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Spawning, egg production and stock size of mackerel
(Scomber scombrus L.) in the North Sea 1968-1975.

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INTRODUCTION

Mackerel in the North Sea starts spawning in late May. It is a so-called serial spawner, with continuous development of oocytes throughout the spawning season (MACER 1976), which usually ends in late July.

The Institute of Marine Research started a sampling programme for mackerel eggs and larvae in the North Sea in the summer 1968 and has been carried out each summer since. The intentions behind this investigation were:

- 1) To delineate the exact spawning area
- 2) To see if the numbers of mackerel eggs found during a single coverage of the spawning area could be used to give a proper estimate of the parent stock.

IVERSEN (1973) gives the distributions of mackerel eggs both horizontally and vertically and an estimate of numbers of mackerel eggs in the North Sea north of 57°N during the five years from 1968-1972. These estimates were based on a single coverage of the area. This paper deals with some of those results and in addition deals with the years 1973-1975.

MATERIALS AND METHODS

Fig. 1 shows station grids and Table 1 gives sampling periods. From year to year there have been some modifications of the station grids.

From 1968 to 1972 a Juday net (80 cm) was used for sampling in vertical hauls from 50 m depth to the surface. In 1970-1972 four Clarke Bumpus plankton samplers were used additionally. The sampling depths were 0, 10, 20 and 30 m. In 1973 the sampling design was changed, and from this year onwards only Clarke Bumpus plankton samplers were used. The depths were changed to 0, 5, 10 and 15 m. The mesh size of the different plankton samplers was 500 μ . The plankton samples were preserved in 4% formaldehyde. The volumes of the samples were measured in the laboratory after the cruises, and the mackerel eggs were identified and separated into two groups, those in early development (no visible larval embryo) and those in later development stages (with visible larval embryo). In the first group the eggs are less than two days old (DANIELSSEN and IVERSEN 1977). Mackerel eggs were identified from descriptions given by EHRENBAUM (1905-1909), DANNEVIG (1919) and HIEMSTRA (1962).

The amount of zooplankton and numbers of mackerel eggs per square meter were calculated for each station. These amounts were smoothed out in accordance with the formula $(a + 2b + c)/4$ where a, b and c are the values from three following stations and b is the value to be smoothed. These values were plotted in charts and isolines were drawn. The amounts of plankton and mackerel eggs were then estimated by integrating the areas within the isolines. This was done by counting squares of 5 x 5 mm drawn on a transparent plastic sheet within the isolines and this was then multiplied with the value of the isoline. The isolines drawn in these charts were 5, 10, 30, 50, 60, 70, 80, 100 and 150 ml zooplankton per square meter surface area and 5, 10, 20, 30, 50, 80, 100, 200, 300, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 1800, 2000 mackerel eggs per square meter surface area. In the charts presented here some isolines are omitted.

RESULTS AND DISCUSSION

The vertical distribution of the mackerel eggs is shown in Fig. 2. As shown here only few mackerel eggs are found below 15 m, and there is no significant difference in the vertical distribution of eggs with and without embryos. In accordance with this, the sampling design was changed in 1973 to sample in the uppermost 15 m of the water column. Over 90% of the eggs were taken in the uppermost 12-13 m (Fig. 3).

The youngest eggs (those without visible embryos) have probably not drifted far away from the spawning location. These eggs were used to indicate the spawning area during the cruises 1968-1975 as shown in Figs. 4-11. The distributions demonstrate that the North Sea stock is separated from the stock west of the British Isles at the time of spawning. The most important spawning area is the central and southernmost part of the North Sea. The spawning along the coast is small compared to the intense spawning further out in the central part of the North Sea. The Ekofish area seems to be very important as a spawning locality. As seen from the egg distribution charts, only the northern part of the spawning area was covered until 1973. Figs. 9, 10 and 11 show that the area south of 57°N is very important for spawning. In 1975 the coverage of the area north of 57°N was not complete (Fig. 11). The distributions of mackerel eggs the last two years (Figs. 10 and 11) indicate that some spawning takes place south of 55°N. However, the results presented here and in JOHNSON and DAWSON (1975) show that the main spawning area for mackerel is north of 55°N.

The spawning in Skagerrak during these years is also relatively small compared to the area further west. The concentration of mackerel eggs in this area is higher along the Norwegian coast than along the Danish coast.

The distribution of zooplankton for the years 1968-1972 is shown in Figs. 12-16. These distributions are based upon plankton samples taken by Juday net (80 cm). The mackerel, which is a zooplankton

feeder, feeds during the spawning period. The distribution of mackerel eggs (Figs. 4-8) and the distribution of zooplankton the same years (Figs. 12-16) demonstrate that the mackerel spawn in areas where they can feed.

The mean surface temperature in the spawning area during the different years varies from 11.3°C in 1971 to 14.5°C in 1969 (Table 2). It is known that the mackerel spawns in waters with temperatures 12°-13°C and higher (ORTON 1920). JOHANSEN (1925) found that the spawning in the middle and northern part of the North Sea took place at 11°-14°C in June and at 13°-17°C in July. As shown in Table 3 the quantity of zooplankton in 1969 was the highest during the period 1968-1972. The 1969 year-class of the North Sea mackerel is very strong, in fact the best in several years. The year-classes from the following years are poor. The total number of mackerel eggs found during cruises in the different years (Table 4) shows that the number found in 1969 was not particularly high. Unfortunately, only the northern part of the spawning area was covered during the first years, including 1969. If eggs found north of 57°N are used as an index for the total egg production, the proportion of the mackerel stock spawning here must be constant every year. A more southern spawning one year among the others will result in an underestimated index. The spawning activity at the time of the coverage of the spawning area will also affect this estimate. The index: number of eggs without visible larval embryos/number of eggs with and without visible larval embryos (Table 4) can be used as an indication of spawning activity; a low index means that the investigation that particular year has been carried out late in the spawning season. This was the case in 1968 and 1969 (Table 4).

According to data collected by the Institute of Marine Research (unpublished) the mackerel spawning seems to last for 30 days, and the spawning activity seems to be more or less the same all through this period.

If the mackerel eggs without visible embryos are, on average, one day old, then the estimated amount of eggs without visible embryos

in the covered area is 1/30 of total production of mackerel eggs during the spawning period. In 1974 55% of the total egg amount was found south of 57°N (Table 4). In 1972, according to data in Table 4 and JOHNSON and DAWSON (1975), this proportion was again 55%. In general, 50% of the eggs seem to be spawned south and 50% north of 57°N. The total estimated amount of eggs produced in the North Sea during the spawning season (30 days) is shown in Table 5. An estimate of the size of the spawning stock can be made from data on weight and fecundity. Two estimates were made, the first by using the mean length and weight of mackerel three years of age and older caught in the Norwegian purse seine fishery in the autumn of the years referred to. This data, however, do not give a correct fish size at spawning because a large increase in weight is gained in the early autumn (CASTELLO and HAMRE 1969). In the other estimate therefore, the mean weight of the fish the autumn before the spawning has been used. The fecundities used are those estimated by the formula $y = 7.602 x^{-45510}$ given by MACER (1976) where y is the fecundity and x is the cube of the length. The results are shown in Table 5. DANIELSSEN and IVERSEN (1977) observed an average mortality of about 10% in mackerel eggs the first day after spawning at 12°C. The size of the spawning stock (Table 5) has been raised accordingly.

The stock as estimated from egg observations in 1968, 1969 and 1970 is much lower than the size the stock estimated by tagging experiments.

| | Years | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|-----------------------|------|------|------|------|------|------|------|------|
| Size of spawning stock $\times 10^{-6}$ tons | tagging experiments | 1.50 | 1.20 | 0.51 | 0.41 | 1.25 | 1.30 | 1.00 | 0.80 |
| | egg data (Table 5) | 0.39 | 0.17 | 0.18 | 0.62 | 1.51 | 1.44 | 0.94 | 1.32 |

The stock estimates from tagging include mackerel two years of age and older, and give the size at the beginning of the year (ANON 1977). As mentioned earlier the estimation of the egg numbers in 1968 and 1969 was carried out too late in the spawning season to give a proper

estimate. The estimate in 1970 is probably underestimated because of the coverage of the spawning area. This year there was lesser zooplankton north of 57°N (Table 4) than the other years, and maybe this independent types of estimates are in relatively good accordance with each other. The best years are 1972, 1973 and 1974. By including data for 1972 from JOHNSON and DAWSON (1975) these are the three years with the most comprehensive coverage of the spawning area.

