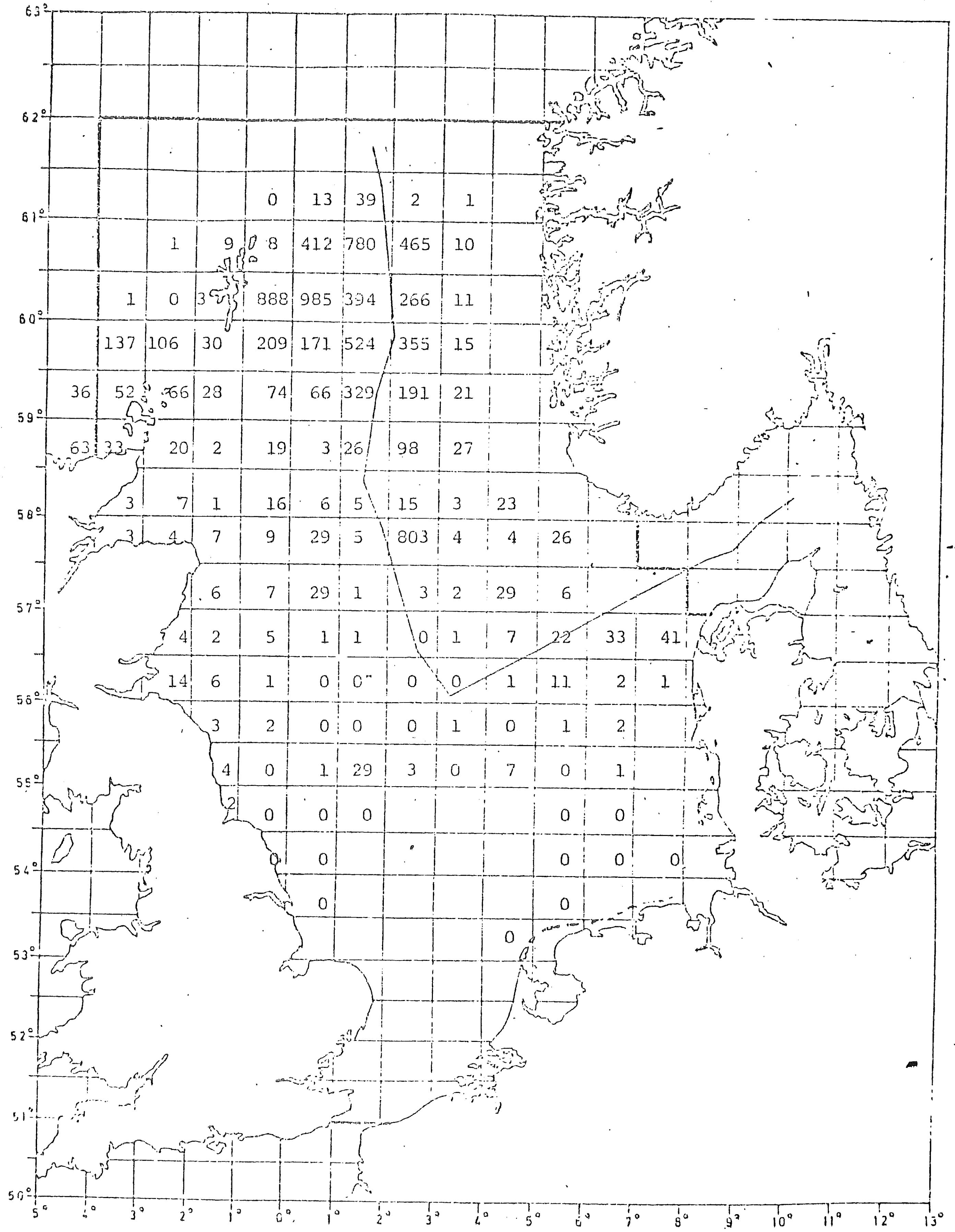

Fig. 8. Haddock 0-group. Mean number per hour, 1974 - 1978.

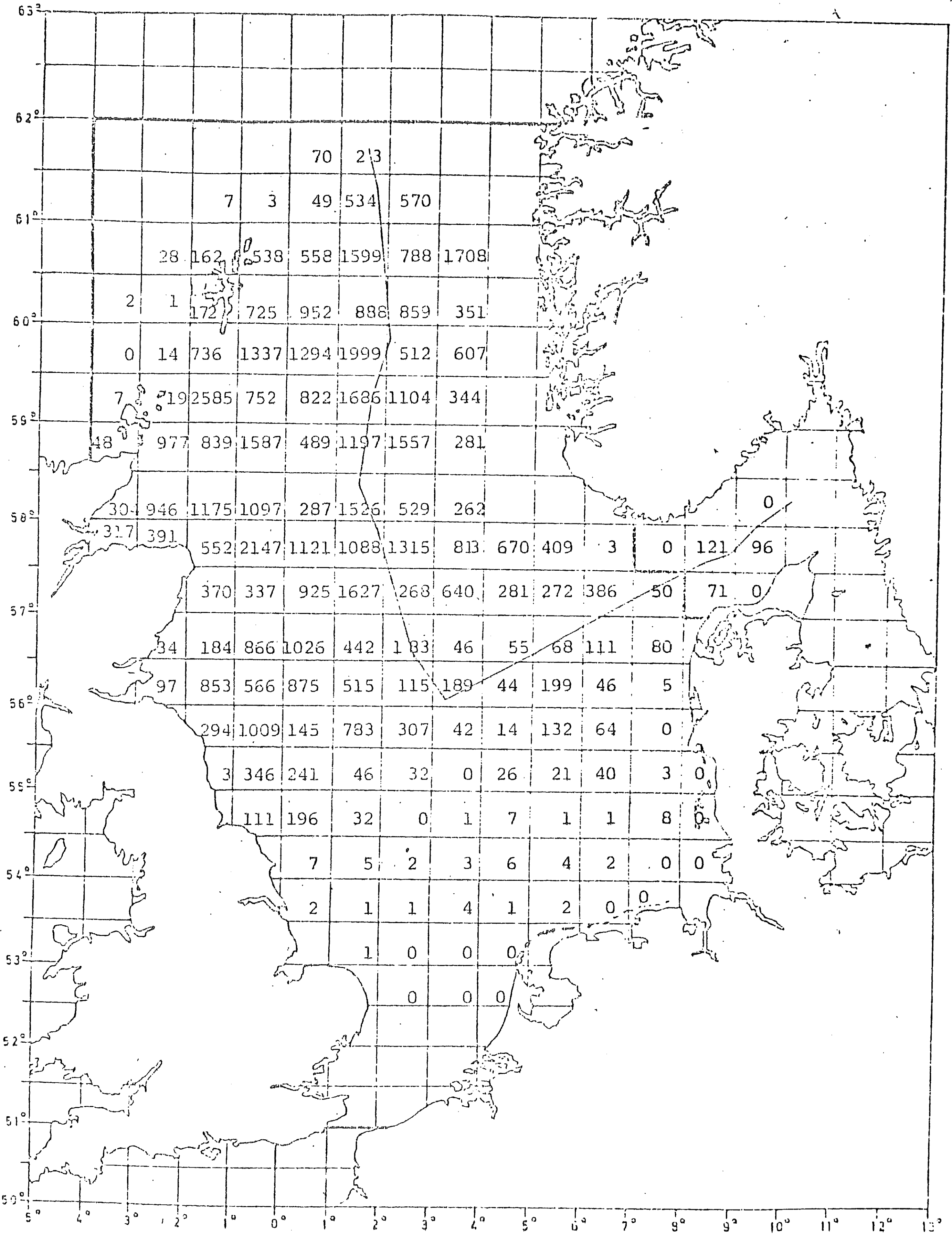

Fig. 9. Haddock 1-group. Mean number per hour, 1974 - 1978.

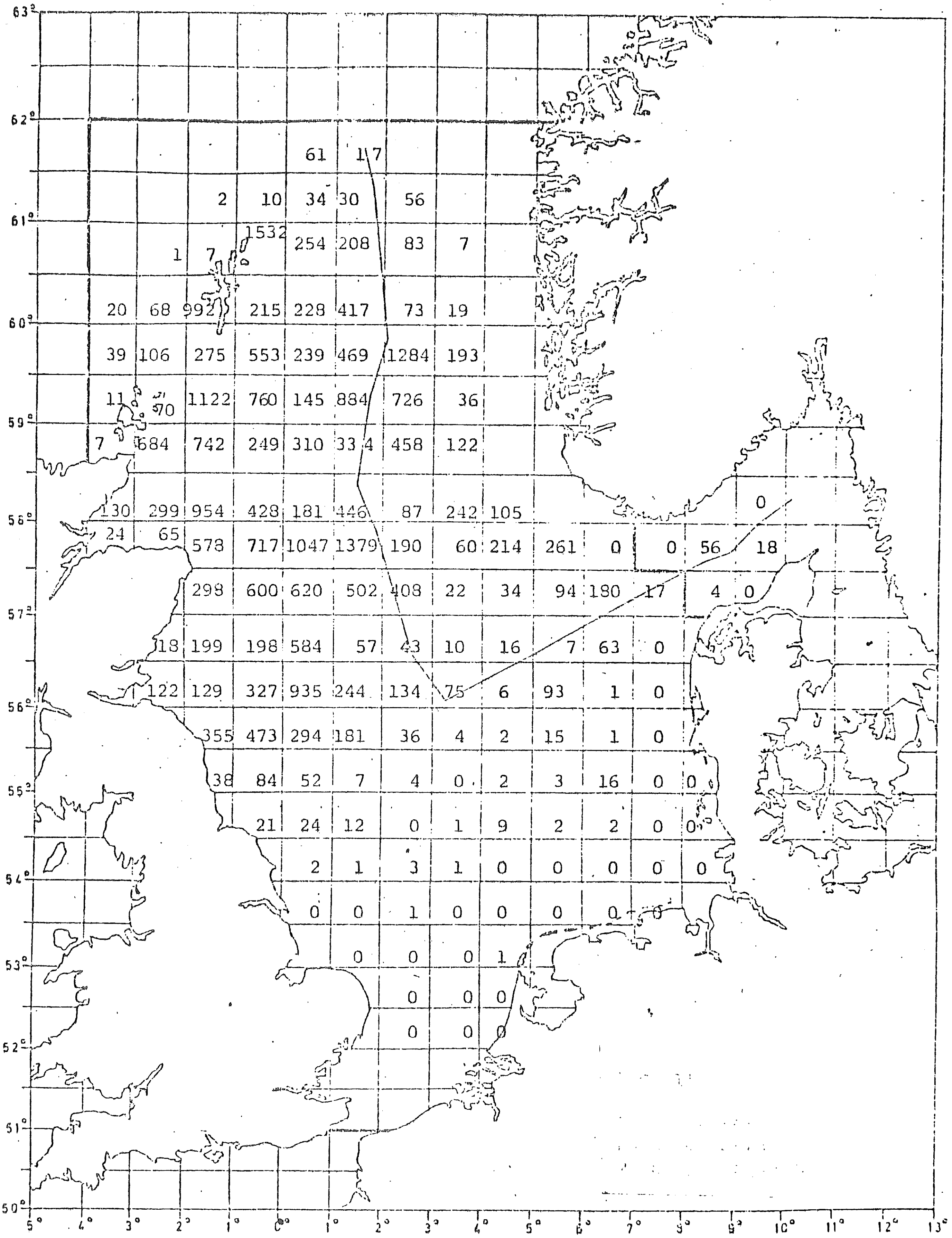

Fig. 10. Haddock 2-group. Mean number per hour, 1974 - 1978.

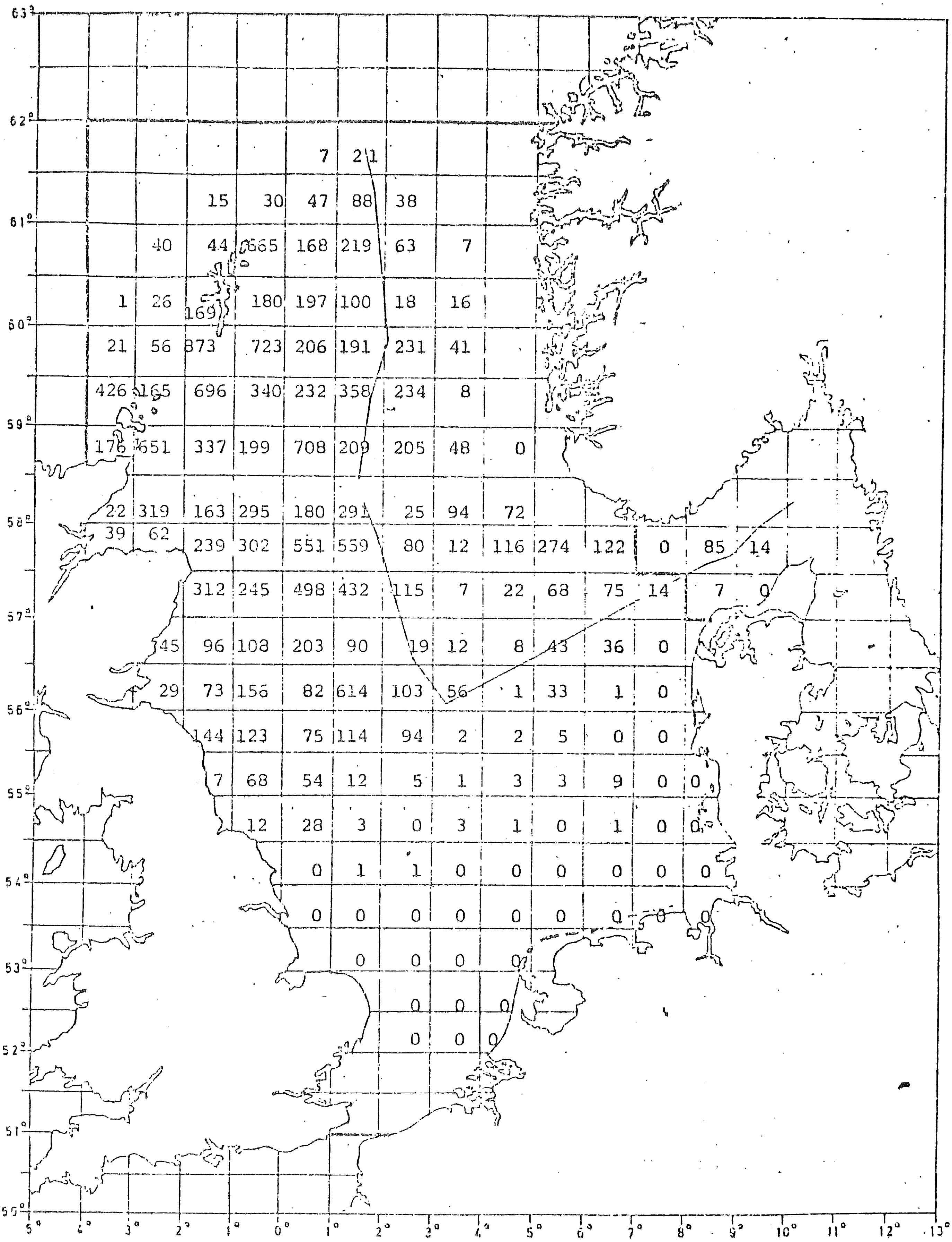

Fig. 11. Haddock 3+-group. Mean number per hour, 1974 - 1978.

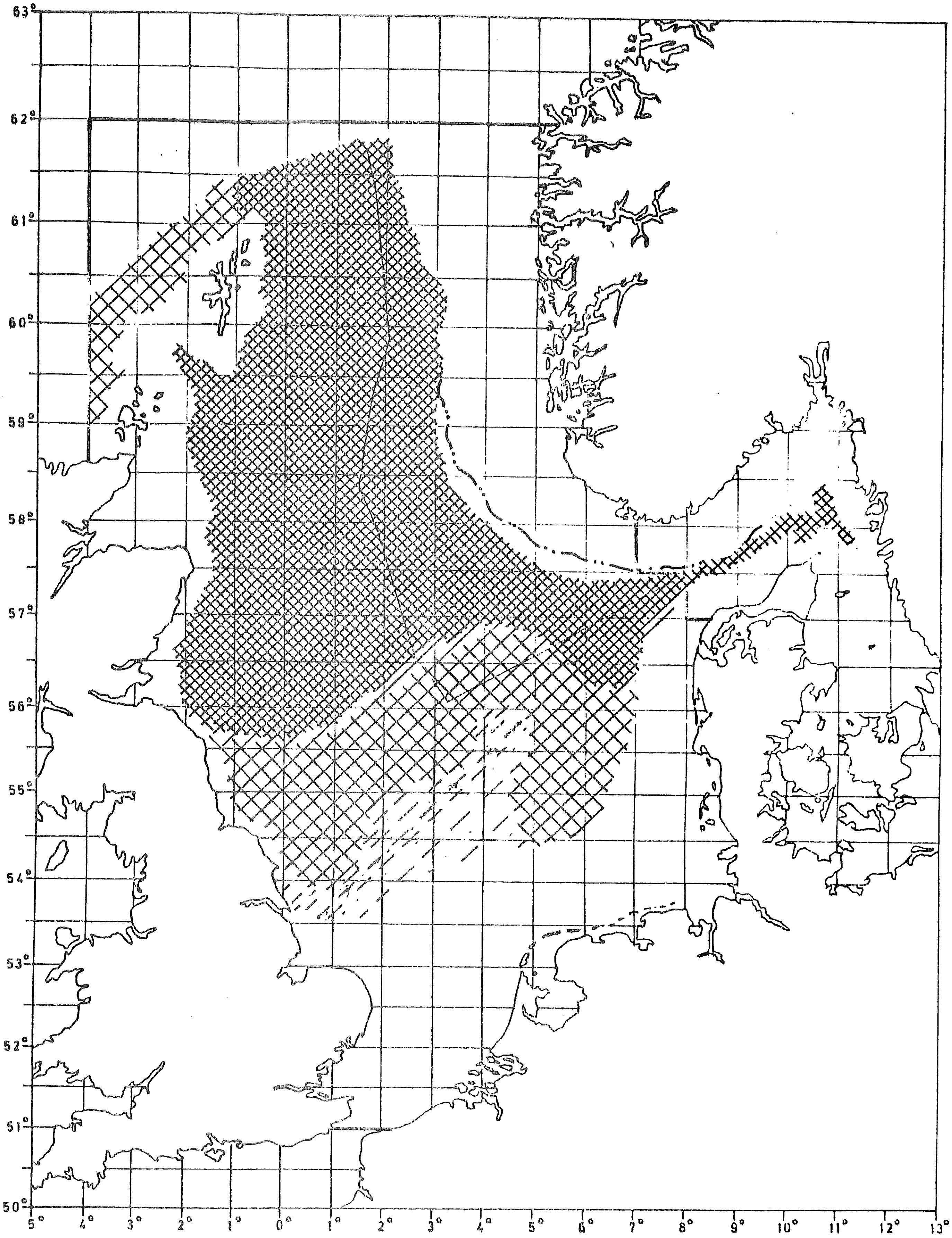

Fig. 12. Spawning region of the haddock in the North Sea (After Thompson 1928).

4. Whiting

1. Distribution of eggs and larvae

The spawning season in the North Sea is a long one. Eggs are found in the southern part in January and small larvae are still found in the northern part in September. The spawning grounds are not well defined. The pelagic life tends to be longer for this species than for other members of the cod family; 0-group fish, of a length of 10 cm, may still be found pelagically in October. Sufficiently extensive surveys for the eggs or larvae stages of this species have not been carried out to illustrate their distribution over the North Sea as a whole, and to estimate the proportions of the total within the EEC and Norwegian zones. In view of the preponderance of both adult fish and juveniles, within the EEC zone, however, it would be logical to conclude that the distribution of the planktonic egg and larval stages would also be predominantly within the EEC zone.

2. Distribution of juveniles: 0- and I-group

0-group

Results from the ICES 0-Group Gadoid Surveys have been summarized for the years 1974 - 1978 (Fig. 1). In addition Soviet data from whiting surveys have been summarized for the years 1973 - 1976 (Fig. 2).

The coverage of all of these surveys is likely to have resulted in some underestimate of the proportion in the EEC zone because of the lack of sampling in the southern part of the North Sea. The better coverage of 1974 and 1975 in the ICES surveys gives results more in agreement with those derived from the Soviet surveys; of 26% in the Norwegian zone and 74% in the EEC zone.

Table 1. Mean number per hour of 0-group whiting (%).

Year	Norwegian Zone	EEC Zone
1974	17.5	82.5
1975	31.9	68.1
1976	1.0	99.0
1977	11.8	88.2
1978	19.2	80.8
Mean	16.3	83.7

1-group

Results from the ICES Young Herring Surveys have been summarized for the years 1960 and 1965 - 1978 (Figs 3 - 5). In Table 2 the percentages of 1-group whiting in both zones are given for the years 1974-78.

Table 2. Mean number per hour of 1-group whiting (%).

Year	Norwegian Zone	EEC Zone
1974	3.5	96.5
1975	3.1	96.9
1976	2.5	97.5
1977	6.0	94.0
1978	9.6	90.4
Mean	4.9	95.1

Over the period 1974 - 1978 the proportional distribution of 1-group whiting has been rather stable.

3. Distribution of adult fish - Research surveys

The data on the distribution of adult whiting (group 2, 3 and older) are mainly derived from the same source as that of the 1-group (Figs. 6 - 14).

The seasonal data for the adult whiting in 1960, given in Table 3, indicate that the seasonal variations are very small.

Table 3. Seasonal distribution of whiting, 1-group and older in the EEC and Norwegian Zones.

		Proportion (%)			
	Age group	EEC Zone	Norw. Zone	EEC Zone	Norw. Zone
	Numbers	Spring		Autumn	
1960	1-group	82.7	17.3	82.6	17.4
	2 "	93.7	6.3	89.2	10.8
	3 "	91.6	8.4	95.2	4.8
	4 "	89.3	10.7	96.9	3.1

The distribution of 2 and 3 group from the International Young Herring Surveys are given in Table 4.

Table 4. Mean number per hour of adult whiting from International Young Herring Surveys (%).

Year	2 group Norw. Zone	2 group EEC Zone	3 group Norw. Zone	3 group EEC Zone
Mean 1965-1975	3.4	96.6	-	-
1974	1.2	98.8	15.4	84.6
1975	5.8	94.2	4.6	95.4
1976	2.3	97.7	8.6	91.4
1977	3.5	96.5	27.0	73.0
1978	1.1	98.9	5.1	94.9
Mean 1974-1978	2.8	97.2	12.1	87.9

Comparison of the distribution between the 2-group and older whiting shows an increase of about 8% in the Norwegian zone.

Table 5 gives the percentage distribution of all adults based on numbers and biomass.

Table 5. Comparison between numbers and biomass of adult whiting (%).

Year	Numbers Norw. Zone	Numbers EEC Zone	Biomass Norw. Zone	Biomass EEC Zone
1974	2.7	97.3	-	-
1975	5.2	94.8	-	-
1976	3.9	96.1	5.1	94.9
1977	11.4	88.6	17.6	82.4
1978	4.7	95.3	3.3	96.7
Mean 1974-1978	5.6	94.4	-	-
Mean 1976-1978	6.7	93.3	8.7	91.3

The figures given in Table 5 show that the calculations based on numbers and on biomass give almost the same results.

4. Distribution of adult fish - Commercial landings

The nominal whiting landings, with reference to the Norwegian and EEC zones are given in the tables 6 and 7. These were taken from Anon. (1974), but with the data for England and Wales included.

Table 6. Percentages of Sub-area IV landings coming from the Norwegian zone of the North Sea

Country	Whiting
Belgium	< 5
Denmark[1)]	13
France	0.5
Germany, Fed. Rep.[2)]	13
Netherlands	4 - 10

Norway[3)]	50
Poland[4)]	15
UK (England)[4)]	1
UK (Scotland)[4)]	9
USSR	N.A.

1) Based on 1975 data

2) Approximate figures for 1970-73

3) Averaged figures 1972-76

4) Averages for 1974 and 1975

N.A. Not available

Table 7. 1975 landings from sub-area IV subdivided according to the Norwegian zone and the EEC zone (Based on percentages in Table 6)

Country	Whiting	
	Norwegian Zone	EEC Zone
Belgium	82	3 197
Denmark	8 052	53 889
France	100	19 979
Germany, Fed. Rep.	58	388
Netherlands	985	13 093
Norway	6 619	6 619
Poland	133	755
UK (England)	52	5 194
UK (Scotland)	2 517	25 452
Sub-total	18 598	128 566
Percentage	13	87
Remainder unallocated	6 245	

According to Table 7 the total quantity of whiting landed from the Norwegian zone amounts to 13%, a figure which is similar to those (whiting 2 group and older) of stock distribution derived from the various international surveys.

5. Migration

The migrations of whiting in the North Sea are not very well investigated. However, two tagging experiments (Bertelsen and Knudsen, 1962, Williams, 1966) covering large parts of the North Sea give some indications of the extent and direction of migrations.

The English tagging experiments, carried out from 1959 - 1964, (Williams 1966) show that tagged whiting do not migrate very much.

