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THE SPAWNING AND DISTRIBUTION OF MACKEREL EGGS IN THE NORTH SEA
RELATED TO THE HYDROGRAPHY

by

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ABSTRACT

The distribution of mackerel eggs in the North Sea have been studied several years to estimate the spawning stock size. During these surveys the hydrographical regime has been mapped. Spawning intensity and hydrographical data have been collected during the spawning season at fixed localities.

Some of these data are analyzed in this paper to investigate relationships between the spawning period, the geographical distribution of mackerel eggs and hydrographical parameters.

RÉSUMÉ

La distribution d'oeufs de maquereau dans la Mer du Nord s'étudie depuis plusieurs ans, avec le but de calculer la grandeur de la population de frai. Pendant ces investigations on a enregistré le régime hydrographique. L'intensité de frai et les données hydrographiques ont été collectionnées pendant la saison de frai aux lieux déterminés.

On analyse dans ce traité quelques unes de ces données pour examiner les relations entre la période de frai, la distribution géographique des oeufs de maquereau, et les paramètres hydrographiques.

INTRODUCTION

Since 1968 Norway has carried out investigations in the mackerel spawning area in the North Sea during the summer (IVERSEN, 1977, IVERSEN and WESTGÅRD, 1984).

Some general patterns as the total distribution area of mackerel eggs are rather similar from year to year, while on a smaller scale within the general distribution area there are considerable differences.

In the present study the hydrographical conditions are compared with the egg distribution obtained during the surveys in the North Sea and spawning intensities obtained at a fixed position in the Cod area.

The mackerel eggs in the North Sea are distributed in the upper part of the water column. In calm weather more than 90% of the eggs are in the upper 5 m (IVERSEN, 1973 and 1977). Earlier investigations have concluded that mackerel mainly spawn in waters warmer than 12°C, (JOHANSEN, 1925, DANNEVIG, 1948).

During the years 1968-1972 mackerel eggs in the North Sea were normally most abundant in waters warmer than 12°C and occasionally in waters as cold as about 10°C (IVERSEN, 1973).

Due to the vertical distribution of mackerel eggs the temperature in the surface layer is important both for the development and survival of the eggs. WORLEY (1933) experimented with American mackerel eggs and found the optimal survival temperature to be 16°C. Similar investigations on mackerel eggs from the stock west of UK demonstrated high survival (80-90%) over a rather wide range of temperatures, 9.7°C-15.1°C (LOCKWOOD et.al. 1981). DANIELSSEN and IVERSEN (1977) carried out

experiments with eggs from mackerel caught in Skagerrak. The experimental temperature range was 12-22°C, the best survival was observed in 12-14°C. The incubation period varies with different temperatures. Eggs from mackerel caught in Skagerrak hatched in about 6 days at 12°C and in about 2 days at 22°C.

MATERIAL AND METHODS

During the period May-August the spawning intensity has been monitored at a fixed position from a standby vessel in the Cod area. Each mid-day two replicat samples were collected by a Juday net working vertically 40-0 m. The periods of sampling are shown in Table 1. Since autumn 1979 hydrographical observations were regularly done at standard depth on the same position; during the periods with plankton sampling simultaneously with hauls every second day.

Table 1. Periods for plankton sampling at Cod (57°04'N, 02°26'E).

Year	
1981	18 May - 23 August
1982	9 May - 19 August
1983	2 May - 15 July

Unfortunately, due to technical reasons the sampling in 1983 ended 15 July. The samples were fixed and stored in 4% formaldehyde and sorted later. The mackerel eggs were sorted according to the following development stages:

- I eggs without visible embryo
- II with embryo covering < 180° of the yolk
- III with embryo covering < 270° of the yolk
- IV with embryo covering < 360° of the yolk
- V with embryo covering > 360° of the yolk

The daily spawning intensities are presented for each of the years in Figs 1-3. The intensities are expressed as the percentages of both stage I and older eggs obtained each day of the total amount of eggs collected during the sampling period.

Isopleths of temperature ($t^{\circ}\text{C}$), salinity ($^{\circ}/\text{oo}$) and stability ($10^3 \frac{\Delta \sigma_t}{\Delta z}$) from the corresponding seasons are shown in Figs 4-6.

Since 1980 the mackerel spawning area in the North Sea has been surveyed several times per season to estimate the total egg production and spawning stock size. The plankton samples are collected by a 20 cm Bongo net working stepwise five minutes in each of the depths 20, 15, 10, 5 and 0 m. The mackerel eggs were aged according to appearance of embryo or not. The stage without visible embryo includes eggs from hatching inclusive formation of the primitive streak.

Simultaneously with the biological surveys hydrographic programs were performed in order to analyse the significance of the physical milieu on the spawning and distribution of eggs and larvae. On these surveys CTD sonde were used.

RESULTS AND DISCUSSION

The size of the mackerel spawning area in the North Sea varies both within season and from year to year. During the last years the main concentrations of eggs have always been observed within the area delineated to the north by 58°N , to the south by 55°N and to the west by 1°E . Some spawning of lesser quantitative importance also takes place outside this area. Variations in egg distribution both within and outside the main spawning area are observed within and between the seasons.

Spawning conditions

The water masses in the Cod area is vertically mixed in the winter and during the summer splitted in a nearly homogenous bottom mass and a light layered upper one by a transition zone

of high stability. The stability and depth of this layer varies from one summer to the next. The Figs 4-6 demonstrate that the stability of the transition zone must approach 50 in $10^3 \frac{\Delta \sigma_t}{\Delta z}$ before the warming up of the upper masses become significant. The level and increase of the temperature also depend of the thickness of the upper mass.

In 1982 the transition zone was well developed by early June and the thickness of the layer above was in the order of 10 m, while in 1981 and 1983 a corresponding thickness was approximately 20 m and a similar stability in the transition zone occurred half a month later. This conditions caused that temperature above 12°C in the spawning layer appeared at the beginning of June in 1982 and medio July in 1981 and 1983.

The distribution of mackerel eggs obtained during the surveys the different years demonstrate that the spawning at Cod varies considerably. According to this the observed concentration of eggs in the Cod area in 1981 was poor, less than 5 eggs/m² (IVERSEN, 1982). In 1982 the concentrations in this area was considerably, as much as 100-200 eggs/m² (IVERSEN and ELTINK, 1983). In 1983 the observed abundance was much lower, but not as scarce as in 1981 (IVERSEN and WESTGÅRD, 1984). Therefore both in 1982 and 1983 it seems that the Cod area was part of the main spawning area. Due to the variability in importance of Cod as a spawning area the obtained spawning patterns may not be comparable for all the years. However, a common feature is the considerable variation from day to day even within periods of maximum spawning. This is probably caused by several factors. The mackerel spawns in several batches. If the same fish spawns over a certain period at the same spot the batches might be of different size or maybe no spawning fish are available at the sampling spot every day. As demonstrated by IVERSEN (1973) the mackerel eggs are always distributed in patches of variable size. Likely the day to day variation of the quantity might be more outstanding on the fringe than in the center of such patches, and Cod is normally situated on the western border of the main spawning area.

In spite of this short term fluctuation of the intensity the start of the main spawning evidently varies from year to year coordinated with a lower threshold of temperature 11-12°C at 10 m depth (Figs 1-3).

In 1981 the main spawning took place during the period 1-12 July, in 1982 25-29 June with a significant spawning between the 5th and 12th of the same month and in 1983 during the 29 June-14 July.

In order to describe relationship between physical processes and the spawning of eggs in the investigated area observations from 1982 are used. The area was surveyed four times during the period 2 June-30 July. The grid of CTD stations is indicated in the Figs 7-10, which show the surface temperature and salinity distribution. The distribution of mackerel eggs without embryo are shown in Figs 11-12. The spawning took place in the central and eastern part of the North Sea. Rather large patches of eggs are recognised within the spawning area.

In its broad feature the distributions of temperature and salinity in the surface represent the condition of the whole water mass above the transition layer which principally occurred between 10 m and 30 m depths.

To the south of 55°N, however, the thickness of the upper layer was less than 5 m on the first survey. The significant decrease in temperature from the first to the second survey on this sector is caused by cold water from below being mixed into the surface mass (Figs 7 and 8). It seems that this drop in temperature influenced the mackerel spawning. The egg production observed during these two surveys were rather similar. The temperature did not get below 12°C which is well above the limit for spawning. Therefore the drop in temperature just seemed to delay the spawning in giving a similar egg production rate over a larger period rather than giving a distinct maximum in spawning as observed in 1983 (IVERSEN and WESTGÅRD, 1984).

In Fig. 13 the change of surface temperature by time as observed in the years 1981-1984 is indicated, interpreted by average value between 2° and 5°E on every full latitude from 54°N to 58°N. Also intervals of monthly mean temperature according to ANON. (1962) on corresponding localities are shown. Evidently the level and variation of the surface temperature in the spawning area appear differently from year to year. In 1982 the temperature was significant higher than normal while the opposite was the case in 1981 and 1983. In the summers of these two years temperatures above 12°C did not occur before July to the north of 56°N. This is in good accordance with the development in temperature conditions at Cod.