SUMMARY

1. This paper deals with mackerel eggs and zooplankton data in the North Sea and some years in Skagerrak in 1968-1975 during the summer.
2. The mackerel eggs are distributed in the upper layer of the water column. Over 90% of the eggs are found in the upper 12-13 m.
3. The most important spawning area is located in the central part of the North Sea. The spawning along the coasts both in Skagerrak and the North Sea is scarce. Generally it seems in normal years that about 50% of the spawning takes place north and 50% south of 57°N.
4. The mean temperature in the covered part of the spawning area varies between 11.3°C in 1971 and 14.5°C in 1969.
5. The 1969 mackerel year-class is a very strong one, and this is a favourable year both in zooplankton- and temperature conditions.
6. The estimates of the size of the spawning stock by egg production and tagging experiments give more or less the same results. This is true when there is a proper coverage of the spawning area and the investigations is not carried out too late in the spawning period.

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Table 1 Time and area investigated the different years.

| Year | Time | THE NORTH SEA | | | SKAGERRAK |
|------|-------------------|---------------|----------|----------|-----------|
| | | 57°N-60°45'N | 56°-57°N | 55°-56°N | |
| 1968 | 17 June - 5 July | Yes | No | No | No |
| 1969 | 10 June - 8 July | Yes | No | No | Yes |
| 1970 | 8 June - 6 July | Yes | No | No | Yes |
| 1971 | 6 June - 25 June | Yes | No | No | Yes |
| 1972 | 22 June - 7 July | Yes | No | No | Yes |
| 1973 | 30 May - 18 June | Yes | Yes | No | Yes |
| 1974 | 25 May - 11 July | Yes | Yes | Yes | Yes |
| 1975 | 11 June - 11 July | Yes | Yes | Yes | No |

Table 2 The estimated numbers of mackerel eggs (including both the developmental stages) in the area the different years.

Numbers og egg x10⁻¹⁰

| Year | Area | THE NORTH SEA | | | | | | | | SKAGERRAK | index of spawning-activity | |
|------|------|---------------|---------|---------|---------|---------|------------|------------|------------|-----------|----------------------------|------------|
| | | 55-56°N | 56-57°N | 57-58°N | 58-59°N | 59-60°N | 60-60°45'N | 55-60°45'N | 56-60°45'N | | | 57-60°45'N |
| 1968 | | | | 591 | 139 | 111 | 27 | - | - | 868 | - | 0.21 |
| 1969 | | | 643 | 51 | 9 | 0 | - | - | 703 | 93 | 0.11 | |
| 1970 | | | 156 | 53 | 14 | 1 | - | - | 224 | 14 | 0.40 | |
| 1971 | | | 473 | 139 | 56 | 4 | - | - | 677 | 10 | 0.44 | |
| 1972 | | | 1121 | 170 | 31 | 4 | - | - | 1326 | 18 | 0.53 | |
| 1973 | - | 1197 | 1077 | 59 | 20 | 17 | - | 2372 | 1173 | 13 | 0.58 | |
| 1974 | 513 | 747 | 841 | 181 | 16 | 3 | 2306 | 1788 | 1041 | 58 | 0.43 | |
| 1975 | 422 | 956 | 956 | 130 | 18 | 9 | 2491 | 2069 | 1113 | - | 0.57 | |

Table 3 The mean surface temperature in the mackerel spawning area.

| Year | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|------|------|------|------|------|------|------|------|------|
| T°C | 13.5 | 14.5 | 13.3 | 11.3 | 12.8 | 12.3 | 14.0 | 11.7 |

Table 4 The estimated biomass of zooplankton in $m^3 \times 10^{-3}$ based on a single coverage of the area.

| Year | THE NORTH SEA | | | | | SKAGERRAK |
|------|---------------|---------|---------|------------|------------|-----------|
| | 57-58°N | 58-59°N | 59-60°N | 60-60°45'N | 57-60°45'N | |
| 1968 | 640 | 360 | 310 | 230 | 1540 | - |
| 1969 | 2730 | 1660 | 1310 | 510 | 8210 | 23 |
| 1970 | 660 | 230 | 270 | 120 | 1280 | 27 |
| 1971 | 740 | 830 | 300 | 180 | 2050 | 6 |
| 1972 | 970 | 450 | 790 | 330 | 2540 | 12 |

Table 5. The estimated total production of mackerel eggs in the North Sea and the size of the spawning stock from 1968 to 1975.

| Year | Total number of eggs $\times 10^{-10}$ | Mean length of spawning fish cm | Mean weight kg | Fecundity $\times 10^{-10}$ | Total number of male and female spawners $\times 10^{-6}$ | Size of spawning stock $\times 10^{-6}$ tons | Adjusted for 10% egg mortality $\times 10^{-6}$ tons | Spawning stock from tagging experiments $\times 10^{-6}$ |
|------|---|------------------------------------|-------------------|--------------------------------|--|---|---|---|
| 1968 | 12 152 | 1) 35.2 | 0.41 | 286.0 | 849.8 | 0.35 | 0.39 | 1.5 |
| | | 2) 37.1 | 0.48 | 342.6 | 709.4 | 0.34 | 0.38 | |
| 1969 | 5 152 | 1) 38.3 | 0.52 | 386.0 | 266.9 | 0.14 | 0.16 | 1.2 |
| | | 2) 35.2 | 0.41 | 286.0 | 360.3 | 0.15 | 0.17 | |
| 1970 | 5 972 | 1) 39.5 | 0.56 | 423.0 | 282.4 | 0.16 | 0.18 | 0.51 |
| | | 2) 38.3 | 0.52 | 386.0 | 309.4 | 0.16 | 0.18 | |
| 1971 | 19 858 | 1) 35.9 | 0.45 | 306.2 | 1 297.1 | 0.58 | 0.64 | 0.41 |
| | | 2) 39.5 | 0.56 | 423.0 | 938.9 | 0.53 | 0.59 | |
| 1972 | 46 848 | 1) 35.0 | 0.40 | 280.4 | 3 341.5 | 1.34 | 1.49 | 1.25 |
| | | 2) 35.9 | 0.45 | 306.2 | 3 060.0 | 1.38 | 1.53 | |
| 1973 | 45 348 | 1) 36.1 | 0.45 | 312.1 | 2 906.0 | 1.31 | 1.45 | 1.30 |
| | | 2) 35.0 | 0.40 | 280.4 | 3 234.5 | 1.29 | 1.43 | |
| 1974 | 29 837 | 1) 36.7 | 0.46 | 330.2 | 1 807.2 | 0.83 | 0.92 | 1.0 |
| | | 2) 36.1 | 0.45 | 312.1 | 1 912.0 | 0.86 | 0.95 | |
| 1975 | 42 289 | 1) 37.4 | 0.50 | 352.1 | 2 402.1 | 1.20 | 1.33 | 0.80 |
| | | 2) 36.7 | 0.46 | 330.2 | 2 561.4 | 1.17 | 1.30 | |

- 1) Data from the autumn the actual year
2) Data from the autumn the previous year