The tagged whiting released off Shields, on the NE coast of England, as well as those released in the Southern Bight were mainly caught within the area of release; none travelled across the middle of the North Sea.

A tagging experiment covering a major part of the North Sea was conducted in 1956-1959 by Bertelsen and Knudsen (1962). Of 668 whiting tagged in the Norwegian zone no recoveries were reported. 4363 whiting were tagged in the EEC zone; the recoveries from these showed a movement in a north-south direction, with some slight movement westwards towards the English coast. A few fish also moved east and were caught in Division IIIa.

6. Spawning areas

Distinct spawning areas, where ripe males and females aggregate at a certain time, are not known. Normally whiting spawn later in the northern North Sea than in the southern North Sea.

7. Exploitation rate and Management

In the 1950s the mean yield was 75 000 tons. In the 1960s the recruitment to the fisheries increased, resulting in a mean yield of 153 000 tons in 1966 - 1976, with a maximum of 216 000 tons in 1969 (Table 8).

Table 8. Nominal catch of North Sea whiting (metric tons) (Bulletin Statistique)

Year	Tons	Year	Tons
1966	157 573	1971	113 044
1967	91 245	1972	109 532
1968	144 920	1973	141 191
1969	215 829	1974	188 585
1970	181 506	1975	140 166

A very considerable proportion (50 - 60%) of the catch is taken as a by-catch in small meshed fisheries.

In addition to the loss of potential yield due to the by-catch of undersized fish in small meshed fisheries there is an additional loss due to the use of too small a mesh size in the human consumption fisheries. It has been estimated that an increase of the minimum mesh size to 90 mm would result in a long-term gain of 12% in the human consumption yield (Anon. 1978). In practice the gain could be higher than this because such a mesh increase would largely reduce the losses, due to discarding which amount to at least 30-40 000 tons per year.

Despite the total allowable catches which have been recommended by ICES since 1975, the fishing mortality rate is still considerably in excess of the Fmax value appropriate to the current exploitation pattern.

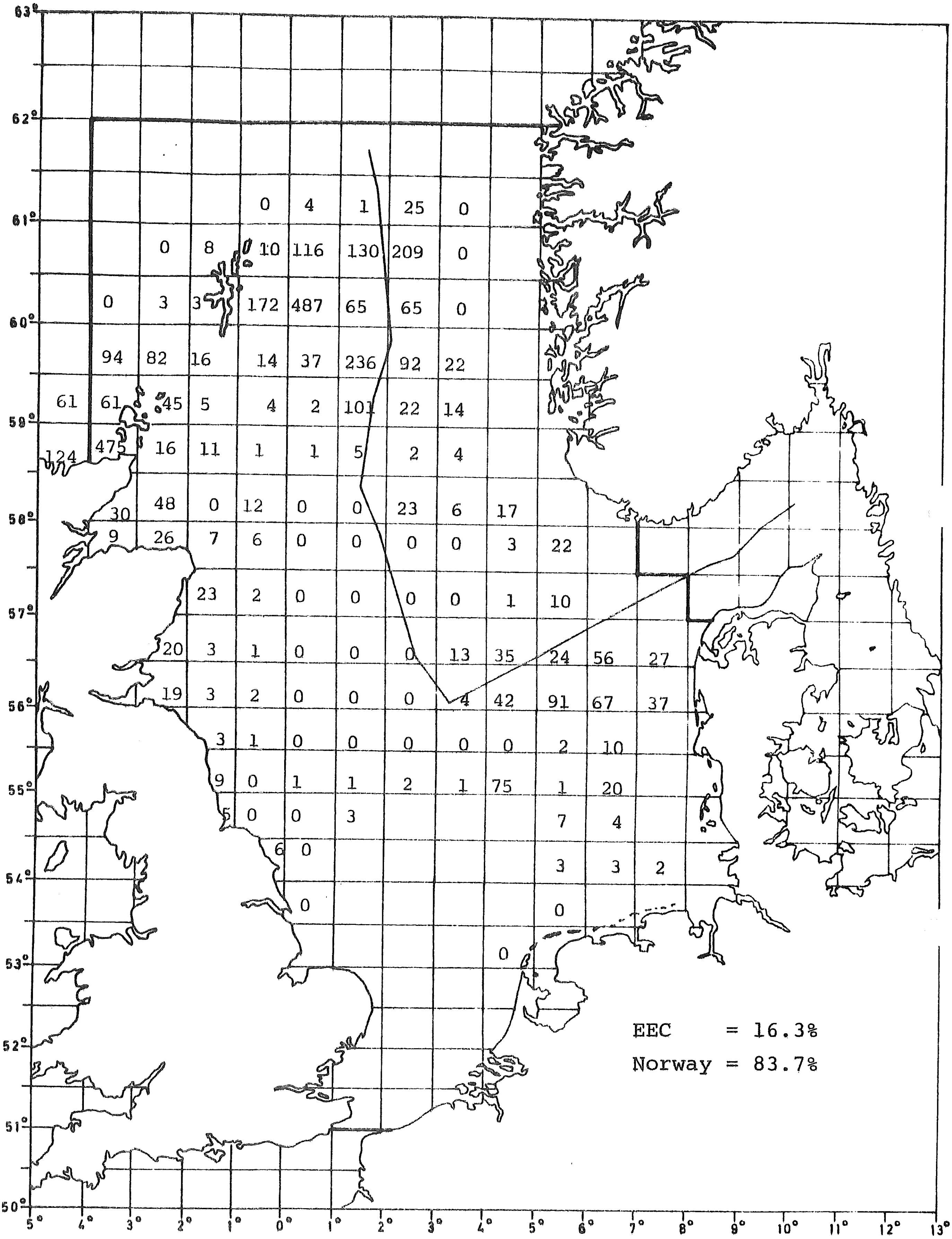

Fig. 1. Whiting 0-group. Mean number per hour, 1974 - 1978.

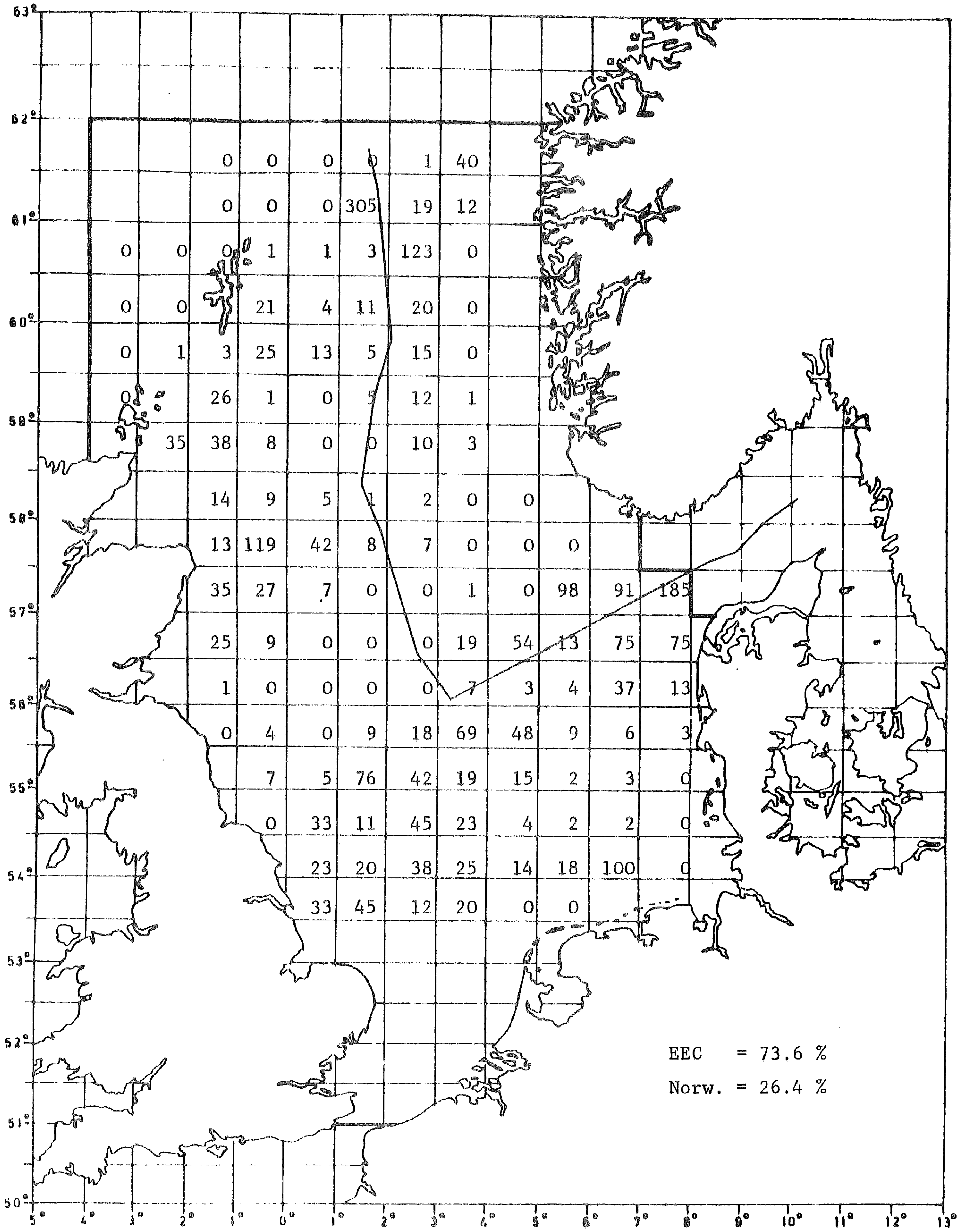

Fig. 2. Whiting 0-group. Mean number per hour, 1973 - 1976.

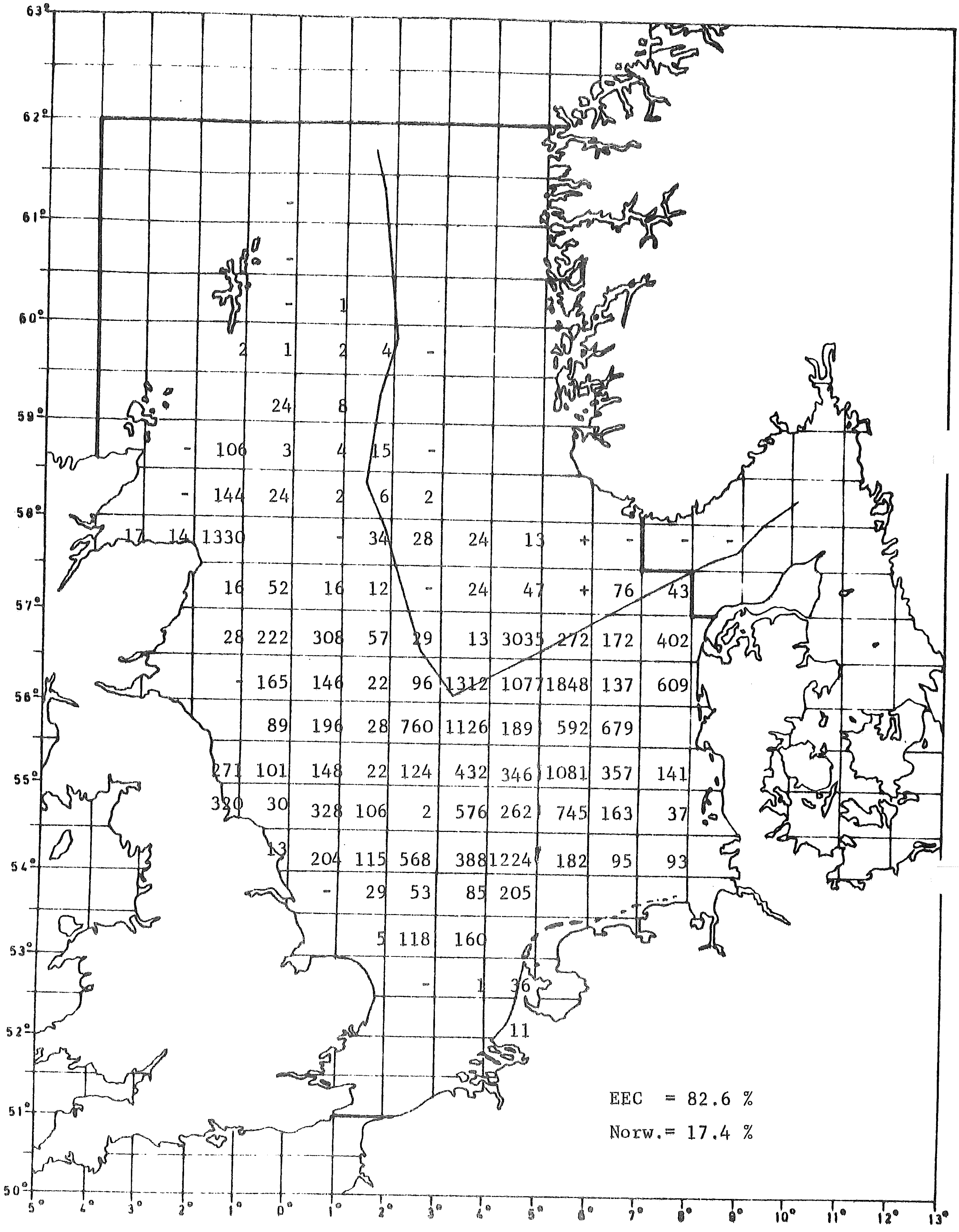

Fig. 3. Whiting 1-group (1959 year-class). Mean number per hour. Autumn 1960.

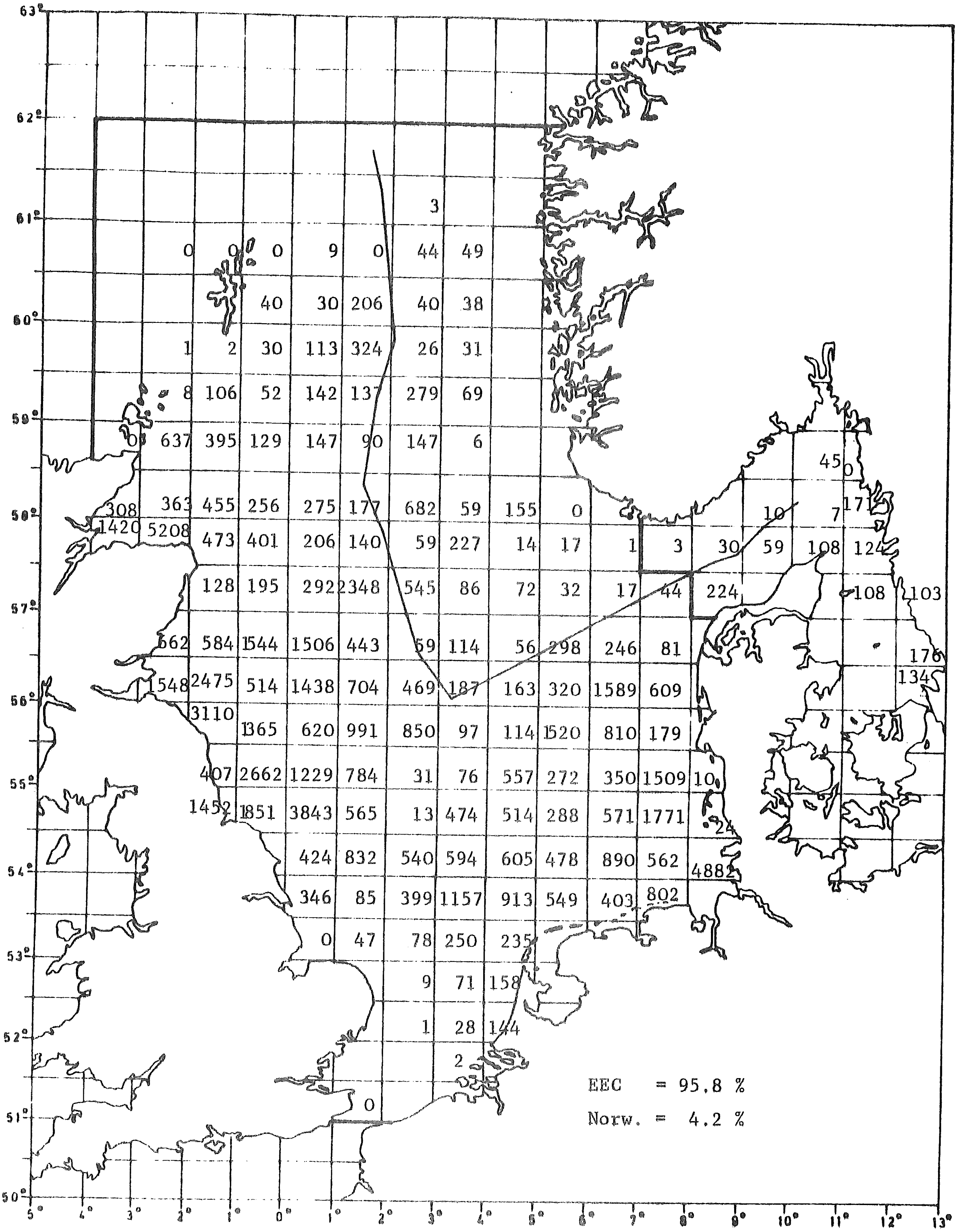

Fig. 4. Whiting 1-group. Mean number per hour, 1965 - 1975.

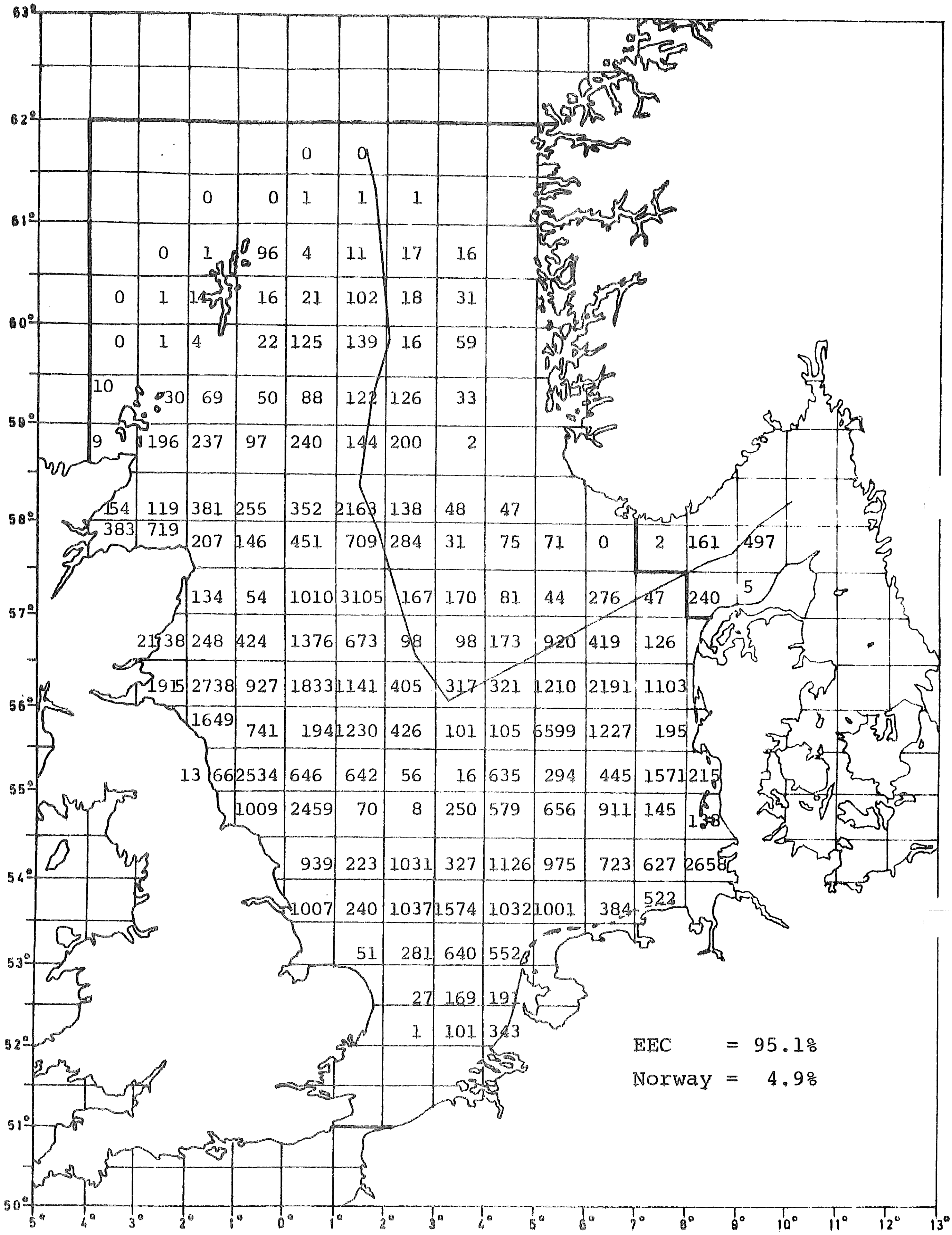

Fig. 5. Whiting 1-group. Mean number per hour, 1974 - 1978.

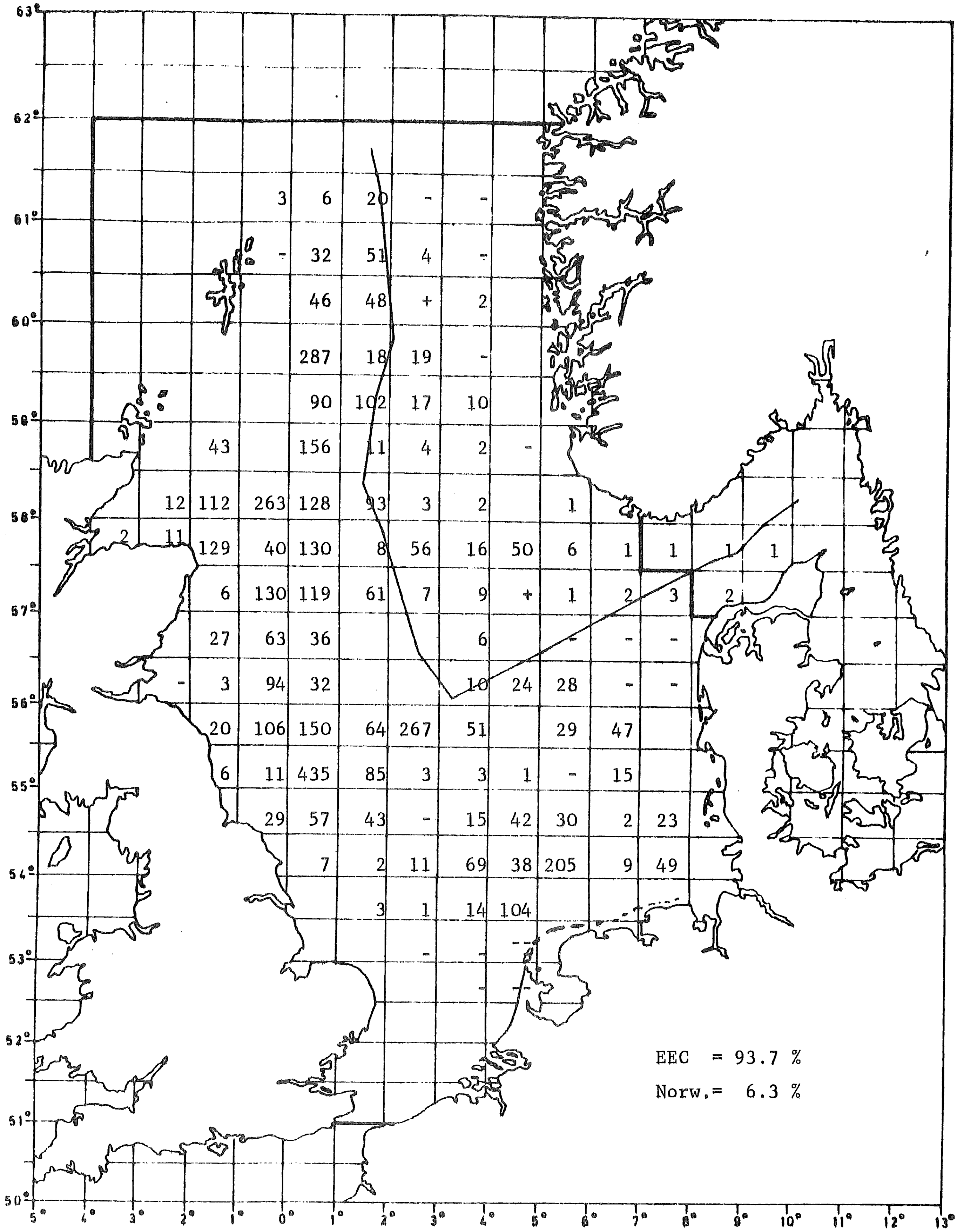

Fig. 6. Whiting 2-group (1958 year-class). Mean number per hour, Spring 1960.

