DISTRIBUTION, DRIFT AND CONDITION OF HERRING LARVAE OFF WESTERN NORWAY IN 1985.

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ABSTRACT

The recruitment to the Norwegian spring-spawning herring have during
the last twenty years been on a very low level. However, the size of
the spawning stock has increased in recent years and in 1983 a rich
year class was produced. The increase of the stock as well as
development of new gears and methods was the background for a new
project to study the recruitment mechanisms.   The present report
presents some preliminary results from a pilot study in April 1985.
It deals with the horizontal and vertical distribution of herring
larvae in relation to physical conditions as well as growth and diet.

INTRODUCTION

During the sixties the Norwegian spring-spawning herring was reduced to a minimum. Except for 1983, the recruitment to this stock during the last twenty years has been on a very low level (TORESEN 1985). Only the year classes 1966, 1973, 1979 and 1984 may be rated slightly above the average if the 1983 year class is deleted. However, the size of the spawning stock of the Norwegian spring-spawning herring has gradually increased and in 1983 the stock produced a rich year class (RØTTINGEN 1984).

After 1959 the Norwegian spring-spawning herring have been spawning along the western coast of Norway north of 62^0N. The main spawning area is found between 62^0 and 65^0N at depths of 70-150 m. The spawning last for 4-6 weeks with a maximum intensity during the first part of March. The incubation time is 18-24 days depending on the actual temperature (DRAGESUND et al. 1980).

Sampling of herring larvae along the coast of Norway has been carried out for a long period (e.g. WIBORG 1960, DRAGESUND 1970, BJØRKE 1981). The increase of the stock in more recent years as well as the development of new gears and methods, actualized the formulation of a project to study survival and growth of herring larvae and thereby the recruitment mechanisms. Data on development of hatching, feeding conditions, predation and larval drift in relation to physical conditions will be collected. The following questions will be attempted answered during the project period:

1.   Is the concept of a "critical larvae stage" valid?

2.   Is the recruitment to the stock based on the whole larvae population or only on a specific part of it with a high survival rate?

3.   Are the larval population split into a northern and southern component and if so, what is the driving mechanism?

4.   Are there special retention areas for the larvae and how
       do these influence the survival rate?

5.   What is the major factor governing the larval survival
       rate; predation, feeding conditions or environmental
       variability?

Among problems that arises from these general questions are the
vertical distribution and migration of the herring larvae.

In 1986 the project on the Norwegian spring-spawning herring was
included in a national program to study the consequences on fish eggs
and larvae of oil exploration north of 62^0N (FØYN and BJØRKE 1986).

The present report gives some preliminary results from the
investigation in 1985. This is regarded mainly a pilot study and a
thoroughly discussion of the results is considered to be beyond the
scope of this paper.

MATERIALS AND METHODS

The study was carried out during the period 10 - 18 April with the
main survey during 10 - 16 April (Fig. 1). On each station herring
larvae were sampled with modified conical nets of 0.5 m^2 opening and
375 µm mesh size (ELLERTSEN et al. 1984), from 150 m (or 5m above the
bottom) to the surface, and the vertical hydrografic distributions
observed by CTD casts. Two Argos satellite-tracked, drifting buoys
were deployed (Fig. 1). These were equipped with a 9 m^2 window blind
drogue attached to the buoys via a 30 m elastic nylon tetherline.

The herring larvae were preserved in 2% formaldehyd in 10%. sea water
for morphometric measurements and gut content analysis. Because of gut
content voidance in herring larvae during catching and fixation (HAY
1981, BLAXTER and HOLLIDAY 1963, ROSENTHAL 1969) only a qualitative
analysis were performed with the gut content.

On board the ship, standard length (SL) measurements of up to 50 herring larvae per station were taken to the nearest mm below. In the laboratory a material of 1077 herring larvae was analysed. Up to 20 larvae from each station were staged according to DOYLE (1977). Larvae with standard length <10mm were measured to nearest 0.1mm below, while larger larvae were staged to the nearest 0.5mm below.

If food organisms could be recognized through the epithelium of the gut, they were dissected out and classified into one of the following groups, copepod egg, copepod nauplii or copepodite. No other prey organisms were found. The larvae were rinsed in fresh water, dried to constant weight and weighed on a Cahn electrobalance to the nearest μg.

The vertical distribution study was carried out during a 48 hours period near Buagrunnen 16-18 April 1986 (Location B,Fig.1). A drifting drouque was placed at 30 m depth in a larvae consentration. Sampling was done with a 1 m^2 Mocness sampler (WIEBE et al. 1976) with 20 m depth intervals starting at 160-140 m. Around 30 m^3 was filtered at each interval. Sampling was made each second hour. After 30 hours of sampling the number of larvae caught fell drastically, indicating a drift of the drouque away from the larvae consentration. Sampling was then continued at the point where the droque was released. Light measurements were made at the surface before each haul.

RESULTS AND DISCUSSION

Hydrography

The typical vertical hydrographic structure of the investigated area is shown in Fig. 2. The Coastal Water (t^0<7, S<35) form a wedge above the underlying Atlantic Water. The bottom temperature was between 7.5^0 and 8^0C and the bottom salinity about 35.2 for the whole

area. Surface temperatures and salinities were 4-6^{0}C and 32.5 - 34.0 respectively. There was a pycnocline between 30 and 50 m, seen in the distribution of temperature as well as in salinity. The bottom topography of the area is rather complicated and influence strongly the circulation pattern. One of the most conspicuous bathymetric features is the shallow bank of Buagrunnen (Fig. 6) with a minimum depth of about 50 m.

The temperature and salinity distribution in 30 m (Figs. 3 and 4) give some indications of the currents above the pycnocline. Coastal Water of temperature and salinity below 5^{0}C and 33.5 respectively, intrudes the area from southwest. This water seems to follow mainly the western edge of Buagrunnen. Northwest of this bank, water of Atlantic origin is penetrating eastward. There is indications of an anticyclonic circulation around Buagrunnen. Also in the salinity distribution in 100 m (Fig. 5) the intruding Atlantic Water north of Buagrunnen is clearly seen. This feature is therefore most likely a result of topographic steering of the current which during the winter/spring situation is reflected in the upper layer circulation. Close to the shore in the southern part of the area, a southward transport is indicated (Figs. 3 and 4).

Fig. 6 shows the track of the two Argosbuoys with the drogues in 30 m depth. Position is indicated for each five days period. The most near-shore buoy (dotted line) was drifting southward to about 61^{0}50'N, then west and northwest and entered the investigated area again around 20 May. It needed about 40 days to pass the investigation area. During 15 of these it was circulating over Buagrunnen. The more off-shore buoy (whole line) used approximately 20 days to pass the area. Both tracks indicate the anti-cyclonic movement around Buagrunnen and they leave the area close to the coast in the northern part. They both ended up in the Lofoten area around 67^{0}N after 90 and 112 days.

Horizontal larvae distribution

The horizontal distribution of herring larvae of four different length groups is shown in Figs. 7-10. The distribution of the youngest

larvae (< 9 mm) clearly indicate two separated spawning areas; Buagrunnen and Runde (Fig. 7). From the Runde area, most of the larvae are drifting northwards. A minor part, however, seems to be drifting toward the south. This southward drift is also indicated on the distribution of larger larvae (Figs. 8 and 9) and is in accordance with the drift of the most near-shore Argos buoy (Fig. 6). The drainage of the youngest larvae from Buagrunnen (Fig. 7) is following closely the route of the Argos buoys (Fig. 6).

For the older larvae the horizontal distributions get more complex and the patchiness increase (Figs. 8 - 10). However, it seems possible to deduce the following drift pattern for the herring larvae:

Most of the larvae from the Runde area are drifting northwards around the western edge of Buagrunnen. Here they merge with the drift from this spawning area, flow eastward and northwards along the coast. The more western distribution of the older larva in the northernmost area (Figs. 8-10) is probably due to an offshore movement of the Coastal Water. This is indicated in Fig. 4 as well as by the Argos drifters just north of $63^0 30'N$.

The amount of newly hatched larvae is much higher at Buagrunnen than at the Runde area (Fig. 7). For the older larvae, however, no such feature is evident (Figs. 8-10). This observation invites to several interpretations. It can be a result of differences in spawning time and intensity as well as increased mortality of the larvae from Buagrunnen. The available data offer no preferable explanation.

During the survey, a 38kHz echosounder coupled to an echo integrator was used. Fig. 11 shows the distribution of the echo abundance classified as plankton. As can be seen, the maximum values are found in the same areas as where the spawning took place (Fig. 7). Most likely, this is not recordings of larvae as these at this stage of development do not have swim-bladder (BLAXTER et al. 1981). More probably, it is concentrations of zooplankton like krill and Calanus finmarchicus. Further study of the plankton samples from the vertical net haul and comparison of these with the plankton echo recordings may elucidate this question.