Distribution of eggs

In the spawning season the part of the North Sea under consideration may be regarded as a two layered ocean with motion which is characteristic of such models. By experience we know that eddies of various geographic extent and permanence are distinctive features, and assumingly this motion could be a contributor to the patch-like occurrence of eggs. IVERSEN (1973) and IVERSEN et. al. (1974) demonstrated similar distribution patterns for zooplankton (mainly copepods) and mackerel eggs in the North Sea. The mackerel which is a typical plankton feeder is eating throughout the spawning season. Therefore areas with dense zooplankton concentrations will attract mackerel. The observed patchy distribution of eggs (Figs 11-12) are probably caused both directly and indirectly by the eddies. Plankton organisms and fish eggs will be concentrated due to the eddies. However, the mackerel eggs without visible embryo are less than two days old and could therefore only be transported a limited distance away from the spawning spot. Probably a more important factor causing the patchy distribution of eggs is the attraction of spawning mackerels by the high plankton abundance in the eddies.

A well stabilized mesoscale eddy is shown in Figs 14 and 15. The thickness of the upper layer increases towards the center

of the eddy where lighter water is accumulated. The eddy was traced on the fourth run and completely enveloped the distribution of eggs.

The distribution of mackerel eggs indicate that the mackerel in the North Sea prefer to spawn in water masses with salinity below 35^o/oo which is considered typical North Sea water.

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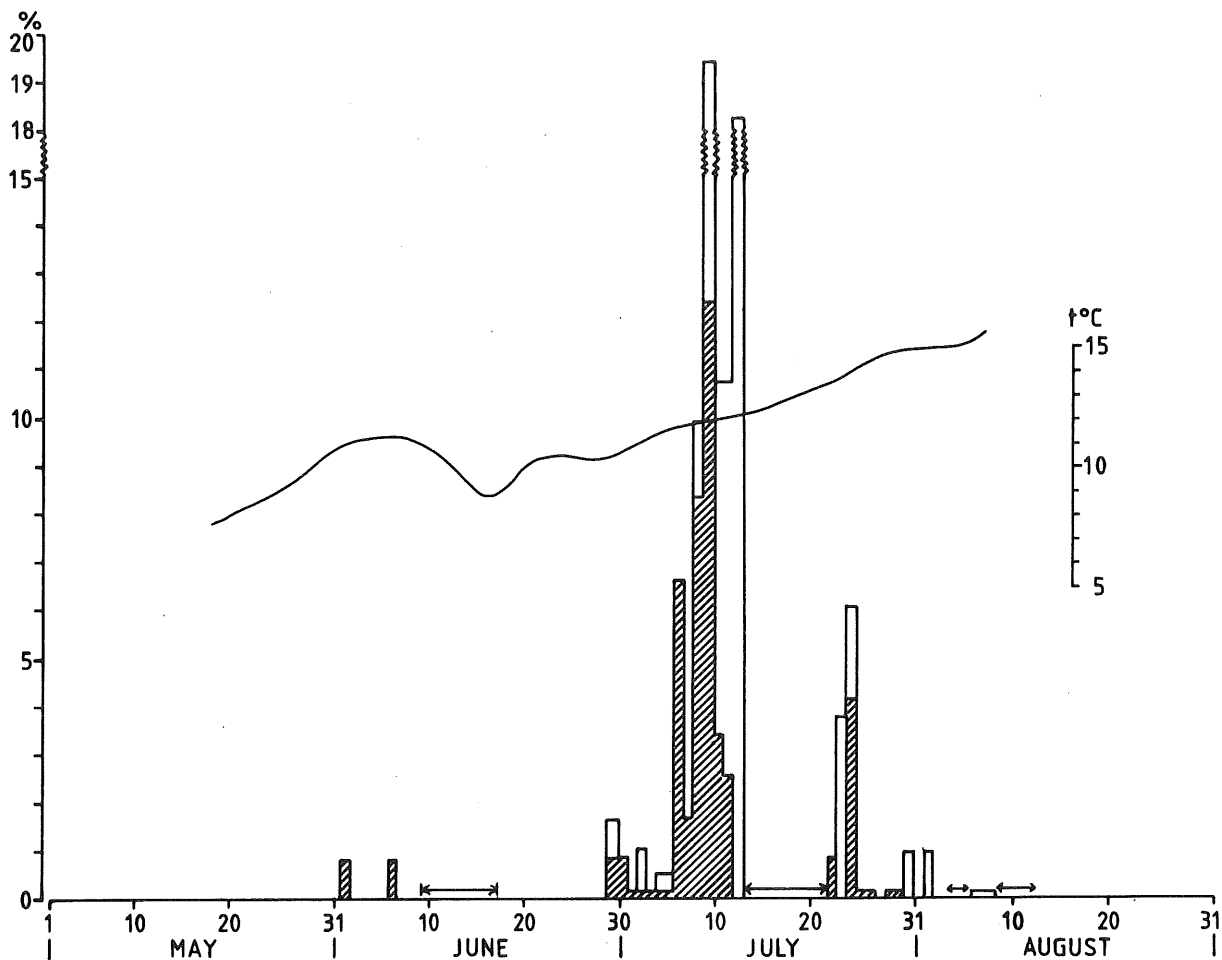


Fig. 1. Daily spawning intensity and temperature in 1981.

■ : stage 1, □ : later stages.

Full line: temperature at 10 m depth (scale to the right)

<—> : No observation.

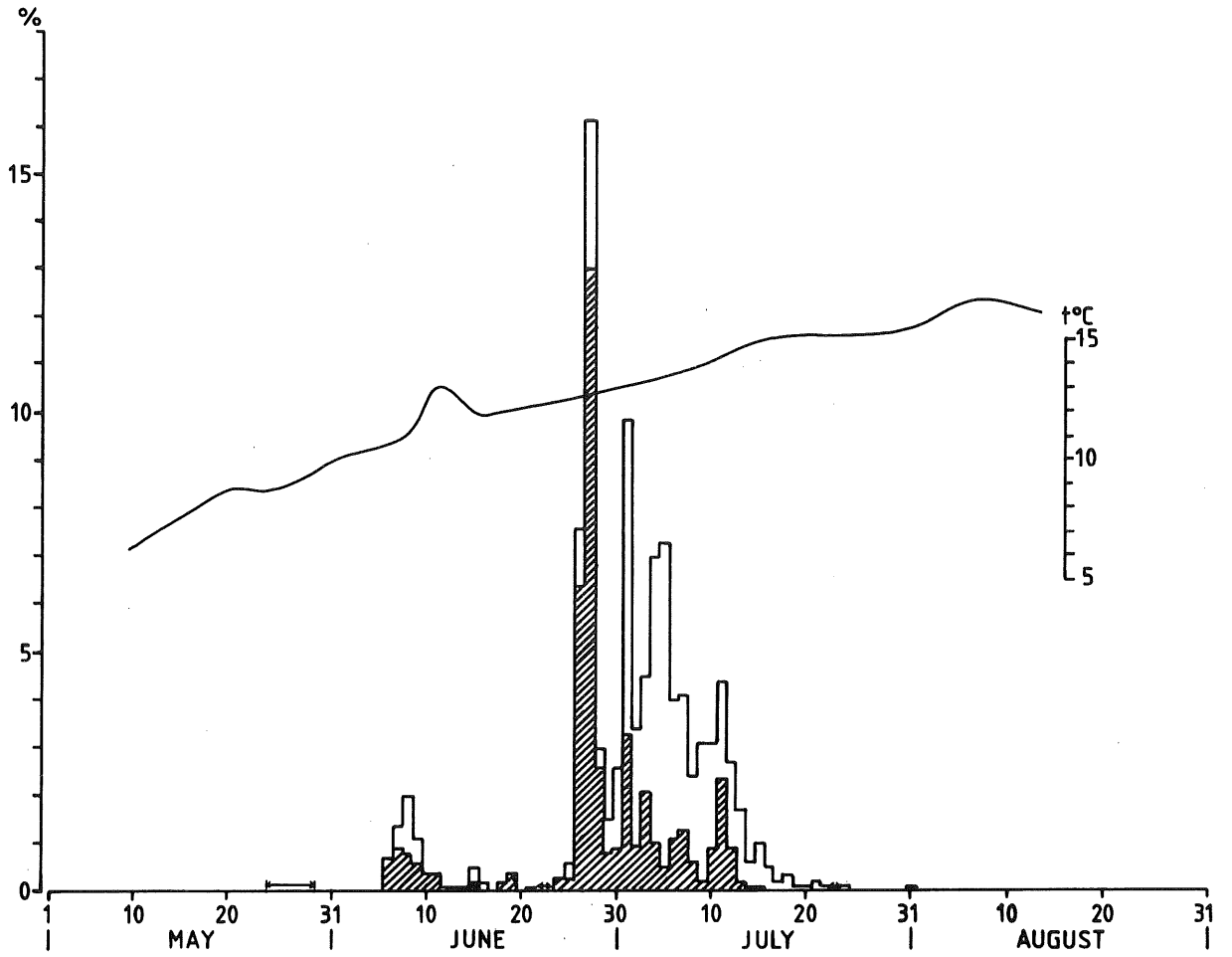


Fig. 2. Daily spawning intensity and temperature in 1982.
(For legend see Fig. 1).