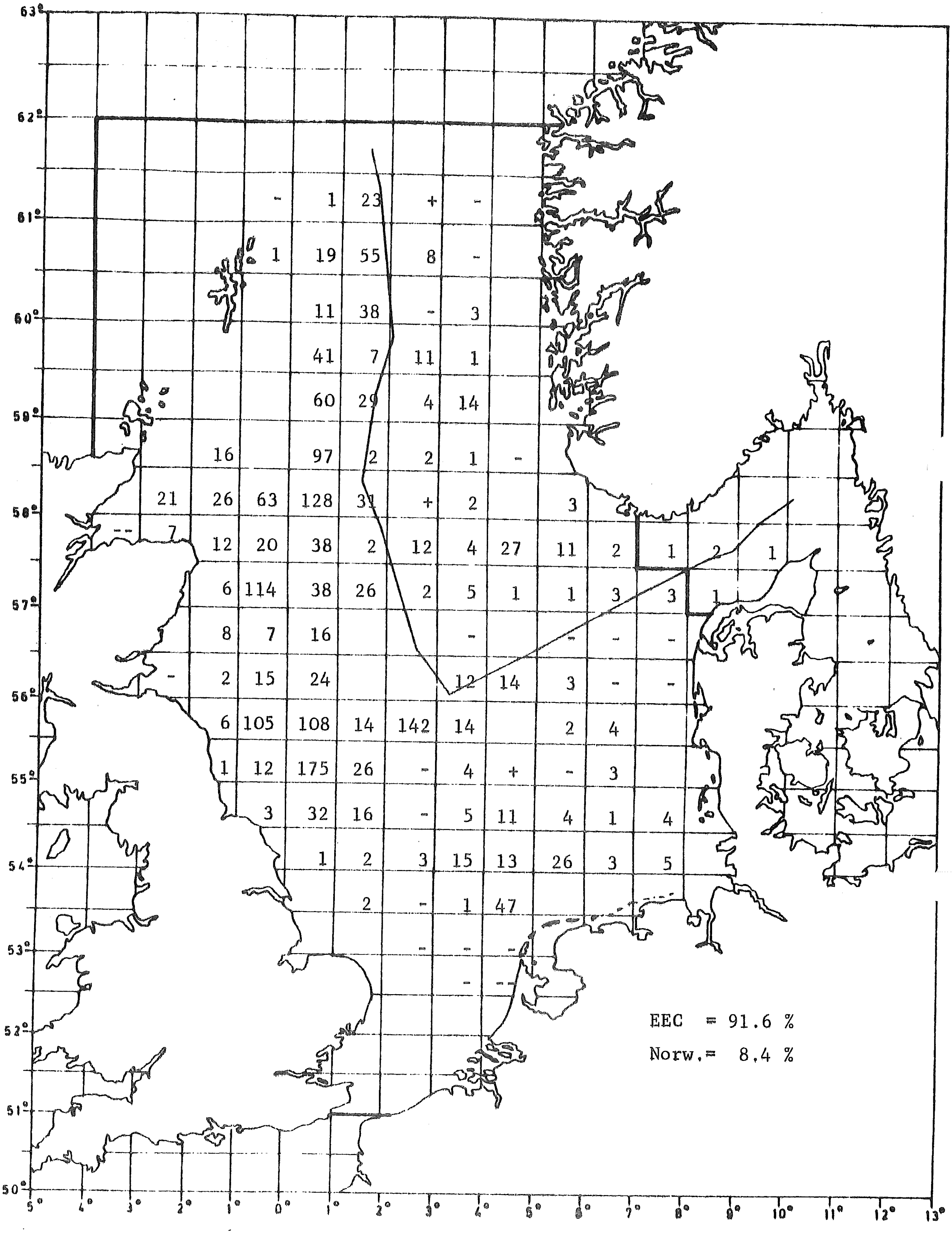

Fig. 7. Whiting 3-group (1957 year-class). Mean number per hour. Spring 1960.

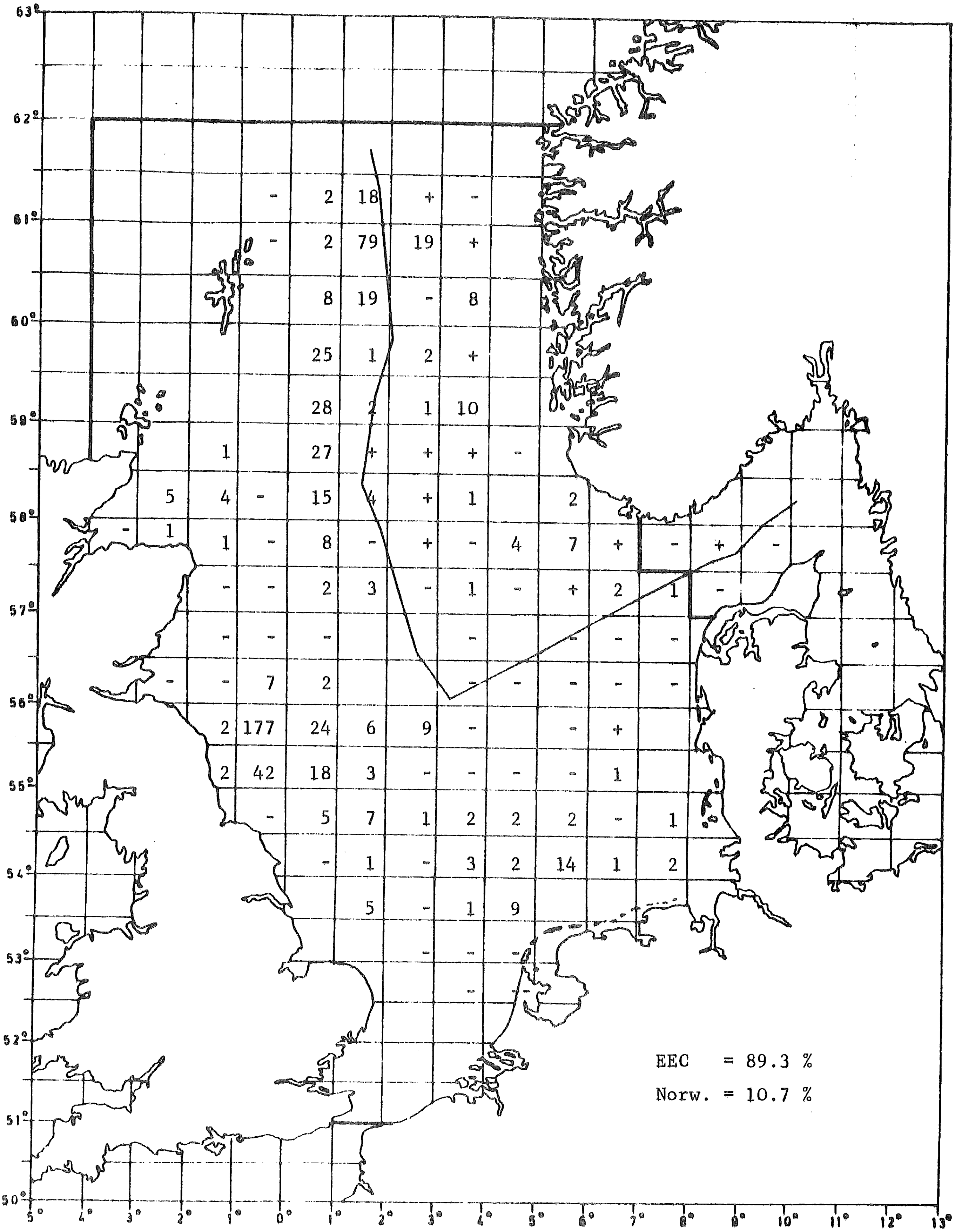

Fig. 8. Whiting 4+-group (1956 year-class and older). Mean number per hour. Spring 1960.

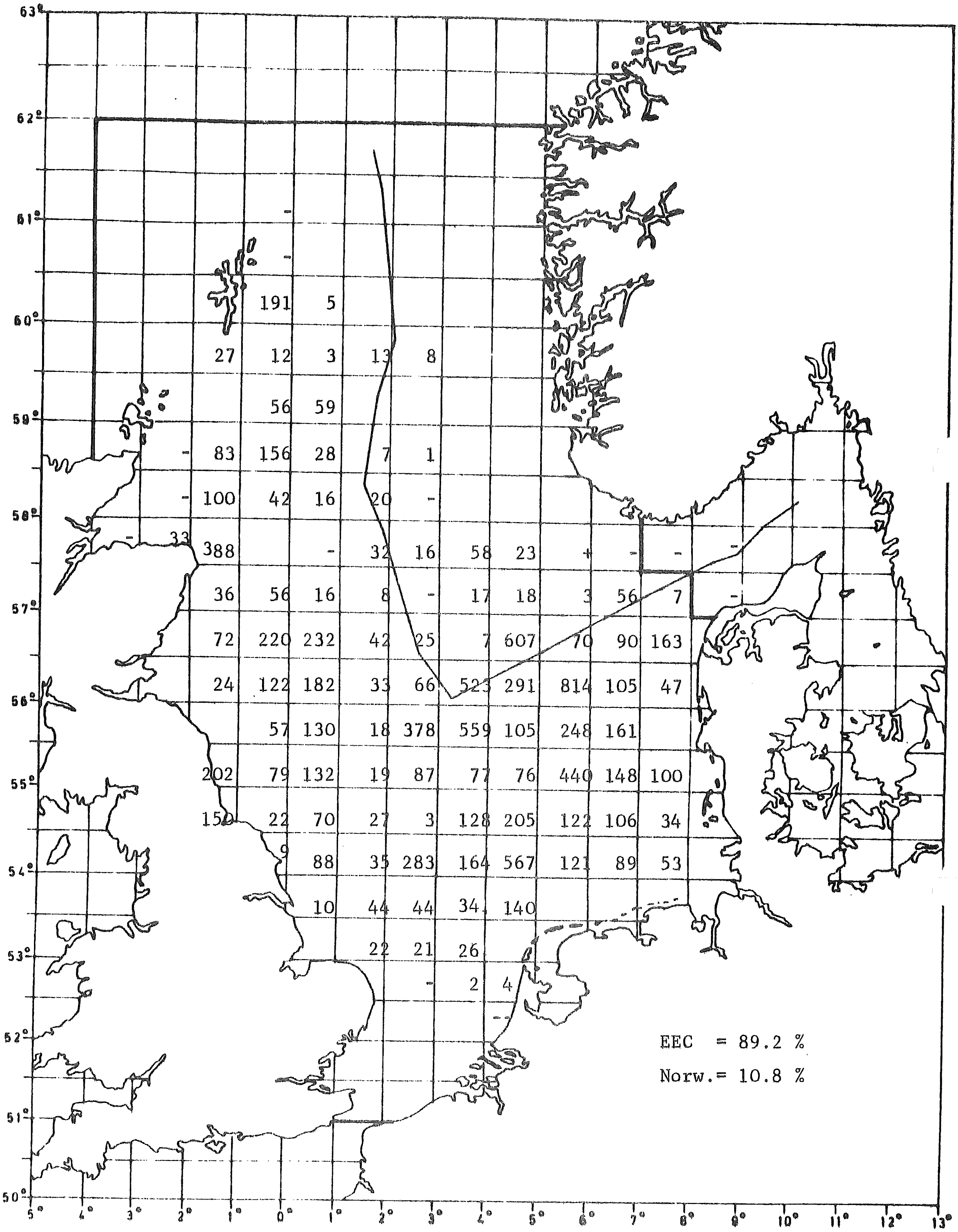

Fig. 9. Whiting 2-group (1958 year-class). Mean number per hour. Autumn 1960.

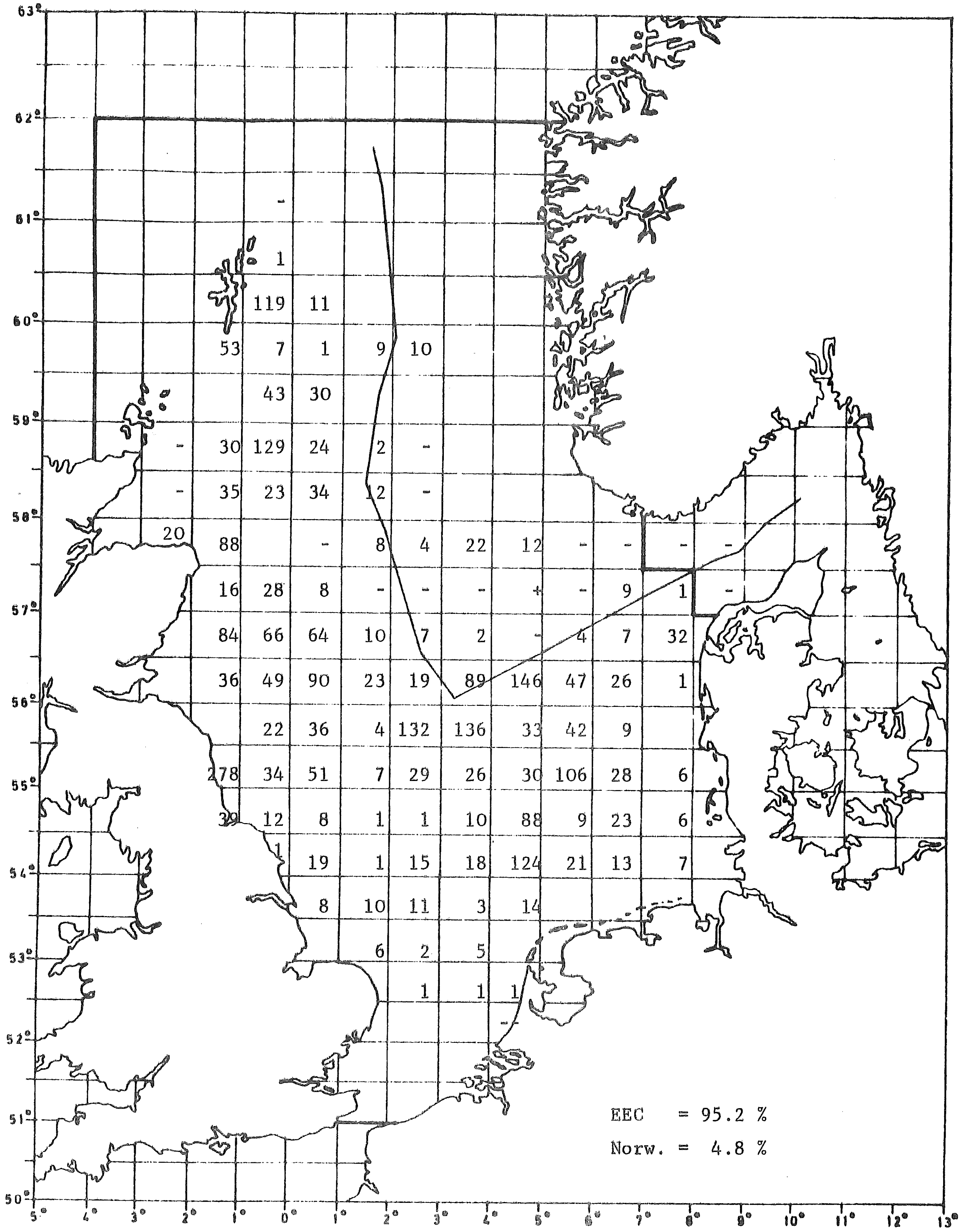

Fig. 10. Whiting 3-group (1957 year-class). Mean number per hour. Autumn 1960.

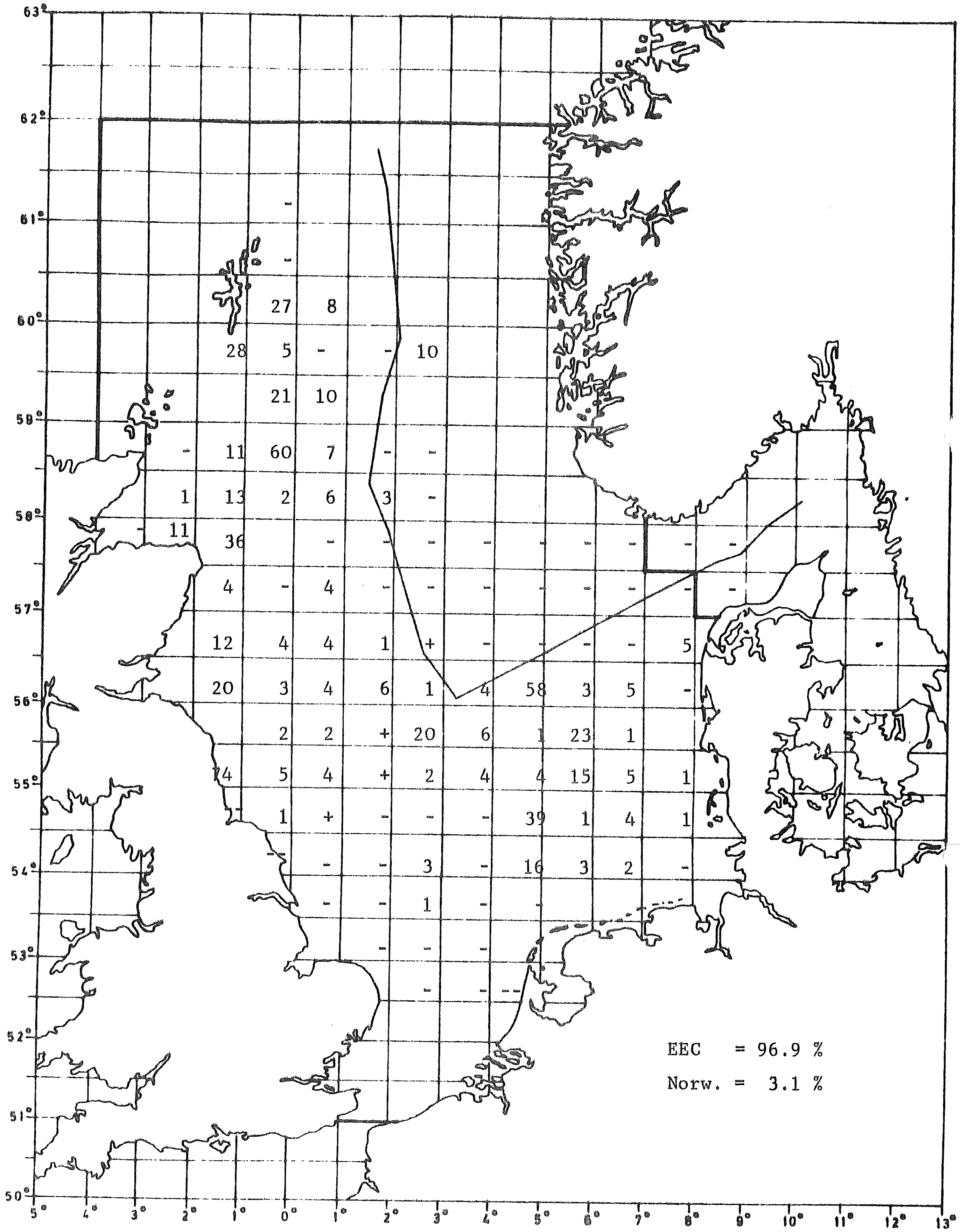

Fig. 11. Whiting 4+-group (1956 year-class and older). Mean number per hour. Autumn 1960.

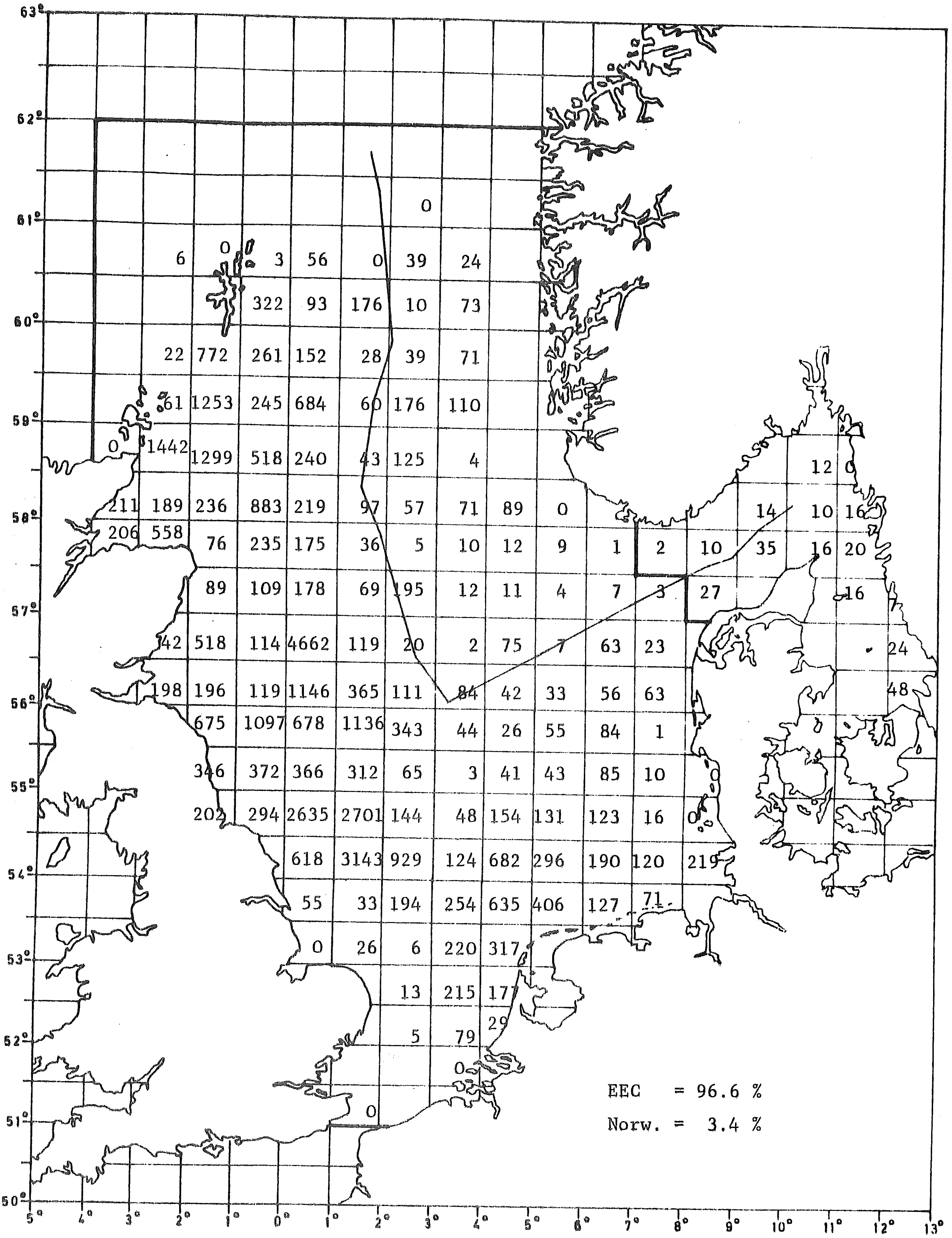

Fig. 12. Whiting 2-group. Mean number per hour, 1965 - 1975.

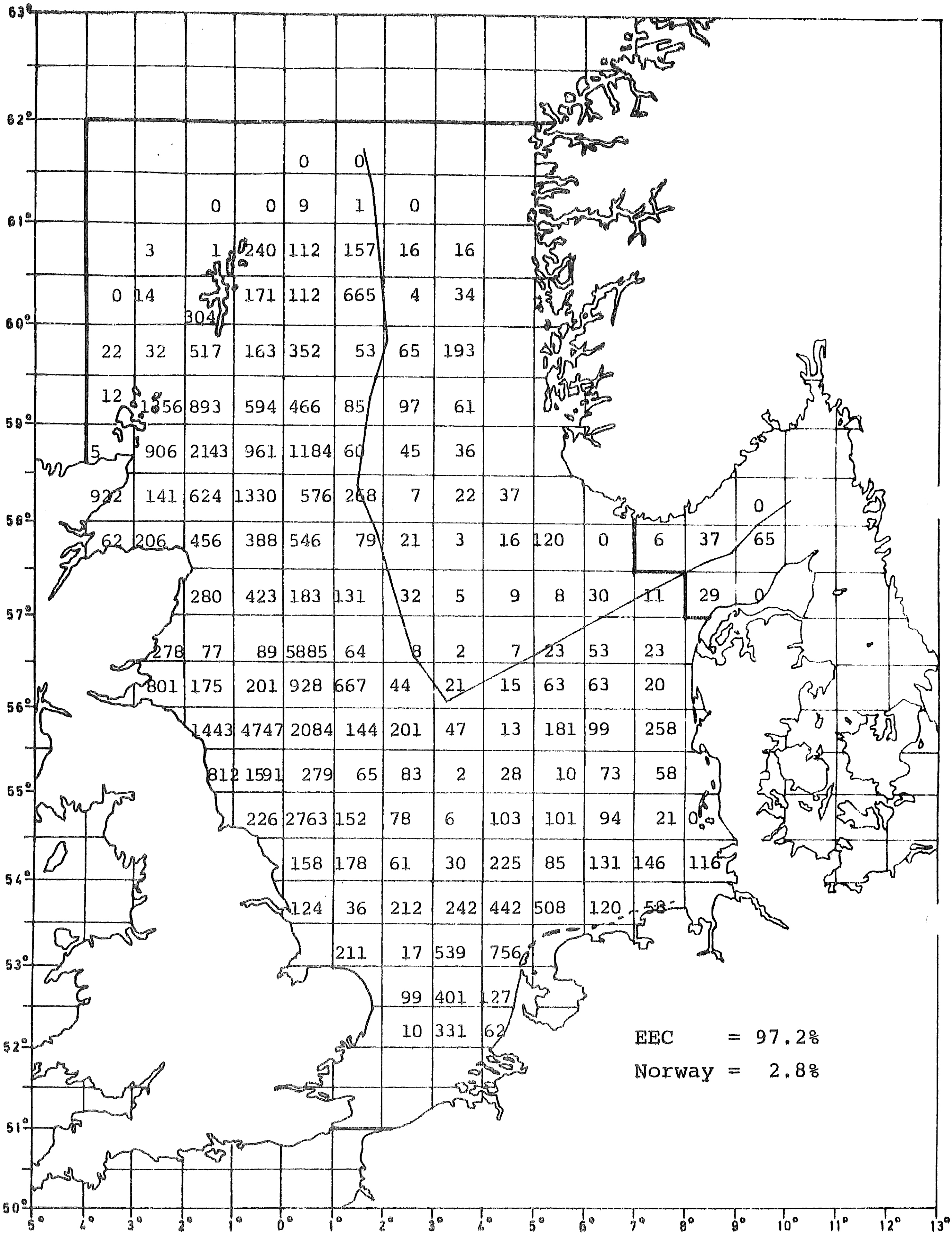

Fig. 13. Whiting 2-group. Mean number per hour, 1974 - 1978.