Vertical larvae distribution

DRAGESUND (1970) found that the larvae of Norwegian spring-spawning herring soon after hatching rose into the upper water layers (50-0m) and were scarce in the depth range 50 to 70m. This was partly in correspondance with earlier findings (DRAGESUND and WIBORG 1963, DRAGESUND 1965, DRAGESUND and HOGNESTAD 1966). Based on these studies the procedure established during previous annual herring larvae surveys was continued, during which only the upper 75 m were sampled. None of these experiments, however, included depths of more than 80m. In 1976 a Gulf III sampler (ZIJLSTRA 1970) was introdused and the sampling took place in the upper 60m.

SELIVERSTOV (1974) found that the larvae of the Norwegian spring-spawning herring could reach an amplitude of diurnal vertical migration of 75-100m. He also found newly hatched larvae of depths of 200m.

Fig.12 shows the vertical distribution of different length groups of herring larvae during a 48-hours sampling period. Few larvae <9 mm were caught and this length group is omitted in the figure. The daytime larvae were caught between 0900 and 1500 hour and the nighttime larvae between 2100 and 0200 hour. Fig. 12 seems to indicate a downward extention of the vertical distribution of all the three length groups. This is not in correspondance with obser- vations made by DRAGESUND (1970) who found that larvae were most abundant in the upper 20 m by night and between 20 an 40 m by day.

Fig.13 shows the percentage distribution of all herring larvae during a 48-hour period, under varying light conditions. No clear migration pattern is evident. The highest concentrasions of larvae were found between 20 and 80 m, and less than 5 % were found below 120 m.

Fig.14 shows the mean vertical distribution of all larvae during the

48-hour period, in addition to salinity and temperature.The highest abundance of larvae were found in the middle of the pycnocline. More than 65 % of the herring larvae were caught in the upper 60 m, while 20 % were caught below 70 m. This means that if herring larvae are to be caught quantitatively the sampling depth must be extended down to at least 150 m.

It should be stressed that these results are preliminary and that further investigations are necessary before any valid conclusions can be made concerning the vertical distribution and migration of herring larvae.

Condition of the larvae

The material consists of 1077 herring larvae of standard length 8-18 mm. A length (SL)/dry weight plot is shown in fig.15.There is a strict relationship between the length (SL) and the dry weight with a exponential correlation coefficient of r^2=0.81. There seem to be very few "runts" in the population and most of the larvae are growing at a steady rate from yolk-sac resorption, corresponding to a mean standard length of 10.3 mm.

The larvae material was staged according to DOYLE (1977). The standard length,dry weight and number of larvae in each stage are shown in Table 1. If all larvae are growing at the same rate, DOYLE's morphometric criteria can be used as an index of age. The following indications of constant growth was seen in the present material

- a strong correlation in the length/weight relationship.
- little standard deviation in dry weight of the larvae resorbing the yolk-sac.

To verify that the growth rate is constant, time consuming daily increment counting is necessary.

Table 1. The mean standard length and dry weight of the larvae in the different stages.

Stage	Mean length SL(mm)	SD	Mean dry weight DW(µg)	SD	N
1 a	8.2	0.9	144	35	62
1 b	9.0	0.7	120	27	118
1 c	10.2	1.1	135	34	87
1 d	10.3	1.2	142	38	193
2 a	13.0	1.2	248	71	632
2 b	16.4	0.9	486	91	45
2 c	17.0	–	700	–	1

The length frequency distribution of the larvae in the different stages is given in in Fig.16. This figure gives additional information of a larval population in growth.

Laboratory experiments with larvae of Norwegian spring spawning herring were performed in Flødevigen, to calibrate DOYLE'S results. (MOKSNESS,pers comm.). A size hierarchy was present in the lab experiments, and there was some overlap between the stages > 1d. The mean duration of the larval substages 1a - 2b after DOYLE(1977),MOKSNESS(pers comm.),ØIESTAD(1983) and MAC LACHLAN et al. (1981) are presented in Table 2.

Table 2. The mean duration of the different substages, (MOKSNESS,pers comm.,DOYLE 1977,ØIESTAD 1983 and MAC LACHLAN et al.1981).

Stage 1a	Stage 1b	Stage 1c	Stage 1d	Stage 2a	Stage 2b
3 days	4 days	3 days	2 days	11 days	5 days

In Fig. 17, the diet of the herring larvae in the substages 1a-2b corresponding to a age of 0-28 days post hatching (Table 2) is shown. The dominant prey organism in number in all size groups of larvae was

copepod nauplii and this prey organism constituted 90% of the gut content of the herring larvae investigated. The youngest larvae found with gut content were in the age group 4-7 days old. In the gut of these larvae a few copepod eggs and copepod nauplii were found, and the relative importance of copepod eggs as food items was higher than in older larvae. The highest number of copepod eggs was found in 8- 10 days old larvae. The importance of copepod eggs. as a food item decreased in larvae older than 10 days, when the yolk-sac was resorbed.

The highest number of copepod nauplii was found in larvae between 11-23 days old,later on this food item will be replaced by copepodites.

Copepodites are sporadically found in the larval guts from 9 days of age, but they are of minor importance until the larvae are about one month old, and larger than 15 mm (SL).

BJØRKE (1978) found a high percentage of copepod eggs in the diet of young larvae. His conclusion was that a large amount of copepod eggs in the gut of the herring larvae could be an expression of mismatch between the first feeding of herring larvae and of their prey. The present material with its high impact of copepod nauplii can be seen as an expression of successful first feeding.

From the mean length and stage duration data,Table 1+2, the growth rate can be calculated. A mean growth rate of 0.36 mm d^{-1} in the period of 1-25 days post hatching was found. The growth rate in the yolk-sac period is somewhat slower with 0.23 mm d^{-1}, and the growth in the post yolksac period 0.42 mm d^{-1}. This results is in accordance with previous results based on the same stock (DRAGESUND and NAKKEN 1973), and results with larvae from other stocks (LOUGH et al. 1982, WOOD and BURD 1976). CHRISTENSEN (1985) reviewed information about field studies on growth rates of North Sea herring. These ranged from 0.16-0.35 mm d^{-1}.

Dry weight can be fitted to the exponential growth equation to estimate the specific growth rate (SGR),k , of the larvae (WARREN 1971).

$$W_2 = W_1 \cdot e^{k(t_2 - t_1)}$$

W_2 = dry weight at time 2

W_1 = dry weight at time 1

t_1 = time 1/ days

t_2 = time 2/ days

The spesific growth rate from day 5 post hatching, when the larvae had the lowest dry weigth, to day 25 was found to be 6.8%. This is an underestimate because of the shrinkage in dry weight due to preservation, but in accordance with the theoretical values calculated by BEYER and LAURENCE(1979) on first feeding herring larvae.

A mixture of larvae from the two spawning components is present at Buagrunnen, while the larval population outside Runde (Fig. 1.) comes from the southern spawning stock. Length /dry weight plots from the larval population in these two areas are shown in Fig.18. No growth differences can be seen between the mixture of larvae and larvae from the southern stock components.

CONCLUSIONS

The circulation pattern of the investigated area seem to be highly influenced by the bottom topography.

The drift of the larvae is in reasonable accordance with the circulation pattern deduced by hydrography and Argos drifters.

If herring larvae are to be caught quantitatively the sampling volume must a least include the upper 160 m. No clear vertical migration

pattern was evident during changing light conditions. The highest abundance of larvae was found in the middle of the pycnocline.

The vertical distribution of three length groups, 9-10 mm, 11-12 mm and >13 mm indicated a downward extension during nighttime.

4-7 days old larvae were found with gut content, and the herring larvae had recovered their hatching weight at yolk resorption.

The larval diet was dominated of copepod nauplii; copepod eggs were found in the smallest larvae and copepodites in the larger ones.

A daily growth rate of 0.36 mm and a spesific growth rate of 6.8 % were calculated.

No growth differences was observed between the larvae from the southern and northern stock component.