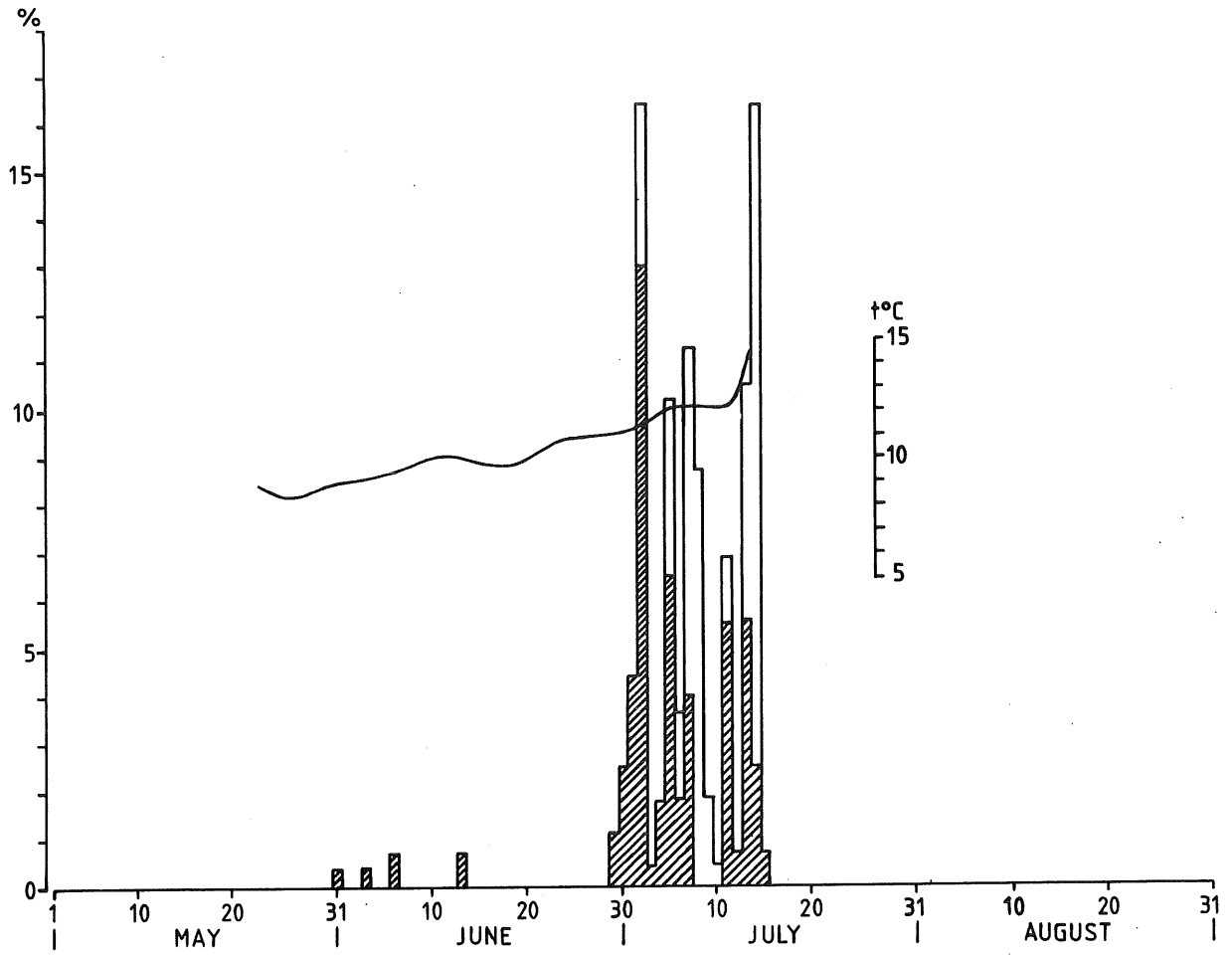


Fig. 3. Daily spawning intensity and temperature in 1983.
(For legend see Fig. 1).

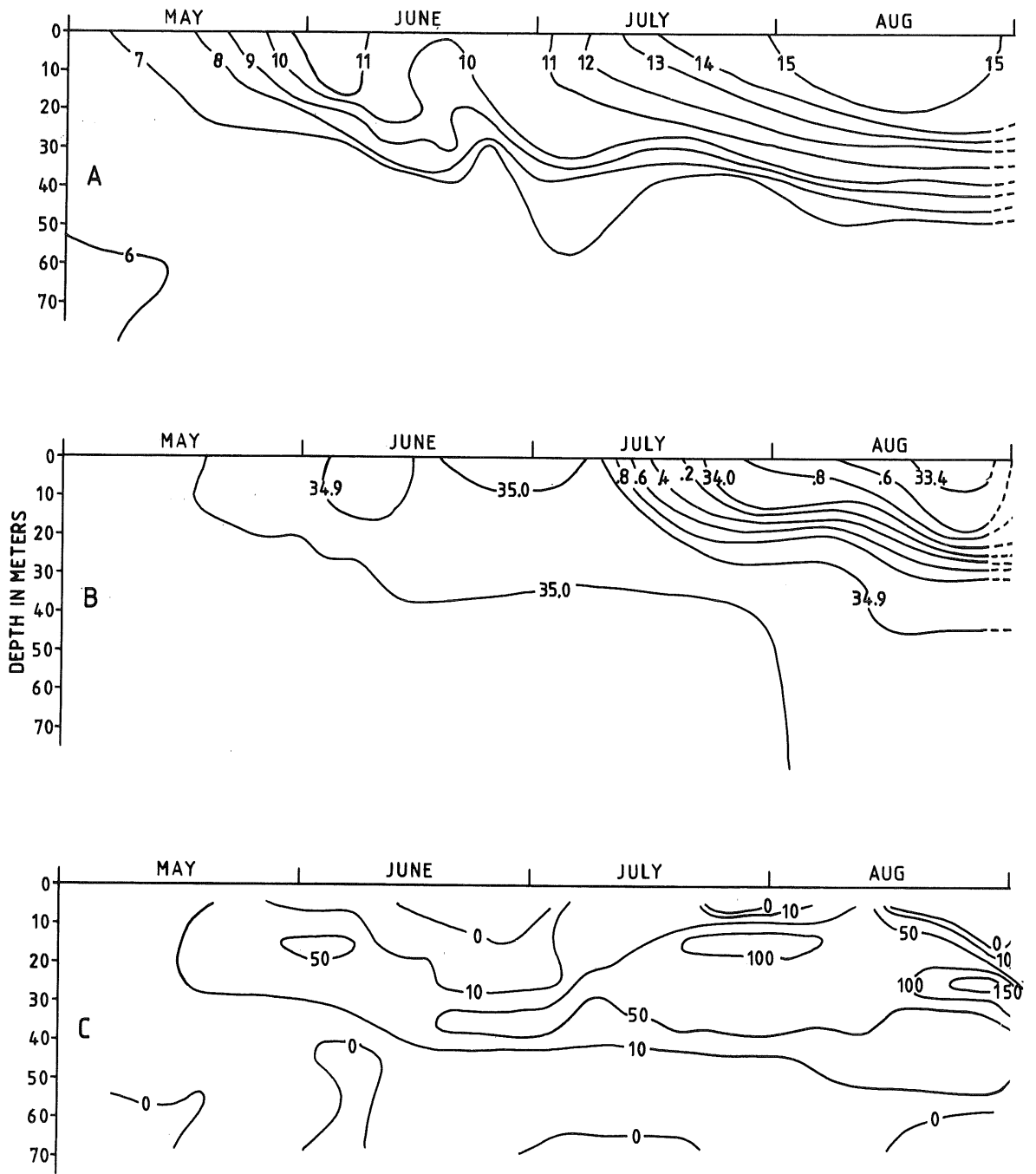


Fig. 4. Isoplet diagram from 1981:
A. Temperature, B. salinity, and C. stability ($10^3 \frac{\Delta\sigma_t}{\Delta Z}$)