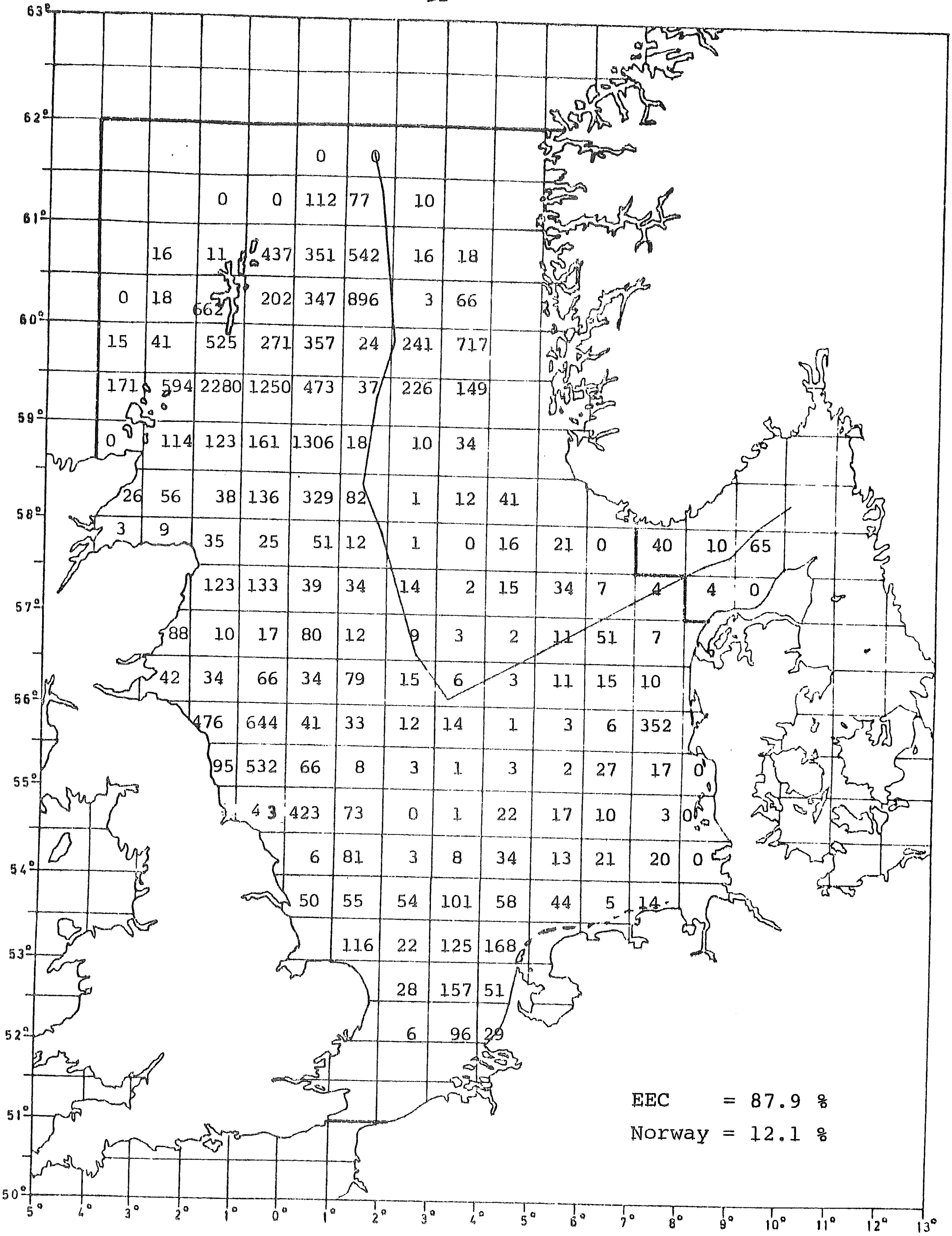

Fig. 14. Whiting 3+-group. Mean number per hour, 1974 - 1978.

5. Saithe

1. Distribution of eggs and larvae.

Saithe spawning starts in February and continues until April, but the peak of the spawning season is generally from mid-February to mid-March.

No recent work has been carried out on this subject. The only surveys to give a reasonable coverage of the North Sea were carried out in 1903-06, and the results were reported by Damas (1909).

These surveys were carried out in February-May and the results are summarized in Figure 1. The largest concentrations of eggs were found in March, generally over the shelf in depths of 80-200m. Areas of particularly high concentrations were found along the edge of the shelf from North of Shetland to the Tampen Bank, in the Viking Bank area and near the Ling Bank. A less dense concentration was found in the area of the Bressay Bank. There was no sampling in the Otter Bank area.

The number of larvae increases from the middle of March. Figure 2 shows the distribution of larvae from Damas (1909). The distribution seems to coincide with that of the eggs. However, the sampling coverage is poor and gives no basis for estimating the proportions within zones.

2. Distribution of juveniles - 0- and 1-group.

Figure 3 shows the average distribution of 0-group saithe from the 0-group Gadoid Surveys in 1974-78. The average is based on the per mille distribution of 0-group saithe per square each year. There are three areas of major concentrations. One extends from the Moray Firth northeast to the Bressay shoal; one covers the area around the Viking Bank extending westwards to the Bressay Ground and southwards to the Bergen Bank. A third covers a relatively small area west and south of the Ling Bank. In 1974-78 no 0-group saithe was recorded south of 56°N. There was no sampling over the Norwegian deep.

Towards the end of May and beginning of June 0-group saithe arrive en masse in the littoral and coastal areas on both sides of the North Sea where they remain in shallow waters for about one year. 0-group saithe occur regularly in the coastal areas of Shetland, Orkney, Scotland and on the English east coast south to 54^{o}N (Damas 1909). They also occur regularly on the Norwegian west coast north of 58^{o}-59^{o}N. They are usually not very numerous on the Norwegian Skagerrak coast and are rarely recorded on the Danish coast.

The 0-group Gadoid survey is carried out in June when part of the 0-group already occurs in coastal areas. One consequence of this is that the numbers of 0-group saithe recorded vary much more than the actual strength of the year classes, probably because of annual variations in availability to the surveys because of the coastal migration. Therefore the distributions between zones from the 0-group Gadoid surveys 1974-78 given in the Table below is based on observations of only part of the year classes and may give biased results.

	Percentage	
	Norwegian zone	EEC zone
1974	10.2	89.8
1975	38.5	61.5
1976	34.6	65.4
1977	75.3	24.2
1978	92.0	8.0

The proportional sub-division between zones in these data is very variable; a mean value estimated from these data would be of little value.

On the Norwegian coast 1-group saithe leave the near-shore region in early summer and move to slightly deeper water, but do not generally start mixing with 2- and 3-group saithe before autumn. Judging from the age distribution in the fisheries, the pattern is basically the same in the western part of the North Sea. Because of the concentration in coastal waters 1-group saithe cannot be quantitatively sampled so no estimate can be made of the distribution of this age group between zones.

3. Distribution of adult fish - Research surveys.

There are no survey data that give any significant information about the distribution of adult saithe in the North Sea. The general outline of the distribution is discussed in the sections on migration and spawning areas.

4. Distribution of adult fish - commercial landings.

Apart from a Norwegian fishery with gillnet for spawning saithe in the Tampen-Viking Bank area, and a purse seine fishery for 2- and 3-group saithe on the Norwegian west coast, saithe in the North Sea are caught chiefly by trawl. The trawl fleets generally operate throughout the year but some concentrate on the spawning grounds during the spawning season.

A summary, made by the ICES Saithe Working Group in 1978 (Appendix to CM 1978/G:3), gave the quantities of saithe caught by the main countries in each zone for various reference years (Table 1). Application of these percentages to catches for a single year, 1976, indicate that 52.3% of the landings were taken in the Norwegian zone and 47.7% in the EEC zone (Table 2). The landings include catches taken in Skagerrak (Division IIIa), but this has no significant effect on the distribution between zones.

5. Migration.

Tagging experiments on the Norwegian west coast show that saithe migrate from the coastal areas to the North Sea plateau at about three years of age (Jakobsen, 1978a). Of the 392 recaptures on the plateau in Sub-area IV, 340 have been reported from the Norwegian zone, especially from an area off the Norwegian southwest coast around 57°N and 5°E. These are chiefly 3-4 year old saithe, that is immature fish. Although the recaptures are clearly dependent on the fishing pattern, other evidence, for example from industrial trawl by-catches, indicate that this is the area of highest density of immature saithe in the eastern part of the North Sea.

There is also a very considerable migration of young saithe from the Norwegian coast north of 62°N to the North Sea (Jakobsen 1978b). The rate of migration of immature saithe to the south decreases northwards along the coast and is negligible in experiments north of about 68°N (Jakobsen 1978c). The recaptures of young saithe, tagged north of 62°N, in the North Sea is more concentrated in the northern part of the North Sea and they are more equally distributed between the zones than those tagged south of 62°N, although more than 60 per cent are still recaptured in the Norwegian zone. However, the southward migration from north of 62°N may be subject to long-term variations, some tagging experiments by Olsen (1959) in 1954-58 showed a basically northward migration from the coastal area around 63°N.

There is also some migration of immature fish from the Norwegian west coast to other areas, e.g. northern Norway, west of Scotland, Faroe and Iceland.

Tagging experiments from the western part of the North Sea are sparse and do not give significant information on migrations in that area. It seems possible however, that saithe migrating from the British coastal areas tend to remain in the EEC zone. According to the commercial fisheries there seems to be a regular occurrence of immature saithe in an area north of Shetland (Muckle Flugga) and on the Bressay Ground.

The results of British and Norwegian tagging experiments (Coop. Res. Rep. no.6) show clearly that there is a regular annual migration of adult fish from the northern Norwegian coast to the spawning grounds to the west of Norway (Halten, Svinøy), and to spawning grounds in the northern North Sea.

There are numerous records of long distance migrations of saithe which provide evidence of some inter-change of fish between the main fishing areas in the north-east Atlantic.

6. Spawning areas

On the basis of the observations of eggs and larvae in 1903-06 a chart of the saithe spawning grounds was produced. These extend over most of the North Sea plateau north of $56^{O}N$, with most spawning taking place along the edge of the plateau. More recent information (e.g. Reinsch, 1976) suggest that there is no significant spawning south of about $60^{O}N$ (Viking Bank) and that the spawning occurs chiefly near the edge of the plateau. The Viking Bank, Tampen, Muckle Flugga and Otter Bank appear to be the most important spawning grounds judging by the fisheries. The spawning areas coincide well with the distribution of eggs (except for egg observations on the Ling bank), larvae and 0-group saithe taking into consideration the hydrographical conditions in the area. In terms of area, the spawning grounds are clearly most extensive in the EEC zone. However, no data are available on the density of the spawning stock within these spawning areas.

7. Exploitation and Management.

Landings of North Sea saithe (Fig. 5.a) including the Skagerrak, increased from about 30 000 tons in 1960 to over 300 000 tons in 1976. During the latter part of this period a large proportion of the catch was taken by the USSR. Since 1976 landings have declined to 145.000 tons (provisional) in 1978. The adult (5+) stock biomass increased rapidly from the early 1960's reaching a maximum level in 1973 (Fig. 5.b). Since then spawning stock biomass has declined, but the current level is well above that in the early 1960's. Recruitment (Fig. 5.c) was at a high level from 1964 to 1973, but appears to have been generally at a lower level in more recent years.

Until recently saithe was an unprotected species. In some years large quantities (up to 60.000 tons) were taken in industrial fisheries, but after 1976 landings from industrial fisheries have been reduced considerably. Young saithe have a predominantly inshore distribution where they are generally inaccessible to capture. As they grow the fish migrate away from the coast into the areas where the main fishing takes place. The majority of fish available to trawlers have a size above the selection range of current or proposed mesh sizes, therefore a change of mesh size from 70/75 mm to 90 mm would be expected to have very little effect on the saithe fisheries. The current level of fishing mortality on age-groups subject to maximum exploitation is believed to be 0.35 which is greater than the F_{max} of 0.22 on the yield-per-recruit curve calculated using the current exploitation pattern (Fig. 5.d).

Table 1. Distribution of the main North Sea saithe catches in relation to zones for different reference years.

Country	Year	EEC Zone	Norwegian Zone	Total
Denmark (1)	1976	43 410	25 385	68 795 (includes by-catch in industrial fisheries)
Norway (1)	1976	4 239	26 699	30 938 " "
Germany,	1974	9 164	11 416	20 580
Fed.Rep. (2)	1975	9 199	9 410	18 609
	1976	No complete data, but saithe now being fished by cutters which will shift balance towards EEC zone.		
England and	1974	4 267	83	4 350
Wales (1)	1975	3 185	275	3 460
Scotland (1)	1974	9 543	1 413	10 956
	1975	8 089	800	8 889
France (3)	1976	24 837	7 715	32 552
Belgium (3)	1976	109	11	120
Netherlands (3)	1976	1 339	4 710	6 049
USSR (4)	1975	37 600	73 100	110 700

Based on: 1) Statistical rectangle data
2) Log book data
3) National returns to EEC
4) Fishing distribution charts published in "Annales Biologiques" and information given to Norway.

Table 2. Proportion of saithe catches taken in the Norwegian zone in 1976.

Country	Total IV + IIIa	Norwegian Zone	
		%	tons
Belgium	127	8.3	11
Denmark (4)	68 795	36.9	25 385
Faroe (1)	425	-	-
France	32 552	23.7	7 715
German Dem.Rep. (2)	2 088	66.0	1 378
Germany, Fed.Rep.(3)	38 698	53.1	20 549
Ireland (1)	119	-	-
Netherlands	6 101	77.2	4 710
Norway	30 938	86.3	26 699
Poland	35 819	66.0	23 641
Sweden (1)	1 271	-	-
UK (England and Wales) (5)	6 300	4.6	290
UK (Scotland (5)	13 034	11.2	1 460
USSR	83 669	66.0	55 222
Total	318 121	52.5	167 060
	Unallocated 1 815 tons		

Notes

1. Excluded from overall total.
2. % in Norwegian zone assumed same as USSR.
3. % in Norwegian zone based on average 1974-75.
   % in 1976 is likely to be lower.
4. Includes by-catches in industrial fisheries.
5. % in Norwegian zone based on average 1974-75.

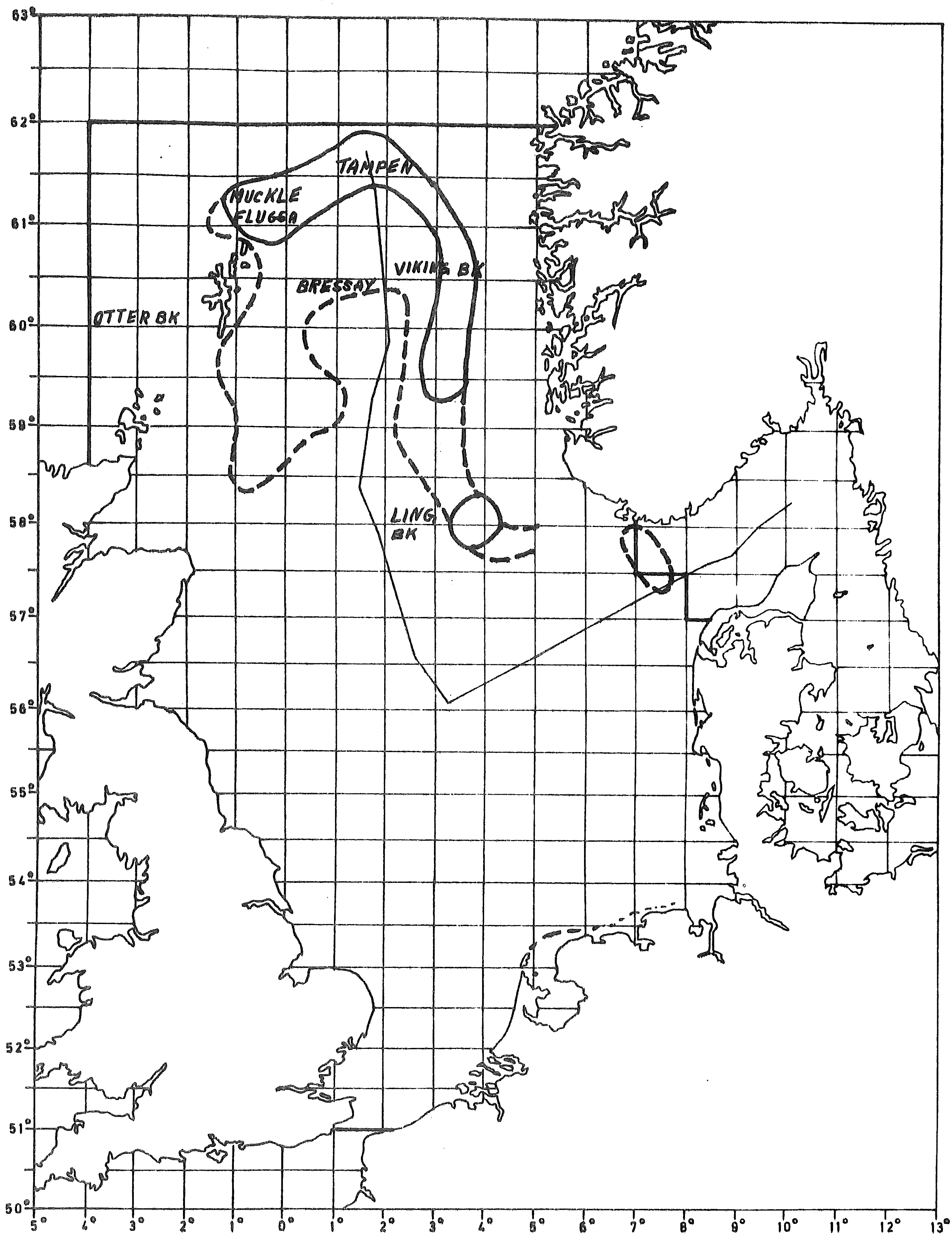

Figure 1. Egg distribution of saithe (based on DAMAS, 1909)
(thick lines surrounding major concentrations)

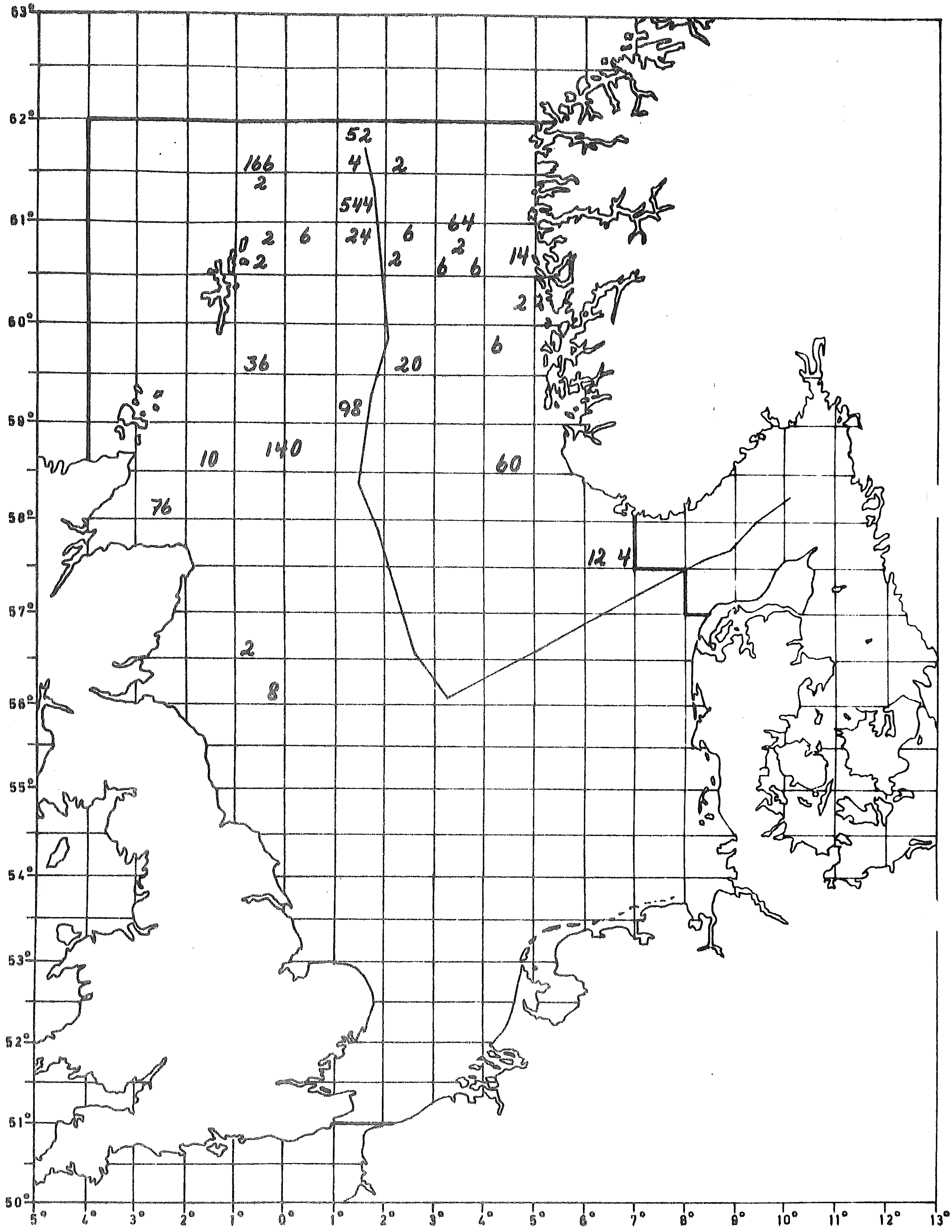

Figure 2. Post larvae distribution of saithe. Number per hour. (DAMAS 1909).

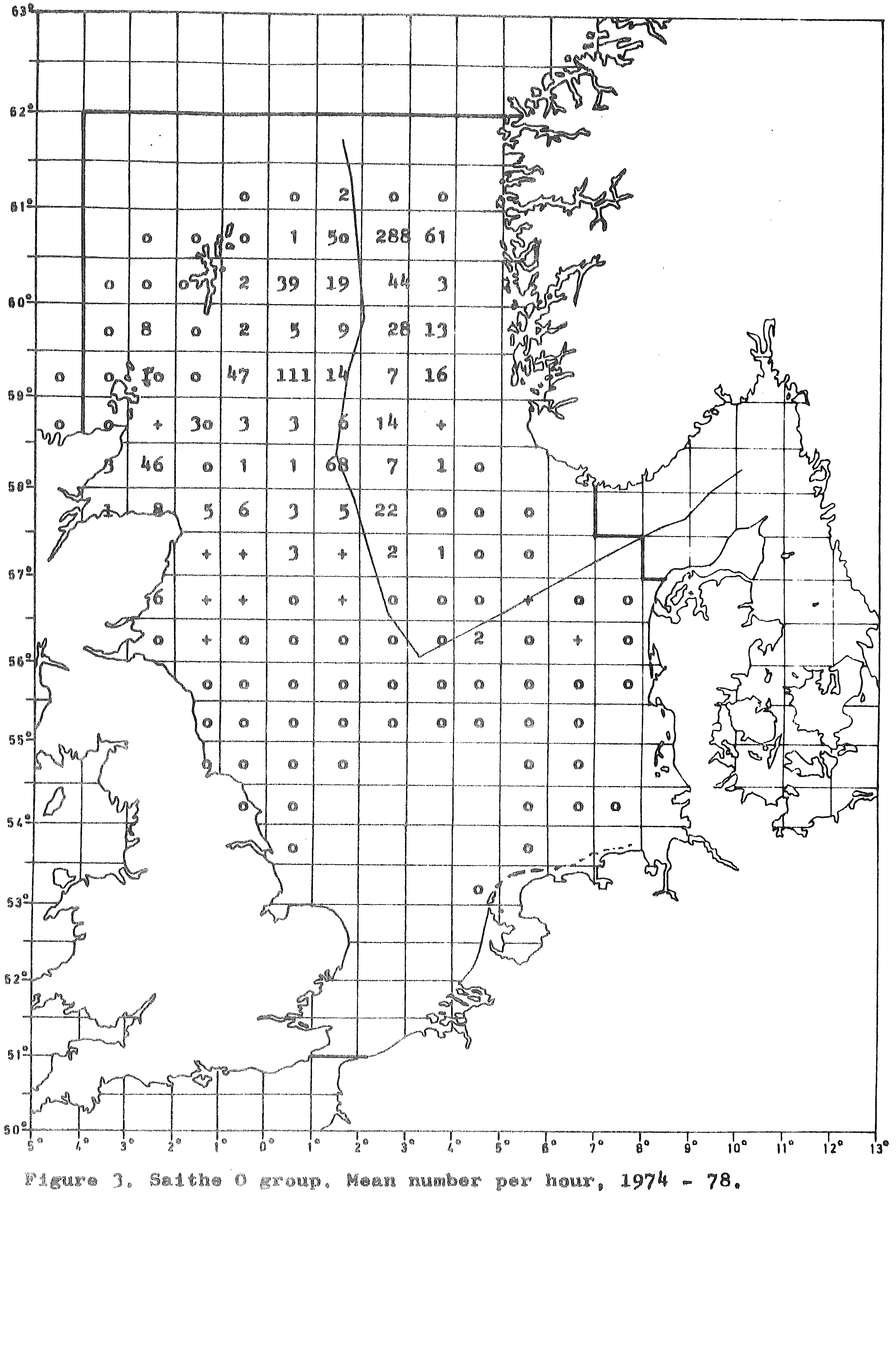

Figure 3. Saithe 0 group. Mean number per hour, 1974 - 78.

