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DISTRIBUTION, DRIFT AND CONDITION OF HERRING LARVAE OFF WESTERN NORWAY IN 1987

By

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INTRODUCTION

After 1959 the Norwegian spring-spawning herring have been spawning along the western coast of Norway north of 62^0 N. During the sixties the stock was reduced to a minimum. In the recent years there has been a slight increase in the spawning stock and in 1983 a rich year class was produced.

In 1985 the Institute of Marine Research started a project to study the recruitment mechanisms of the herring. Preliminary results from the project's larvae investigations in 1985 and 1986 have been reported (BJØRKE, FOSSUM and SÆTRE, 1986, FOSSUM, BJØRKE and SÆTRE, 1987). In addition to the early larvae studies in March-April, the

project includes investigations of drift and distribution in May and in July. In August-September the distribution is covered by the international 0-group investigations in the Barents Sea.

The present report gives some preliminary results from the investigation on the herring larvae in March-April 1987.

MATERIALS AND METHODS

The study was carried out during the periods 28 March - 8 April and 10 - 20 April. The first coverage (Fig. 1) was the most complete while the second one was hampered by bad weather. Herring larvae were sampled with a modified conical net of 0.5 m^2 opening and 375 µ m mesh size (ELLERTSEN et al. 1984) from 150 m (or 5 m above the bottom) to the surface. The vertical distributions of temperature, salinity, nutrients and chlorophyll contents were observed by a CTD sonde with a rosett sampler. Seven Argos satellite-tracked, drifting buoys were deployd. These were equipped with a 10 m^2 window-blind drogue attached to the buoys via a 60 m tetherline.

The materials for the vertical studies were derived from three experiments; one made 10-11 April near Grip, one 12-13 April near Storholmen and one 18-19 April near Sklinna (posisions E, D and F in Fig. 1). The sampling was made over depths of 213, 175 and 147 m respectively. All experiments were made with a Mocness 1 m^2 sampler (mesh 333µ) (WIEBE et al 1976). The tows were made at a speed of 1.5-2 knots from a fixed point in a fixed direction.

Between 50 and 100 m^3 was filtered with the Mocness sampler within each depth interval. At the onset of the experiments the larvae concentrations were located with a vertical plankton haul.

The number of larvae per m^2 surface was calculated by the formula:

$$N = \frac{n\ I}{V}$$

where n is number of larvae in the sample, I is depth interval and V

is volume filtered.

The development of the larvae was classified according to DOYLE (1977), and the duration of the stages are given in Table 1 (below).

Table 1. The mean duration of the different substages. (For references see BJØRKE, FOSSUM, NEDREAAS and SÆTRE 1987)

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

The herring larvae were preserved in 2% formalin for staging (according to DOYLE 1977), for dry weight and gut content analysis. Because of gut content voidance in herring larvae (HAY 1981, BLAXTER and HOLLIDAY 1963, ROSENTHAL 1969), only a comparative analysis with material sampled the two previous year and qualitative analysis were performed. Because of weight loss during formalin fixation (THEILAKER and DORSAY 1980), samples of larvae were also staged and length measured in vivo, dried to constant weight and weighed in the laboratory on a Cahn electrobalance to searest µg.

If food organisms could be recognized through the epithelium of the gut of the preserved larvae, they were dissected out and classified into one of the following two groups; copepod eggs and copepod nauplii. No other food items were found. The larvae were rinsed in fresh water, dried to constant weight and weighed after the presented procedure.

RESULTS AND DISCUSSION

Hydrography

The distributions of surface temperature and salinity during the first

coverage (Figs. 2 and 3) show approximately the same pattern as in 1986 with higher values in the northern offshore areas. The northern part is usually influenced by Atlantic Water masses (S>35) while in the southern part the Coastal Water dominate during this part of the year. The northbound Coastal Water is flowing at the eastern side of the shallow bank centered at about 64° 40' N, 09° 00 E. The Atlantic Water is usually associated with high values of nitrate as seen in Fig. 4. The relativity high values of nitrate in the Coastal Water indicate that the phytoplankton spring-bloom have not reach its peak.

Fig. 5 shows the vertical hydrographic structure in the three sections A, B and C. The location of the sections appear in Fig. 1. In the two southernmost sections (A and B) the Coastal Water is occupying the upper 100 m over the entire shelf area. In the northernmost section, however, the Coastal Water is confined to a narrow zone along the coast. Under the Coastal Water at SECTION C water of Atlantic origin is present. This has penetrated into the trench at the eastern side of the bank from the south and is clearly seen in the horizontal distributions of temperature and salinity from the deeper layers.

Fig. 6 shows the drifting tracks within the investigated area from the seven Argos buoys while Fig. 7 shows the total tracks. The circulation pattern of the area is to a large degree governed by the bottom topography. Around the shallower banks an anti-cyclonic circulation is favoured. Six of the buoys are confined to the Coastal Current while one was brought into the Atlantic water flowing along the continental slope.