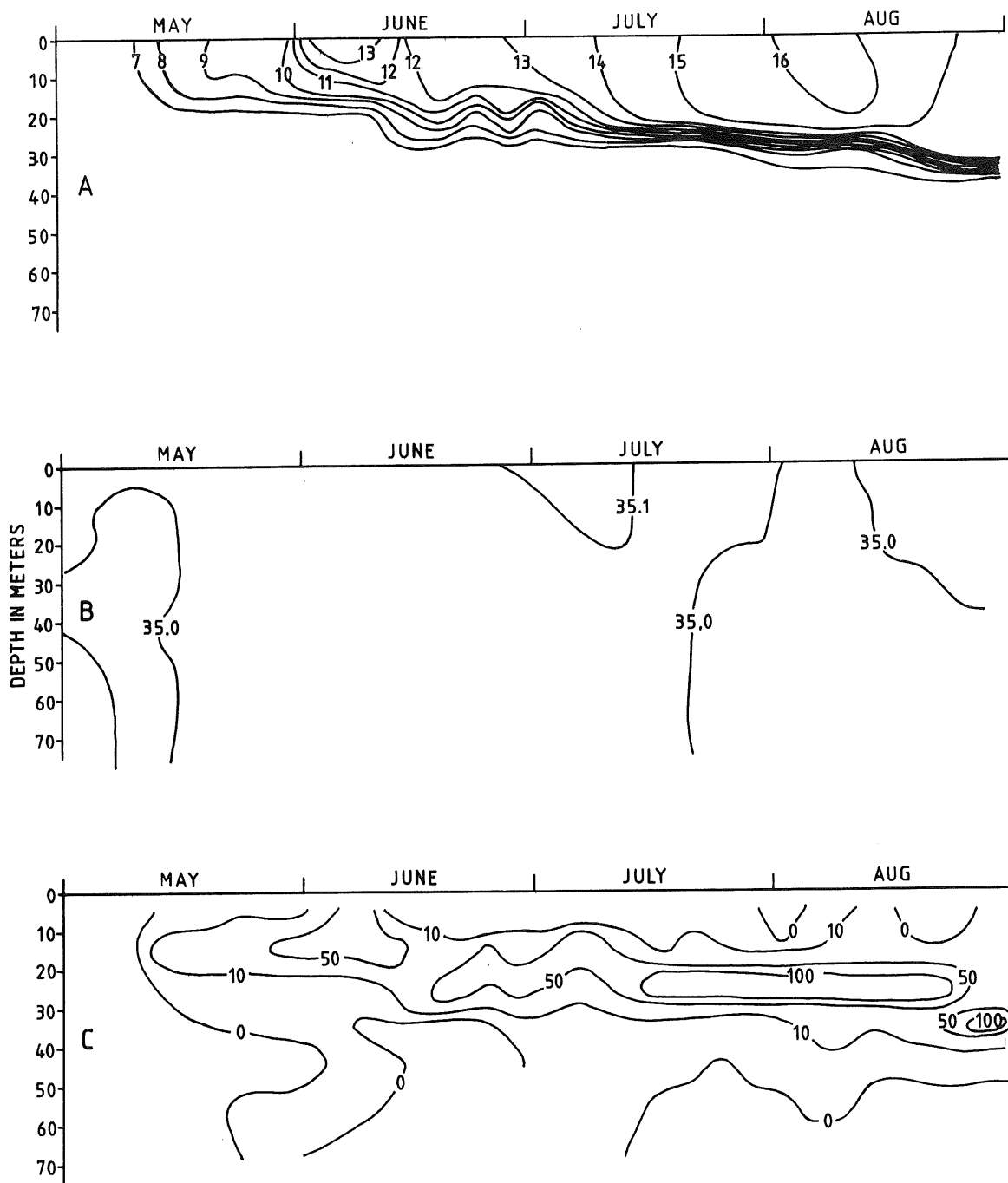


Fig. 5. Isopleth diagram from 1982:
(For legend see Fig. 4).

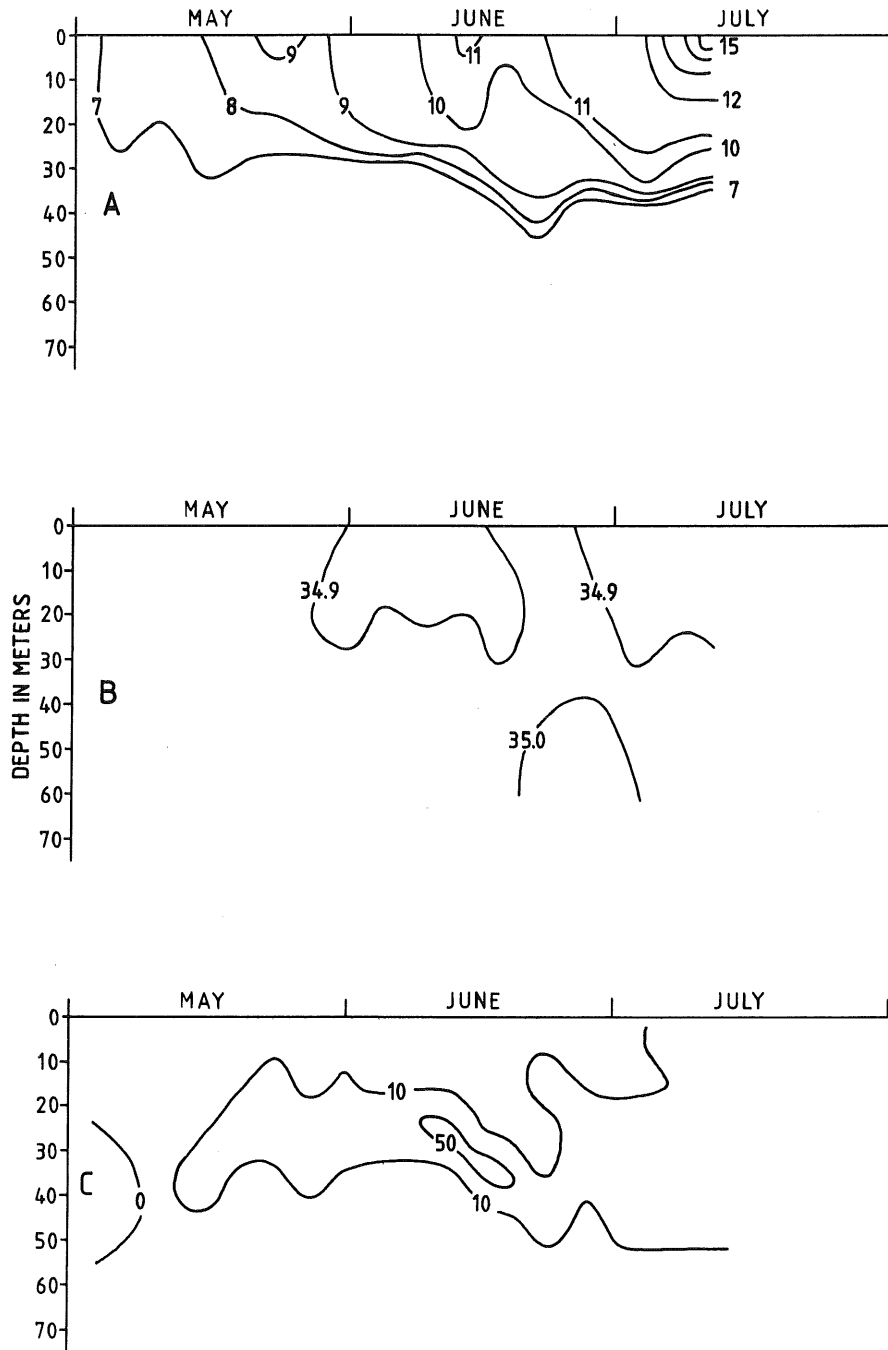


Fig. 6. Isopleth diagram from 1983:
(For legend see Fig. 4).

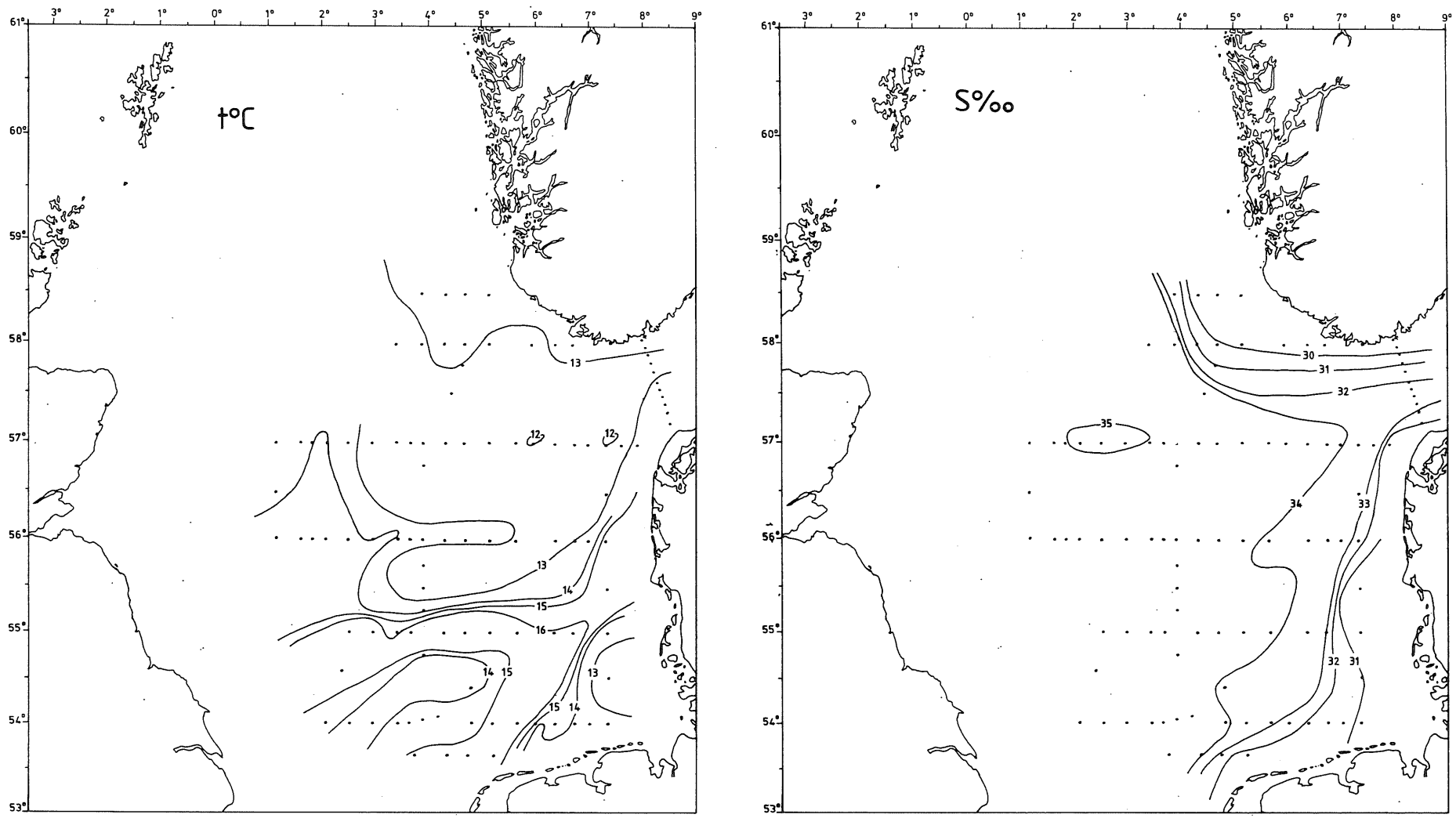


Fig. 7. Sea surface temperature and salinity of the first survey (June 2-16) 1982.
 Dots: CTD stations.