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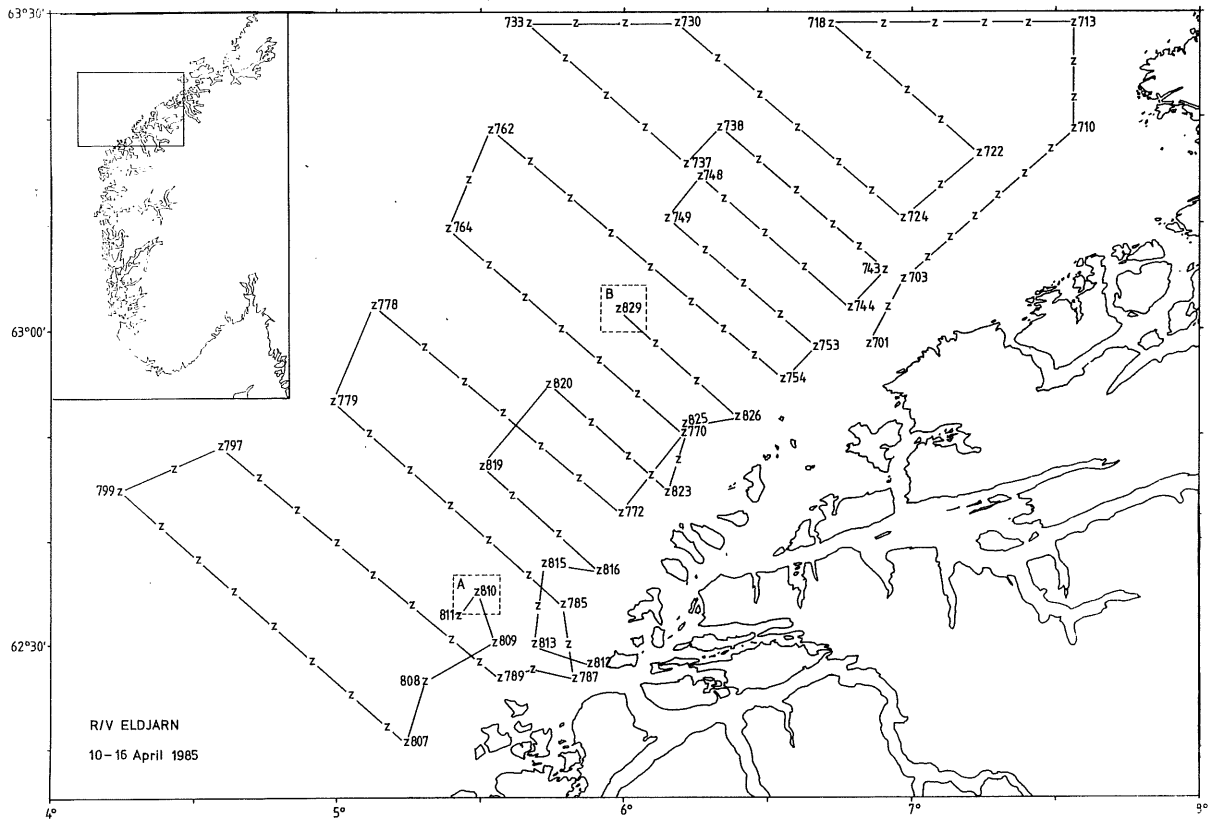
Fig. 1.   Investigated area and grid of stations.
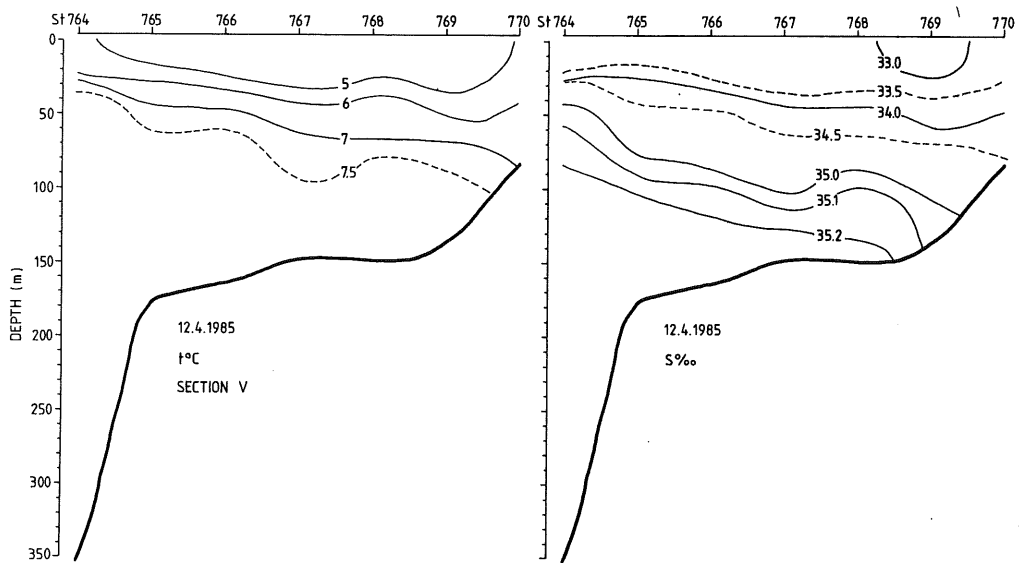
Fig. 2.   Vertical distribution of temperature and
          salinity in the central part of the area.
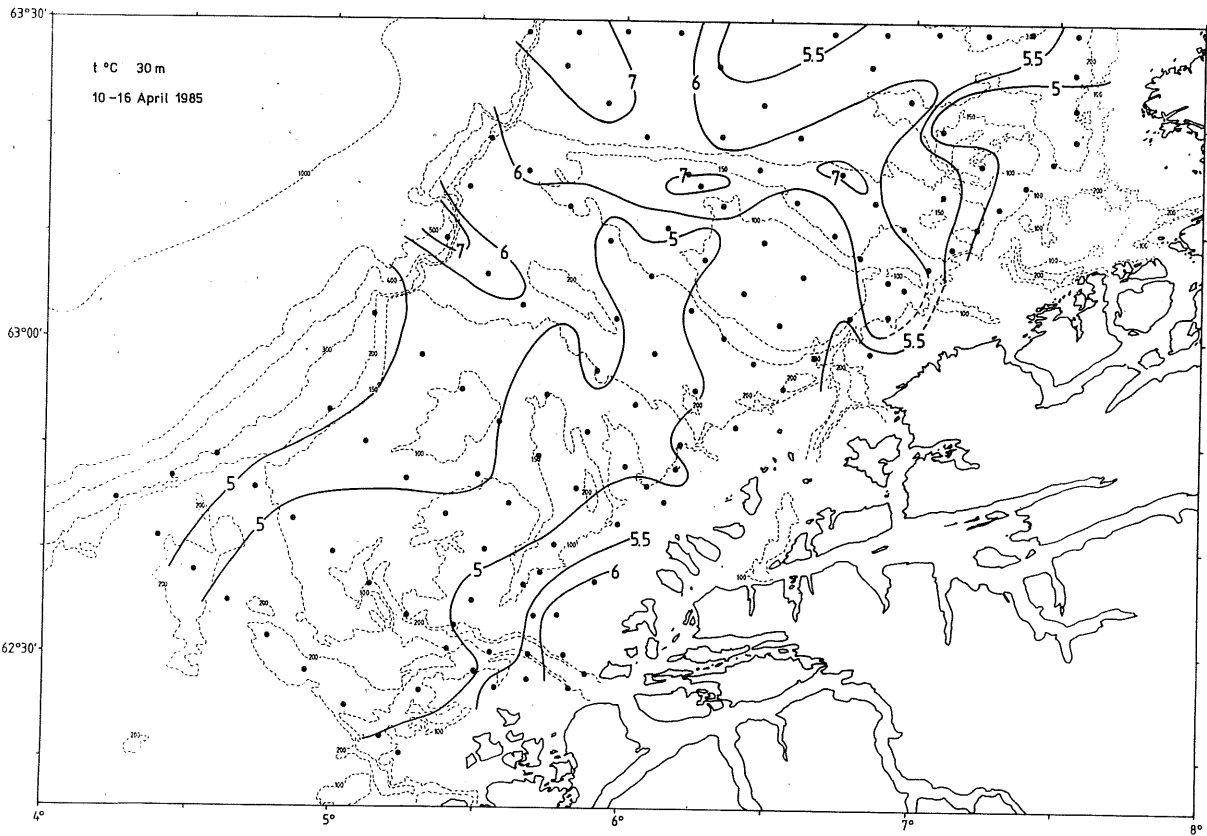
Fig. 3.   Distribution of temperature in 30 m depth.