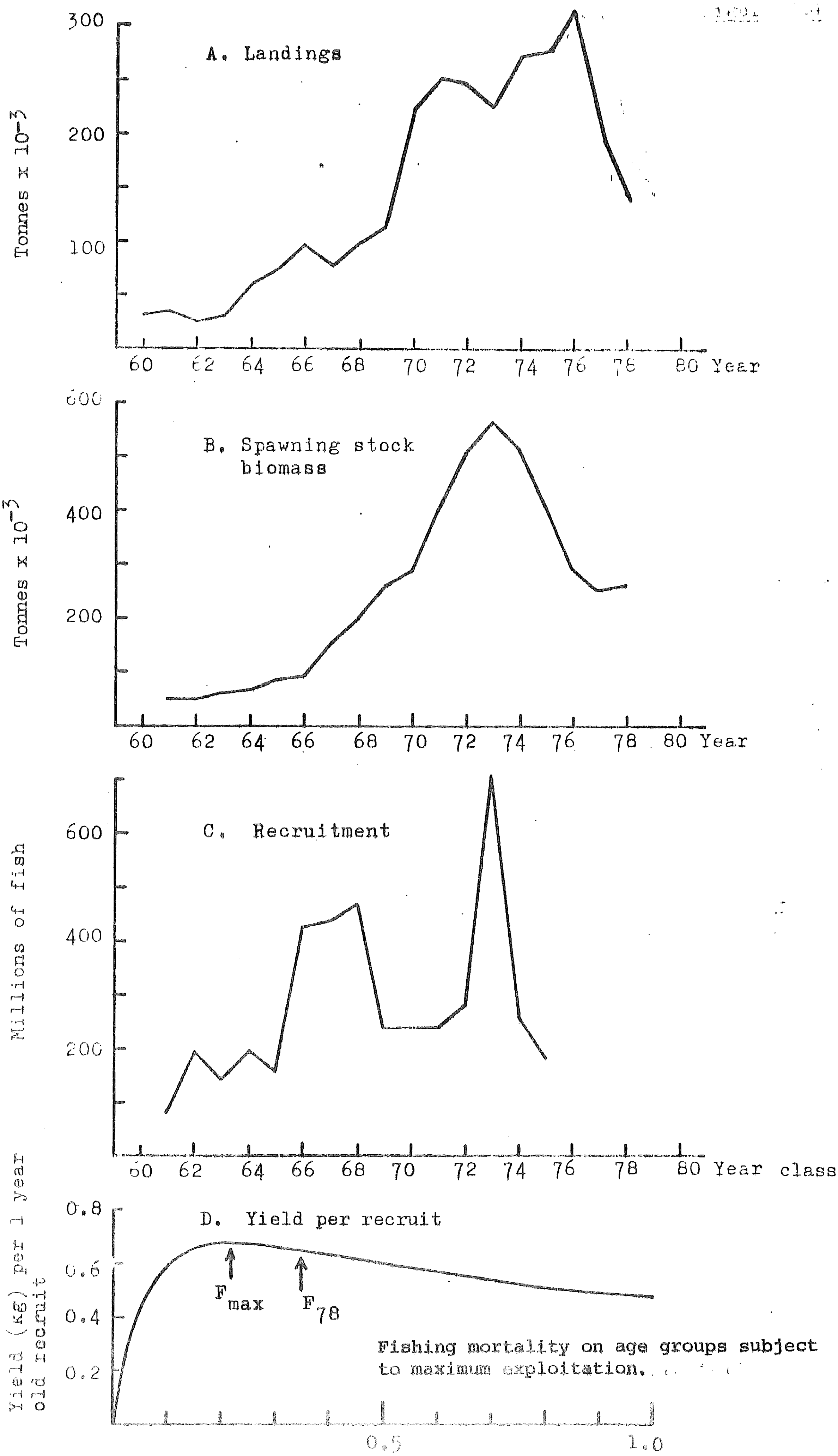

Figure 4, Saithe.

6. Plaice

1. Distribution of eggs and larvae

Eggs and larvae of plaice are found in the period December to March in a continuous belt from the Channel into the southern & central North Sea as shown in Figure 1, based on the best available information on egg distribution (Harding et al. 1978). Along the Scottish east coast egg production is confined to small local patches in the Firth of Forth, along the Aberdeenshire coast and in the Moray Firth.Sampling on these surveys hardly extended at all into the Norwegian zone. There is no reason to think that plaice spawning in that zone is on an appreciable scale, but the distribution shown in Figure 1, which would suggest that almost all the egg production is within the EEC zone, will almost certainly give a somewhat biased estimate because of the distribution of sampling. Indeed recent sampling, with another objective, has shown the presence of a number of plaice eggs in the part of the Norwegian zone lying within Division IVb.

2. Distribution of juveniles, 0 and 1 group

Since 1969 Belgium, Netherlands and the Federal Republic of Germany have sampled, in spring and in autumn, the plaice nursery grounds from the French-Belgian border to the German-Danish border. In the last two years these surveys have been extended further north. Nurseries along the North Sea coast of England have been sampled since 1973. From these surveys an average picture of the relative importance of the various 0-group nursery areas is given as Figure 2. No such surveys have been conducted within the Norwegian zone. It cannot be assumed from this that all of the 0-group plaice are distributed in the EEC zone, but the areas of suitable habitat for 0-group plaice within the Norwegian zone are very restricted, relative to those in the EEC zone, and on that basis it is probably a reasonable assumption that the proportion within that zone is very small.

The distribution of 1-group plaice, derived from the same surveys is shown in Figure 3. This would again suggest that all of this age group are distributed within the EEC zone, but the same factors, regarding habitat preference and distribution of sampling, must be born in mind as those mentioned in relation to 0-group.

3. Distribution of adult fish - Research surveys

No surveys have been done on a sufficiently extensive scale to permit any estimate to be made of the proportional distribution of the exploited stock between the zone. As plaice migrate offshore from the coastal nurseries with increasing age the distribution of the adult stock will be in deeper waters and further offshore than that of the juveniles.

4. Distribution of adult fish - Commercial landings data

The main fisheries for plaice within the Norwegian zone are by Denmark and England. These countries reported to ICES that the percentage of their catches taken in the Norwegian zone were 12.3% (1975-77) and 26% (1968-76) respectively.The plaice catches by other countries in that zone are very small. On this basis the overall percentage of the total North Sea plaice landings made in 1976 within the Norwegian zone is estimated to be about 9%.

5. Migration

Since 1959 tagging experiments on mature plaice have been done in four areas within the main spawning areas. The returns from these experiments show a strong tendency for the fish to return for spawning to the grounds in which they were tagged. The limits of the areas within which recoveries were made from each of these tagging sites are shown in Figure 4. These would suggest rather wide ranging feeding movements outwith the spawning period.

6. Spawning areas

No data are available on plaice spawning grounds which adds anything to that, shown in Figure 1, derived from egg surveys.

7. Exploitation and management

Figure 5A shows the recent level of total plaice catches from the North Sea based on data submitted to Bulletin Statistique with the addition of estimates of unreported landings where appropriate. In the most recent three years fishing effort may have declined somewhat due to a reduction in Dutch beam trawl effort and some diversion of English effort from plaice to cod in 1978. The trend in spawning stock biomass, as measured by VPA is also shown in Figure 5A; this has declined steadily since 1967. The fluctuations in recruitment of 2 years old fish to the exploited stock is shown in Figure 5B. The long-term mean is 380 million fish; the 1972 & 1974 & 1976 year-classes were above this average level.

The fishing mortality rates used for 1978 in the most recent assessment by the ICES working group on the age groups subject to maximum exploitation were 0.51 for males and 0.38 for females which correspond to the F max levels. The objective for management in that situation should be to maintain these fishing mortality rates, in as far s this is compatible with maintenance of the spawning stock biomass at about the current level.

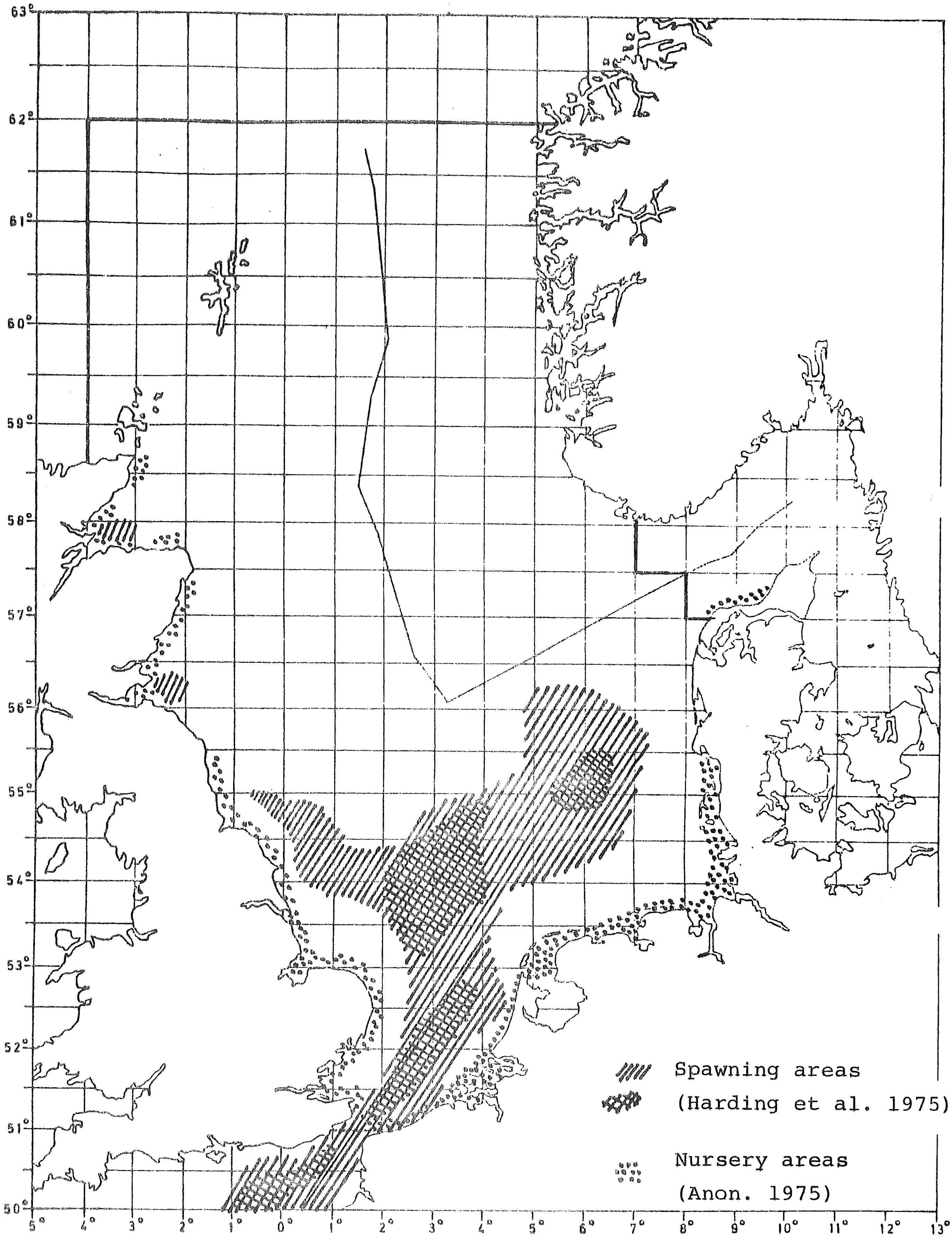

Fig. 1. Spawning and nursery areas of North Sea plaice.

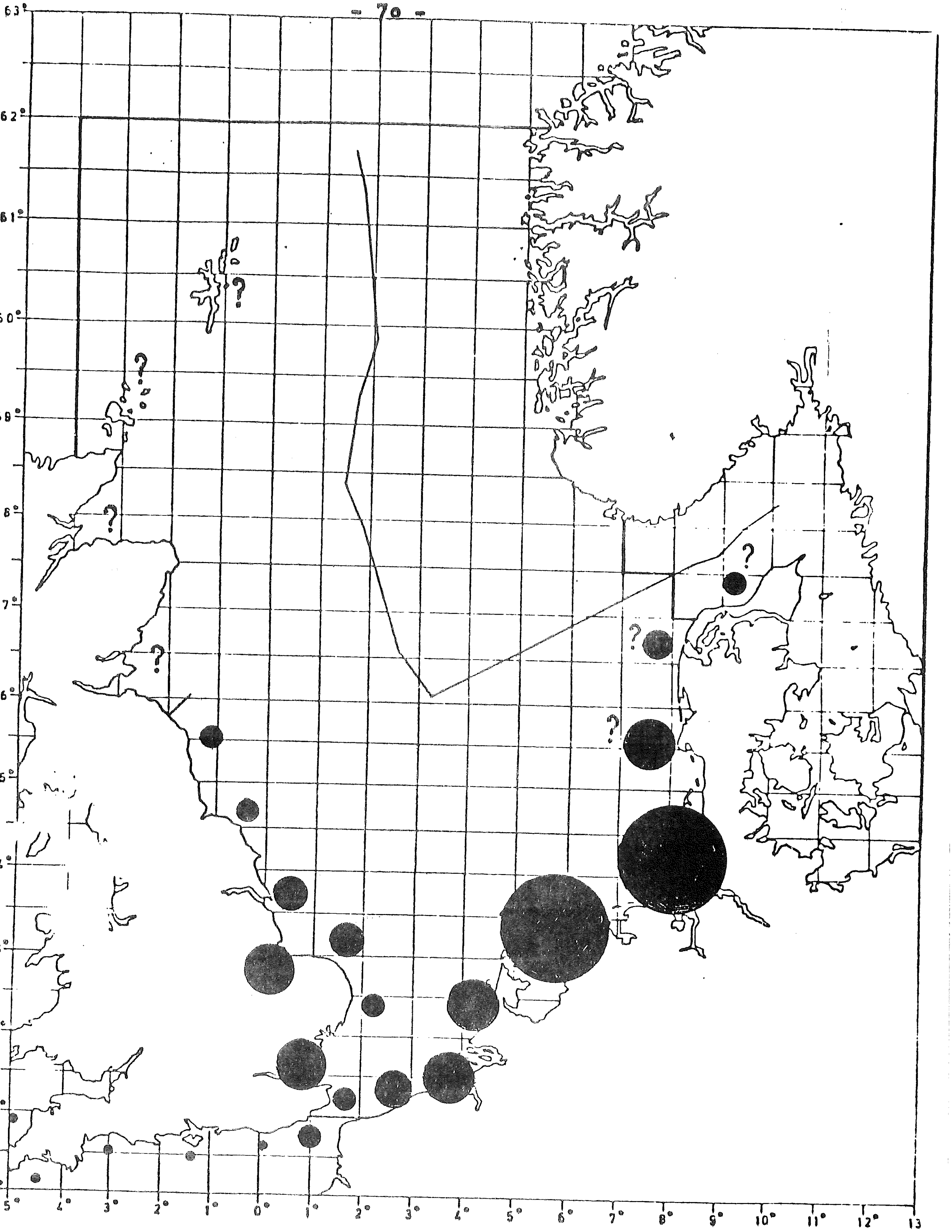

Fig. 2. Relative importance of 0-group plaice in the various North Sea and adjacent waters. In areas with question marks the information is uncertain or lacking.

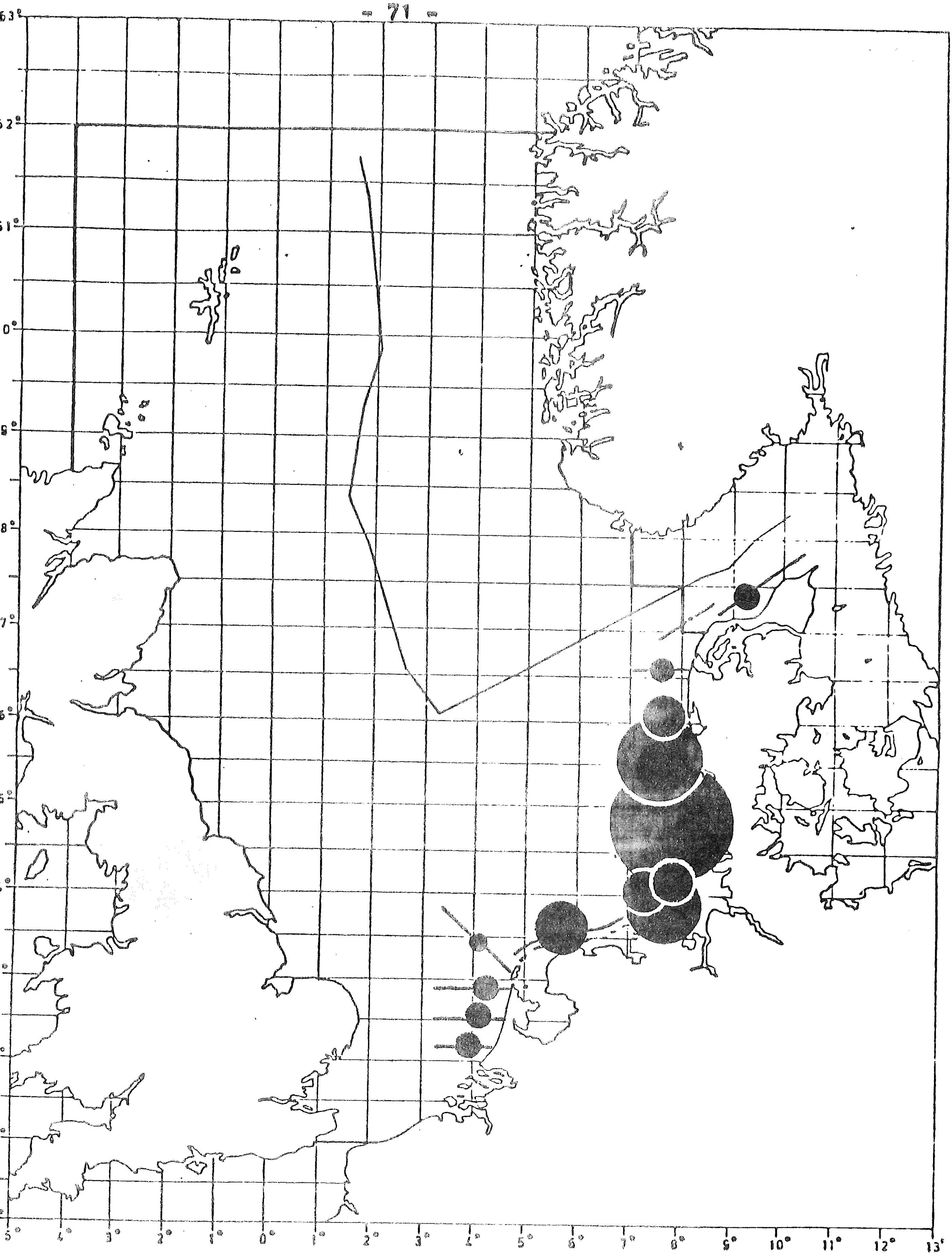

Fig. 3. Average abundance of 1-group plaice in September-October 1969 - 78.

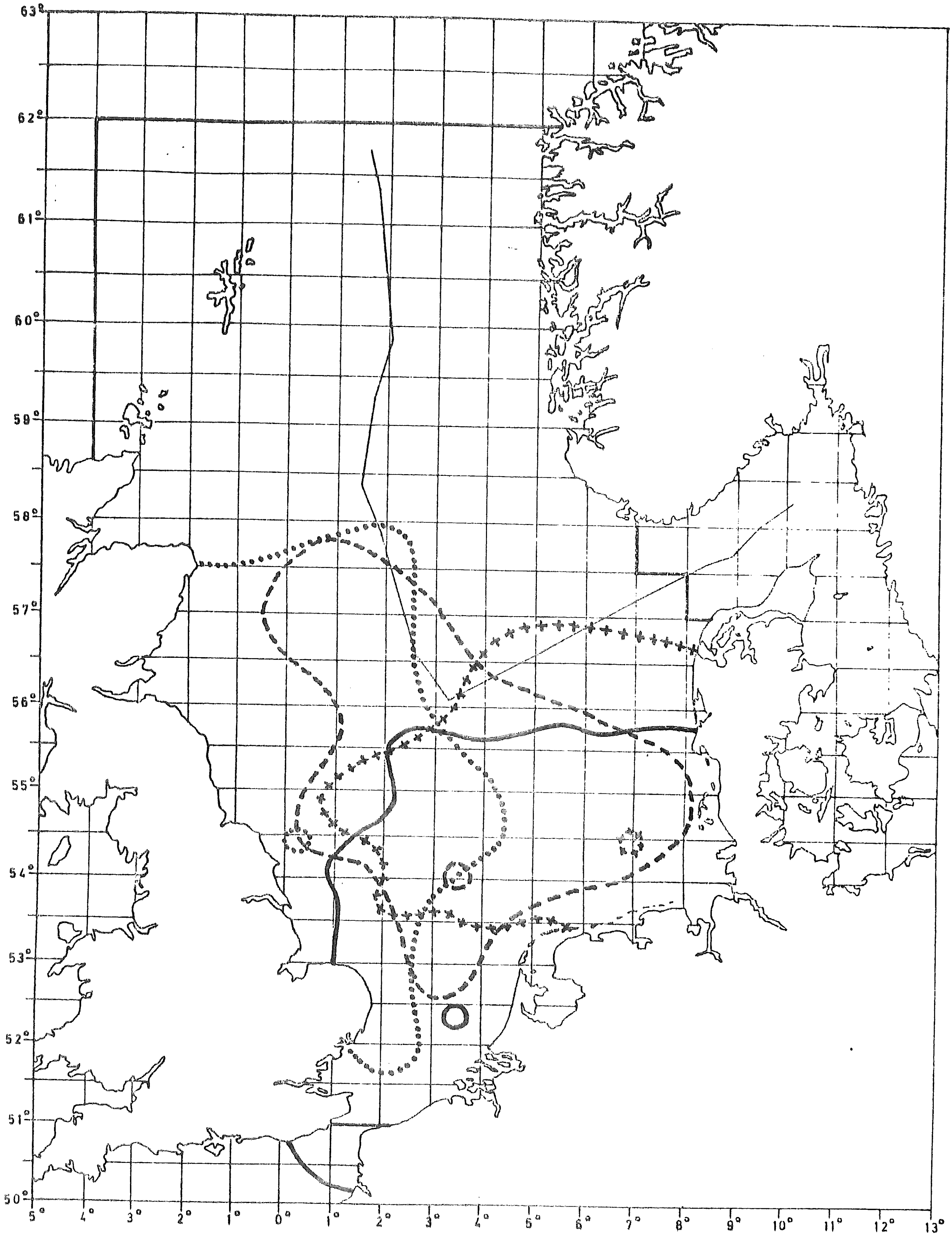

Fig. 4. Results of tagging experiments on plaice. Circles represent major release positions. Lines circumscribe areas of recapture.