The drift tracks also indicate retention areas with prolonged residence time of the water. One is the bank area at about 63° 05' N where the buoy released in that area described anti-cyclonic movement over the bank for 12 days before it grounded at the coast. Another such area is the bank at 63° 40' N where the drifter circulated for about 30 days. These features seem to repeat themselves each year. The same is the case for the apparent meandering of the tracks between 65° N and 65° 30' N which also is an effect of the bottom topography. The irregular movements of two of the buoys just south of 66° N, however, is probably a result of more transient processes along the Coastal

Current front. Instabilities of the frontal system is frequently seen in satellite IR images.

The average transport speed of the drifters between 64° N and 66° N was 10 - 12 nautical miles/day in the Coastal Current and 3 - 6 nautical miles/day along the continental slope.

Horizontal larvae distribution

The hatching of herring larvae started around 10 March with a peak in the last days of March. The hatching continued until about 25 April but with rather small larvae production after the first week of April (BJØRKE, 1988).

The horizontal distribution of herring larvae of three different length groups from the first coverage 28 March - 8 April is shown in Figs. 8 -10. The distribution of the smallest larvae indicate the spawning grounds (Fig.8). In the southern part two such areas are apparent. These are about the same as observed both in 1985 and in 1986 (BJØRKE, FOSSUM and SÆTRE, 1986, FOSSUM, BJØRKE and SÆTRE, 1987). Additionally, spawning have occurred in the northern near-coast area.

The distribution of larger larvae (Figs. 9 - 10) indicate the larval drift routes. Most of the larvae are confined to the Coastal Current close to the coast. A minor part of the larvae seems to follow an outer route along the continental slope as also indicated by one of the Argos drifters (Fig. 6).

As previously mentioned, the second coverage, 9 - 20 April was hampered by bad weather and is therefore incomplete. However, the distribution of the smallest larvae from this coverage is included (Fig. 11) because it indicates minor spawning also north of the area of the first coverage. Fig. 12 shows the distribution of larvae south of 63° N for three length groups during the second coverage. As expected, the numbers of the smallest larvae are low as the peak hatching was over during that period. The number of larvae between 9 and 11mm is approximately as during the previous coverage while the

amount of larvae larger than 12 mm is considerably higher. This may indicate a relatively long residence time of the larvae in this area.

The investigations in 1987 seem to confirm the tentative pattern of drift routes and retention areas put up for the similar studies in 1986 (FOSSUM, BJØRKE and SÆTRE, 1987). The drift speed, however, was apparently higher in 1987 than in 1986.

Vertical larvae distribution

Table 2 shows the number of larvae per m^2 surface sampled during the experiments. Larvae without yolk-sac and without the characteristics of stage 2a described by DOYLE (1977) are omitted from this table.

Fig. 13 shows the vertical distribution of larvae of all length groups when all depth intervals were sampled. Hence the samples from near Grip 11 April at 07 hrs. are omitted. Near Grip and Storholmen the vertical distribution was almost identical with a maximum of larvae in the 0-19 m interval. At these two stations 94 and 99 % of the larvae were sampled in the upper 59 m respectively. Near Sklinna the vertical distribution was different with the majority of the larvae in the 40-59 m interval. At this station only 52 % of the larvae were sampled in the upper 59 m.

Were any differences in vertical distribution observed at daylight and at night? Fig. 14 shows the vertical distribution of larvae caught by day and by night during the experiments. The larvae caught during the day were sampled between 0900 and 1500 hour and the larvae caught during the night were sampled between 2100 and 0200 hours GMT, both hours included. Only larvae from Table 1 are included in these figures. Near Grip the larvae seemed to concentrate in the 0-19 m interval by night and in the 20-39 m interval by day. Near Storholmen the majority of the larvae were found in the 0-19 m interval both by day and by night. Near Sklinna larvae were found throughout the investigated water column though mainly below 40 m. There seems to be no clear changes in vertical distribution during a 24-hrs. period at these stations.

Figs. 15-19 shows the vertical stage distribution of the larvae shown in Fig. 14. It is clear that while stage 2a was in majority near Grip and Storholmen, stage 1b was in majority near Sklinna. Hence the vertical distribution of these stages will be reflected in the vertical distributions shown in figure 14. Near Grip stage 2a was most common in the 20-39 m interval by night and in the 0-19 m interval by day. Near Storholmen, however, this stage was found mainly in the 0-19 m interval both by day and by night. Near Sklinna larvae in this stage were found in rather low numbers, but they tended to consentrate in the 0-19 m layer at night.