Fig. 4.   Distribuiton of salinity in 30 m depth.
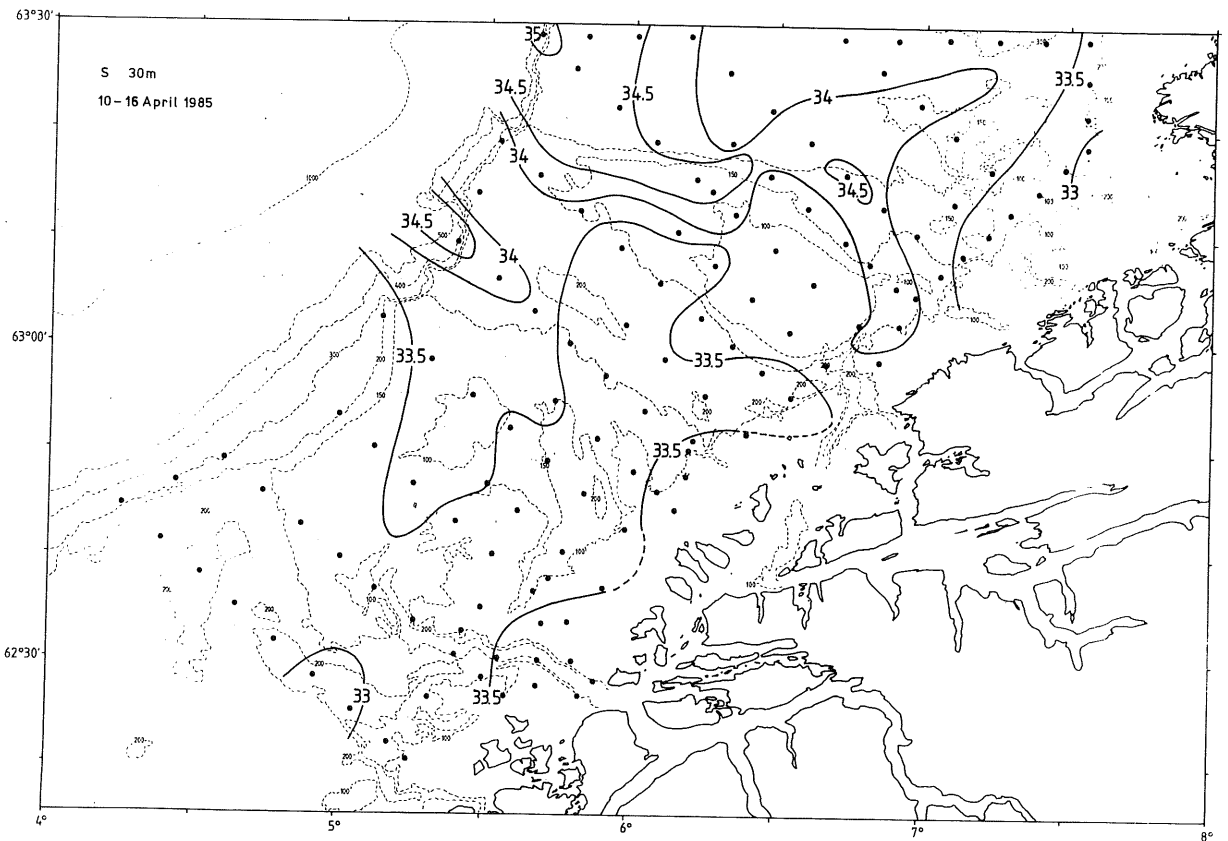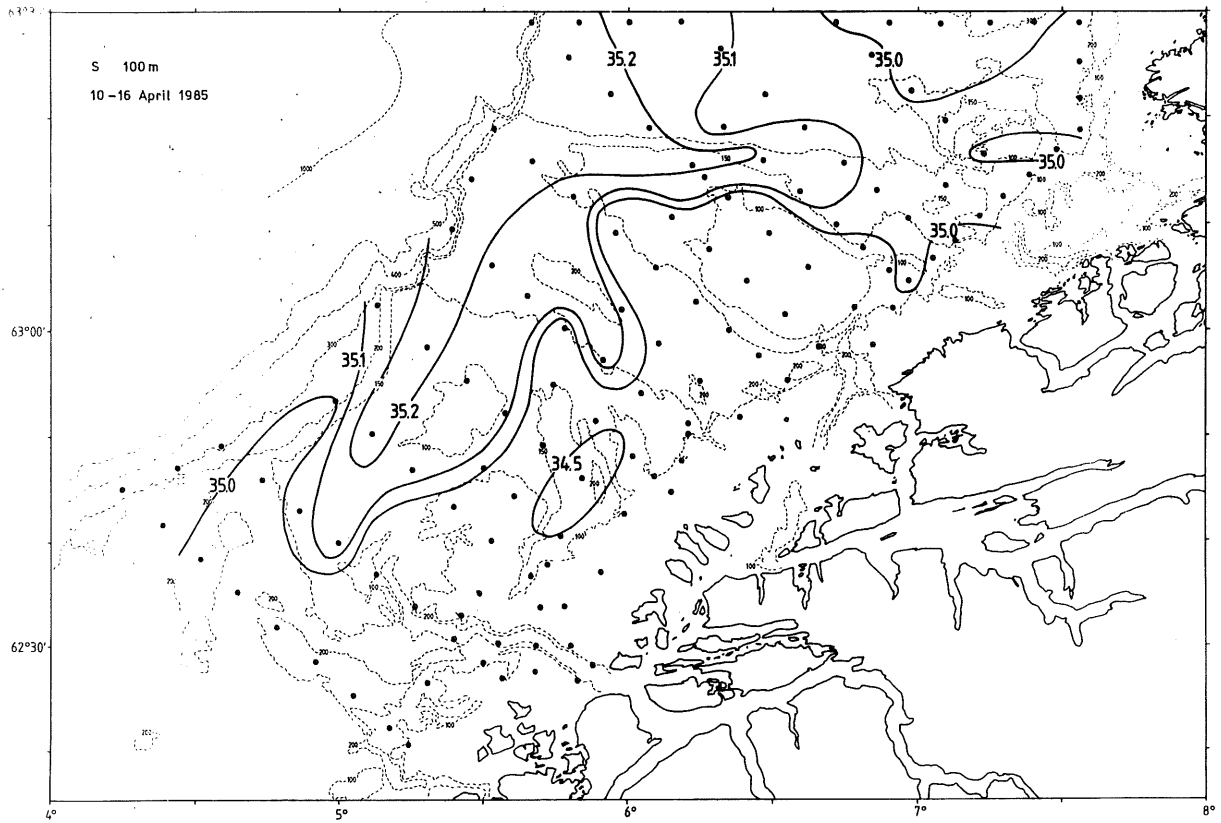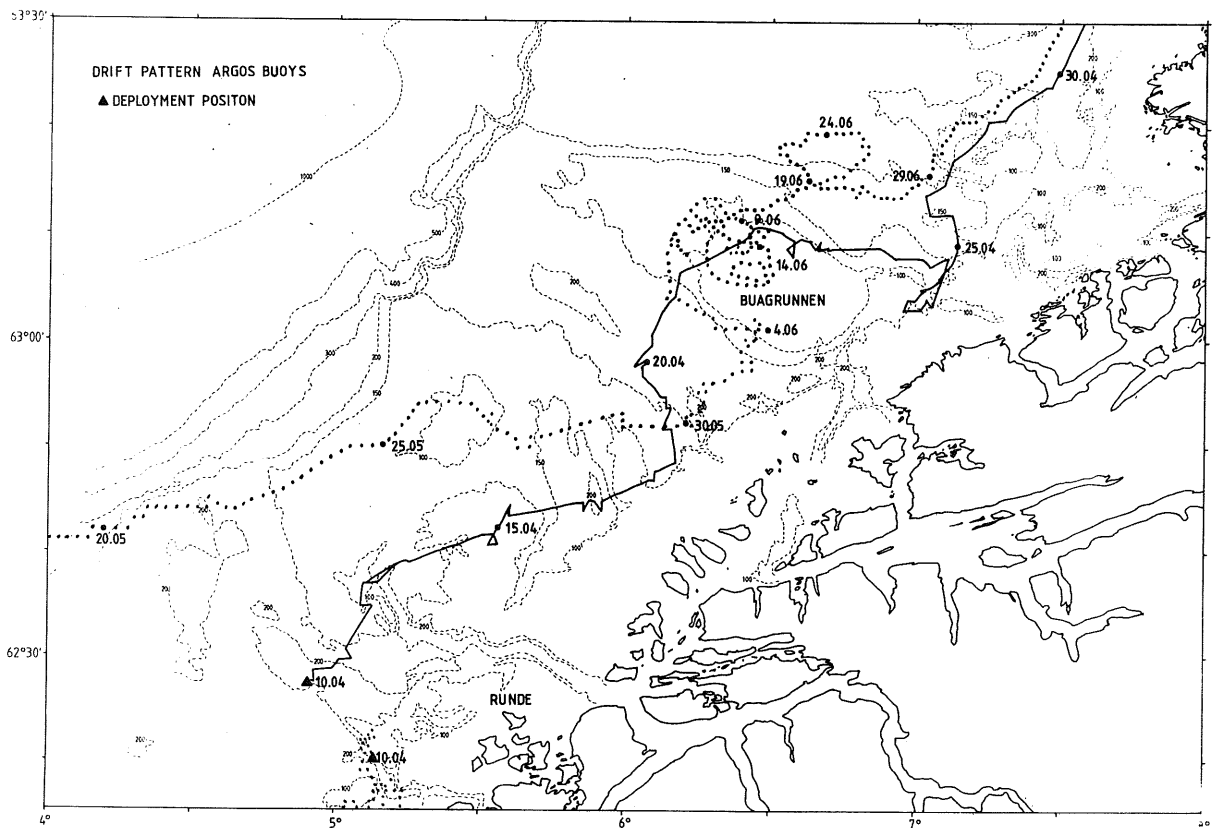
Fig. 5. Distribution of salinity in 100 m depth.