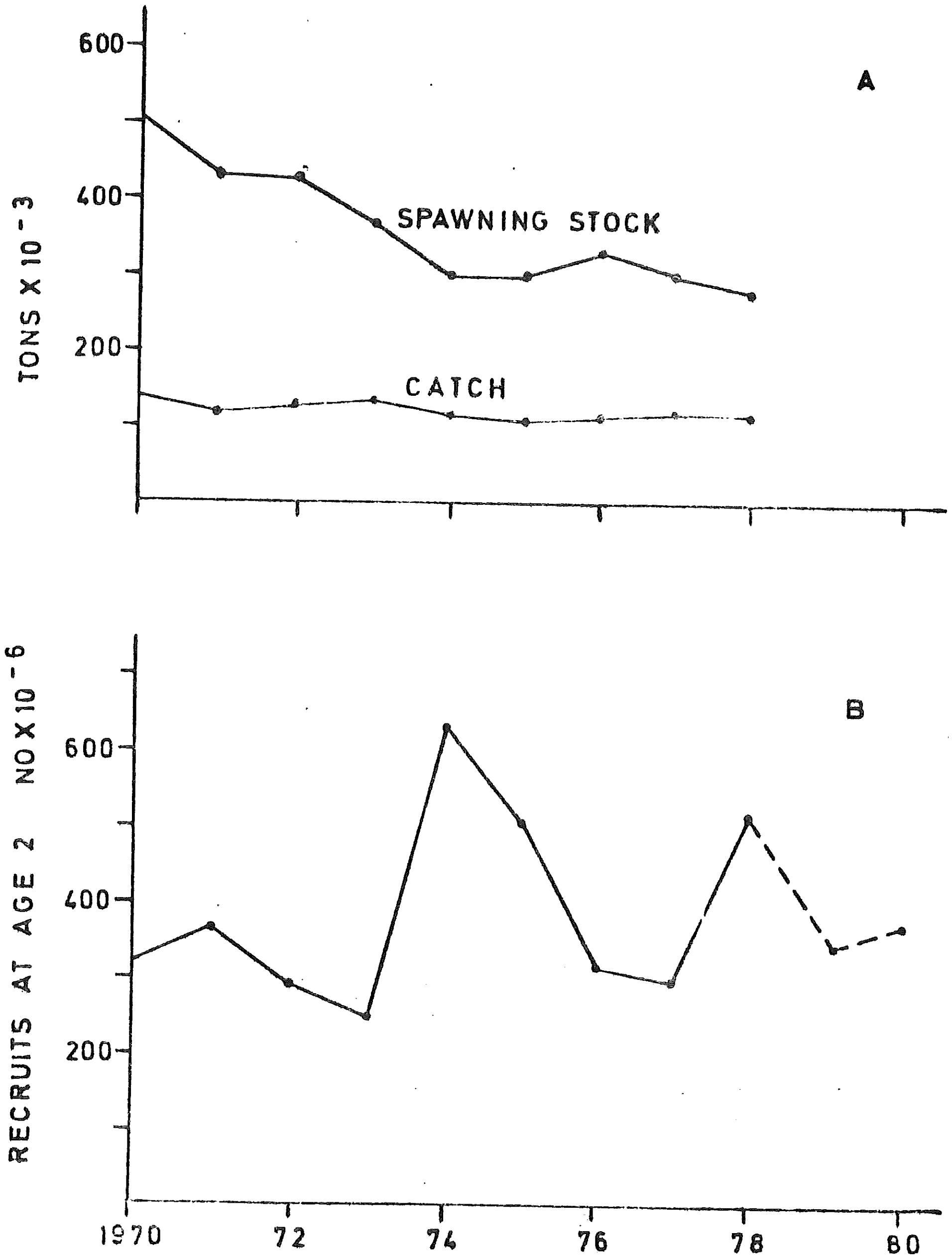

Figure 5, Plaice, Spawning stock biomass & catch (A), and recruitment (B).

7. Herring

1. Racial composition

Herring in the North Sea can be split into several distinct, self contained races or populations. At present the most important of these are the autumn spawners of the central and northwestern North Sea. These autumn spawners can be divided into 3 major subgroups: Shetland-Orkney spawners, Aberdeen Bank spawners and Central North Sea spawners (Fig.1). Although there is little difference in racial characters between these groups, each of them represents a more or less independent stock, or even a cluster of separate populations.

Another population, which has been important in the past, is the Eastern Channel winter spawners. Although these herring have their spawning grounds mainly outside the North Sea proper, they spend the greater part of the year in the North Sea. For assessment purposes, the ICES Herring Assessment Working Group for the area South of 62^{O}N has always grouped the Eastern Channel winter spawners together with the autumn spawners of the central and northwestern North Sea into one "North Sea herring stock". Data on stock size and mortality rates given in report of this Working Group always refer to this combination of populations.

Apart from the autumn and winter-spawning populations mentioned above, there are (or have been) several populations of spring spawning herring in the North Sea, but at present these constitute only a minor component of North Sea herring. In the past, the spawning grounds of the Atlanto-Scandian herring stock extended into the North Sea. With the decline of this stock, however, no significant spawning has been reported south of 62^{O}N since 1958. Spring spawning herring (up to 20% of the catches) are also found near the Shetland Islands. These fish resemble the Atlanto-Scandian spring spawners, but their relationship to the stock that spawns off the Norwegian west coast is not clear.

Another type of spring spawning herring is found in the estuaries of large rivers such as the Thames and Elbe. These are small populations, consisting of fish with a very characteristic growth pattern, that do not seem to migrate far from their spawning grounds.

2. Distribution of eggs and larvae

Surveys of herring eggs have seldom been made as the herring deposits its eggs directly on the bottom and quantitative sampling of these eggs is virtually impossible. However, the approximate position of the spawning grounds can be deduced from the distribution of small herring larvae, which are regularly sampled during the ICES herring larval surveys and on the distribution of fish in spawning condition. The location of the spawning grounds shown in Figure 1 is based on these criteria. All of them are found within the EEC-zone.

As the larvae grow older they drift to various coastal areas bordering the North Sea. There is still a great deal of uncertainty about the exact drift routes, since the systematic study of this part of the herring's life cycle has only recently been started. Part of the larvae born in autumn in the western part of the North Sea grow up in the inshore waters along the British coast. Another part of these larvae cross the North Sea in a southeasterly direction, and are found over a wide area of the North Sea, including the Norwegian zone, during the ICES Young Fish Surveys in February (Fig. 2). Most of these larvae will end up in the coastal waters of the German Bight, but some of them may arrive further north, in the Skagerrak area or along the Norwegian west coast (Fig. 3). The material collected during these surveys is still too limited to assess the relative abundance of large herring larvae in the two zones.

3. Distribution of juveniles

0-group herring are found in most of the coastal waters around the North Sea, but the highest concentrations are found in the

German Bight area (Fig.3). Here the 0-group herring are taken as a by-catch in the sprat fisheries when they leave the in-shore waters in autumn. No large scale survey has been conducted for this age group and it is therefore impossible to quantify the relative importance of the various nursery areas. The 0-group herring found in Skagerrak and Kattegat may contain some local spring spawners, but part of the juvenile herring in these areas is thought to be North Sea autumn spawners. Along the Norwegian west coast, small quantities of 0-group herring are caught as a by-catch in the sprat fishery. It is likely that these juveniles also belong to the North Sea sutumn spawners.

The distribution of I-group herring is better known from the results of the annual ICES Young Herring Surveys.By this time of their life, herring have left the inshore waters and are concentrated in the southeastern part of the North Sea. In addition to this main centre of distribution, smaller concentrations are found along the British coasts, for instance in the Moray Firth. Figure 4 shows the average distribution of 1-group herring in the month of February, based on the surveys in 1974-78. The great majority (97%) of 1-group herring are found within the EEC zone. For the individual years, the percentage within the EEC zone were:

1974	-	99.5 %
1975	-	91.4 %
1976	-	99.9 %
1977	-	97.9 %
1978	-	98.7 %

There is a possibility that these surveys, by using a bottom trawl, underestimate the abundance of 1-group herring in deeper waters. This,however, may have occured in both zones and it cannot be demonstrated that the results are biased in this way.

4. Distribution of adult fish - Research surveys

No surveys of adult herring have been carried out on a regular basis and covering the whole of the North Sea. The ICES Young Fish Surveys are aimed at catching juvenile herring, and they do not provide any reliable data on the distribution and abundance of adult herring.

5. Distribution of adult fish - Commercial landings data

Table 1 gives catches of herring in the North Sea after World War II, broken down by ICES Divisions. This split has to be used as the best approximation to zones of extended fisheries jurisdiction, as there is no more detailed information available on the origin of the catches made by some major fishing countries.

In practice, Division IVa east (east of 2^{O}E) is almost coincidental with the Norwegian zone, and Division IVa west (west of 2^{O}E) is almost entirely within the EEC zone. Division IVb contains several statistical rectangles belonging to the Norwegian zone (Fig.5). Division IVc is entirely within the EEC zone.

The best index available of the distribution of commercial catches between zones is given in Table 1 as the ratio of the catch in IVa east to the total. This shows that up to 1955 less than 1% of the total catch was taken in the Norwegian zone.From 1955 to 1959 this proportion increased to about 15%. In 1960 it increased sharply to about 38% and then grew more slowly to a peak level of 54% in 1967. The fishery in this area thereafter declined very rapidly, and since 1970 the proportion of the total catch coming from this area has consistently been around the 4%level. As stated above the Norwegian zone encroaches to some extent into Division IVb. In some years considerable catches have been taken in these rectangles, but at present these cannot be quantified. The proportion of herring caught in IVa East will therefore underestimate the share of the Norwegian zone, but this underestimation is likely to be small.

It should be noted that catches of Atlanto Scandian herring have already been deducted from the figures given in Table 1.

6. Migrations

In their 3rd year of life, herring leave the nursery areas in the southeastern North Sea and join the adult stock on its feeding grounds in the western North Sea. During the feeding season, from May until August, adult herring are found from the Sheltand Islands down to about 55^{O}N. The adult feeding grounds are situated mainly within the EEC zone (Fig.6-7).

Spawning occurs in August-September in the Shetland-Orkney area and also near the Aberdeen Bank. In the central North Sea, spawning takes place in September-October, and in the eastern Channel in December-January.

The present overwintering grounds of North Sea herring are not exactly known, but they are assumed to be mainly in the western part of the North Sea (Fig.7). In recent years there have been reports of overwintering herring concentrations near Shetland, and also further south near Farne Deep.

In the years prior to 1970 large concentrations of immature and adult herring were found in the northeastern North Sea and Skagerrak in June-July and also throughout the winter. These herring probably belonged to the autumn spawning populations of the central and northwestern North Sea and of the Kattegat (Fig.6). Since 1970, with the marked decline in these populations, there have been very few herring in the northeastern North Sea.

7. Spawning areas

The spawning areas shown in Figure 1 are based on the occurrence of newly hatched larvae in samples collected during the ICES herring larval surveys and of catches of spawning herring.

All the known spawning grounds of autumn spawning herring are within the EEC-zone.

8. Exploitation and management

The methods of exploitation remained largely unchanged until the second half of the 20th century. The main fishing was done by drift nets, and this fishing method never exploited the resources beyond their capacity. The maximum catch level during this period was around 700 000 tonnes a year.

The use of echo sounders in conjunction with bottom trawls was introduced after 1950, and this proved to be much more efficient than the drift net, which was almost completely abandoned during the 1950s. Bottom trawls were used effectively on the feeding ground, but even more on the spawning grounds. In addition to the trawl fishery for human consumption, an industrial fishery for juvenile herring developed in the central and eastern North Sea in the early 1950s.

In the early 1960s, some more new and very efficient fishing methods were introduced. This started with the two-boat mid-water trawling, followed by the introduction of the purse seine. By the end of the 1960s, the one-boat pelagic trawl was also developed to a high degree of perfection.

The development of these highly efficient fishing methods, and the absence of adequate conservation measures led to a continuous decline of most North Sea stocks after 1950. In addition to the changes caused by fishing, there have also been some changes which may have been caused by natural factors. In addition to the fisheries on the adult stocks, from the mid-1950s there was a major increase in exploitation of juvenile herring in the eastern Central North Sea. By 1975, the total North Sea herring stock had been reduced to approximately 10% of its immediate post-war level. After 1970, the overall recruitment to the North Sea stocks started to decline. Yearclasses 1970, 1971 and 1973 were only of average strength, while 1972, 1974, 1975, 1976 and 1977 were far below normal. The deterioration of the stocks led to the introduction of protection measures after 1970. From 1971 to 1974, closed seasons were in force and subsequent data suggest that these had little effect in reducing the exploitaion rate on, or halting the decline of, the stock. After 1 July 1974, catch quotas were agreed between the various countries. However, the principle of TACs was probably accepted too late for realistic values to be readily accepted and as a result the levels agreed were too high to achieve the objective of rebuilding the stock. In October 1975, the ICES Liaison Committee advised a total ban on directed herring fisheries and maximum restrictions on the by-catch of juvenile herring in the industrial fisheries. It was not until March 1977, however, that the ban on directed fisheries was finally implemented.

If the various sub-populations of the North Sea were given a chance to rebuiled, the long-term sustainable yield could theoretically be 700-800 thousand tons annually. This is also the level of total annual catches that was obtained until the drastic changes in the stock occured after 1960. The long-term yield, however, is very dependent on the pattern of exploitation. The figure of 700-800 thousand tons per year is based on a fishing mortality on 1-group of not more than 1/10th of that on adults. This would entail continuance of the prohibition of directed fisheries on juvenile herring and more restrictions on the by-catch in other fisheries.

Table 1. Herring. Total catch in '000 tonnes 1947 - 1976,
North Sea and Eastern Channel.

Year \ Divisions	IVa West	IVa East	IVb	IVc + VIId, e	Total North Sea + Eastern Channel	IVaE % Total
1947	211.3	0.3	214.4	160.6	586.6	.05
1948	169.4	1.9	168.3	162.5	502.1	.38
1949	134.2	2.0	179.0	193.3	508.5	.39
1950	125.1	1.6	186.7	178.3	491.7	.33
1[illegible]	123.0	1.2	310.6	165.6	600.4	.20
1952	168.4	6.6	253.3	236.1	664.4	.99
1953	178.8	7.5	303.0	209.2	698.5	1.07
1954	168.0	4.3	313.7	276.9	762.9	.56
1955	287.8	67.4	282.8	168.4	806.4	8.36
1956	194.5	79.1	267.6	134.0	675.2	11.72
1957	209.0	97.3	253.9	122.7	682.9	14.25
1958	164.7	98.2	315.0	92.6	670.5	14.65
1959	259.6	144.2	303.5	77.2	784.5	18.38
1960	101.1	264.0	266.2	64.9	696.2	37.92
1961	61.0	274.8	262.7	98.2	696.7	39.44
1962	37.6	291.8	243.7	54.7	627.8	45.48
1963	73.1	301.3	295.9	45.7	716.0	42.08
1[illegible]	66.1	444.0	304.5	56.6	871.2	50.96
1965	298.3	580.8	267.9	21.8	1168.8	49.69
1966	278.6	424.0	181.3	11.6	895.5	47.35
1967	117.3	373.7	193.1	11.4	695.5	53.73
1968	286.7	256.8	164.7	9.6	717.8	35.78
1969	213.1	148.1	161.2	24.3	546.7	27.09
1970	326.9	21.4	187.7	27.1	563.1	3.80
1971	288.8	17.3	190.4	23.4	519.9	3.33
1972	235.1	22.7	216.6	23.0	497.4	4.56
1973	297.7	14.7	193.4	30.2	486.0	3.03
1974	84.2	15.4	168.2	7.4	275.2	5.60
1975	95.8	9.7	181.9	25.5	312.9	3.10
1976	101.6	2.3	41.5	17.5	162.9	1.41

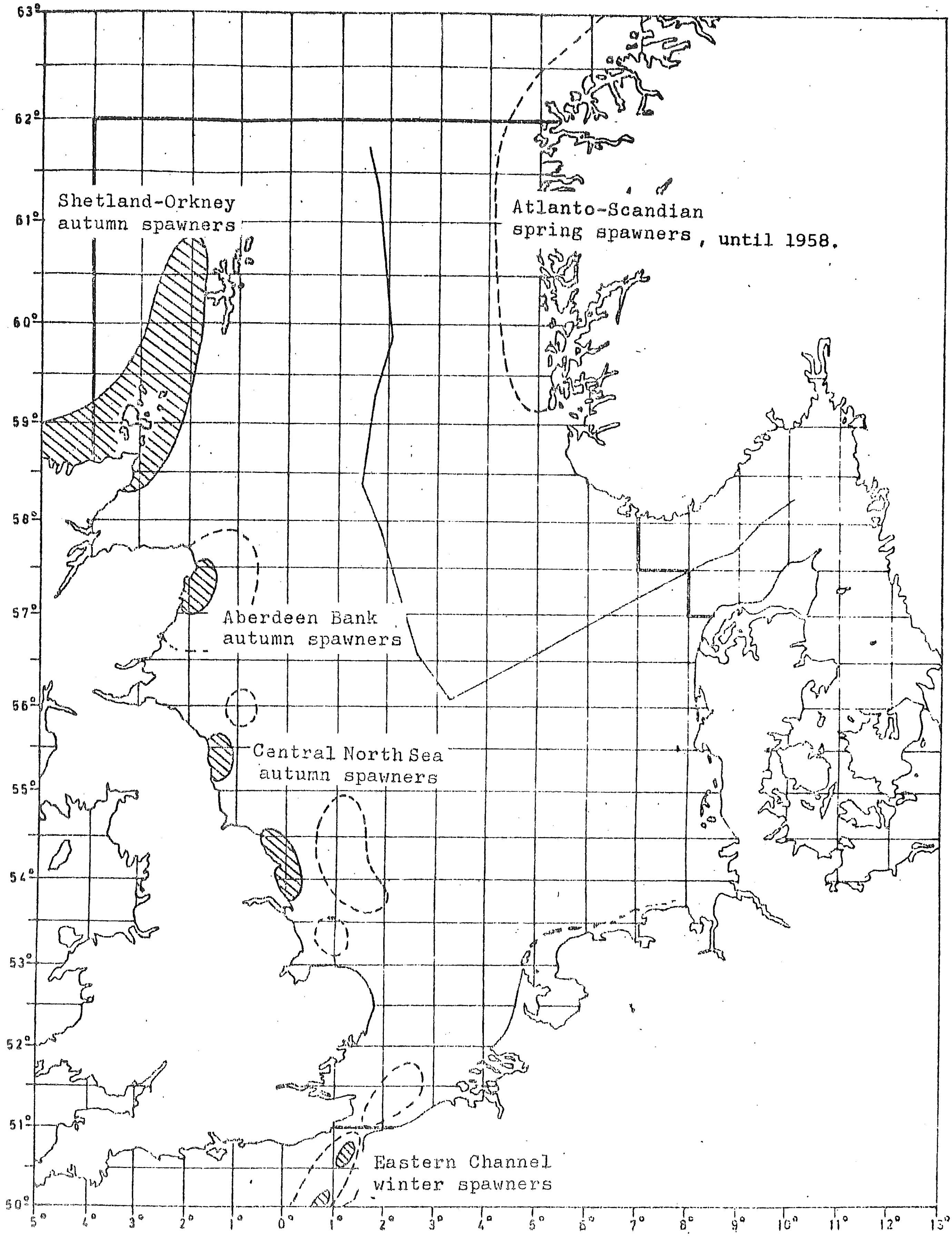

Figure 1. Present spawning grounds (shaded) and former ones for various **herring populations.**

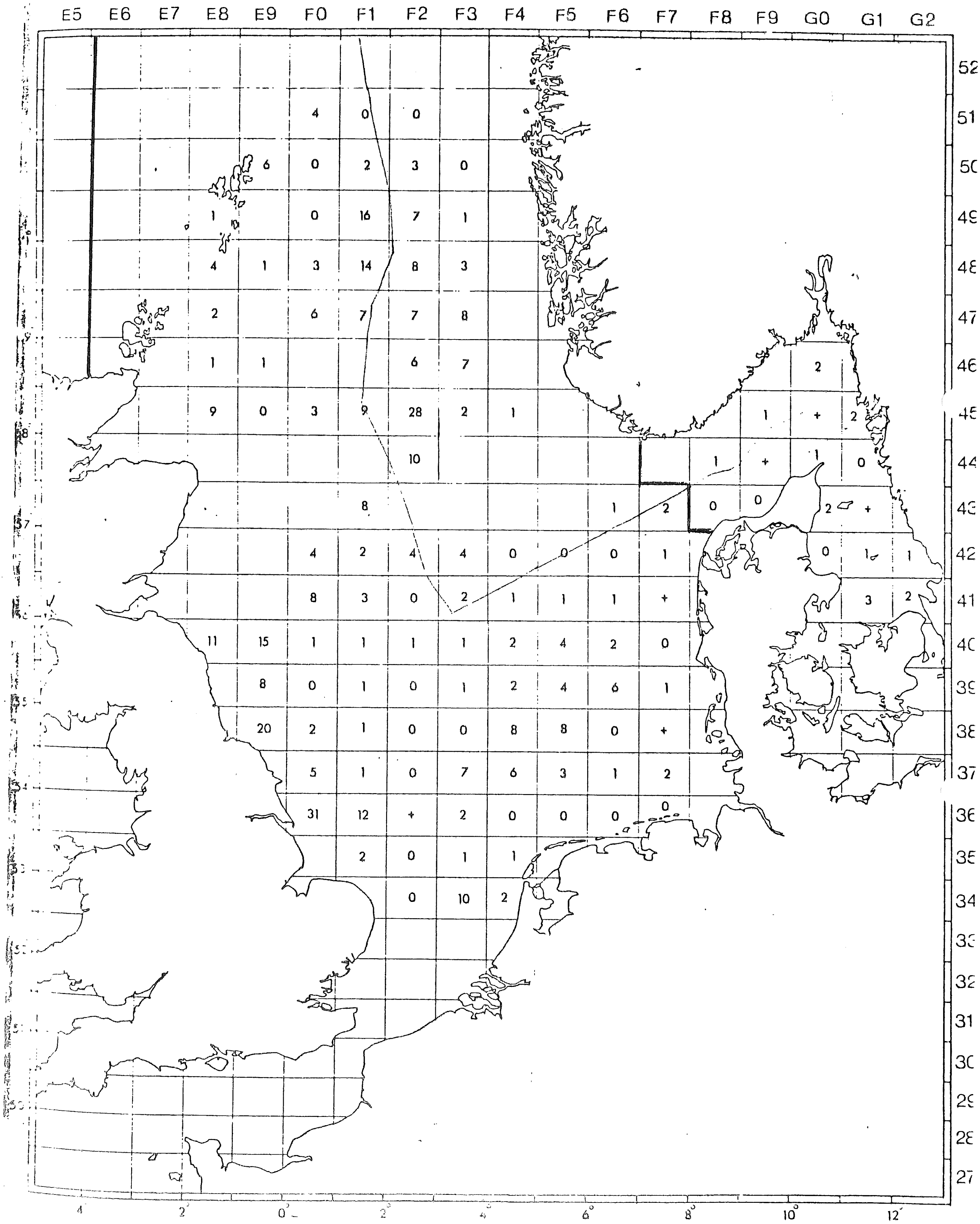

Fig. 2. Distribution of large herring larvae in February 1978 (numbers per tow).

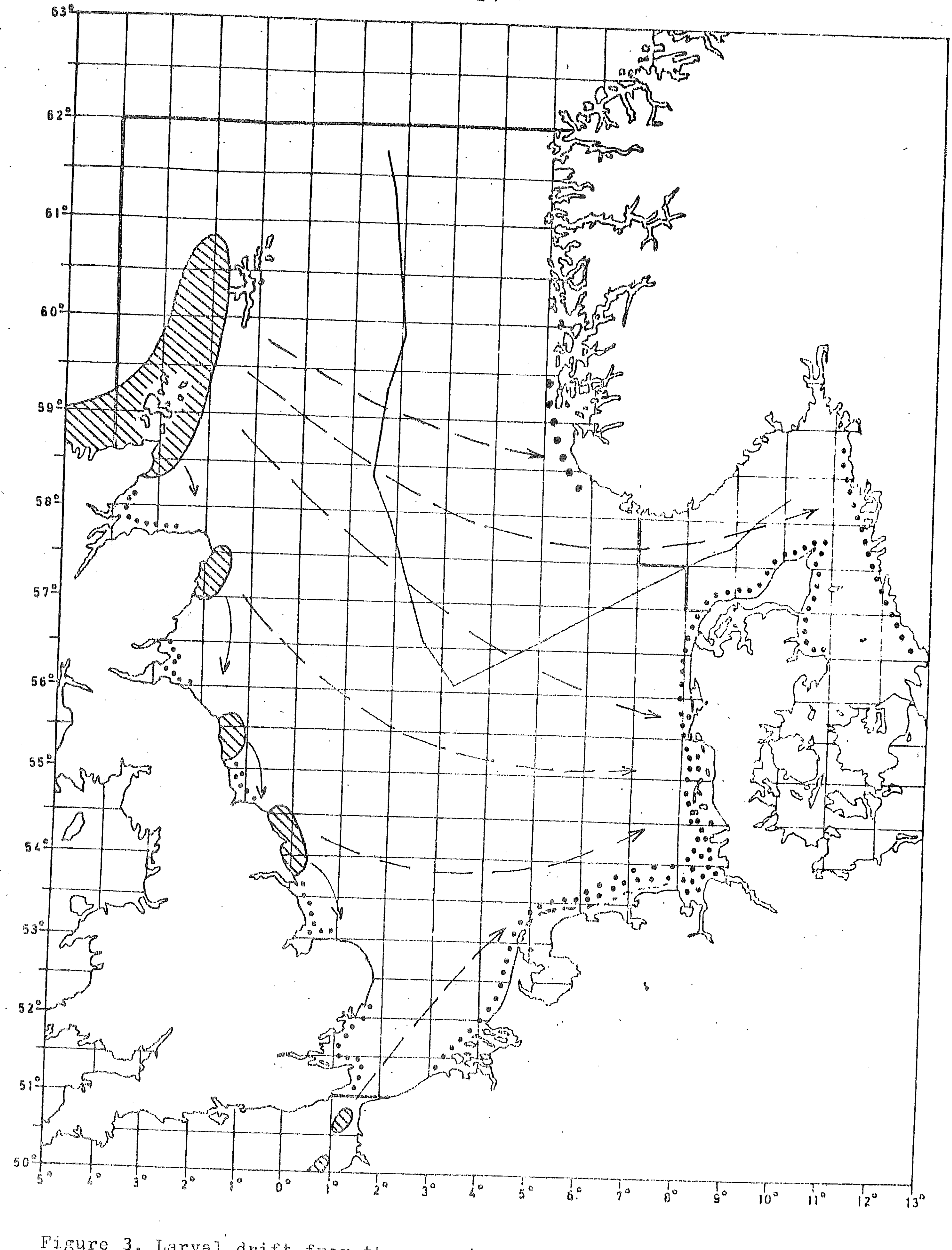

Figure 3. Larval drift from the spawning areas and nursery areas for O-group herring (dotted).