Near Sklinna larvae in stage 1b was in majority. Here, this stage was found throughout the investigated water column though mainly below 40 m. There seems to be no clear changes in vertical distribution during the 24-hrs. period. Near Grip and Storholmen larvae in this stage was found in higher numbers in the 20-39 m interval by night and in the 0-19 m interval by day. However, the number of larvae in this stage (1b) at these stations is too low to draw any firm conclutions. By the same reason no firm conclusions can be made concerning the stages 1a, 1c og 2b.

Both at the stations near Grip and Storholmen stage 2a was most abundant. The larvae in this stage were, however, differently distributed by day at these stations. While they were most abundant in the upper 19 m at the station near Grip, they were most abundant in the 20-39 m interval near Storholmen. The hydrographical conditions were almost identical with no pronounced pycnocline (Fig.14). Food conditions could have been different at these stations. Samples are taken, but have not been worked up yet. Light conditions could also have been different, but these were unfortunately not measured. This is highly recommended during further trials. Hence, this far, no explanation can be given for the observed differences in the vertical distribution of stage 2a near Grip and Storholmen.

Conclusion: Herring larvae 12-32 days old are mainly found in the upper 59 m and they seems to concentrate in the upper 19 m by night. Larvae 3-7 days old are found throughout the investigated water column

though mainly below 40 m. There seems to be no clear changes in vertical distribution during a 24 hrs. period of larvae in this stage. These observations does not deviate from observations made during similar studies in 1985 (BJØRKE et al. 1987) and 1986 (FOSSUM, BJØRKE and SÆTRE 1987).

Condition of herring larvae

The material consisted of 1770 herring larvae of standard length 8-18 mm and dry weight 50-1265 µg. 1692 larvae were preserved in formalin, while 78 were staged and measured in vivo. The mean standard length and dry weight of the larvae in different developmental stages are given in Table 3 and 4. The larval material sampled on this survey was composed of both yolksac-larvae and post-larvae. The development of the larval population was somewhat delayed compared to what was found in 1985 when the population was composed of post-larvae in stage 2a. Compared to 1986, however, when the larvae were in the yolksac stage, the larvae had reached a more advanced stage in the present material (FOSSUM, BJØRKE and SÆTRE 1987).

It can be seen from this tables that the larvae shrink during fixation, and tests of the means of length and weights before and after fixation all show a highly significant length and weight loss ($47<t<11.6$). The percent shrinkage is given in Table 5. The larval samples are from the second coverage. The material sampled the previous year had only half the length-shrinkage compared to the present (3.3-6.5%). while the weight loss was slightly higher (38.6-45.5%), (FOSSUM, BJØRKE & SÆTRE 1987).

In fig. 20 length/weight plot of the larvae not exposed to formalin is shown. There is a strong length/weight-relationship indicated by a correlation coeffisient $r=0.97$. The slope is higher than was seen with the unpreserved material for 1986. 0.095 compared to 0.082, indicating a faster growth in 1987 than in 1986.

The plots of the preserved material is shown in figs. 21-23. There is a slightly higher growth parameter (the slope of the curve) during the

second coverage, and a test of the condition shows that this is significantly higher on the second than on the first coverage ($t=4.14$). The reasons for this are not fully understood. There can be problems with the sampling procedure, the prey conditions can have improved (not an item for the investigation this year) or it can be a general condition-improvement of growing larvae. A plot of the condition factor ($k=1(mm)3/10w(\mu g)$ versus standard length for the two coverages is shown in figs. 24 and 25. The material is somewhat scattered but there is a tendency of decreasing condition towards yolkresoption, and then the condition is increasing when the larvae starts to grow. So the reason for the difference in condition between the two coverages may be that the samples contain larvae of different age. Length/weight plots of preserved material have weaker length/weight relationships, because of variable weight loss during fixation, $r=0.85$ for the first coverage and $r=0.93$ for the second. The growth parameter (the slope = 0.08) is higher than in 1986 (0.04) and equal to the parameter found in 1985 (the slope=0.08), indicating reduced growth in 1986.

The diet of the larvae during stages 1a-2b, a time span estimated to be 28 days (BJØRKE, FOSSUM & SÆTRE 1986), is shown in fig. 26. There were found 345 cop. nauplii and 156 cop. eggs in the larval guts. No other food items were found. The low feeding ratio in the larger larvae is most probably due to the emptying of the gut during catching and preservation. The persistaltic movements of the gut must be much stronger in the more advanced larvae. There is a stronger impact of cop. eggs this year than the previous two. The number of cop. nauplii is on the same level as in 1985 and higher than in 1986, another indication of good larvae conditions in 1987. First feeding was seen in stage 1b larvae (3-6 days old). Cop. eggs seems to be an important first feeding item. Later on, the importance of this food item is reduced.