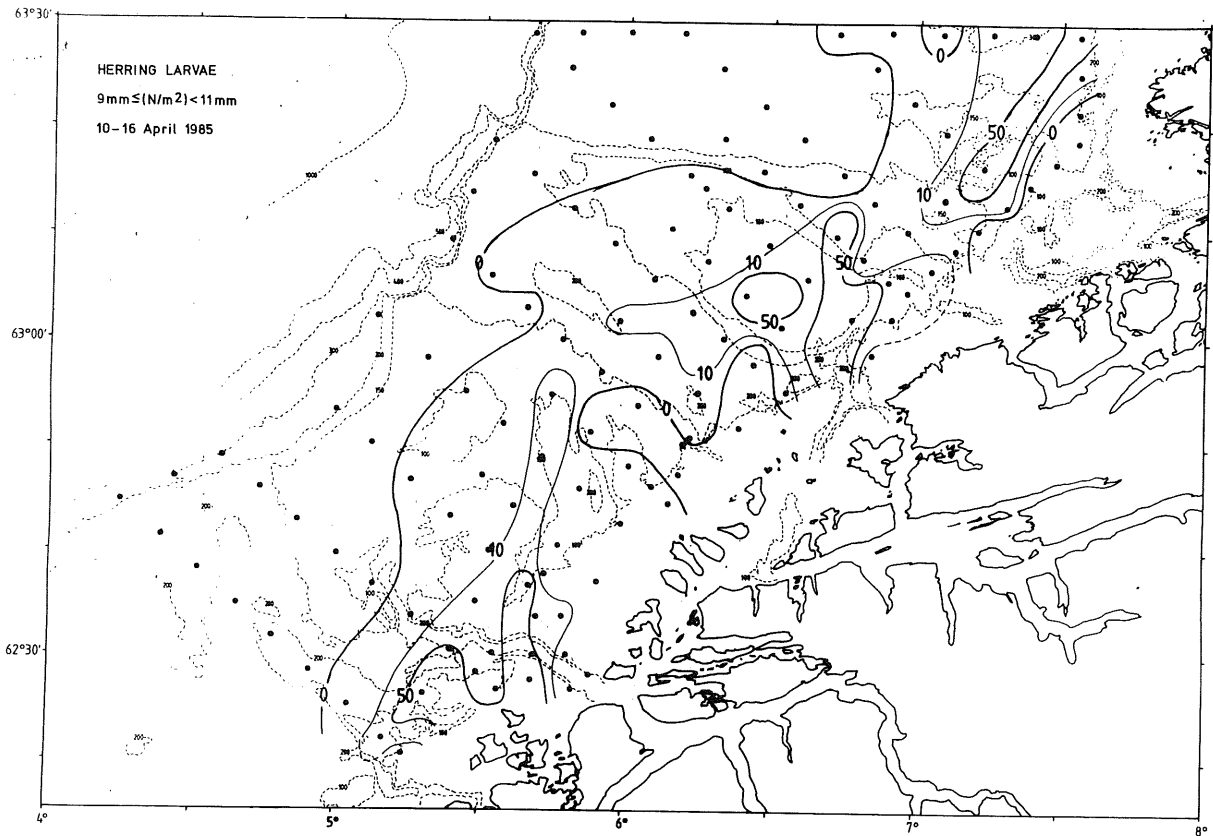Fig. 6. Track of the drifting Argos buoys drogued
at 30 m depth.

HERRING LARVAE
9mm ≤ (N/m2) < 11mm
10−16 April 1985

Fig. 7. Distribution of herring larvae
          < 9 mm (N.m^{-2}).

HERRING LARVAE
(N/m2) < 9 mm
10 − 16 April 1985
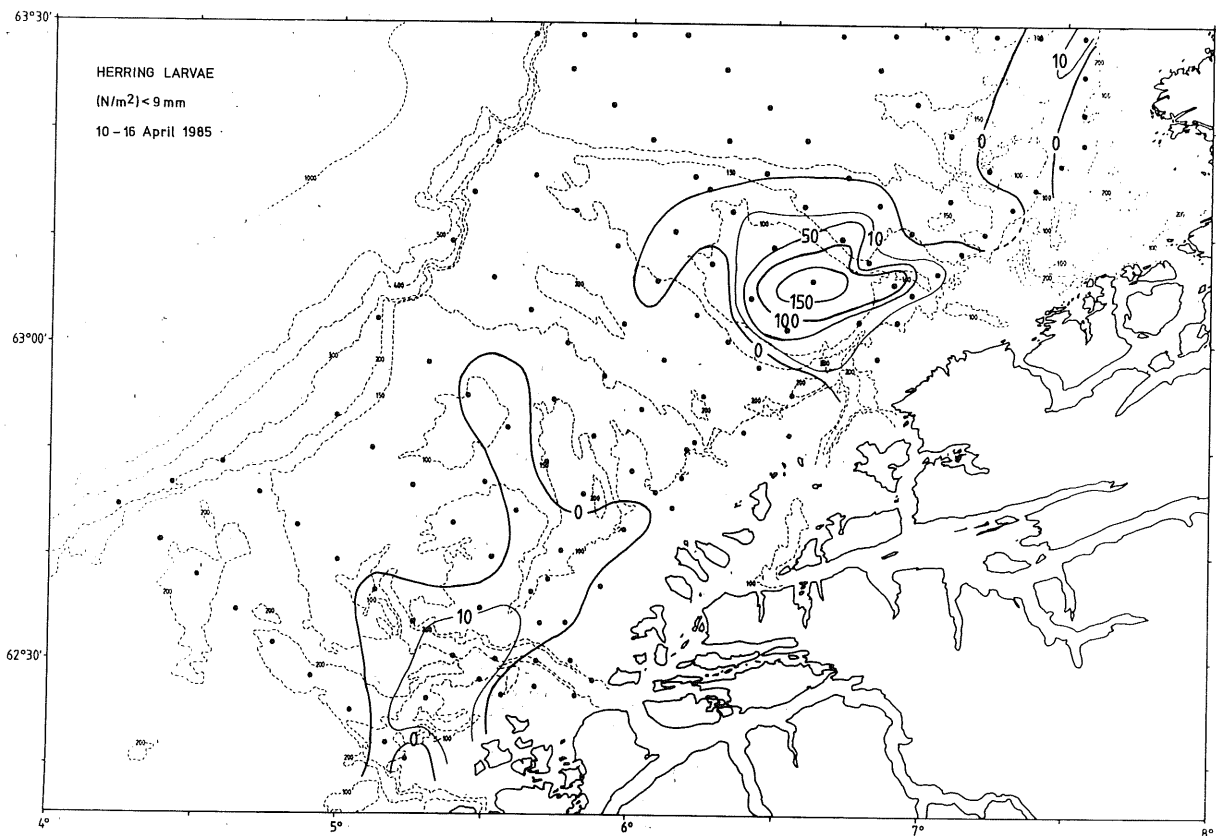
Fig. 8 Distribution of herring larvae
         between 9 and 11 mm (N.m^{-2}).
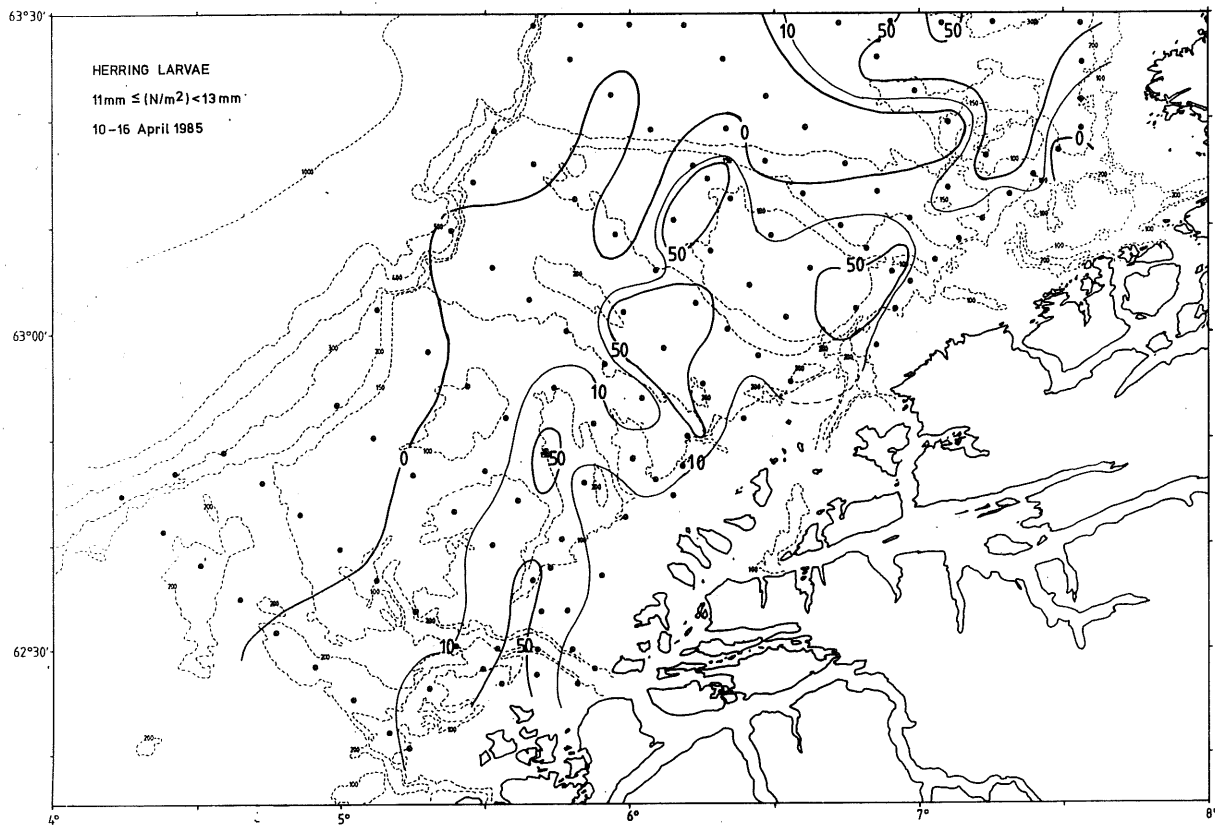
Fig. 9. Distribution of herring larvae
between 11 and 13 mm (N.m^{-2}).
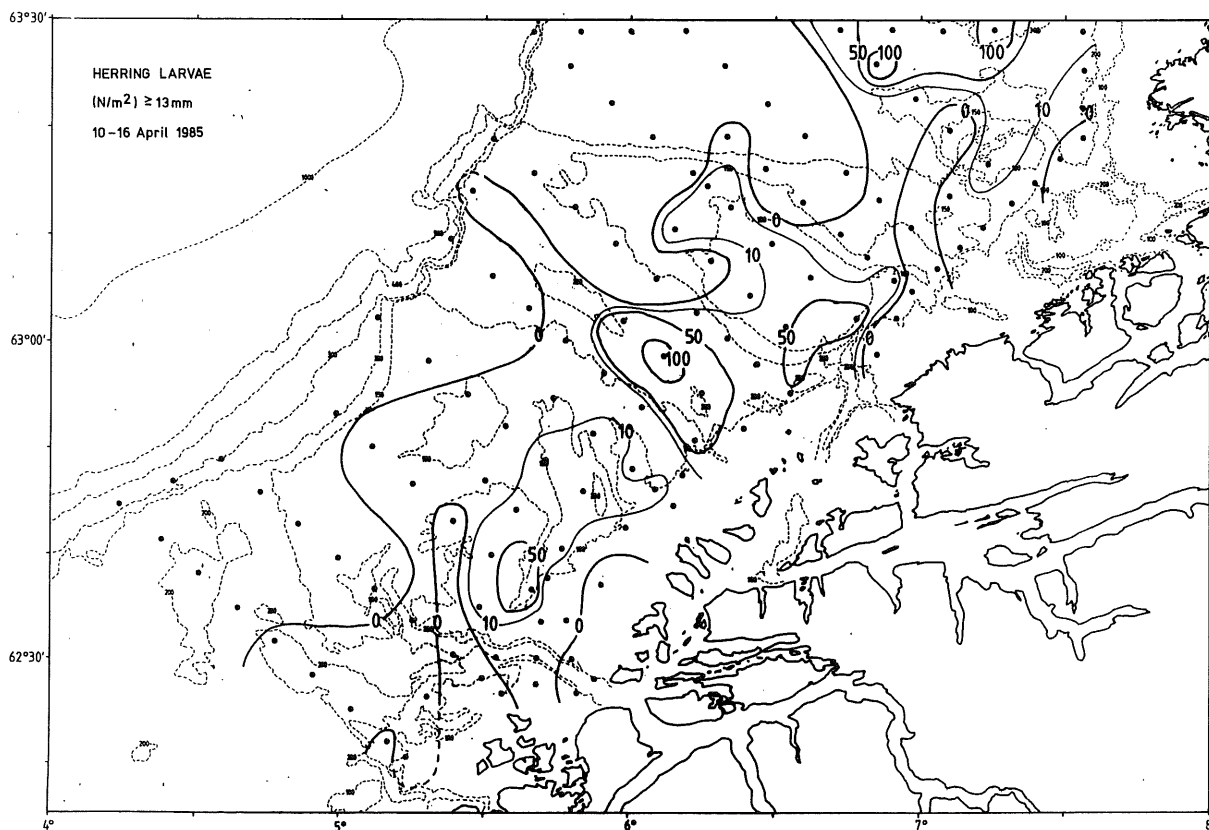
Fig. 10. Distribution of herring larvae
>13 mm (N.m^{-2}).