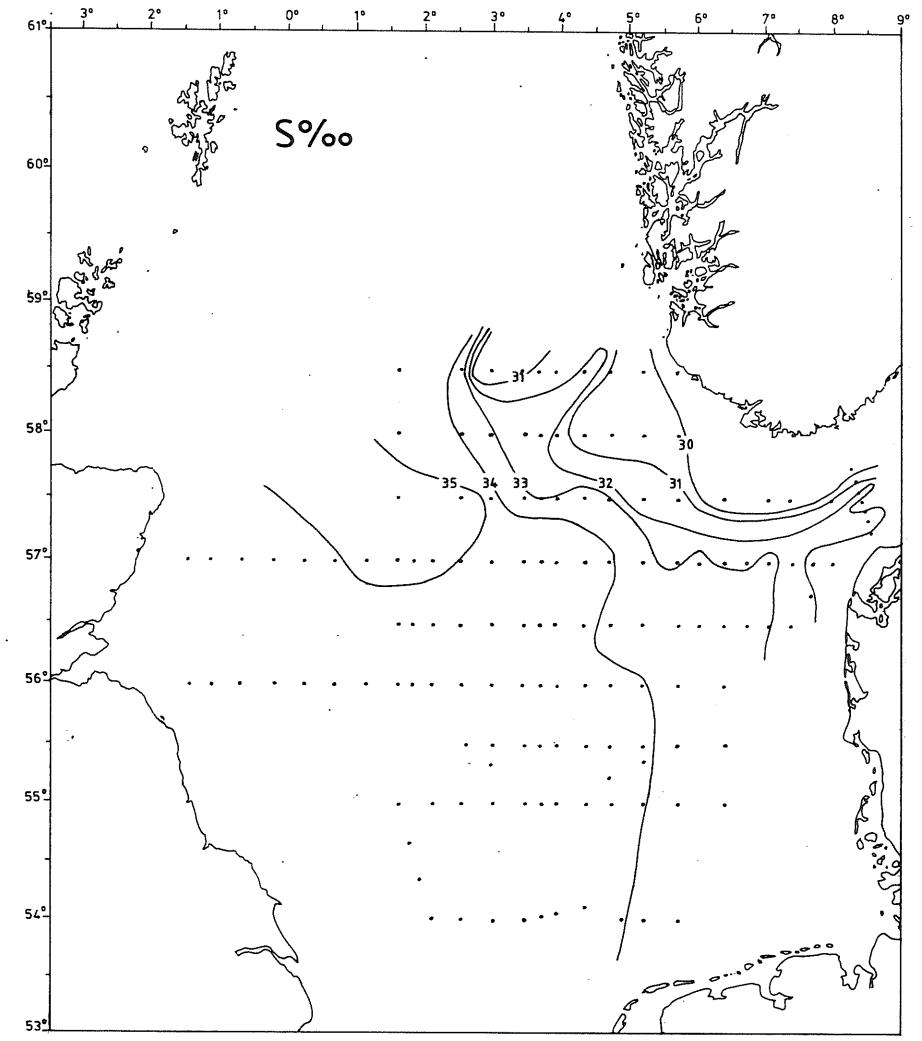
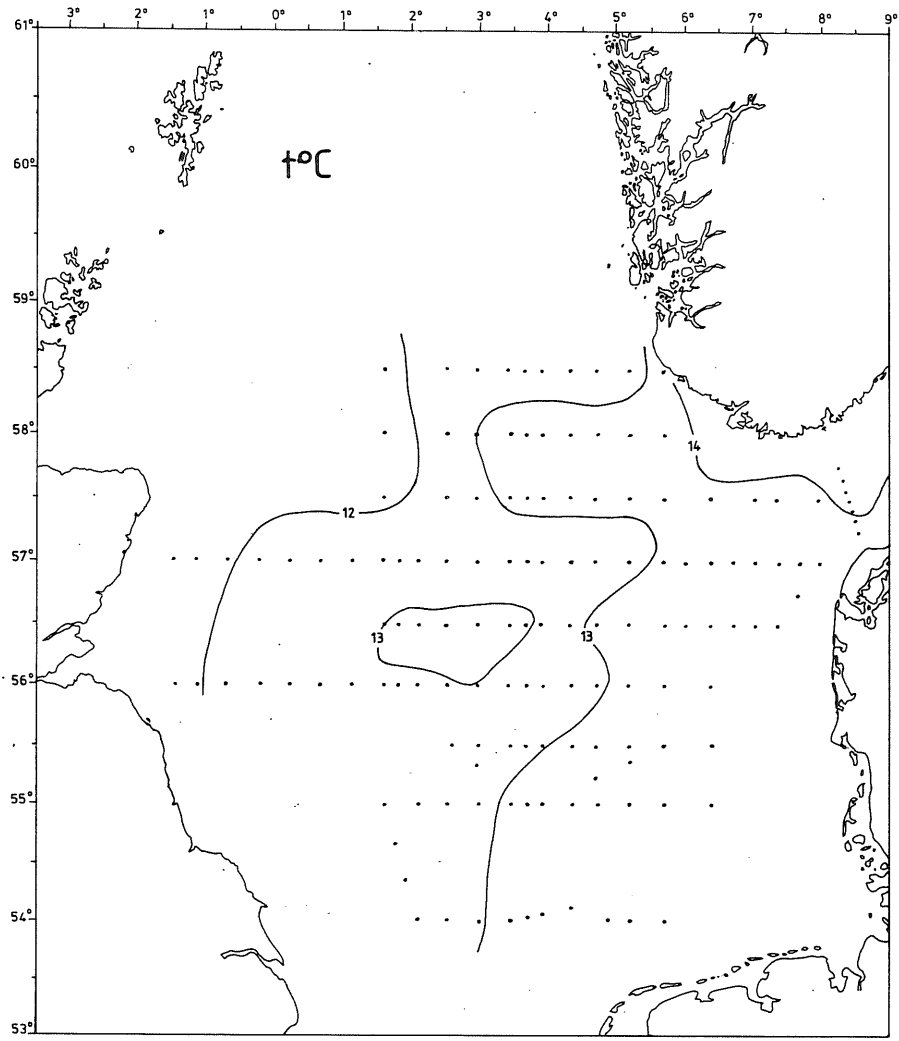


Fig. 8. Sea surface temperature and salinity of the second survey (June 16-30) 1982.

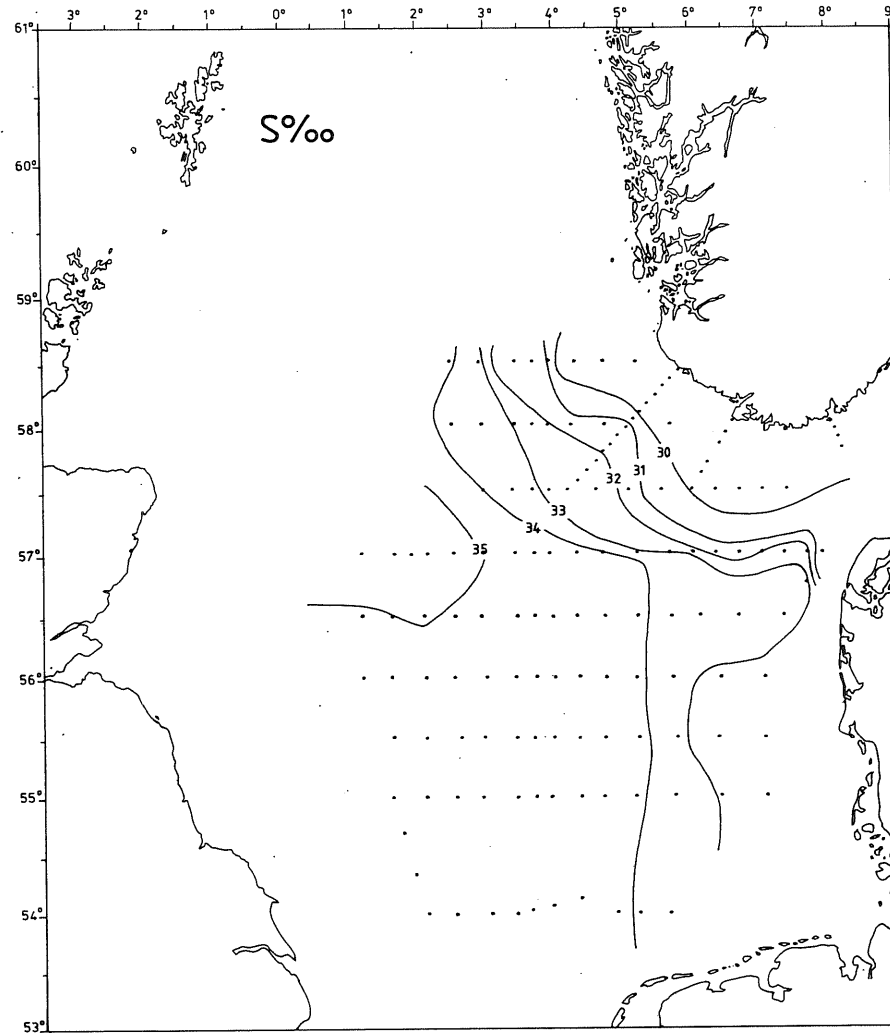
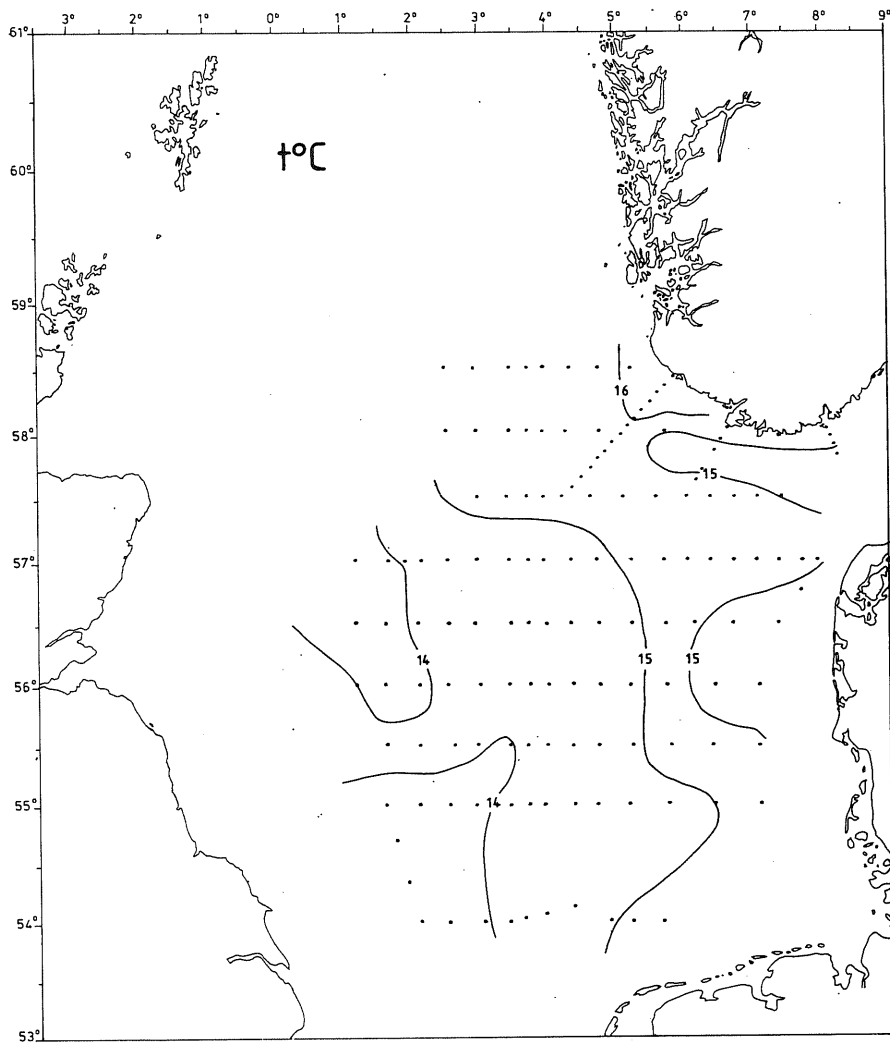