From the mean length and stage duration data the growth rate can be calculated. A mean growth rate of 0.36 mm/day in the period 2-26 days post hatching were found. In the yolksac-period the growth was slower, 0.28 mm/day, but in the post-larval period 0.41 mm/day. The specific growth rate can be calculated to be 6.8%, by the method shown

in BJØRKE; FOSSUM & SÆTRE (1986). Both the growth rate in length and the specific growth rate are almost identical to the rates found in 1985, and are in accordance with previous results on the same herring stock (DRAGESUND & NAKKEN 1973), and with results with larvae from other stocks (LOUGH et al. 1982, WOOD & BURD 1976).

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sampling zooplankton. J. Mar. Res., 34: 313-326.

Table 2. Number of larvae per m^2 surface sampled during the experiments.

St. 444, near Grip.

Date	10 April 1987				11 April									
Hour	17	20	22	24	02	04	05	07	09	12	13	15	17	
Depth														
0-19	48	126	149	95	183	72	25	-	0	18	20	15	61	812
20-39	38	21	4	14	23	37	29	46	32	14	32	25	27	342
40-59	0	2	2	5	29	34	2	11	0	8	27	12	10	142
60-79	1	4	1	2	1	2	2	1	0	1	4	2	1	22
80-99	0	1	0	2	2	1	0	1	0	0	1	0	0	8
100-119	1	3	1	2	1	0	4	0	0	0	1	0	0	13
120-139	0	0	1	0	0	0	2	0	0	0	0	0	0	3
	88	157	158	120	239	146	64	59	32	41	85	54	99	1342

St. 478, near Storholmen.

Date	12 April 1987	13 April 1987											
Hour	20	23	01	03	05	07	09	11	13	15	17	19	
Depth													
0-19	48	40	128	77	0	40	28	14	91	56	85	116	723
20-39	62	10	35	34	0	35	26	18	14	23	11	4	272
40-59	3	3	14	9	4	6	3	0	0	12	1	3	58
60-79	1	0	2	5	5	0	0	0	0	0	0	1	14
80-99	0	0	0	1	1	0	1	0	0	0	0	0	3
100-119	0	0	0	0	0	1	0	0	0	0	0	0	1
120-139	0	0	1	1	0	1	0	0	0	0	0	0	3
	114	53	180	127	10	83	58	32	105	91	97	124	1074

St. 519, near Sklinna.

Date	18 April			19 April									
Hour	19	21	23	01	03	05	07	09	11	13	15	17	
Depth													
0-19	5	11	8	31	8	12	2	2	1	3	7	10	100
20-39	12	14	5	12	1	13	3	3	3	4	3	47	120
40-59	6	18	11	18	5	9	27	15	30	12	19	221	391
60-79	10	22	15	41	11	7	49	30	6	26	13	19	249
80-99	0	3	6	27	27	3	9	6	3	52	7	8	151
100-119	0	6	9	16	1	1	2	2	4	7	1	3	52
120-139	0	6	8	16	2	1	4	6	1	2	1	0	47
	33	80	62	161	55	46	96	64	48	106	51	308	1110

Table 3. Standard length and dry weight in the different developmental stages (preserved material).

Stage	Mean standard length (mm)	Mean dry weight (µg)	Nos. of larvae
1a	8.3 ± 0.8	147 ± 36	86
1b	8.4 ± 0.9	120 ± 26	331
1c	9.4 ± 0.9	123 ± 28	281
1d	10.1 ± 0.8	147 ± 30	338
2a	12.2 ± 1.5	258 ± 104	487
2b	16.4 ± 1.1	636 ± 109	9
2c	17.2 ± 1.0	836 ± 60	5
3a	18.8	1265	1

Table 4. Standard length and dry weight of larvae staged and measured in vivo.

Stage	Mean standard length (mm)	Mean dry weight (µg)	Nos of larvae
1c	11.2 ± 0.4	219 ± 32	5
1d	11.0 ± 0.6	227 ± 32	22
2a	13.6 ± 1.8	440 ± 193	46
2b	17.7	1118	1