PLANKTON ECHO ABUNDANCE

INTEGRATOR READING (mm/n.mile²)

10-16 April 1985
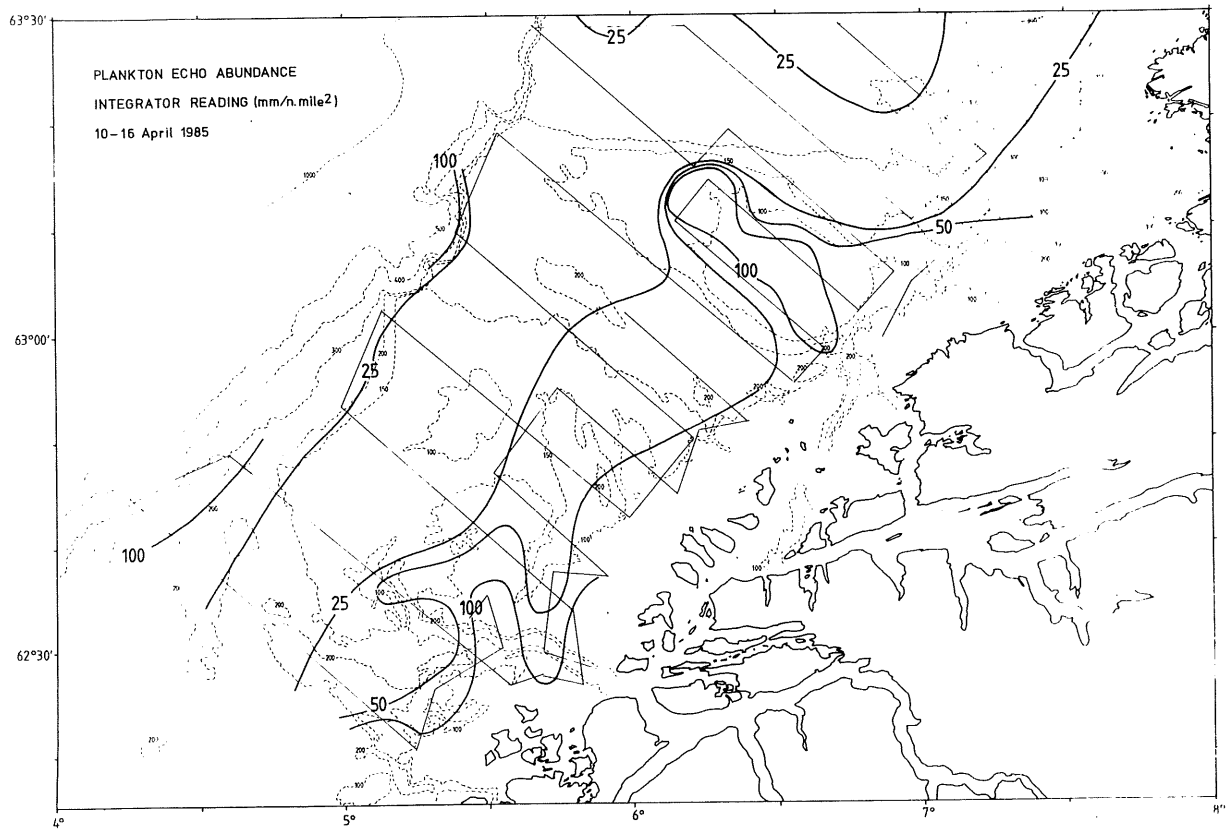
Fig. 11. Plankton echo abundance from
          the 38 khz echosounder.