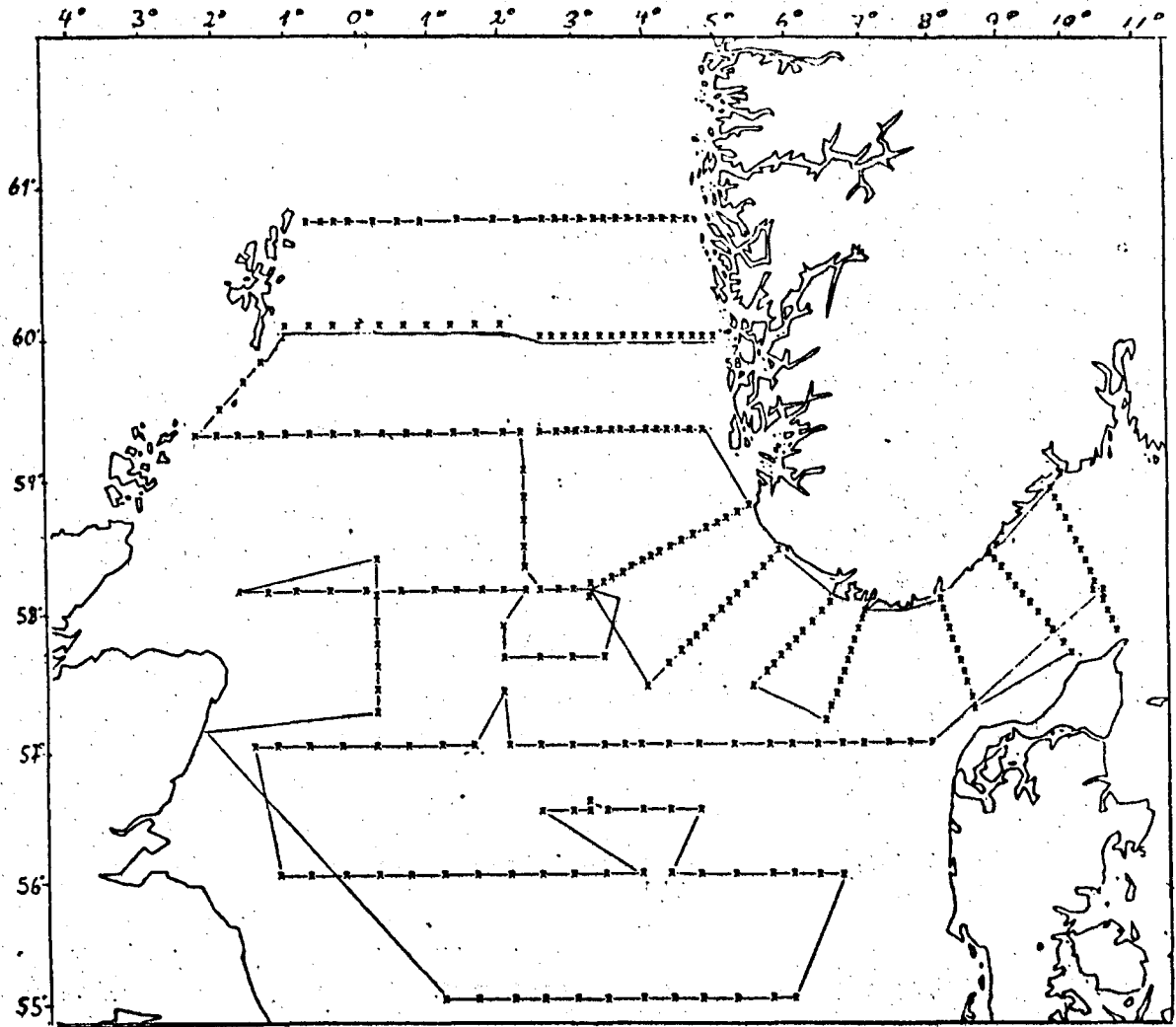


Fig. 1 The main station grids. From year to year there has been slight modifications.

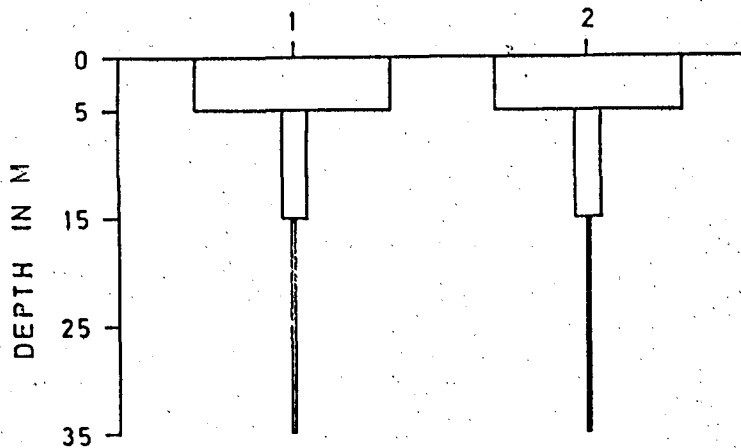


Fig. 2 The vertical distribution of mackerel eggs in the upper 35 m of the water column.
1) Eggs without visible larval embryos.
2) Eggs with visible larval embryos.

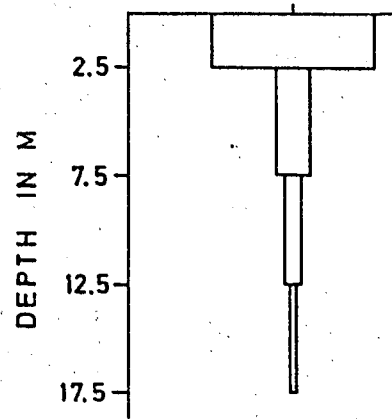


Fig. 3 The vertical distribution of mackerel eggs in the upper 17.5 m of the water column.

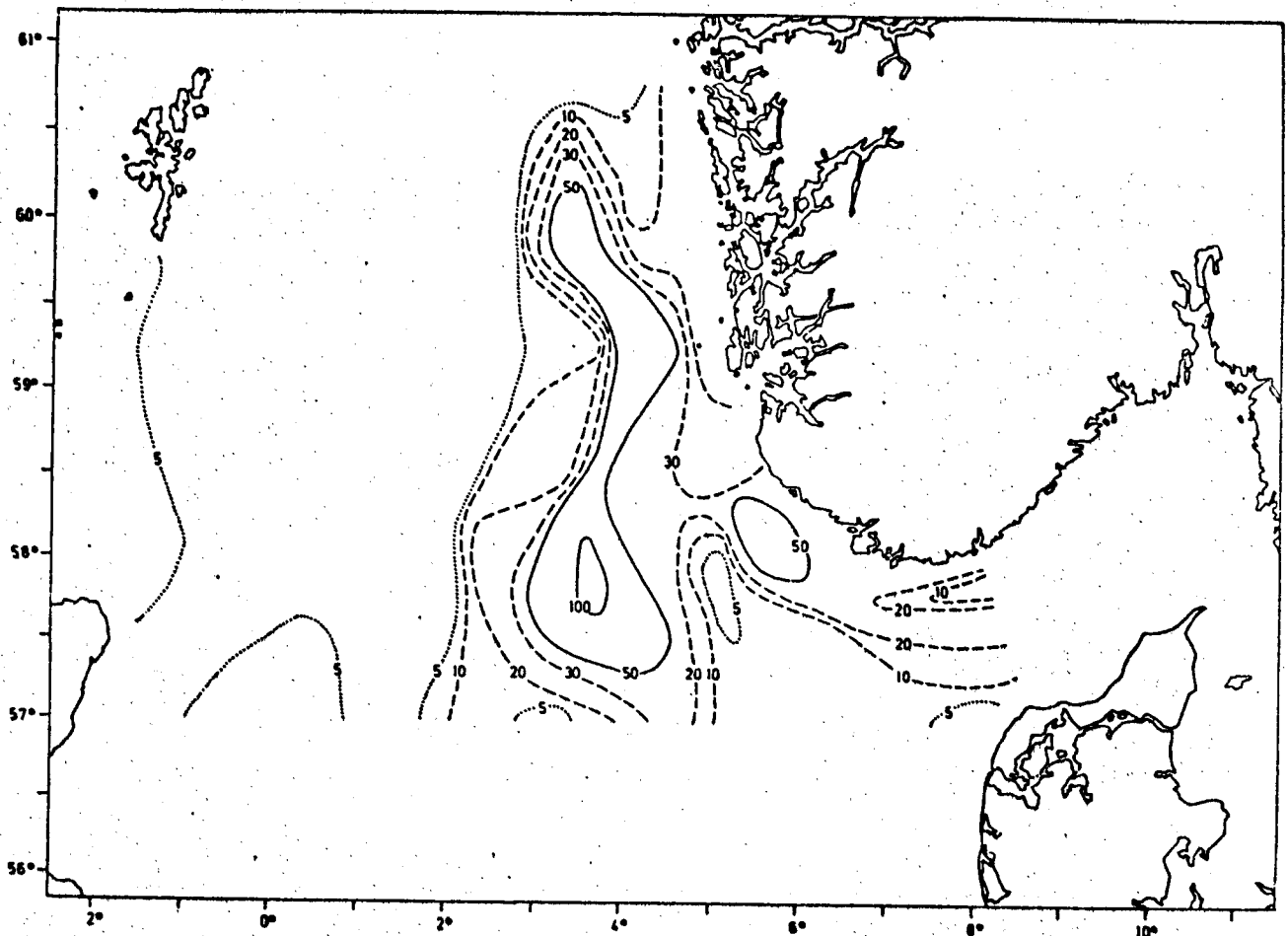


Fig. 4 The horizontal distribution of mackerel eggs without visible larval embryo in 1968.