Table 5. Shrinkage due to fixation

Stage	Length (%)	Weight (%)
1d	10.0	36.5
2a	10.2	38.2

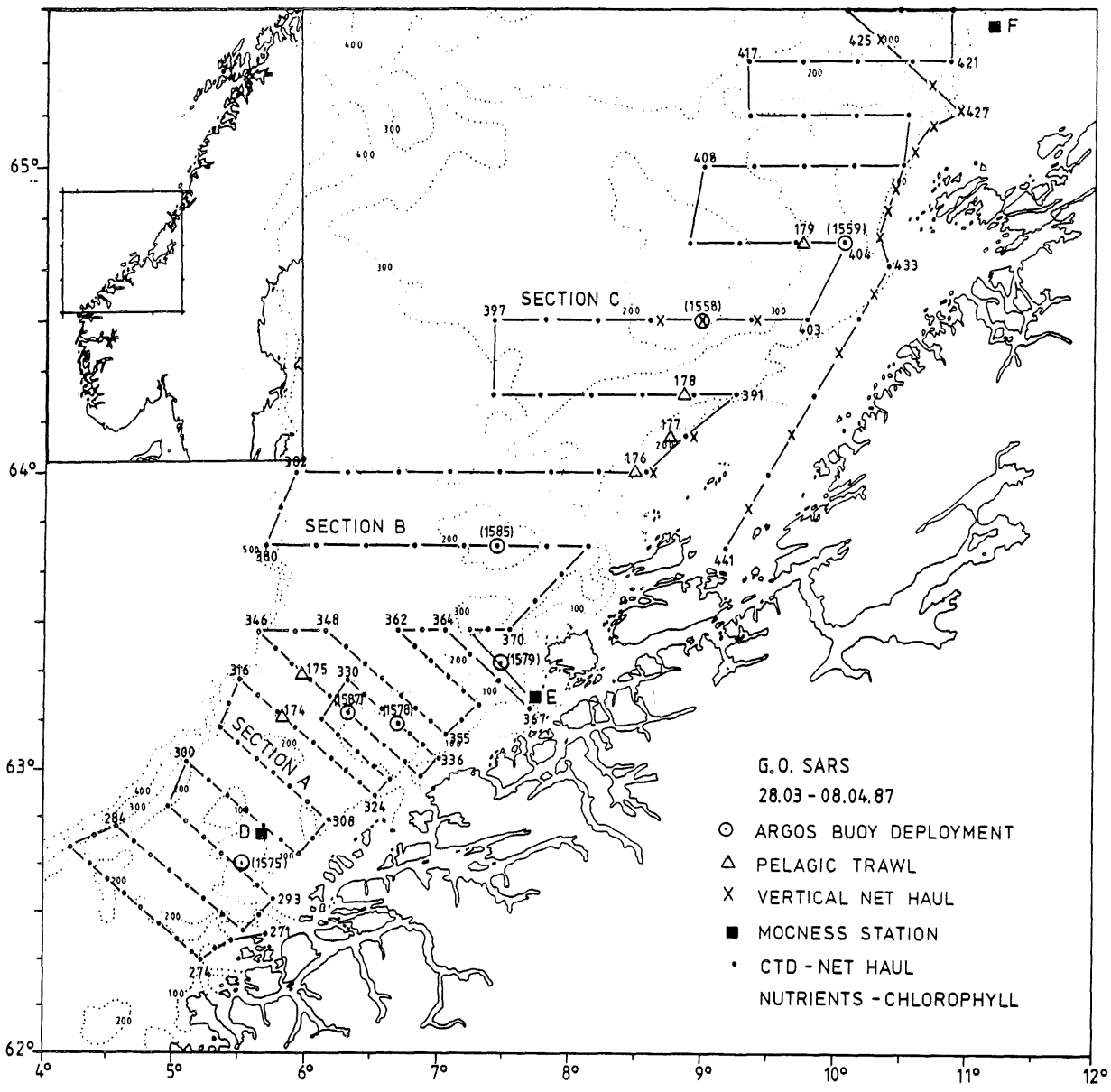


Fig. 1. Grid of stations during the first coverage, 28 March - 8 April 1987. Bathymetric contours for each 100 m are included. Inserted map shows the location of the studied area.