DAYTIME   NIGHTTIME

n=47   n=316   n=631   n=44   n=279   n=379

DEPTH INTERVAL M

0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120
120 - 140   l̄ = 13,25   l̄ = 13,11
140 - 160

100 0 100 0 100 0 100 100 0 100 0 100 0 100   PER CENT
       9 -10   11-12   >13   9 -10   11-12   >13   LENGTH MM
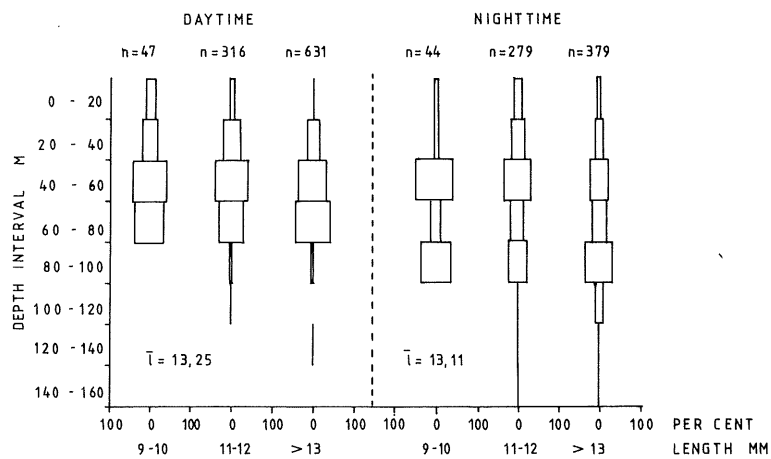
Fig. 12. Vertical distribution of different
          length groups during day and night.
          n = numbers of larvae.
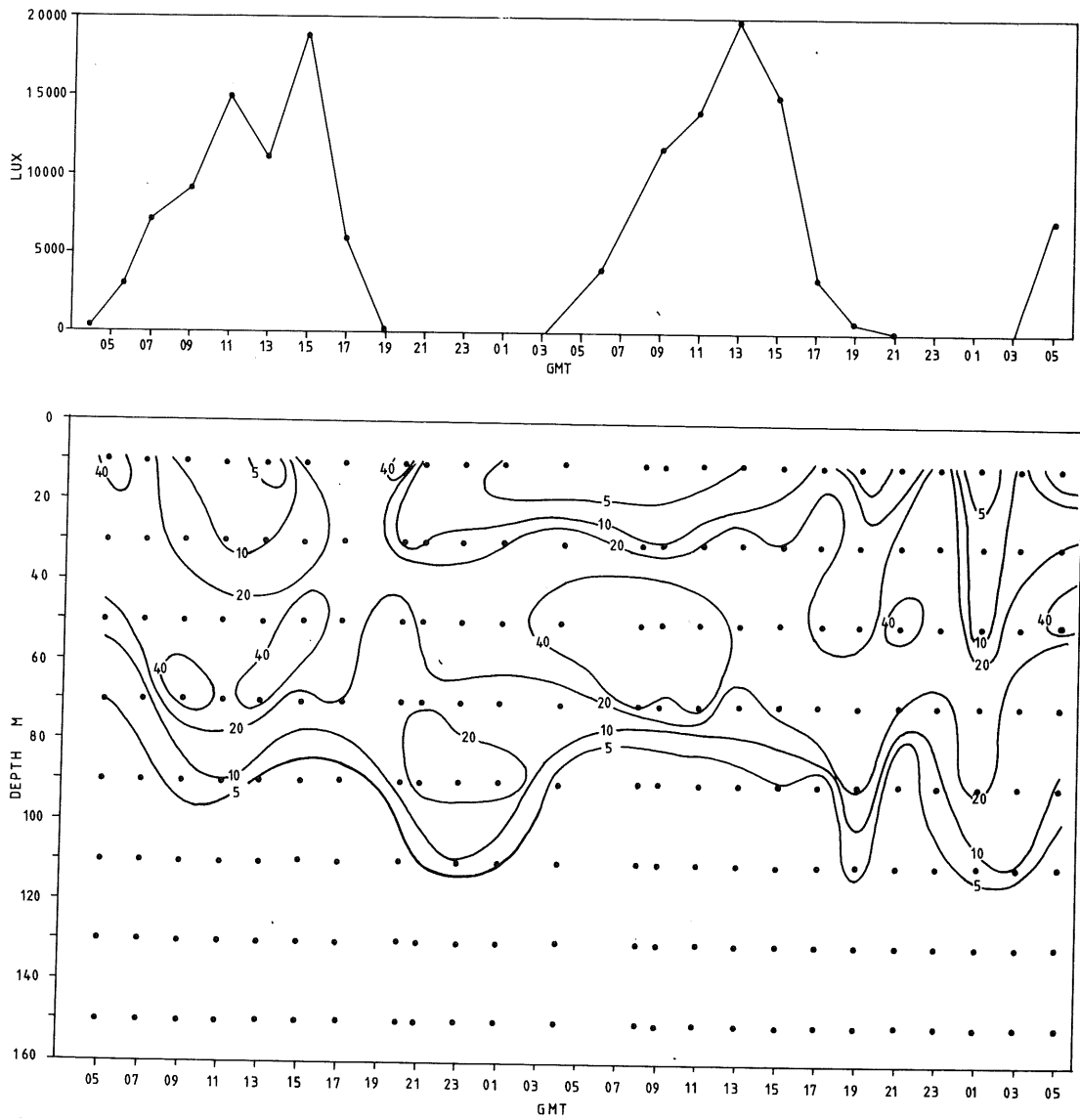
Fig. 13.   Top: Light intensity at surface.
          Below: Percentage vertical distri-
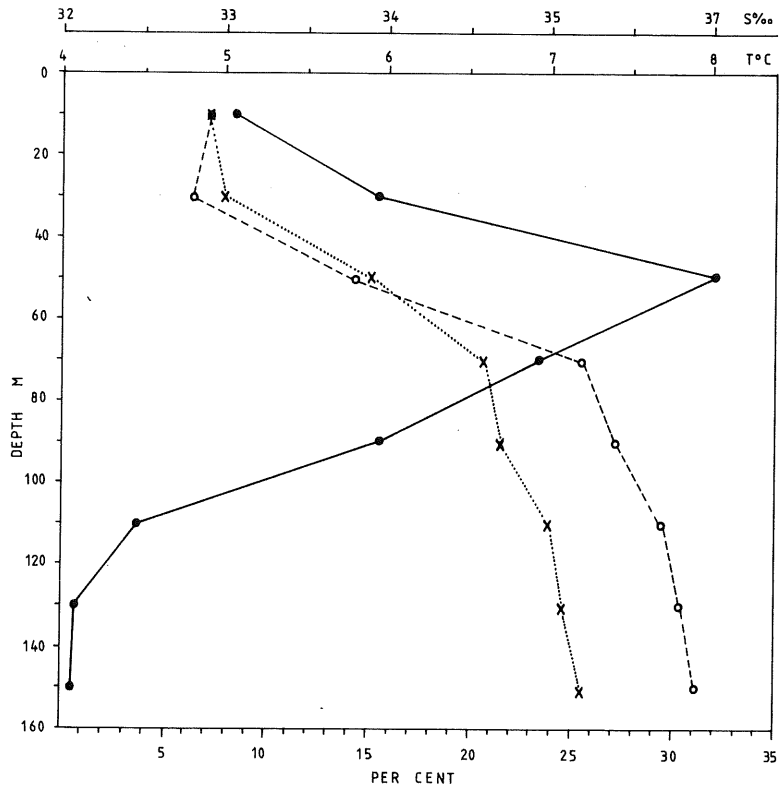   bution all length groups during 48 hours.

Fig. 14   Mean vertical distribution of larvae
           and hydrographic parameters.