Fig. 9. Sea surface temperature and salinity of the third survey (July 1-17) 1982.

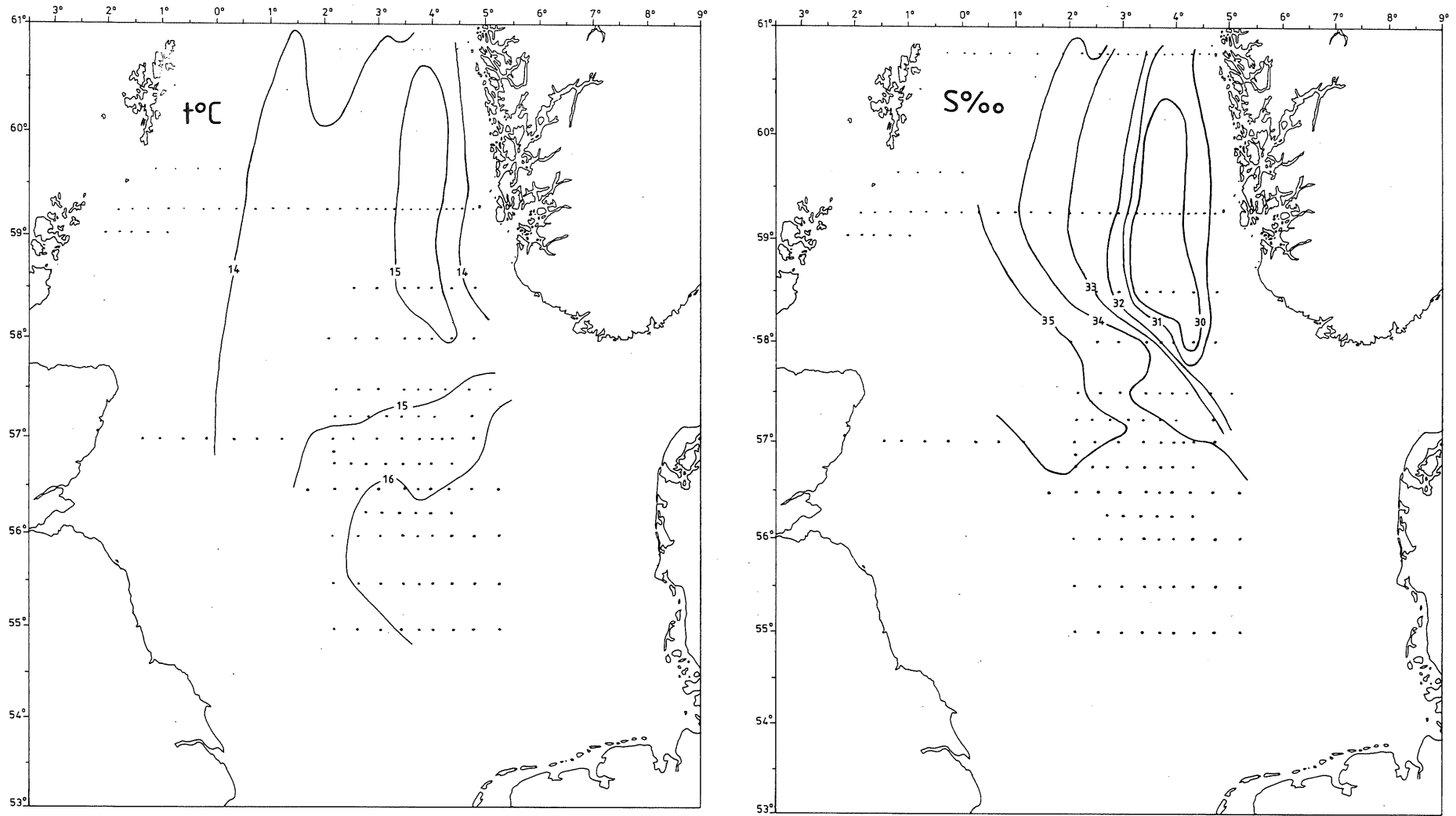


Fig. 10. Sea surface temperature and salinity of the fourth survey (July 18-30) 1982.