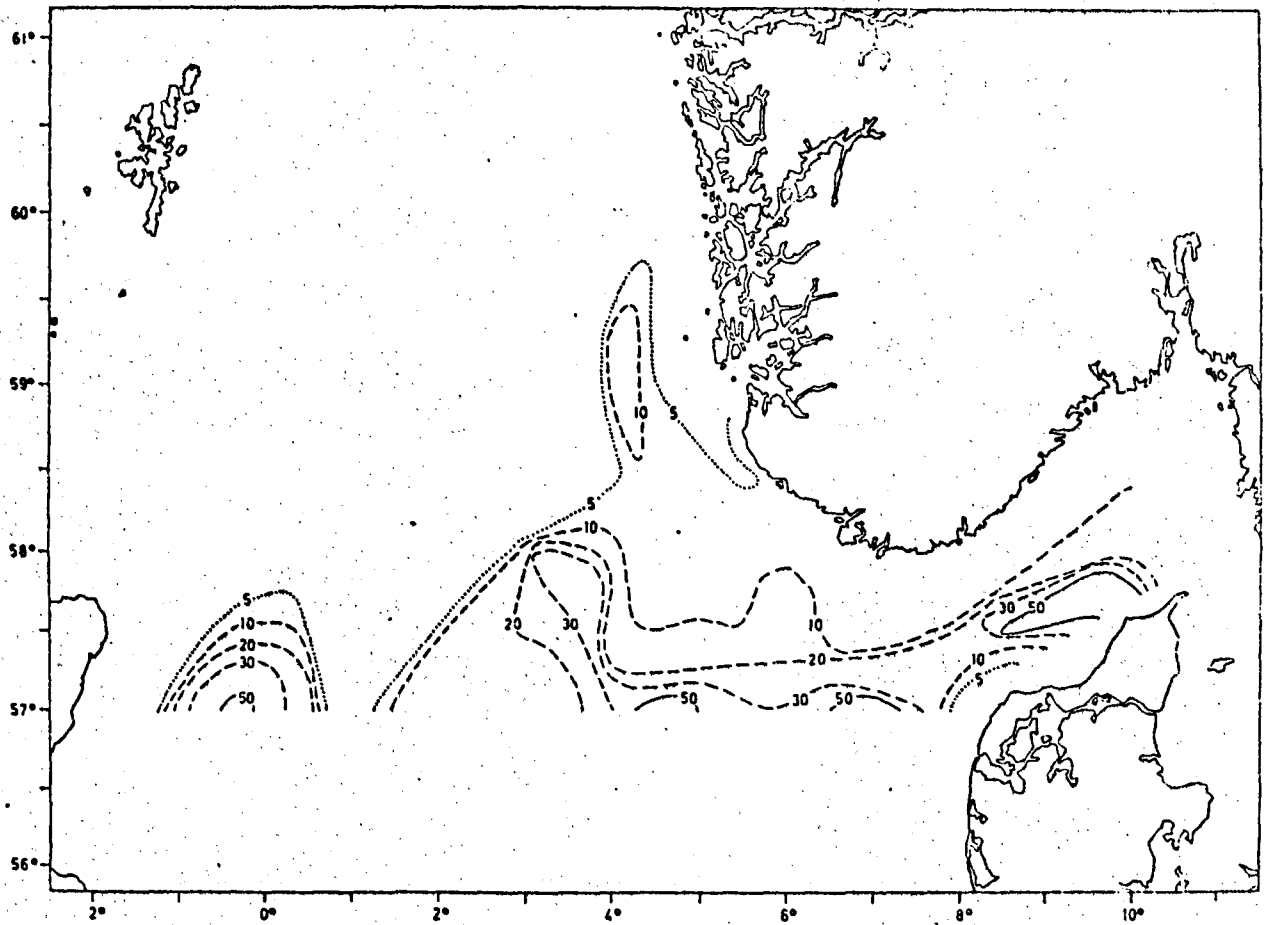


Fig. 5 The horizontal distribution of mackerel eggs without visible larval embryo in 1969.

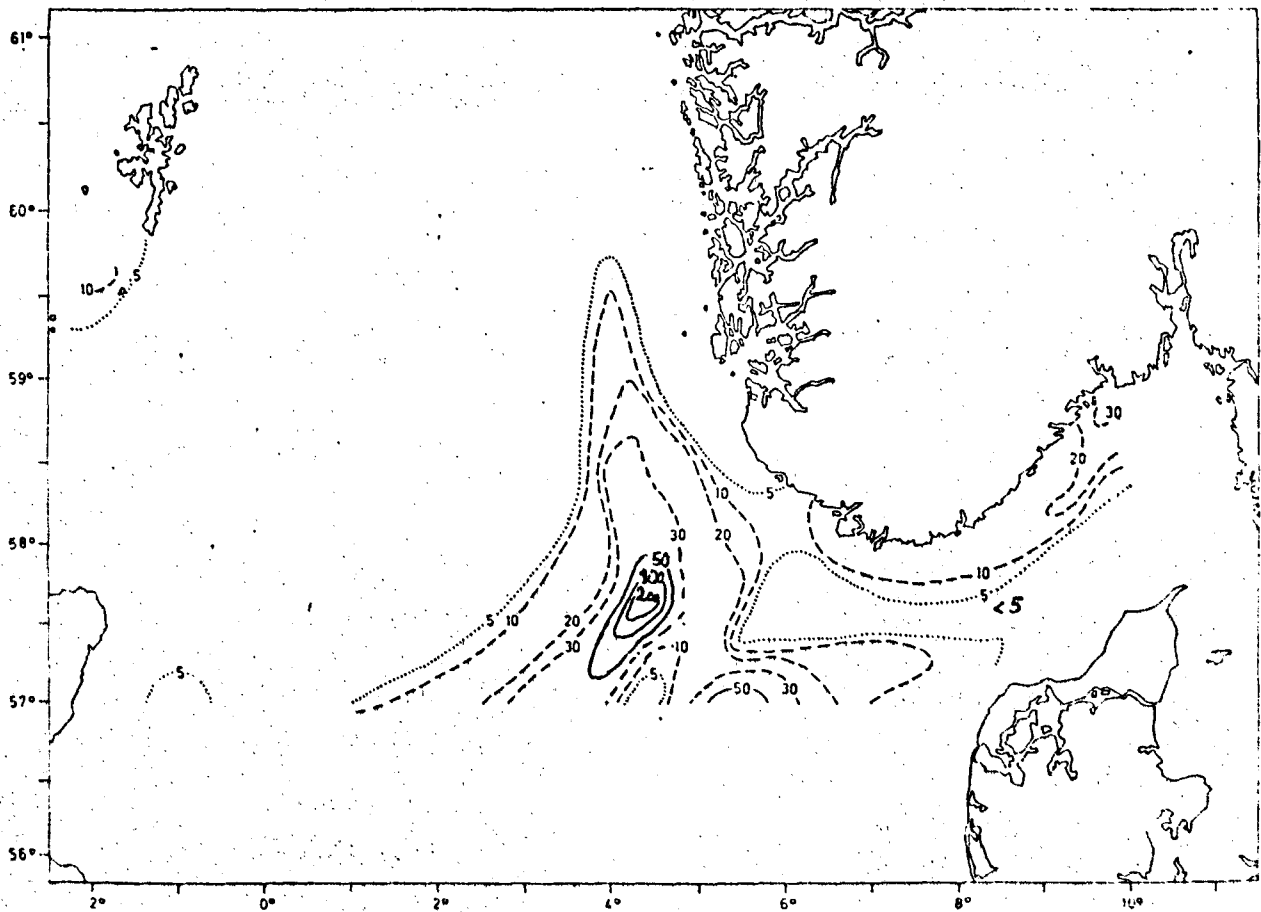


Fig. 6 The horizontal distribution of mackerel eggs without visible larval embryo in 1970.

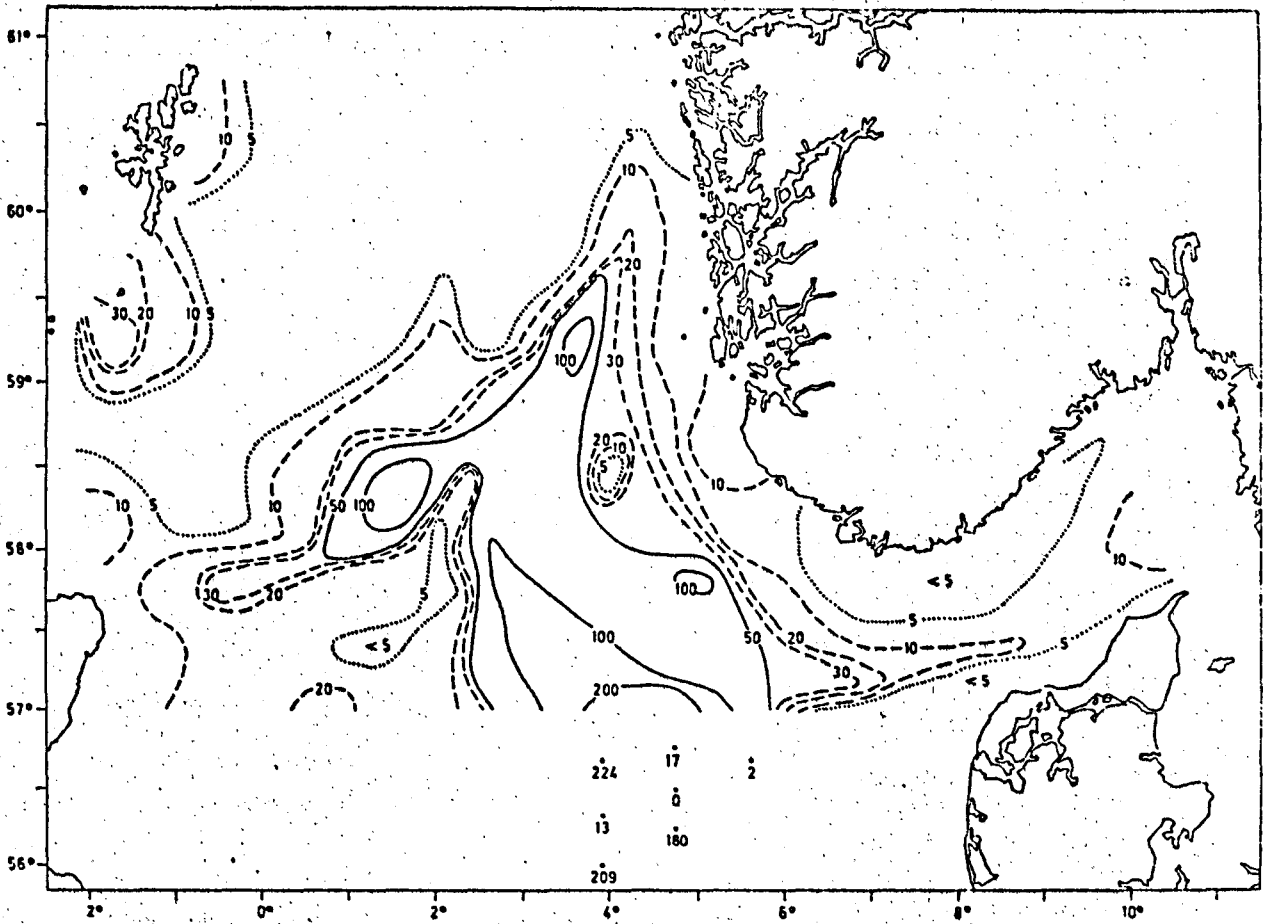


Fig. 7 The horizontal distribution of mackerel eggs without visible larval embryo in 1971.