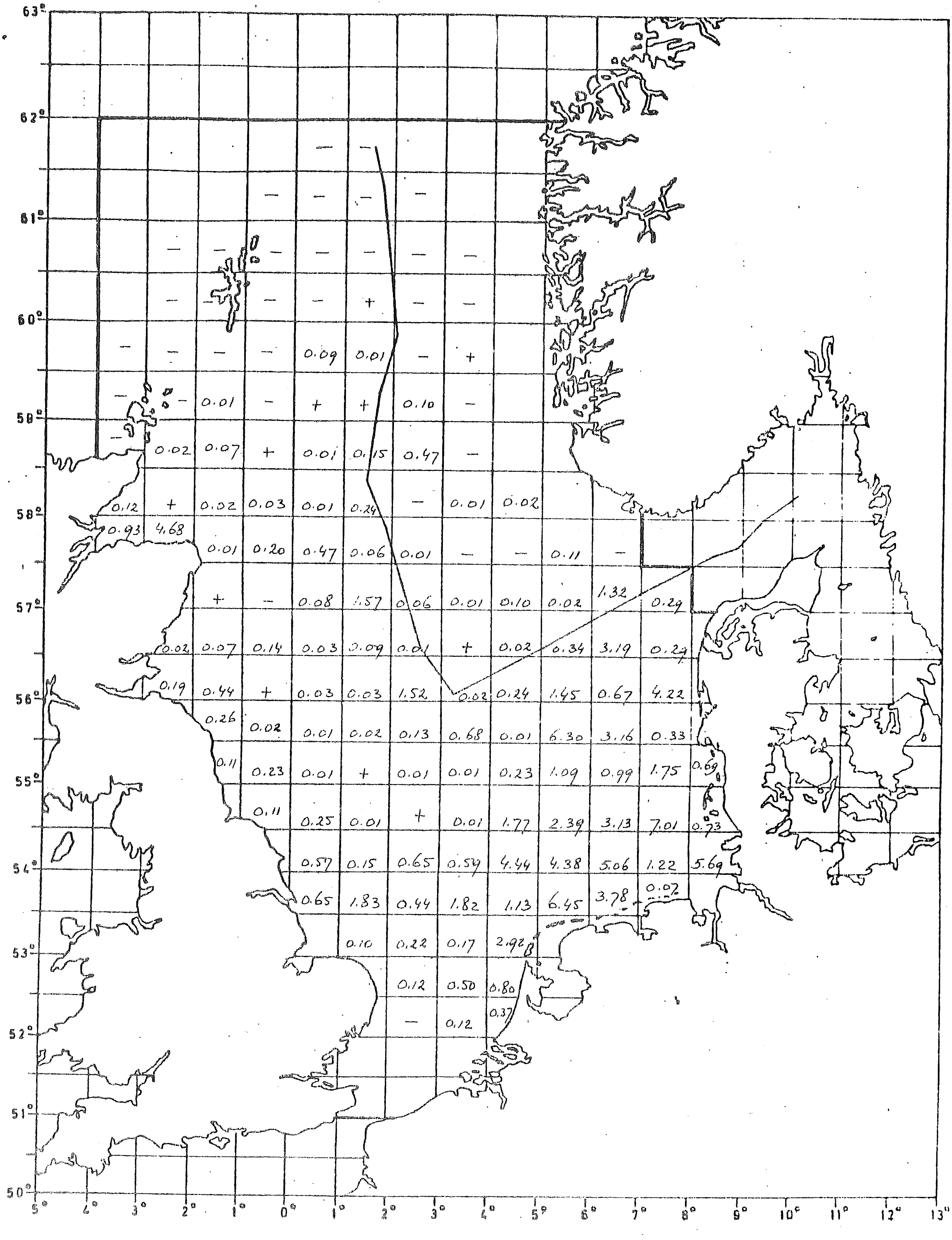

Figure 4. Distribution 1-group herring, based on results IYHS.
Mean percentage/square during surveys in 1974-78.

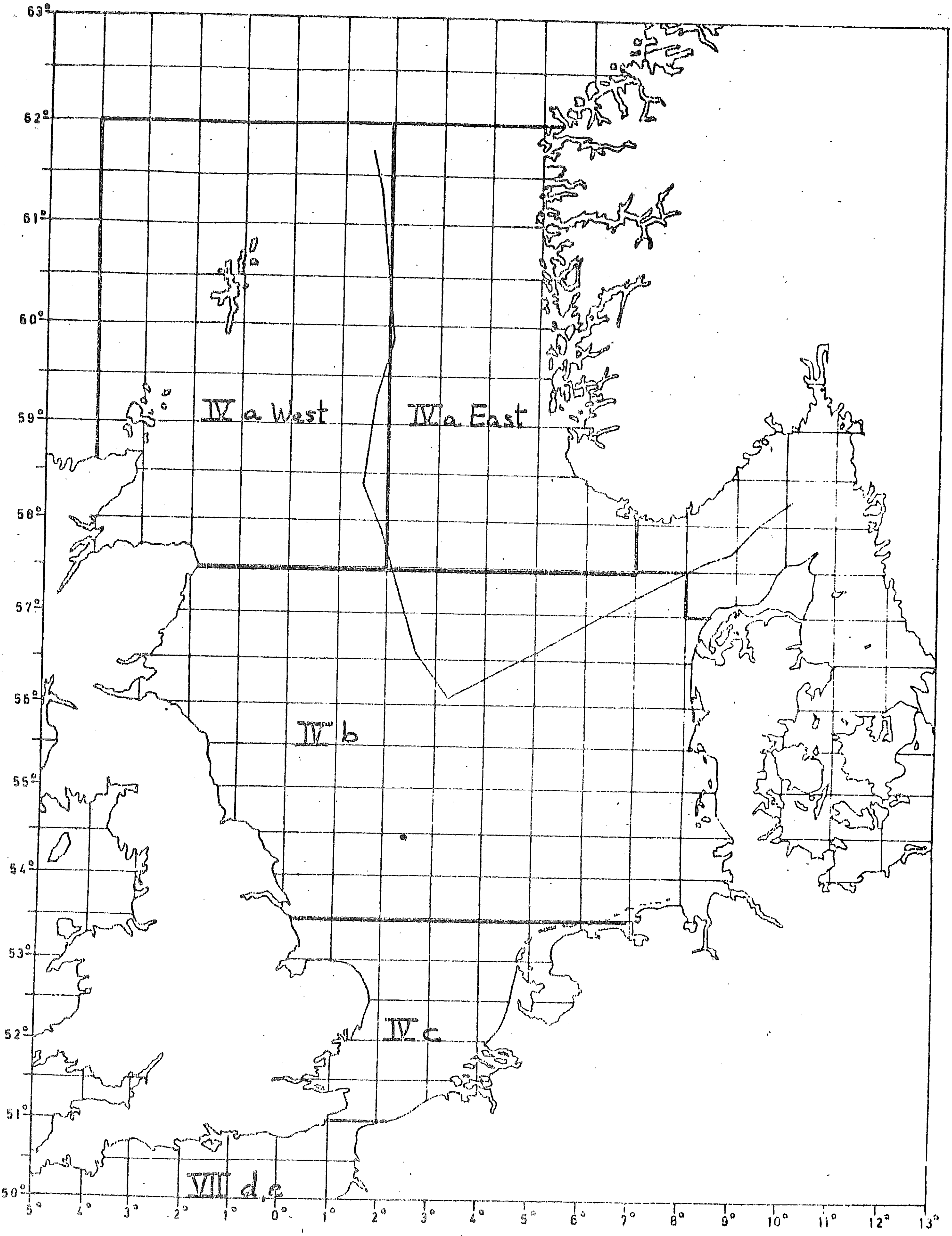

Fig. 5. I.C.E.S. Divisions compared with economic zones.

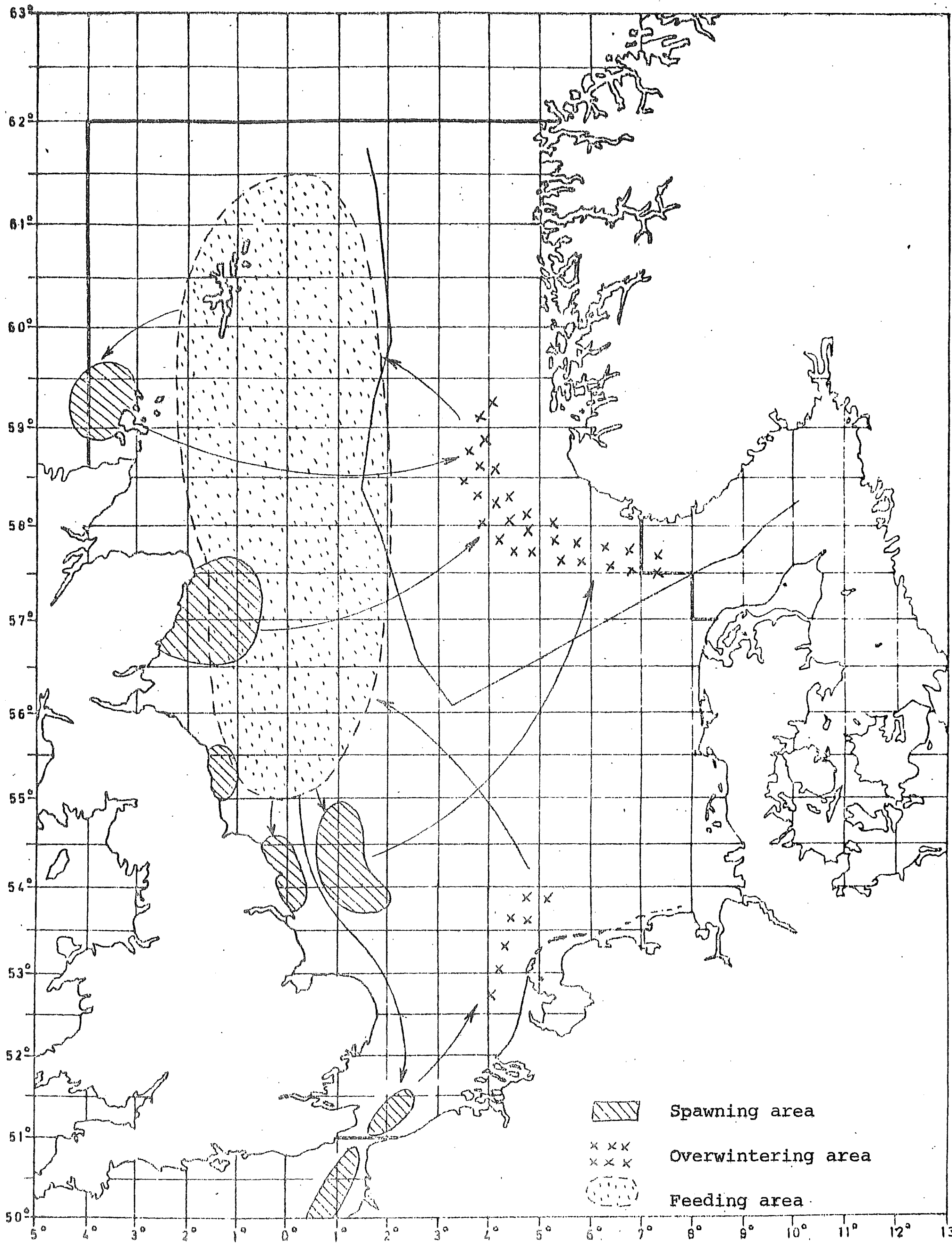

Fig. 6. Adult herring migrations ± 1960.

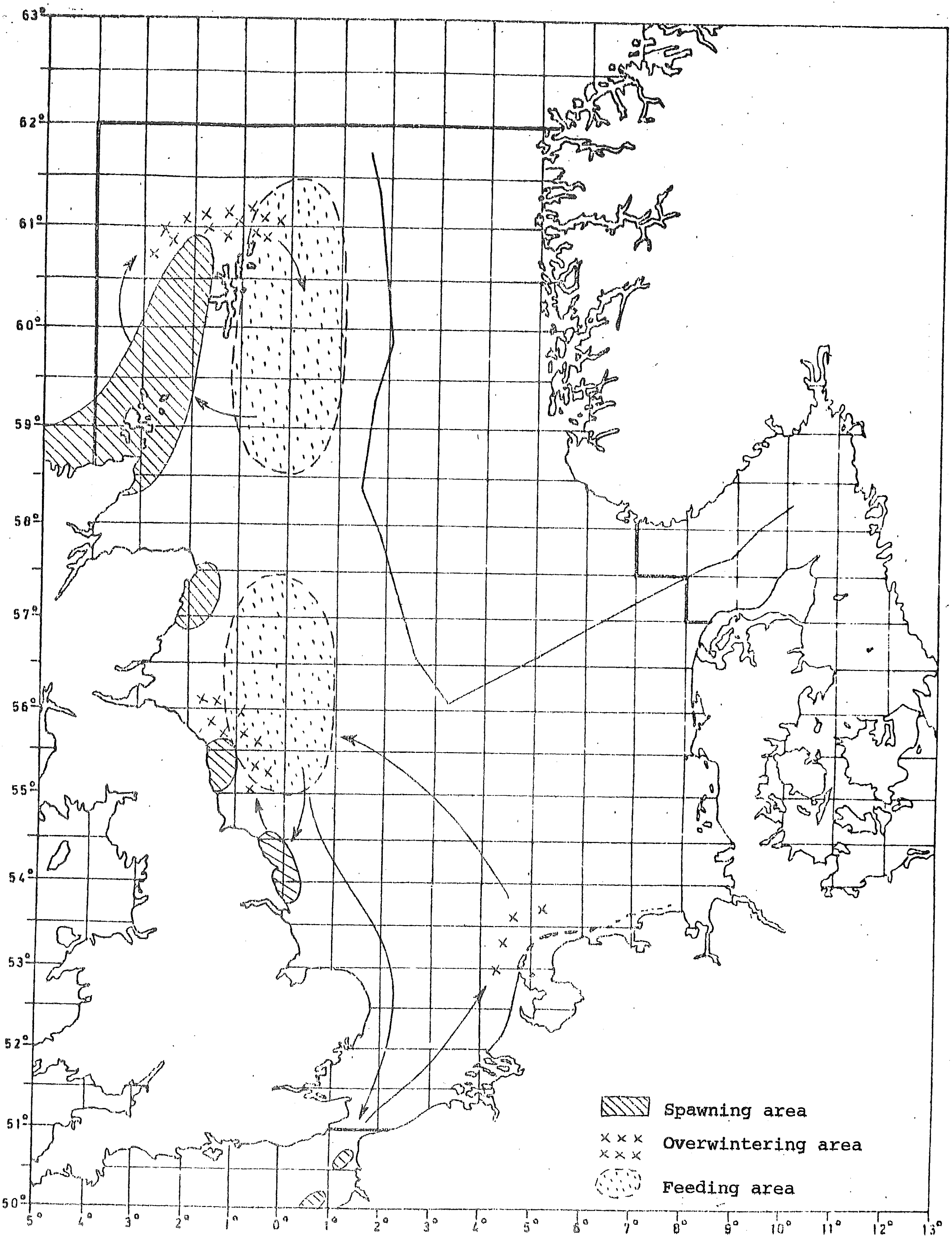

Fig. 7. Adult herring migrations ± 1970.

8. Mackerel

1. Eggs and larvae

Mackerel spawn in the North Sea from late May to late July. Surveys to delineate the spawning area and to try and relate egg abundance to the size of the parental stock have been carried out by Norway each year since 1968. These data, however, suffer from two deficiencies for the purposes of this project:

a) Prior to 1978 they never extended south of 55°N and in some years have been restricted in the area sampled south of 57°N. It is known that mackerel spawning takes place, on an appreciable scale, to at least as far south as 53°N;

b) these surveys have been almost entirely confined to the period mid-June - mid-July and might therefore give a biased picture of the distribution of mackerel eggs and larvae between zones, if there is a seasonal progression in spawning activity over space, as is known to occur, within the North Sea, in several fish species.

Of these deficiencies a) is the more serious because the distribution of this sampling will inherently bias any estimate of mackerel egg distribution in favour of the Norwegian zone. This can be completely overcome only in 1972 when a survey was also carried out by England in June, between 52°N and 57°N. The results of this survey and of the Norwegian one in that year have been put together in Figure 1. The results of the Norwegian surveys (Iversen 1977) were presented as the numbers of eggs without visible embryos caught per square metre whilst for the English survey (Johnson and Dawson 1975) they were given as total numbers of eggs per square metre. Iversen, however, gives the ratio of eggs without embryos to the total for his survey as 0.53 and this has been used to correct his figures to the same base as the English one before using them in Figure 1. From this figure the proportion of the 1972 total egg production in the North Sea within the Norwegian zone was calculated as 30%. It should be noted that this value refers only to 1972 when the spawning stock was appreciable larger than in more recent years. A reduced spawning stock might well spawn over a smaller total area.

In 1978 a Norwegian mackerel egg survey was carried out which extended southwards to $54^{o}30'$N. The contours of total egg distribution in the southern area are open towards the west coast of Denmark, and to a lesser extent to the north-east of the Dogger bank, as shown in Figure 2. This will mean that the estimate of the proportions within zones will be biased to some extent in favour of the Norwegian zone, but this bias will probably not be too serious in this instance. The 1978 survey results also provide an interesting contrast with those of 1972 in that those two years represent two extremes of the adult mackerel population size, which has declined from about 1.4 million tons in 1972 to about 0.6 million tons in 1978. The 1978 results would suggest that about 65% of the eggs were distributed in the Norwegian zone and about 35% in the EEC zone.

It should be noted that this analysis has been confined to the spawning area in the North Sea. This stock also spawns in Division IIIa, but spawning in this area has not been taken into account above.

No survey data are available for mackerel larvae over a sufficiently large area of the North Sea to make any estimate of the proportional distribution of this stage in the life-cycle between the two zones.

2. Juveniles

The available data on the distribution of juvenile (0+ and 1-group) mackerel are also inadequate to make any firm statements about their proportional distribution between zones. As the International 0-group Surveys are carried out in June, at the height of the mackerel spawning season, they provide no information on the 0-group of this species and no other sufficiently extensive surveys have been conducted to allow any estimate to be made of the distribution of this stage between zones.

As regards 1-group mackerel the only available data are those originating from the ICES International Young Fish Surveys carried out in February. The mackerel data from these surveys have been compiled by Walsh (1974, 1977) who has shown they provide a fairly consistent picture of the distribution of 1-group mackerel from year to year, within the constraints of the distribution of sampling. The proportion of the summed total of the mean catch per hours fishing, within each statistical square sampled, taken within the Norwegian zone is given in the text - table below:

Proportion of total catch of 1-Group Mackerel taken in International Young Fish Surveys, caught in Norwegian Zone.

	Percentage in Norwegian zone	Total number caught
1971	52	34 761
1972	6	88
1973	11	286
1974	21	164
1975	95	2 185
1976	6	33

The proportional subdivision between zones in these data is very variable - the Norwegian share varying from 5.5%-94.7%; a mean value estimated from these would be of little value. Taken in conjunction with the summed total - which ought to be some indicator of the overall abundance of this age group - they might suggest that the proportion in the Norwegian Zone is high when abundance is high but low when the abundance is low. The average numbers of this age group caught per statistical square over the period 1971-1973 and in 1975 are shown in Figures 3 and 4. Figure 4 would suggest that in 1975 a major part of the North Sea 1-group mackerel population was distributed north of 59°N and between $2^{O}E$ and $4^{O}E$, where very little sampling was done prior to 1974. The proportions shown above for the years 1971-1973 may therefore be biased towards the EEC zone by lack of sampling in this area in the earlier years. But it should be noted that in 1974 and 1976 this area was sampled but showed little evidence of appreciable concentrations of 1-group mackerel. The bias in 1971-73 may therefore not be very large, as on present evidence the 1975 distribution would appear to be a somewhat aberrant one.

A more serious source of bias in these survey data may be that they represent only the distribution in February, as measured by a bottom trawl. 1-group mackerel may not be representatively sampled by this gear, and indeed may be less available to this gear in deeper than in shallower waters, which might provide some bias in favour of the EEC zone. A more serious factor for a species like mackerel which undergoes major seasonal migrations is probably the fact that these surveys refer only to the winter period. 1-group mackerel are known to occur in appreciable numbers in commercial catches taken in the Norwegian zone in summer. Because of the different nature of the mackerel fisheries in the EEC zone it is not known whether a similar summer distribution occurs within this zone. Therefore this factor cannot be quantified in any proportioning between zones.

3. Distribution of adult fish - Research surveys

No surveys have been conducted, specifically for mackerel, over a sufficiently wide area to be of any help in the context of proportioning the adult stock between zones of fisheries jurisdiction. In view of the wide migrations undertaken by the adult stock within a year such survey data would in any case be of little significance unless repeated at frequent intervals during a year. The ICES Young Fish Surveys are of no value in this context because they are carried out only once a year, in February, and because adult mackerel is not representatively sampled by the fishing gear used on these surveys.

4. Distribution of adult fish - Commercial landings data

In the period up to 1969 the major part of the North Sea mackerel catch was taken in the period autumn - early spring on the over-wintering population on the southern and western slopes of the Norwegian trench - within the Norwegian zone. After 1969 Norwegian national regulations of the mackerel fishery reduced the fishing effort in this area very markedly; and resulted in a major part of the Norwegian mackerel effort being transferred to a summer fishery further north and west, in the EEC zone, where a high proportion of the catch, although taken in the North Sea, originated from the Western mackerel stock. In more recent years with the advent of extended zones of fisheries jurisdiction, much of the Norwegian and Faroes effort has returned to the Norwegian zone for mackerel fishing. In the text-table below the proportions of the total North Sea catch, irrespective of the stock to which it belongs, taken within the zones under consideration are roughly estimated. These are the same figures as given in Anon (1978). More complete data now available on catch distribution have not made any appreciable differences to these original estimates.

	Norwegian zone	EEC zone
1966-69	75	25
1970-74	40	60
1974-77	60	40

In the light of what has been said above it will be appreciated that these proportions are determined at least as much by the constraints under which the fishery has operated as by the distribution and the availability of the fish on which it is based. They have been particularly affected since the early 1970's by Norwegian national regulations of the mackerel fishery mentioned in section 7.

It must be stressed that in the other sections of this report on mackerel the estimates given refer only to the North Sea stock.

In this section on catch data this distinction cannot be made, and the proportions given for commercial catch data refer to catches of a mixture of both the North Sea stock and the Western stock. The proportions of the mixture in the catches from the two zones are certainly different. The highest proportion of the Western stock occurs in the catches from the EEC zone of the North Sea. The catches taken in the Norwegian zone, whilst not exclusively of North Sea stock contain a higher proportion of that stock.

5. Migration

The accepted classical picture of the migrations of the North Sea mackerel stock is that they over-winter in the deep waters of the Norwegian Trench, from about 62°N south to the Skagerrak. In late spring - early summer they must then migrate south-westwards to the spawning areas shown in Figure 1. Subsequent to spawning at least a major proportion of the population migrates north-westwards to the Shetland area where they mix in feeding shoals with migrants from the western mackerel stock. They then undertake a return migration, in autumn, to the over-wintering area. The development of a winter fishery in the last three years, towards the edge of the continental shelf west of the Hebrides and North Rona, on fish which, in terms of biological characters and from tag returns, are predominantly members of the North Sea stock would suggest that this classical picture is over simplified. It would now seem probable that there are two over-wintering components of the North Sea mackerel stock -one in the Norwegian zone and one in the EEC zone. Their relative sizes cannot yet be estimated. A schematic illustration of the known migrations, partly constructed from tagging data and partly from the biological features discussed above is shown as Figure 5.