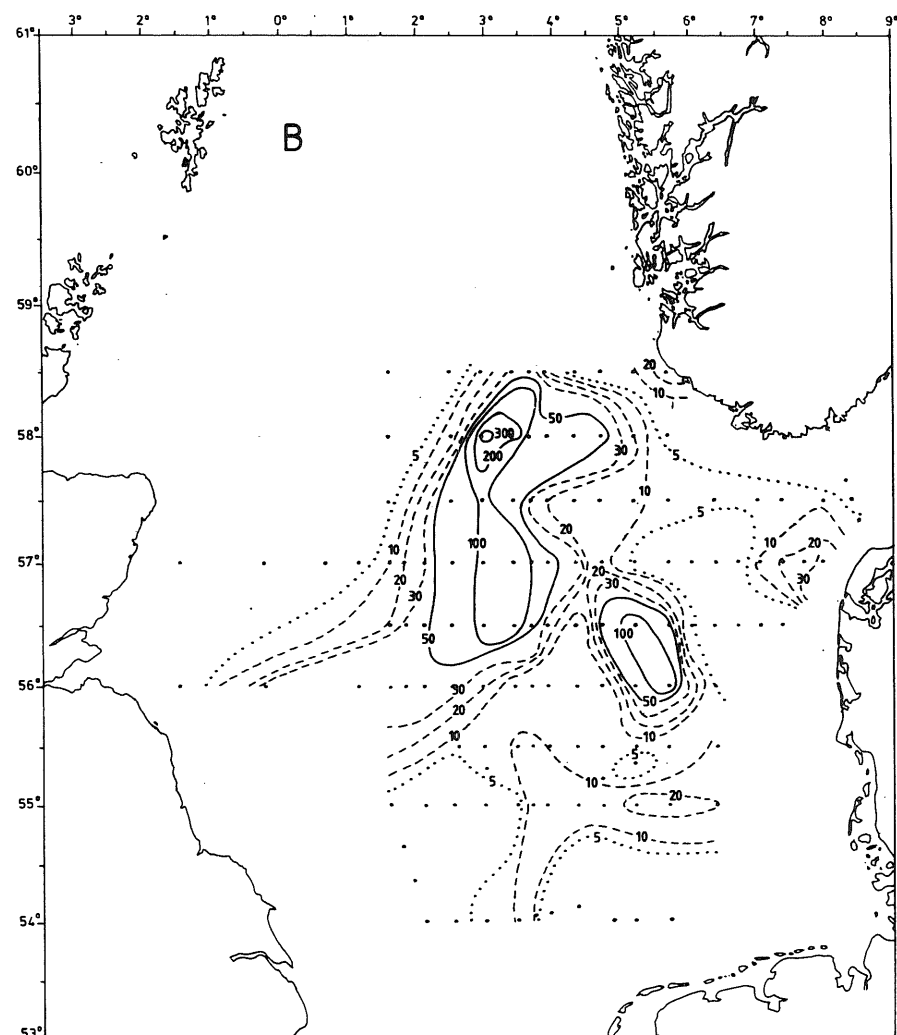
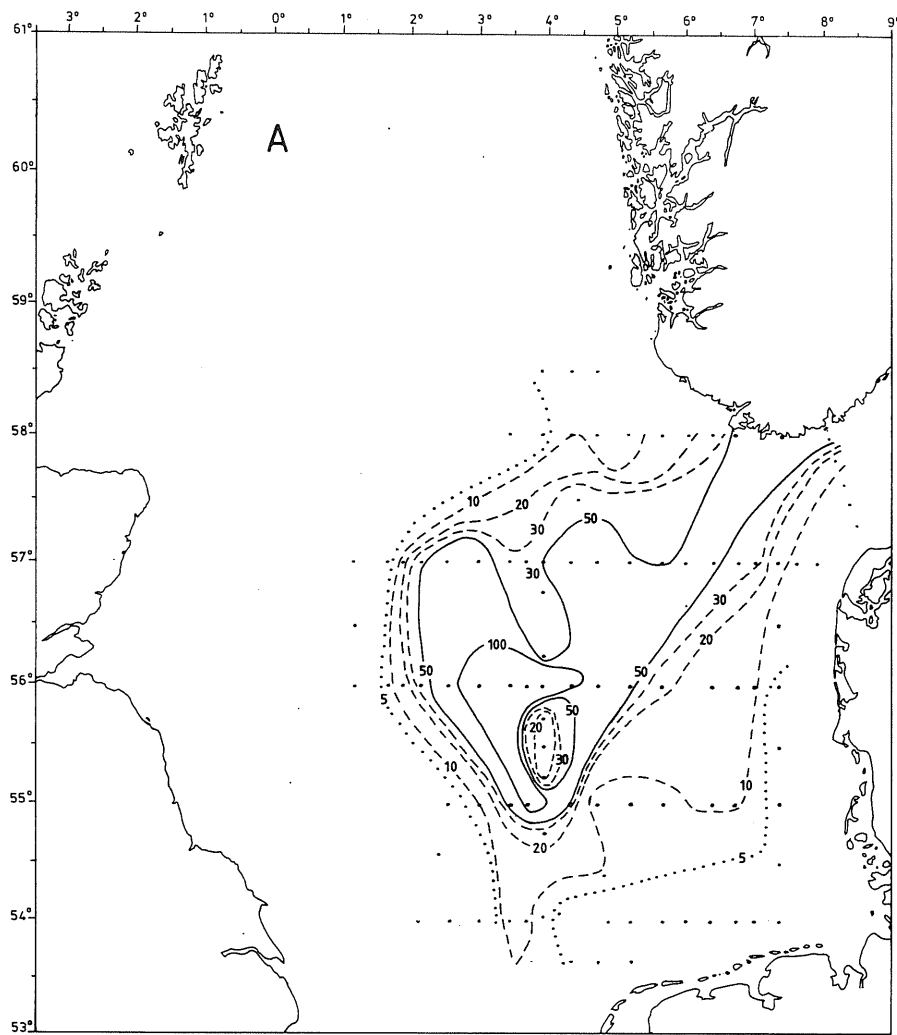


Fig. 11. Distribution of mackerel eggs without visible embryo (numbers/m²)
 A: First survey, B: Second survey, 1982.

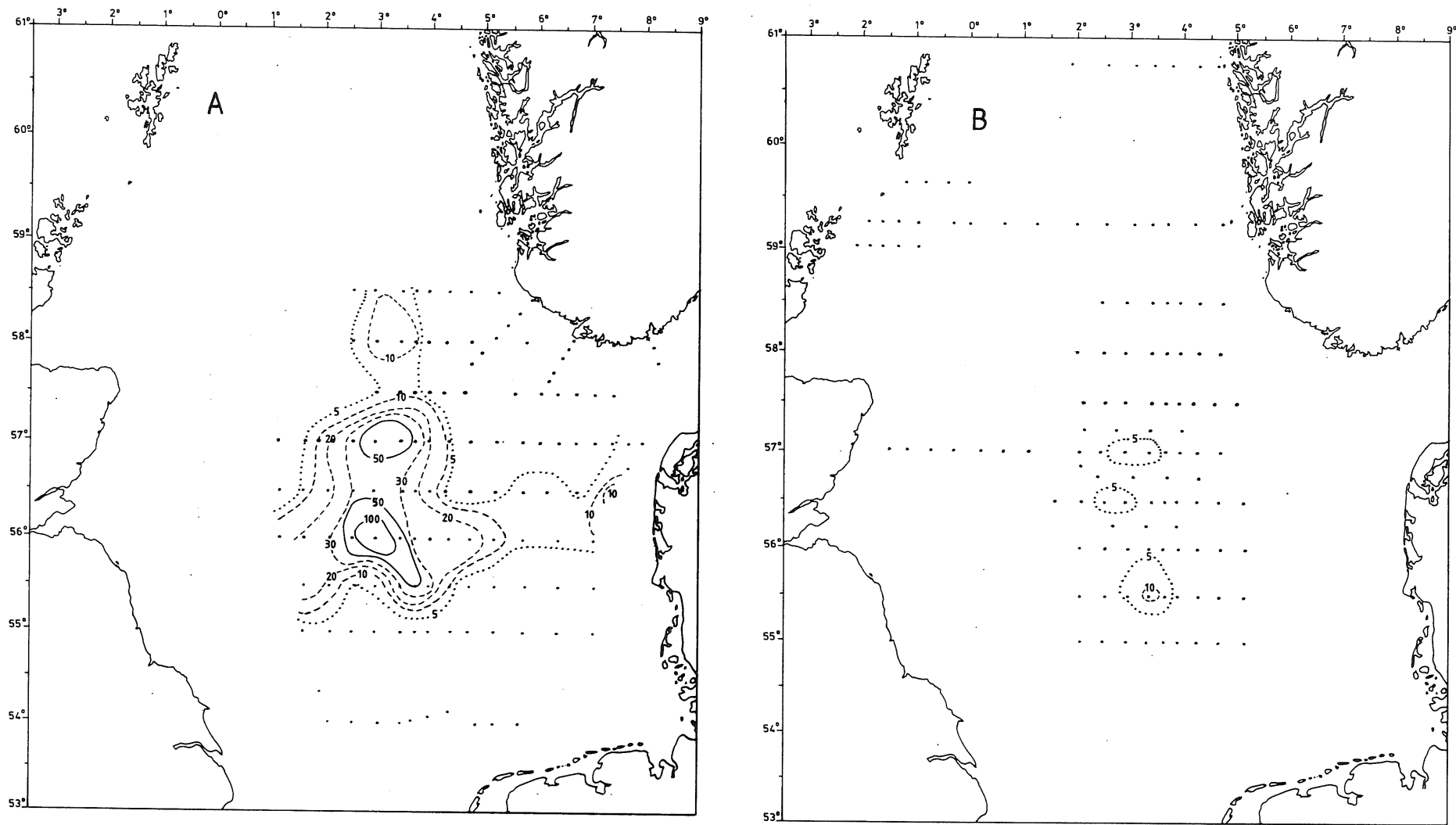


Fig. 12. Distribution of mackerel eggs without visible embryo (numbers/m³)
 A: Third survey, B: Fourth survey, 1982.