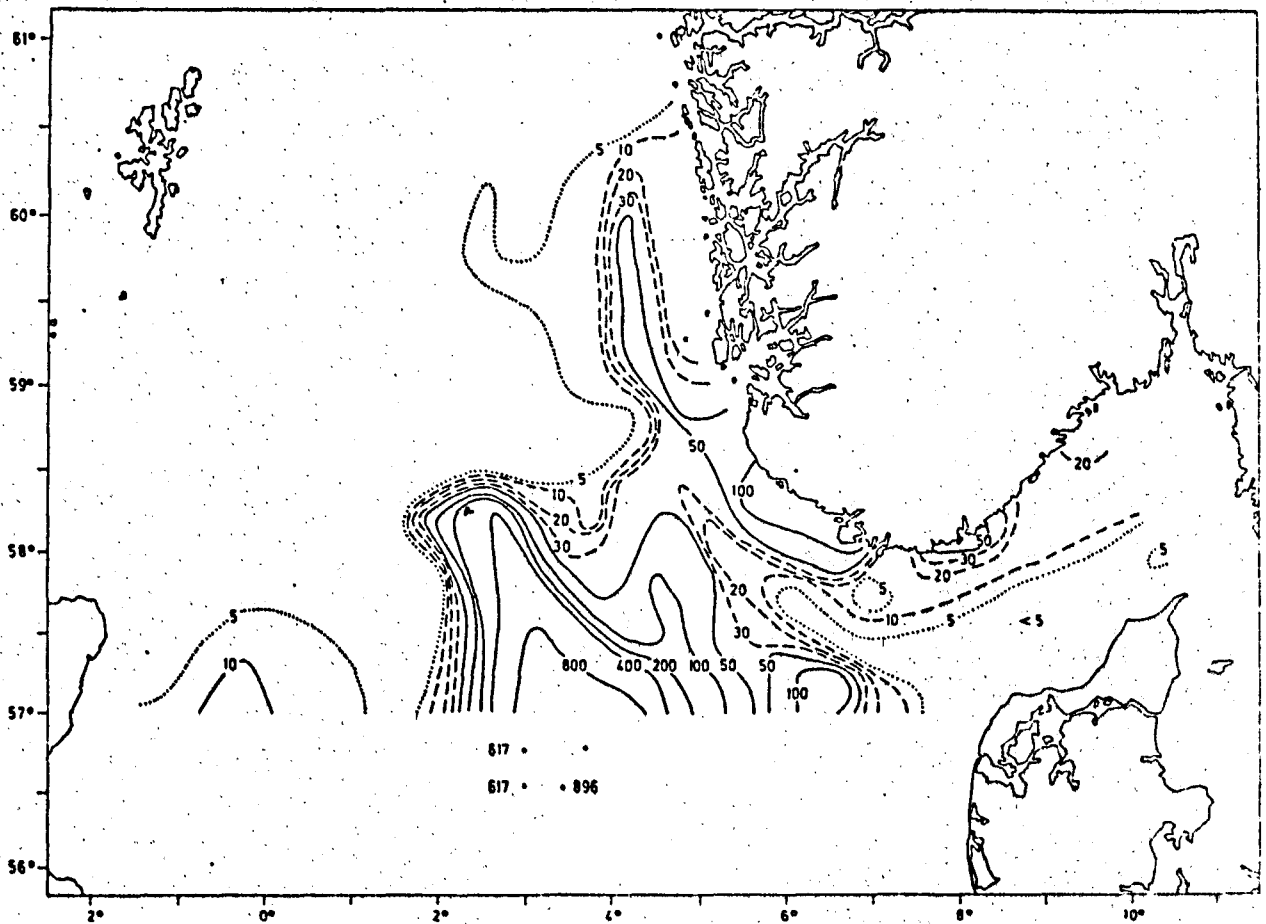


Fig. 8 The horizontal distribution of mackerel eggs without visible larval embryo in 1972.

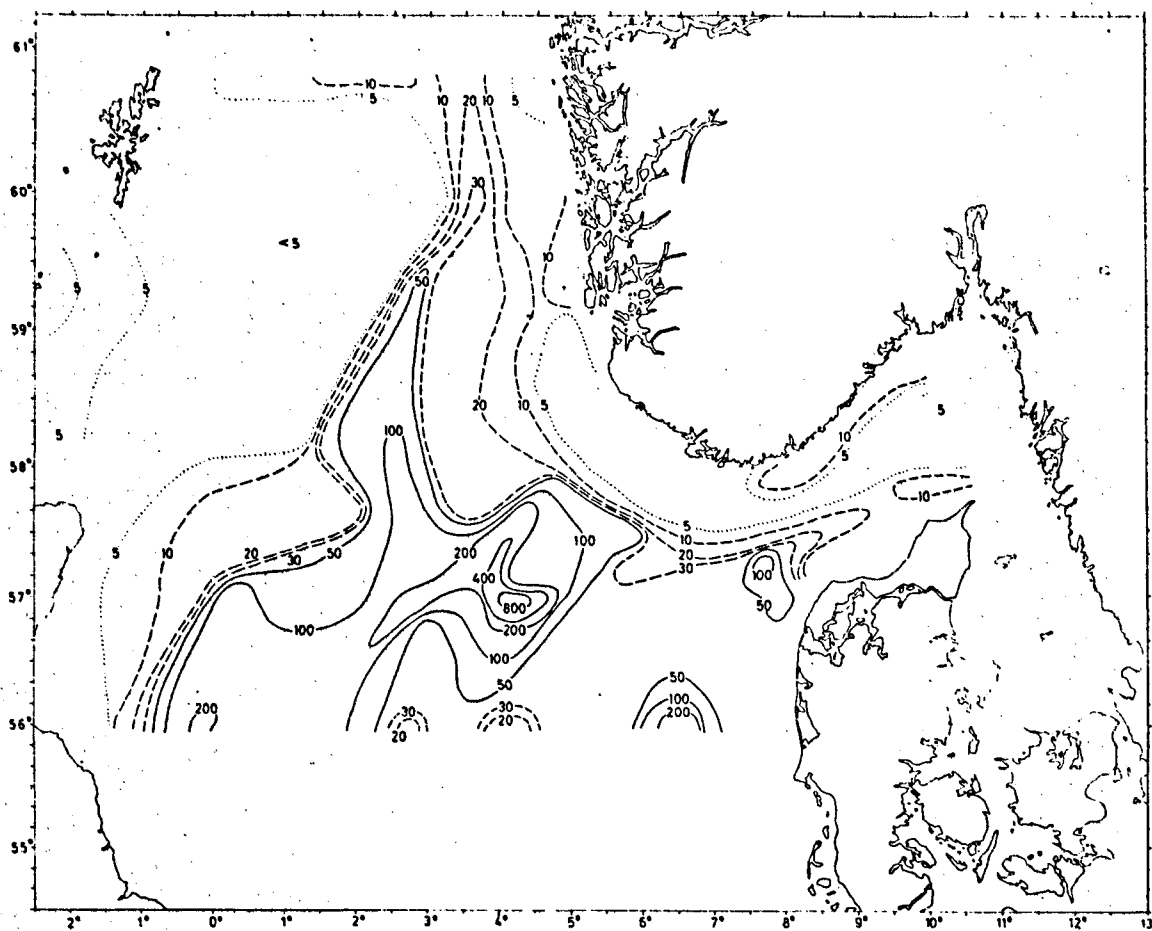


Fig. 9 The horizontal distribution of mackerel eggs without visible larval embryo in 1973.