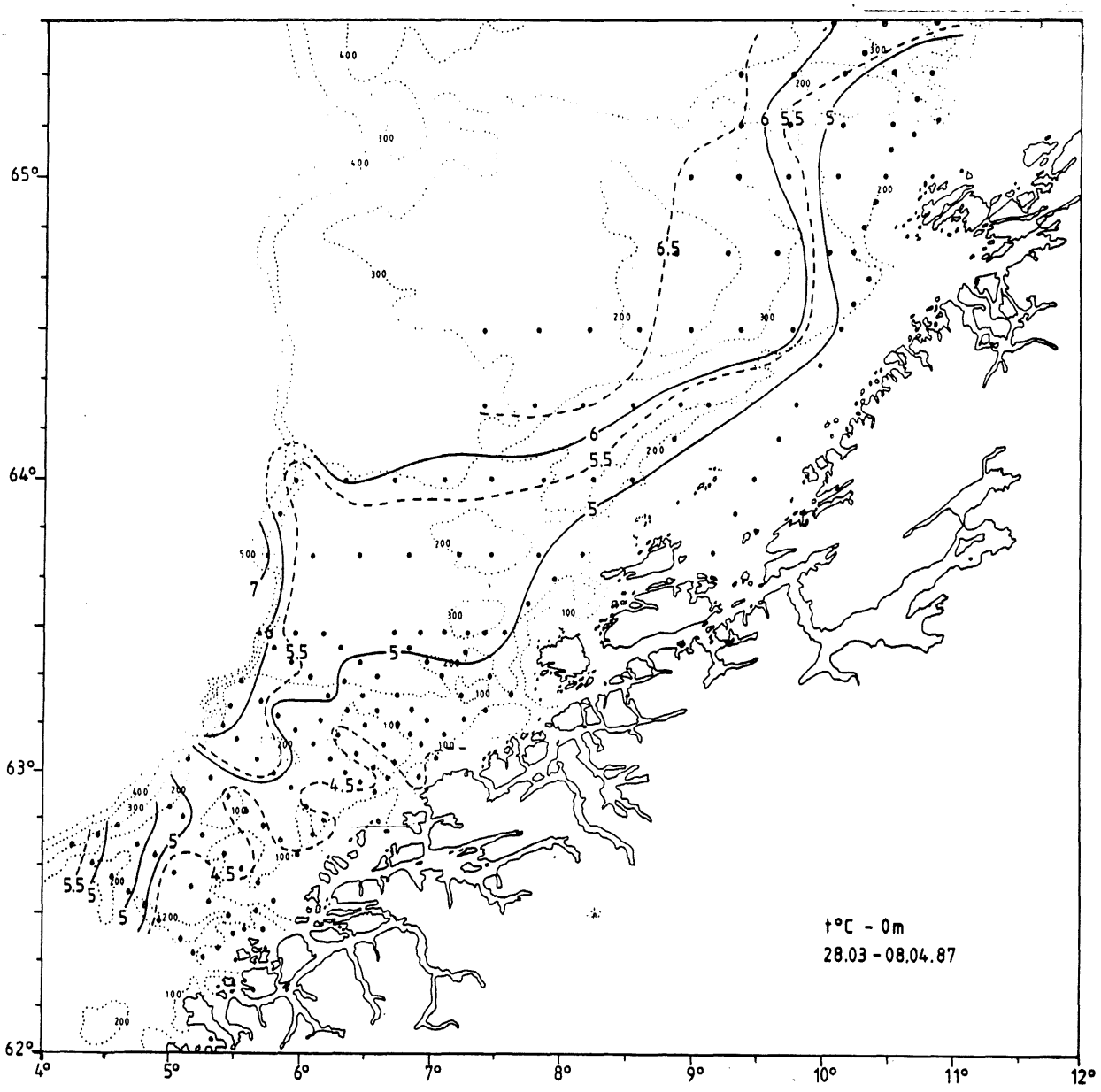


Fig. 2. Surface temperature, 28 March - 8 April 1987.