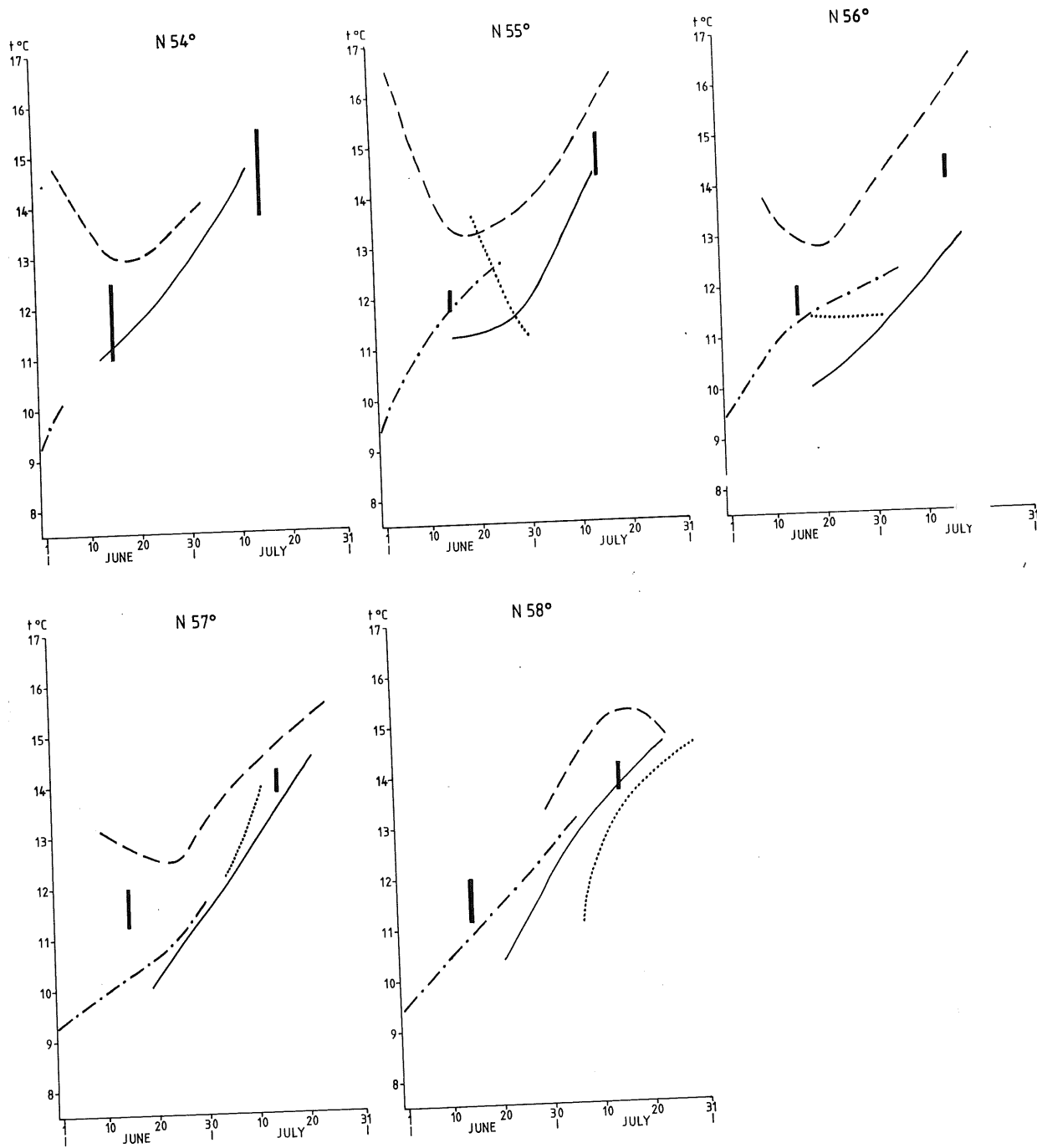


Fig. 13. Temperature variation by time at the sea surface between 2°E and 5°E along indicated latitudes. —: 1981, - - - -: 1982, - · - · - ·: 1983, ·····: 1984. ■ : monthly mean (1905-1954) of corresponding segments.

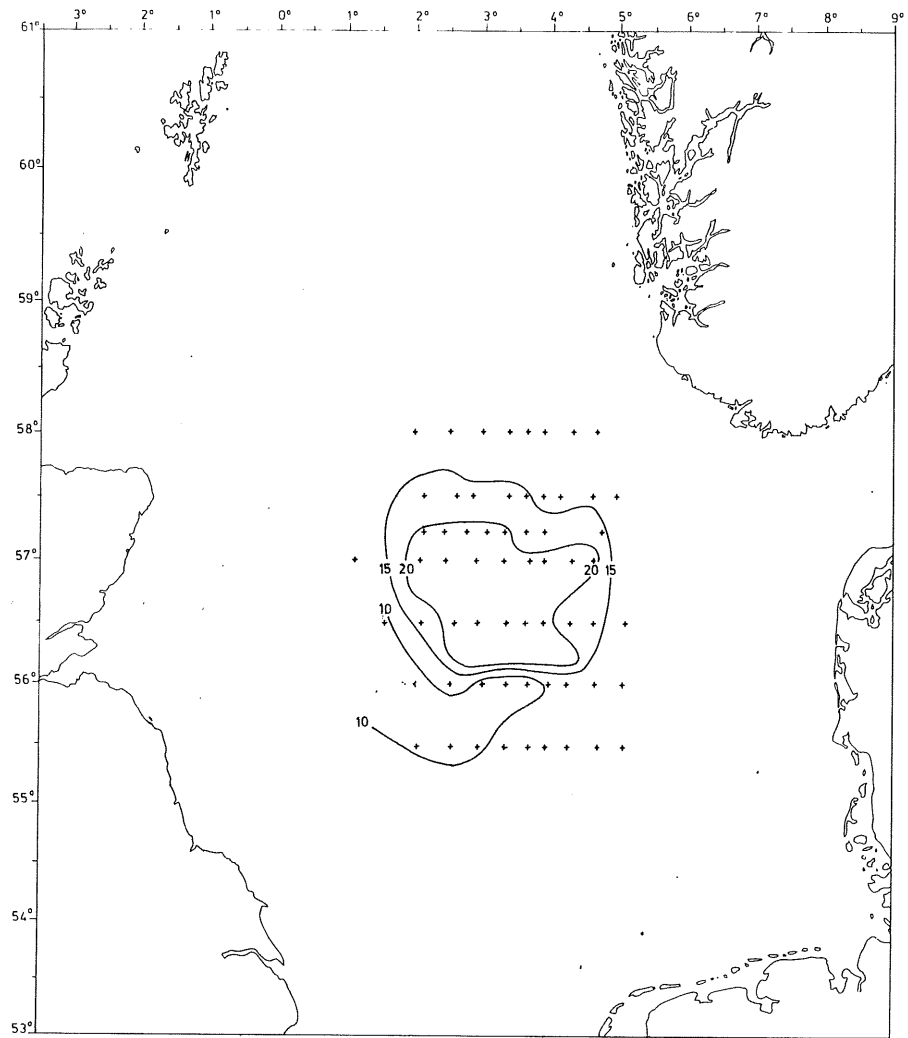


Fig. 14. The thickness in meter of water mass above the transmission layer from the fourth survey 1982.

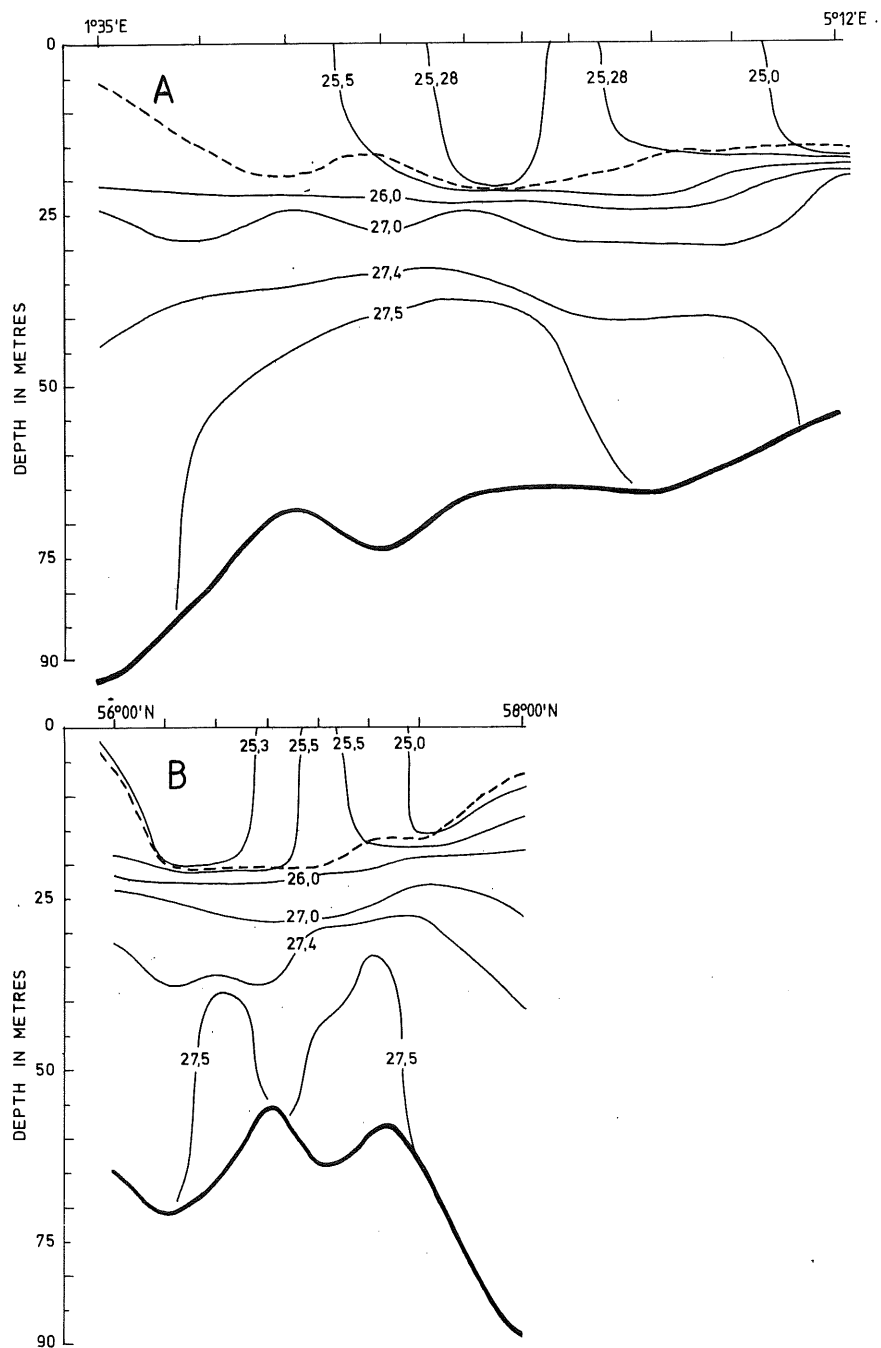


Fig. 15. Section of density (σ_t) from the fourth survey.
A: W-E section along $56^{\circ}30'N$.
B: S-E section along $3^{\circ}40'E$.