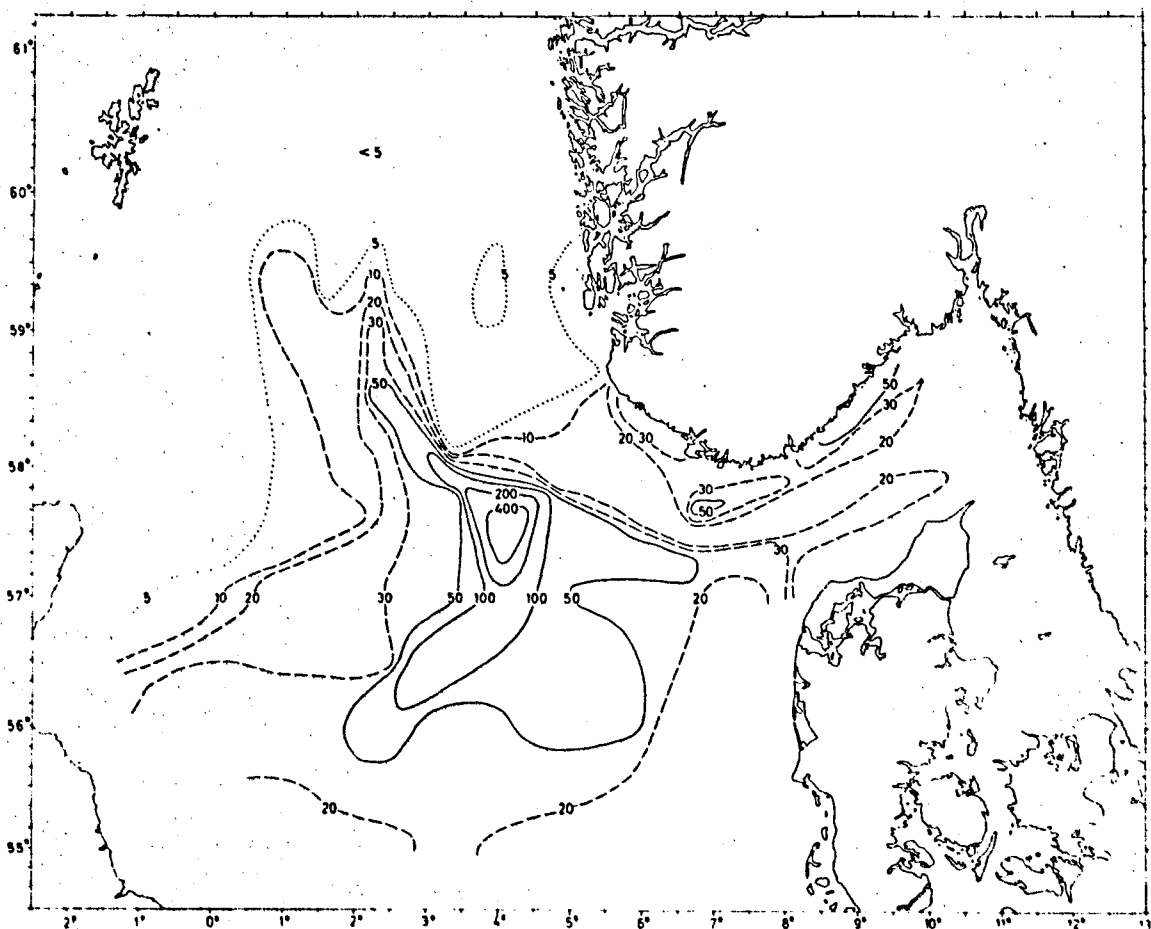


Fig. 10 The horizontal distribution of mackerel eggs without visible larval embryo in 1974.

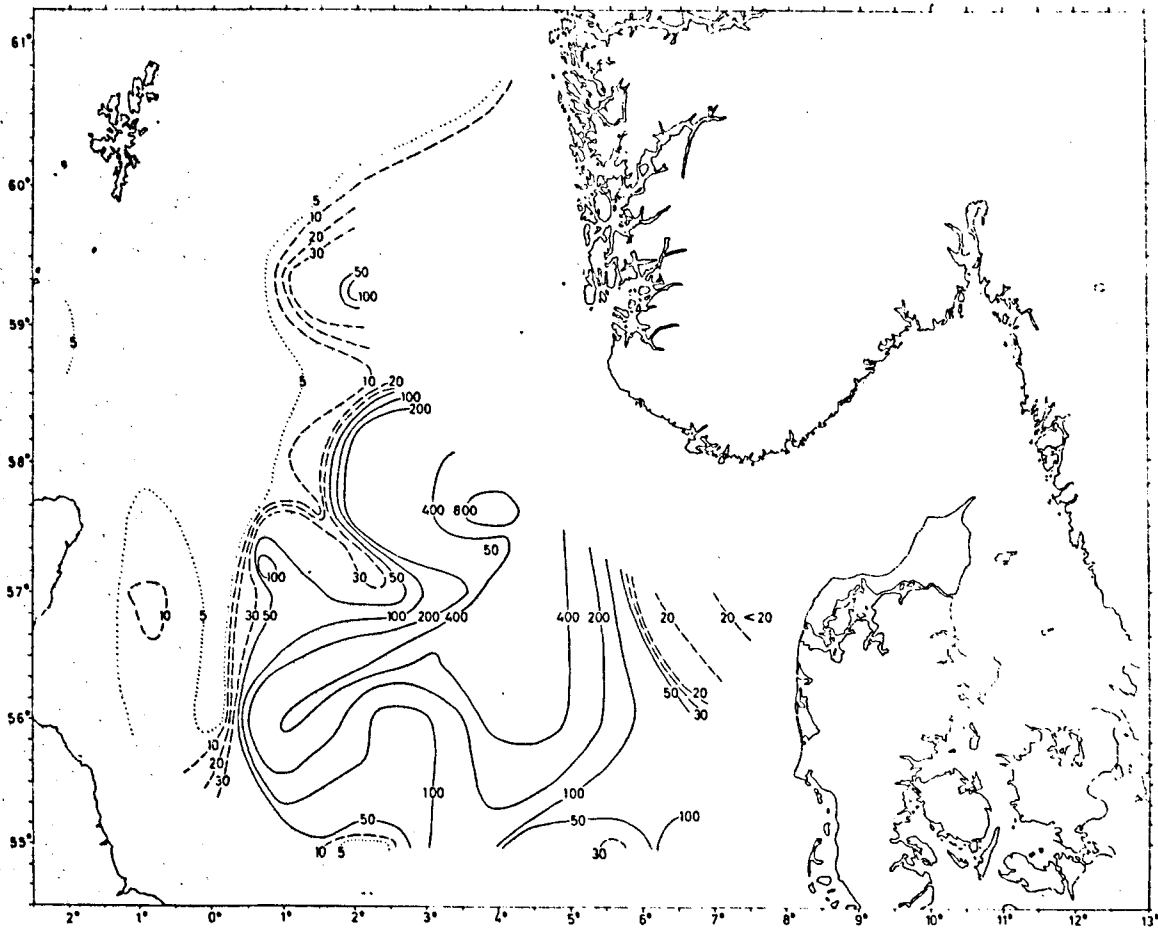


Fig. 11 The horizontal distribution of mackerel eggs without visible larval embryo in 1975.