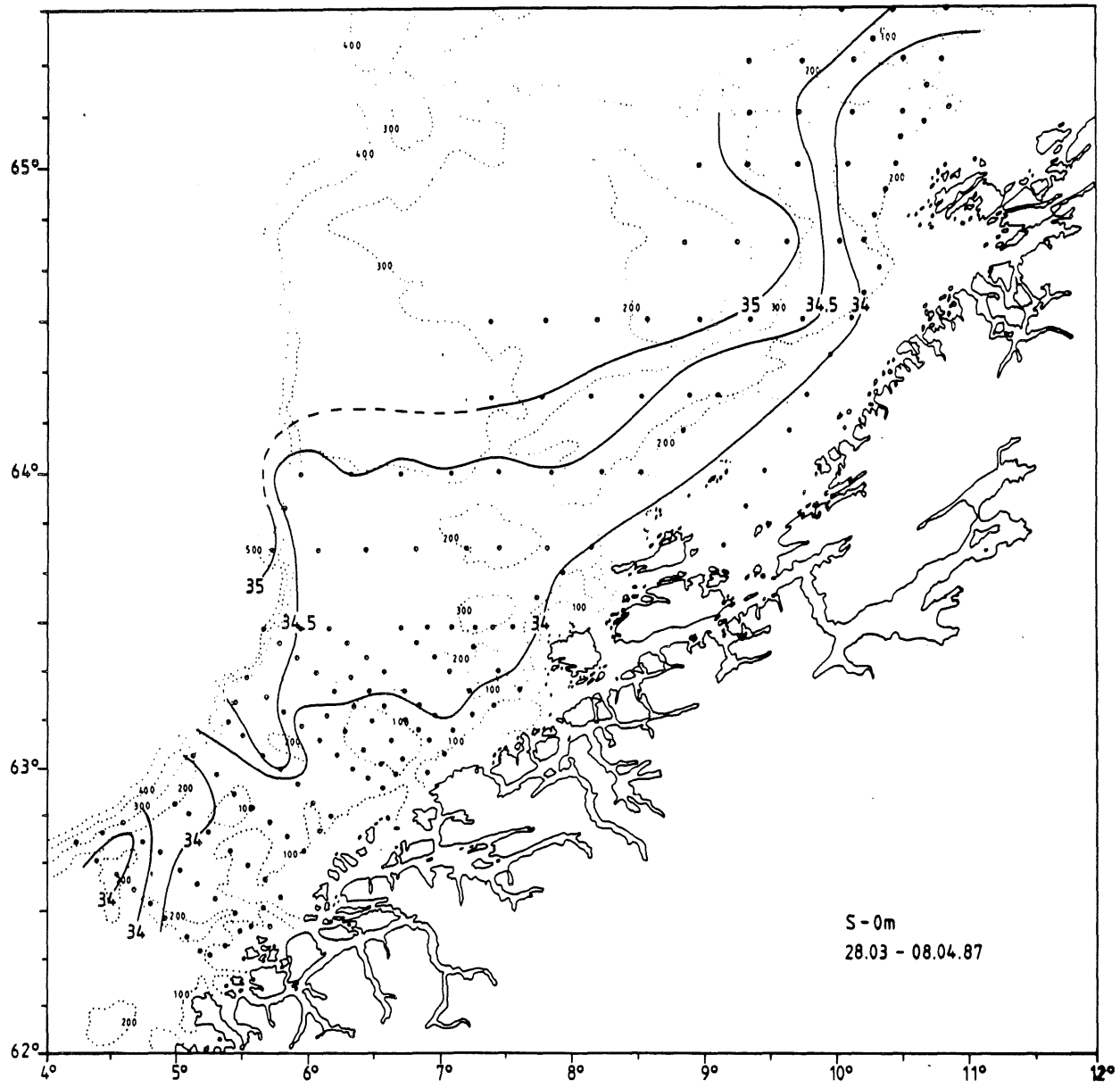


Fig. 3. Surface salinity, 28 March - 8 April 1987.