6. Spawning Areas

Because of the prolonged spawning period of individual fish the spawning area of mackerel cannot be clearly demarcated by the occurrence of fish in spawning condition. Such evidence as is available from examination of the maturity stage of catches of adult fish, however, lends confirmation to the spawning area depicted in Figure 1 from the distribution of mackerel eggs. The latter evidence is inherently the more reliable and accurate.

7. Exploitation and Management

Until 1964, when the mackerel fishery in the North Sea was mainly by demersal trawl, gill net, and hook and line, the total annual catch was less than 100,000 tons. After 1964, due to the development of a Norwegian purse-seine fishery on the mackerel, catches increased rapidly reaching over 900,000 tons in 1967. In subsequent years catches declined sharply reaching only 154,000 tons in 1978. This decline was partly due to Norwegian national regulations of the fishery but the reduction in the size of the stock must also have played an appreciable part in it. It should also be pointed out that the decline in the landings would have been even more rapid but for the diversion of a considerable part of the fishing effort to the Shetland area in recent years, this resulted after 1972 in about 25% of the North Sea landings in most years being taken from the Western stock and as much as 40% in 1974.

The changes in the stock size of the Eastern (North Sea) mackerel population are shown in Figure 6. The rapid decline in stock size in the late 1960s was undoubtedly predominantly the result of the heavy fishery in these years. The recovery in 1972 and 1973 resulted from the recruitment of the strong year-class, born in 1969, to the exploited stock. Subsequent to this year-class recruitment has been very poor and the slower rate of stock decline after 1973 largely resulted from the Norwegian national restrictions on their mackerel fishery discussed below.

The North Sea mackerel fishery had not been subject to effective international management until too late to do more than ameliorate the decline. Prior to 1975 the only international regulation was the prohibition on fishing for mackerel less than 30 cm long for industrial purposes and, with considerable exemptions, the prohibition of industrial fishing in the first half of the year. Norway, however, in 1970 introduced national regulations which included the minimum landing size later accepted by NEAFC, a banning of industrial catches between November and July, a national catch quota, and closed areas. The latter were largely instrumental in the shift of much of the Norwegian mackerel fishery to the Shetland area mentioned above.

Despite these measures, and the subsequent attempts at regulation of international catches by Norway and the Community, the North Sea mackerel stock has continued to decline due to continued low recruitment. With no evidence of even a moderately strong year-class having been produced in the past ten years there would seem to be considerable doubt whether any catch should be taken from this stock until there is evidence of an appreciable recovery. This would entail not only a prohibition of mackerel fishing in sub area IV and Division IIIa but also in that part of sub area VI, shown in Figure 5 as an over-wintering area for the North Sea stock, during the period November-March.

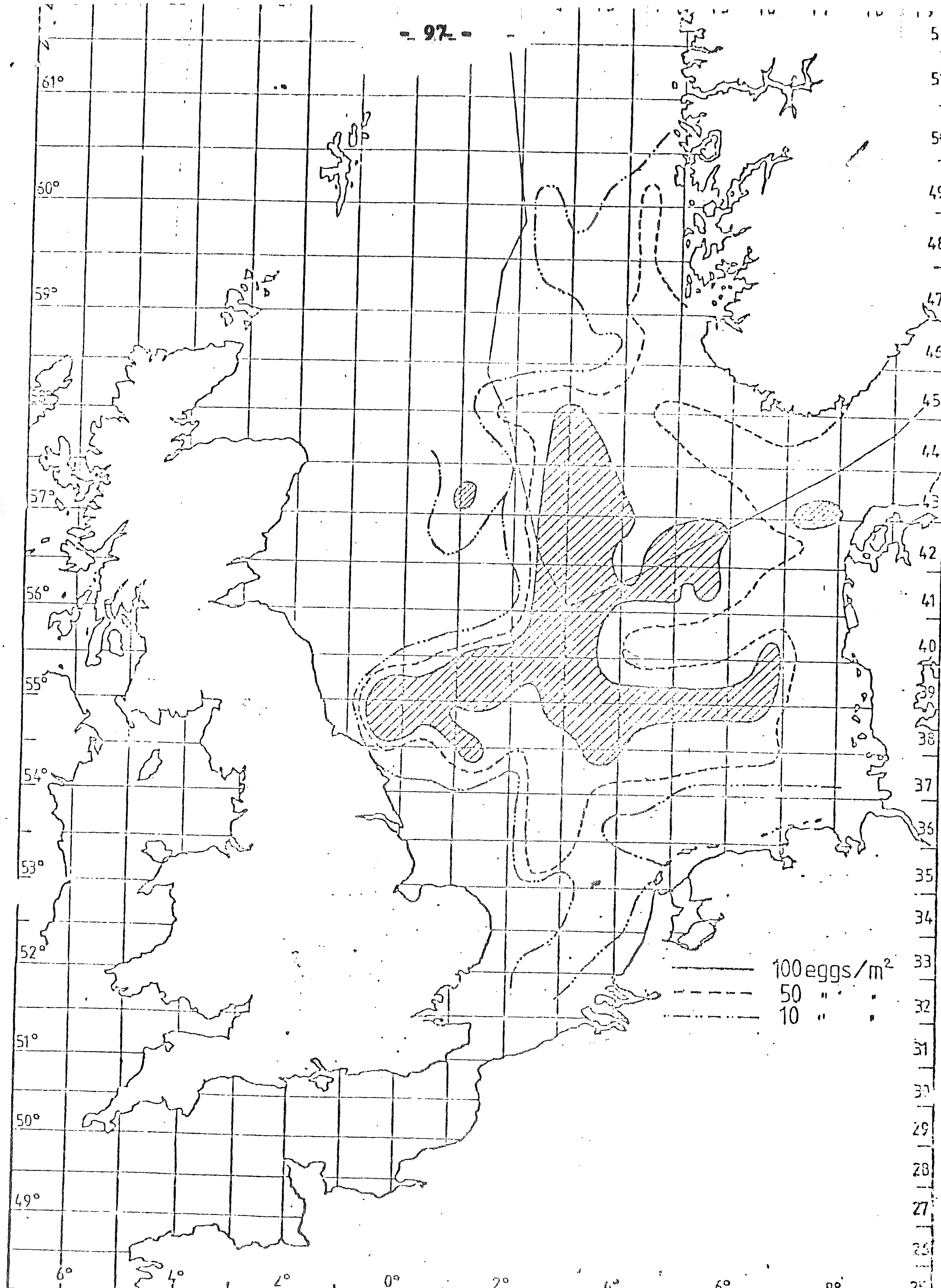

Fig. 1. Distribution of total mackerel eggs in June-July 1972 (adapted from Iversen 1977 and Johnson and Dawson 1975).

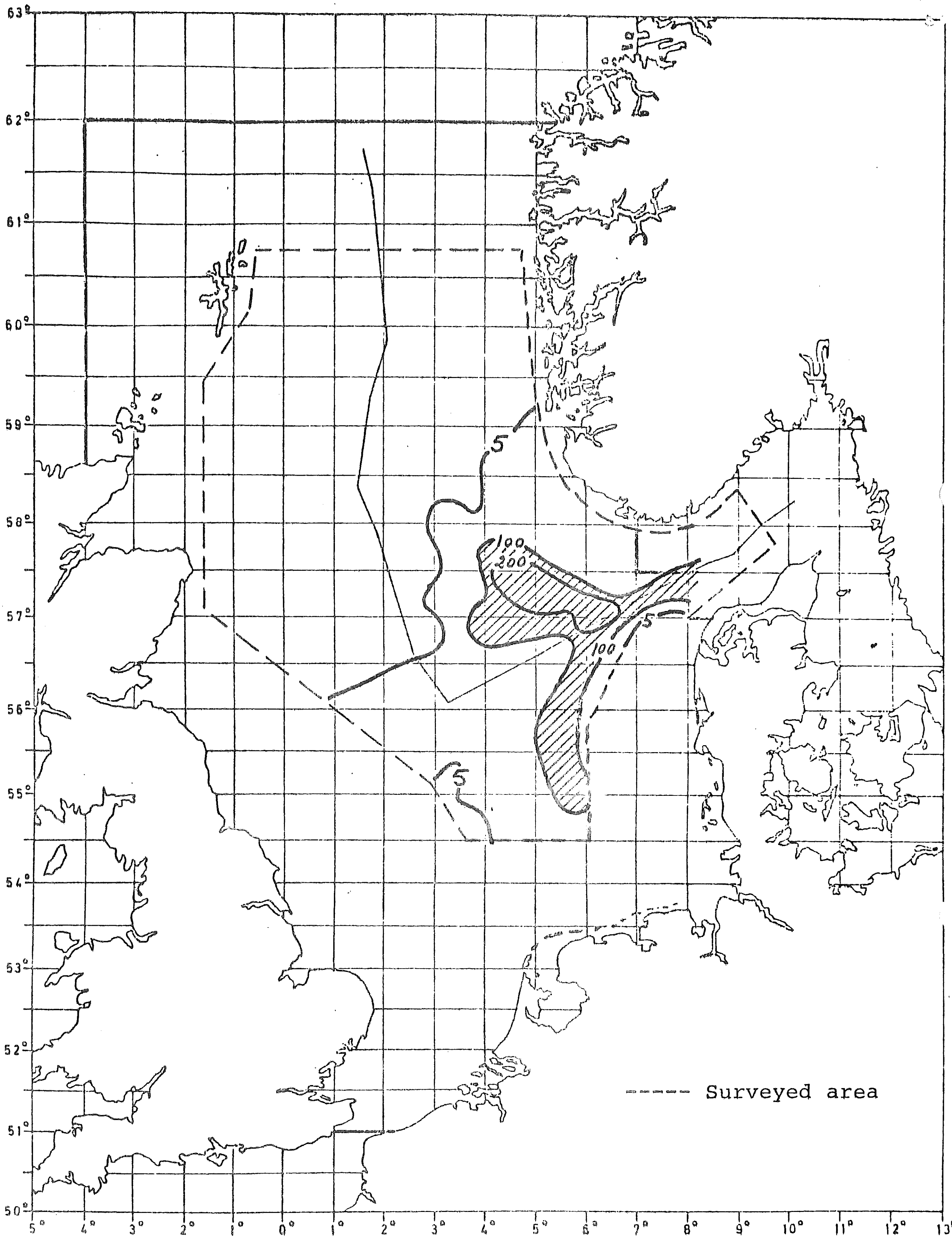

Fig. 2. Distribution of total mackerel eggs, no. per m^2, June - July 1978 (unpublished report by the Institute of Marine Research, Bergen).

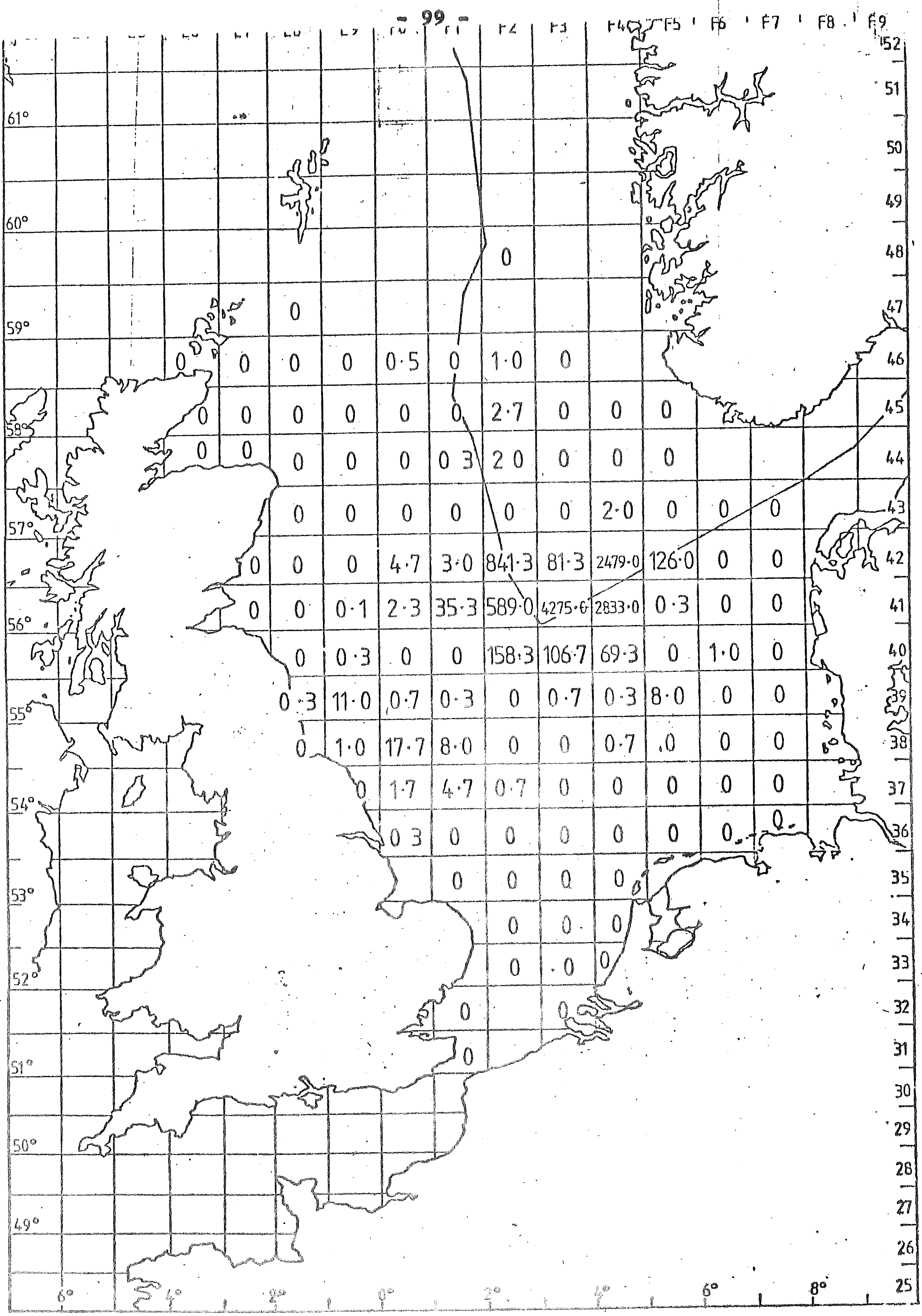

Fig. 3. Mean catch of I group mackerel per statistical square per hours fishing from I.C.E.S. Young Herring Survey 1971 - 1973.

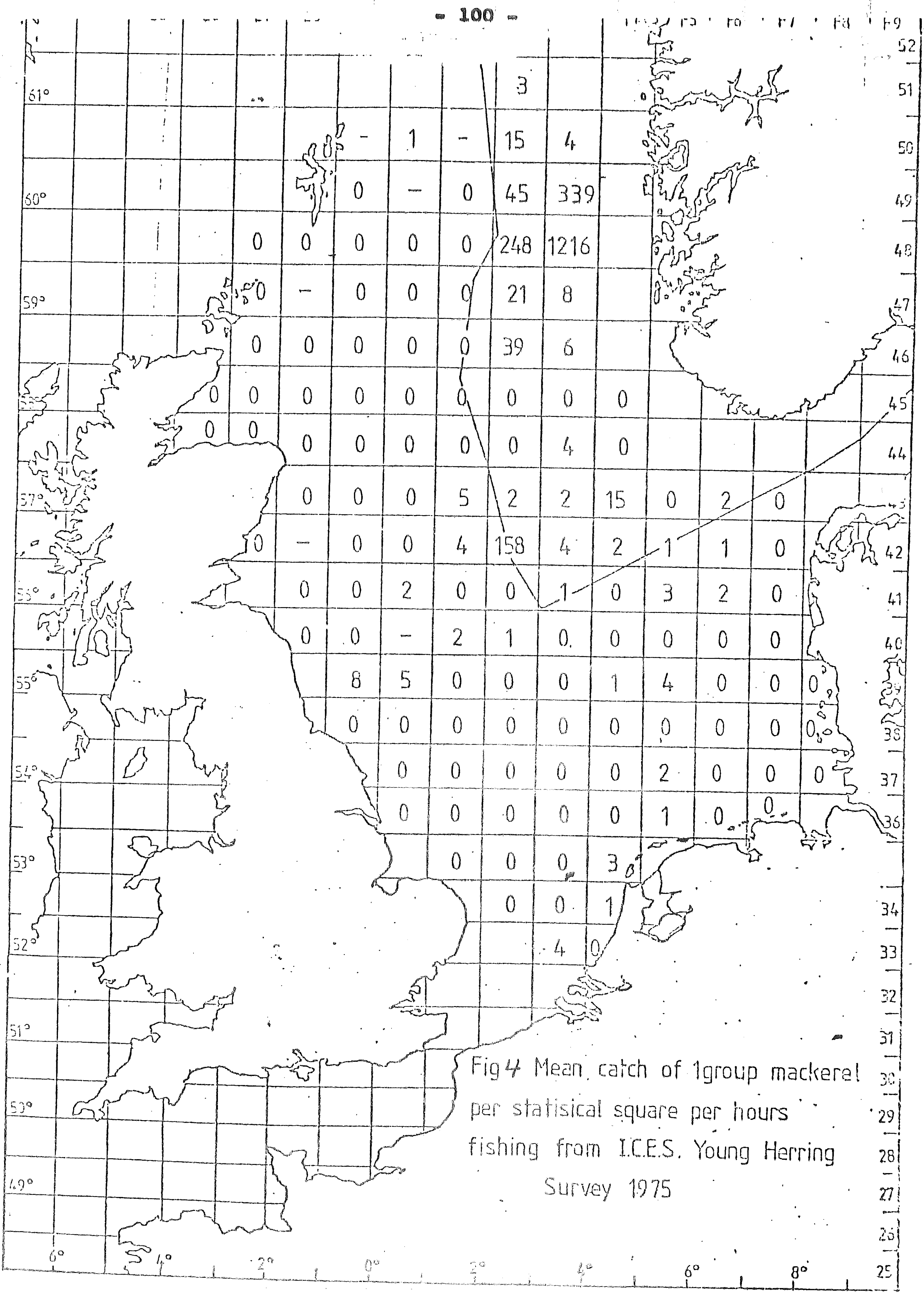

Fig. 4. Mean catch of I group mackerel per statistical square per hours fishing from I.C.E.S. Young Herring Survey 1975.

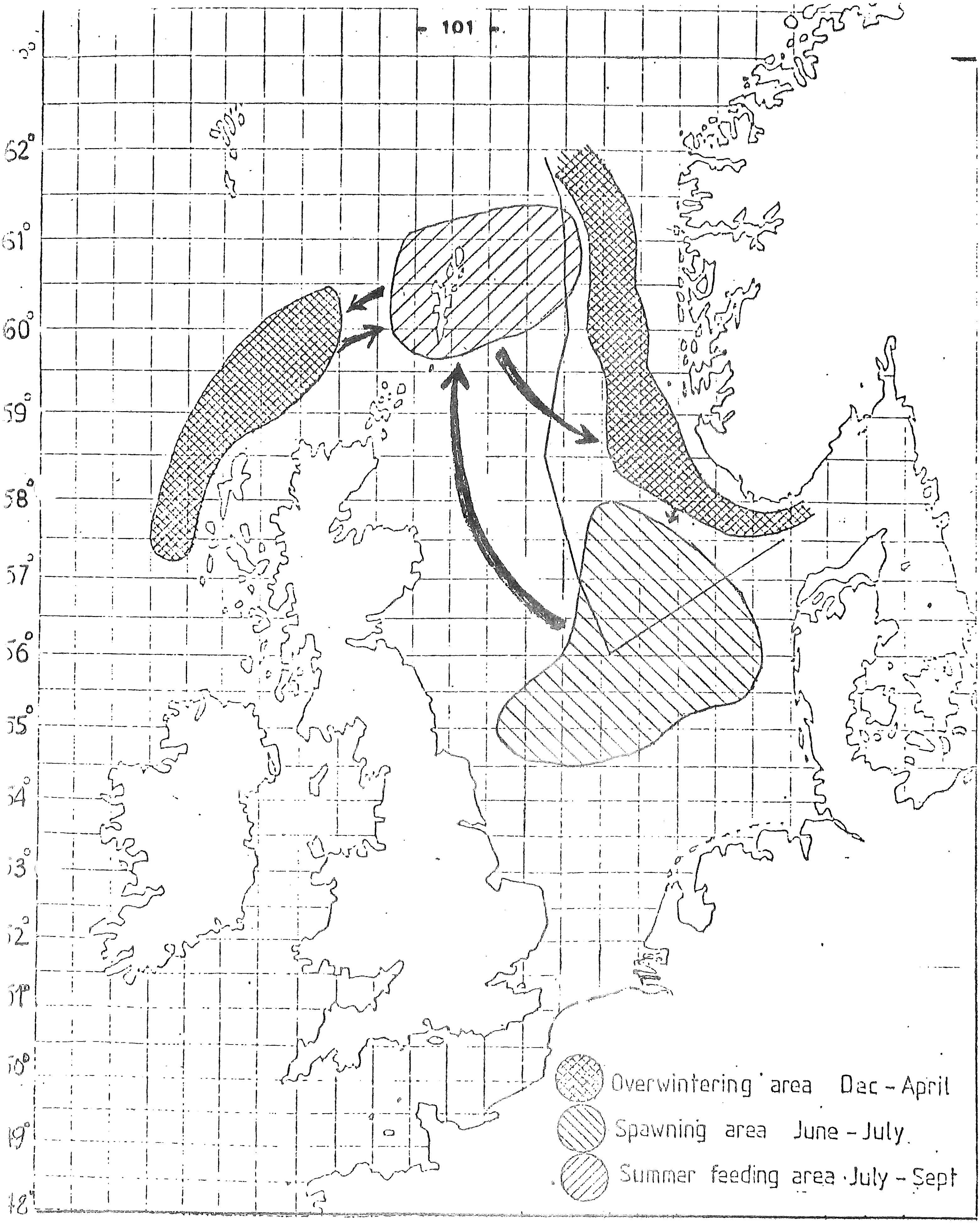

Fig. 5. Schematic illustration of mackerel migrations.

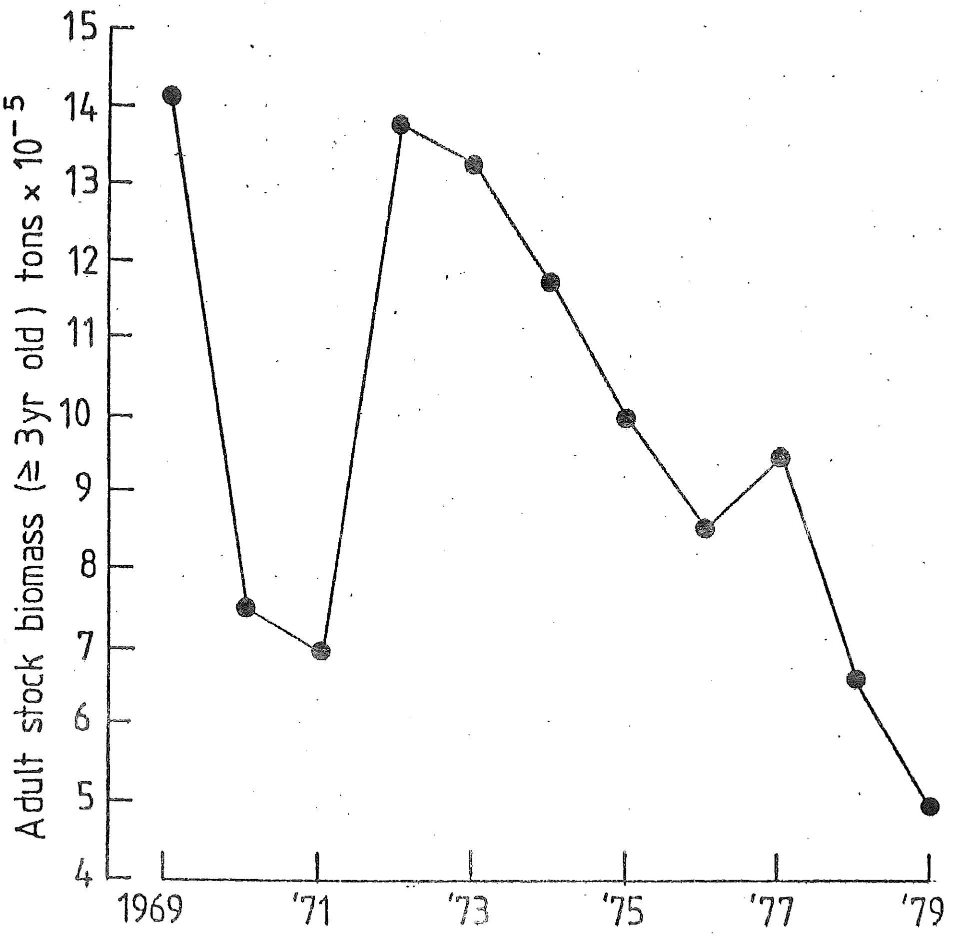

Fig 6 Adult stock size of N. Sea mackerel 1969–79

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