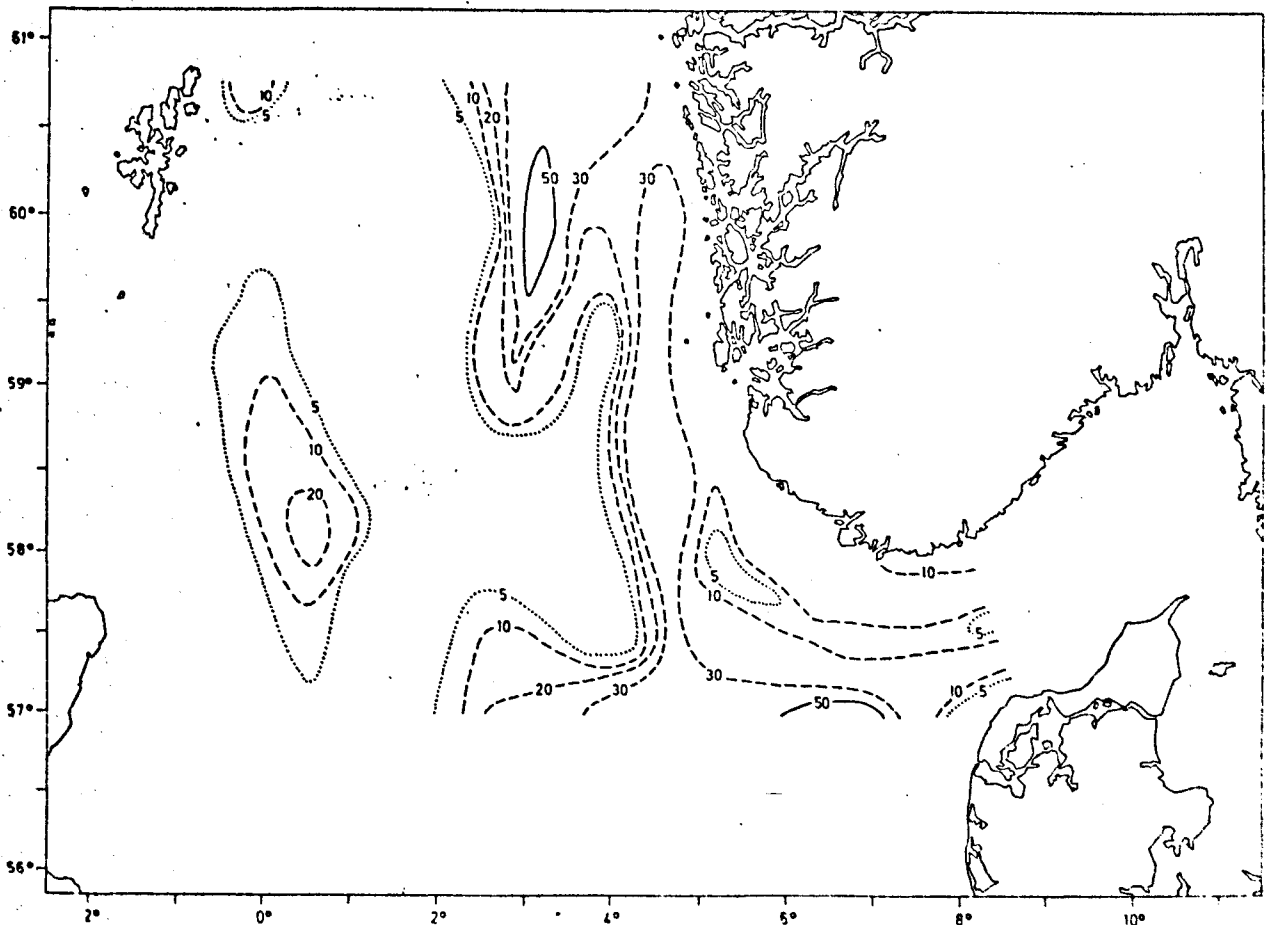


Fig. 12 The zooplankton distribution in 1968.

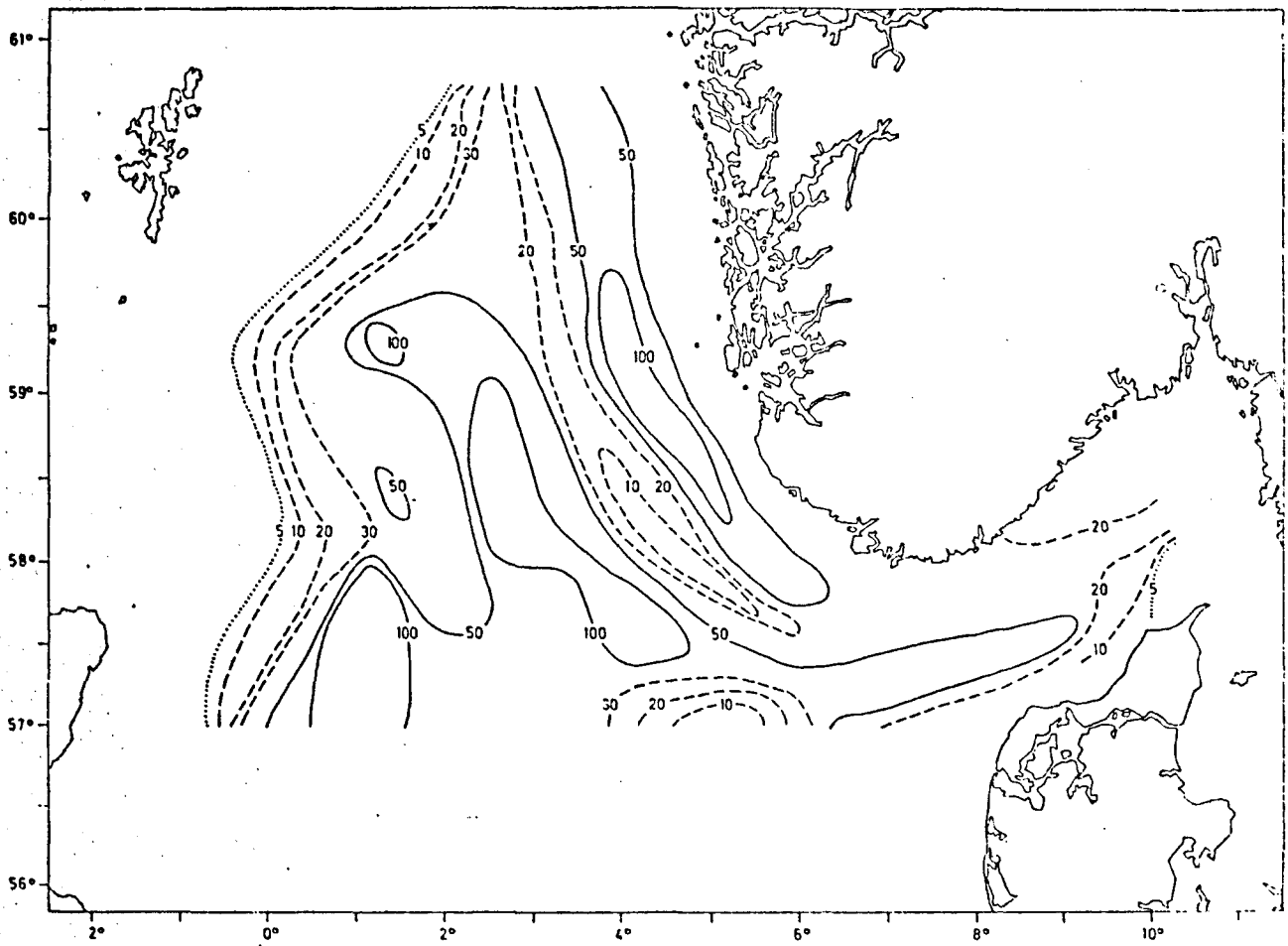


Fig. 13 The zooplankton distribution in 1969.

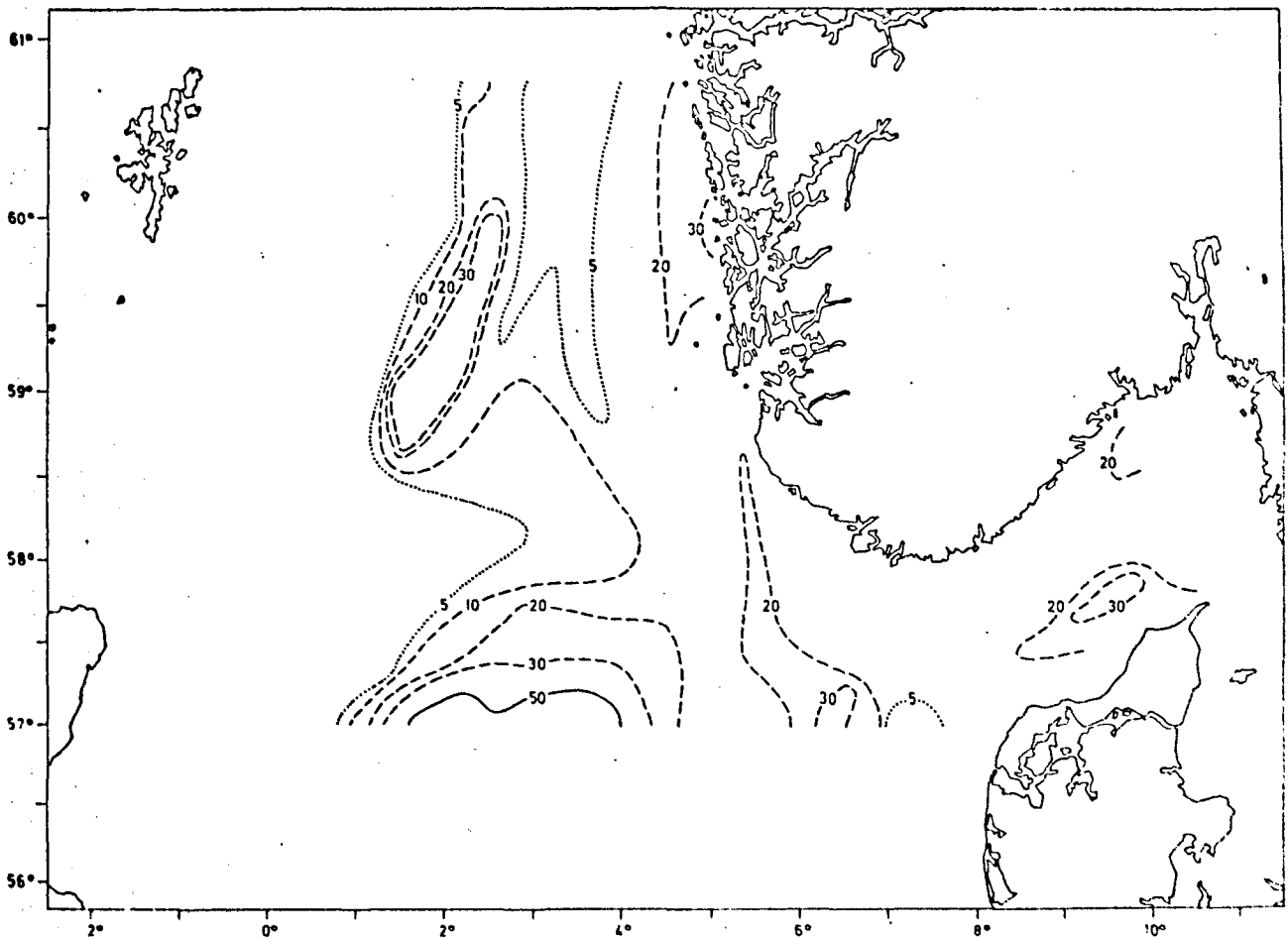


Fig. 14 The zooplankton distribution in 1970.