                • ___ •   Percentage of larvae

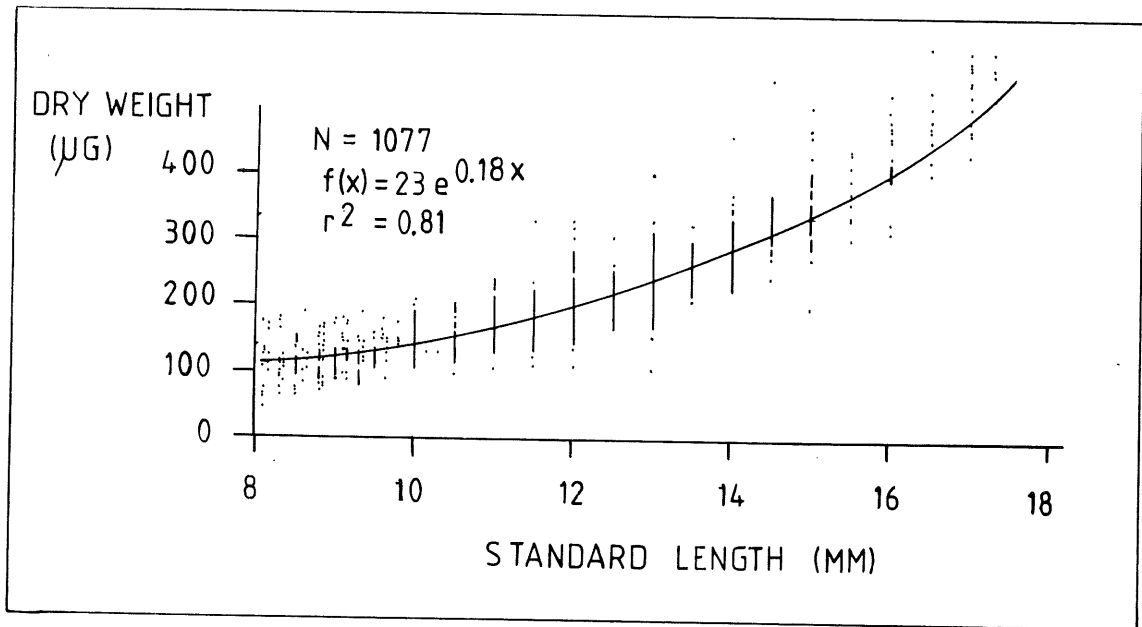   x.....x   Salinity

              o --- o   Temperature

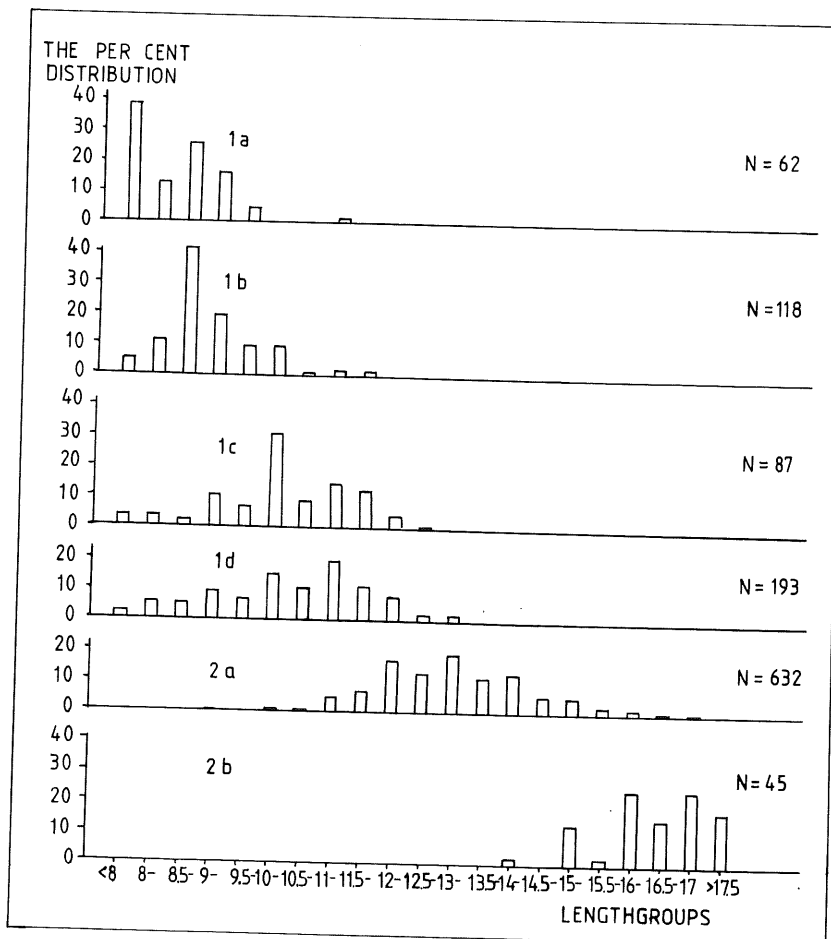Fig. 15. A length/dry weight plot of the present herring larvae material.

Fig. 16. The percentage length distribution of the larvae in the different substages (Doyle 1977).
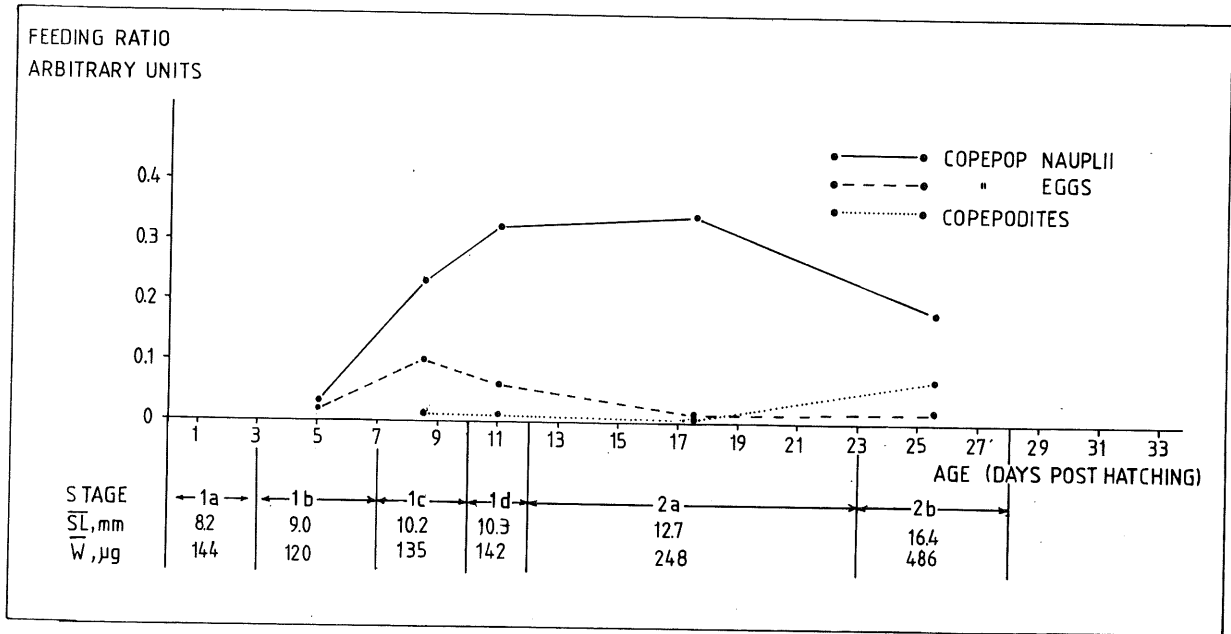
Fig. 17. The diet of the herring larvae in the "age" group
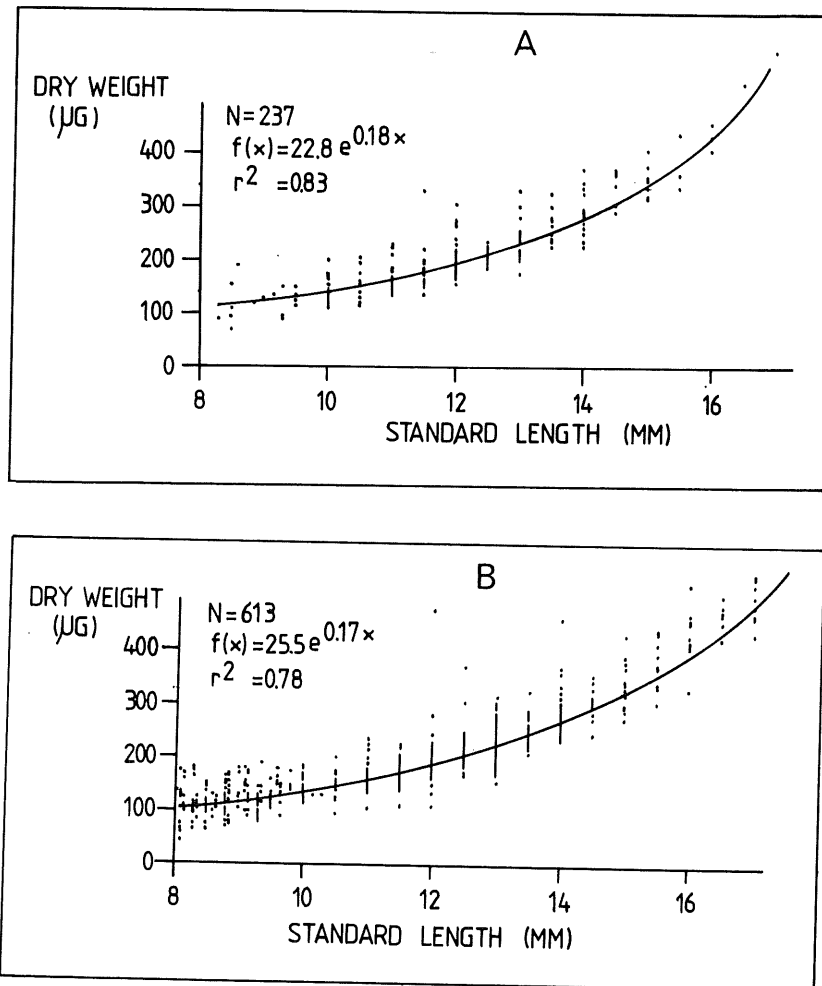4-29 days post hatching.

Fig. 18. A length dry weight plot of the larvae off Runde (A)
and on the Buagrund (B).