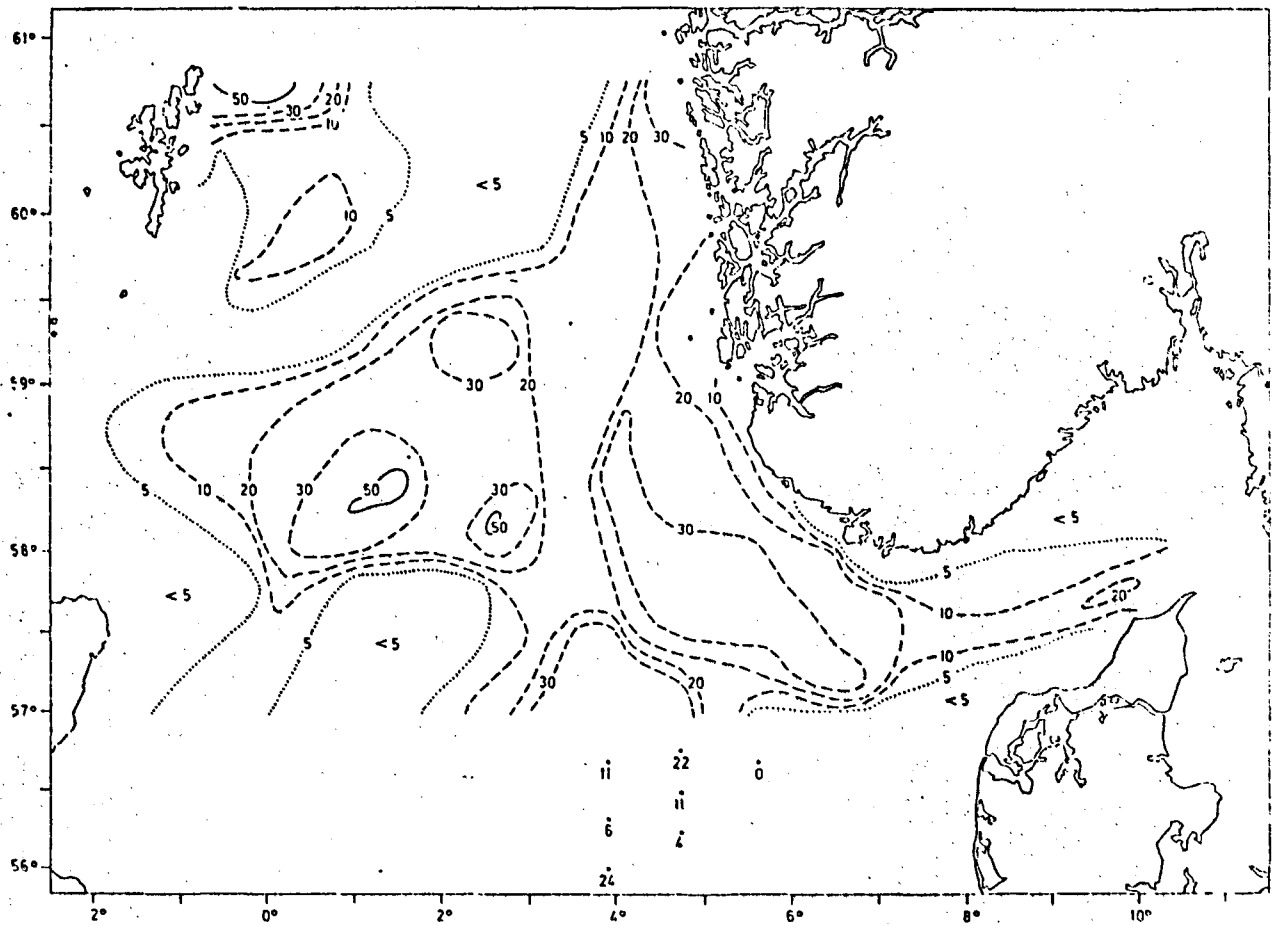


Fig. 15 The zooplankton distribution in 1971.

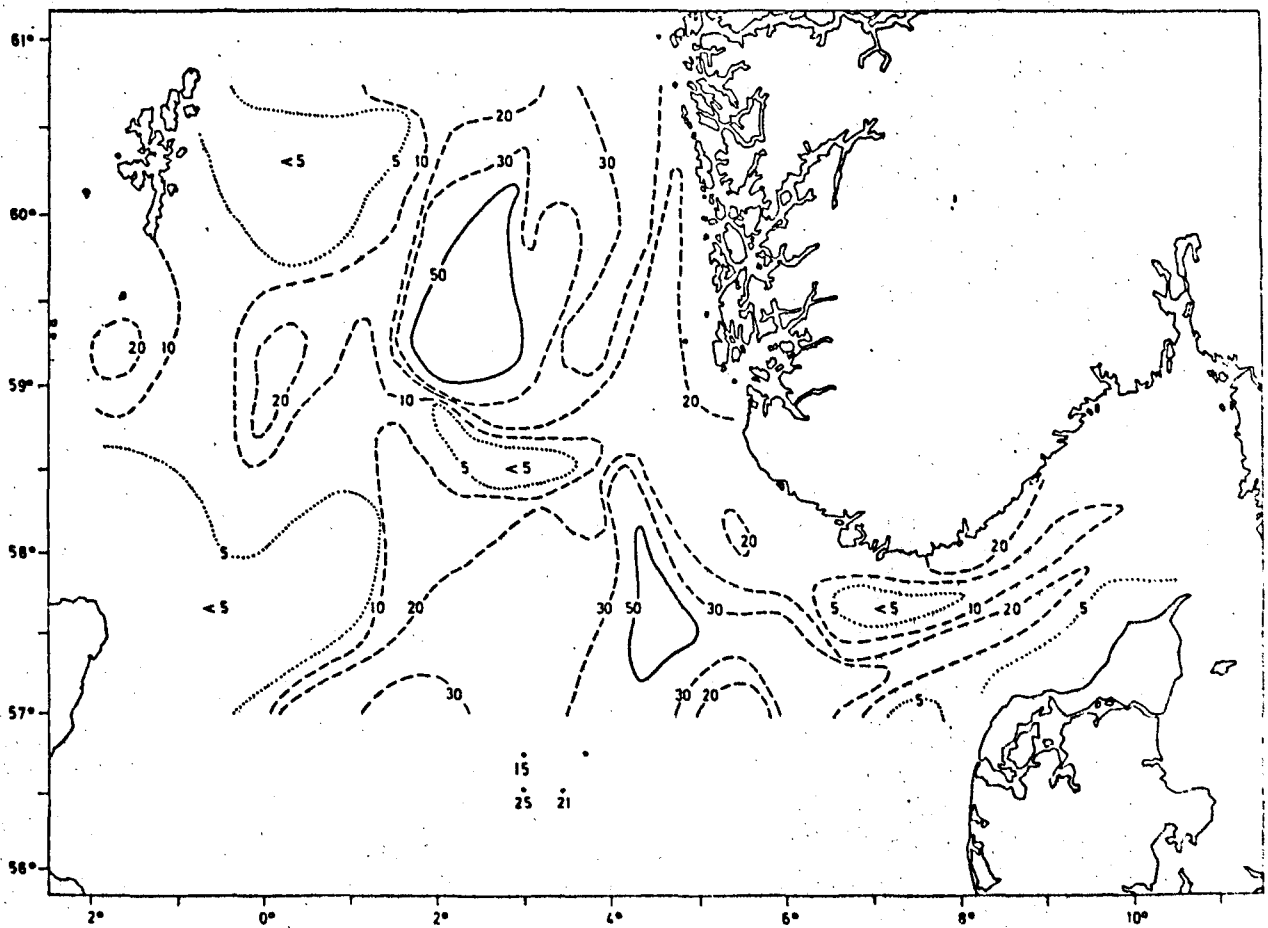


Fig. 16 The zooplankton distribution in 1972.