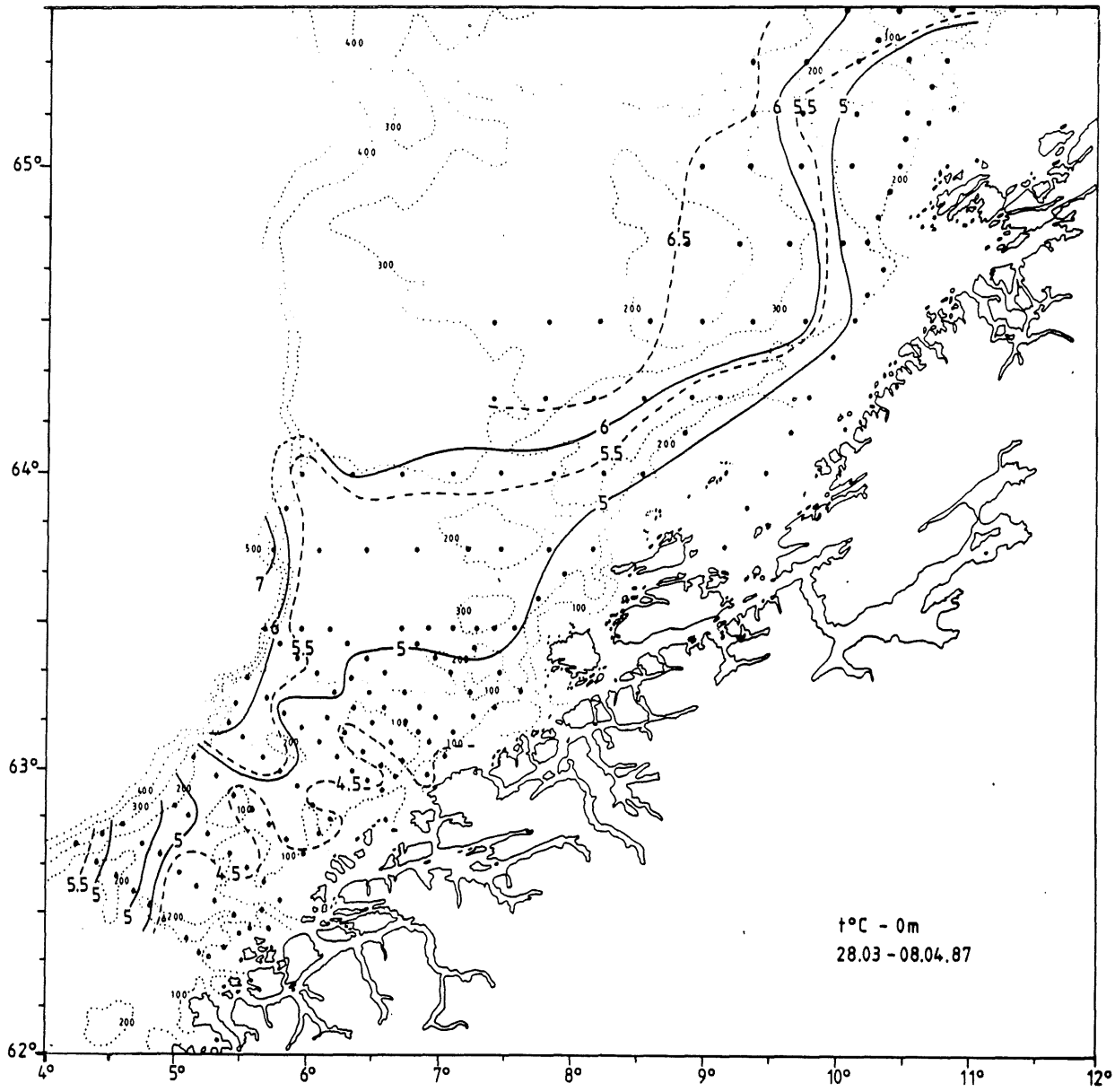


Fig. 2. Surface temperature, 28 March - 8 April 1987.

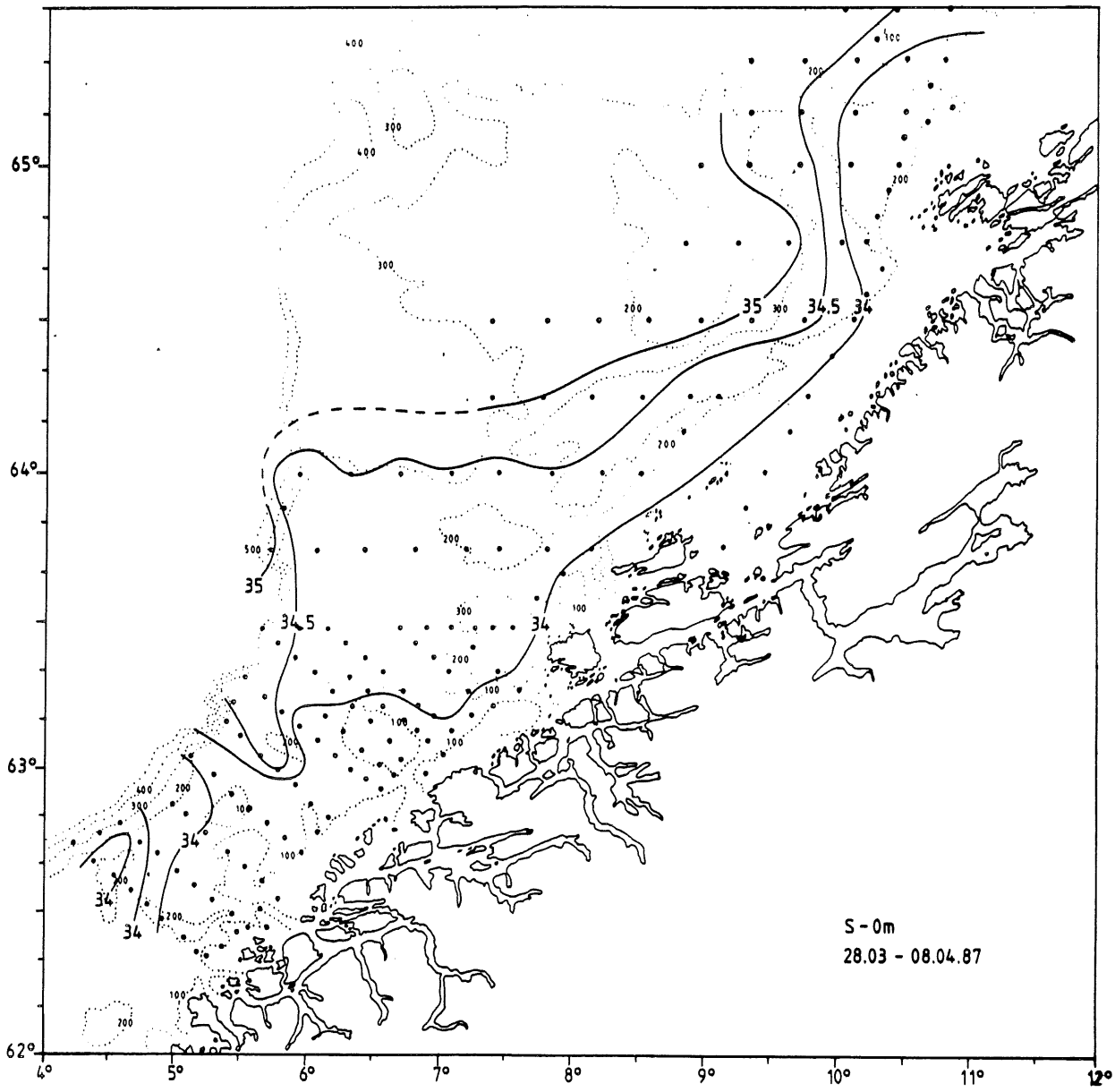


Fig. 3. Surface salinity, 28 March - 8 April 1987.

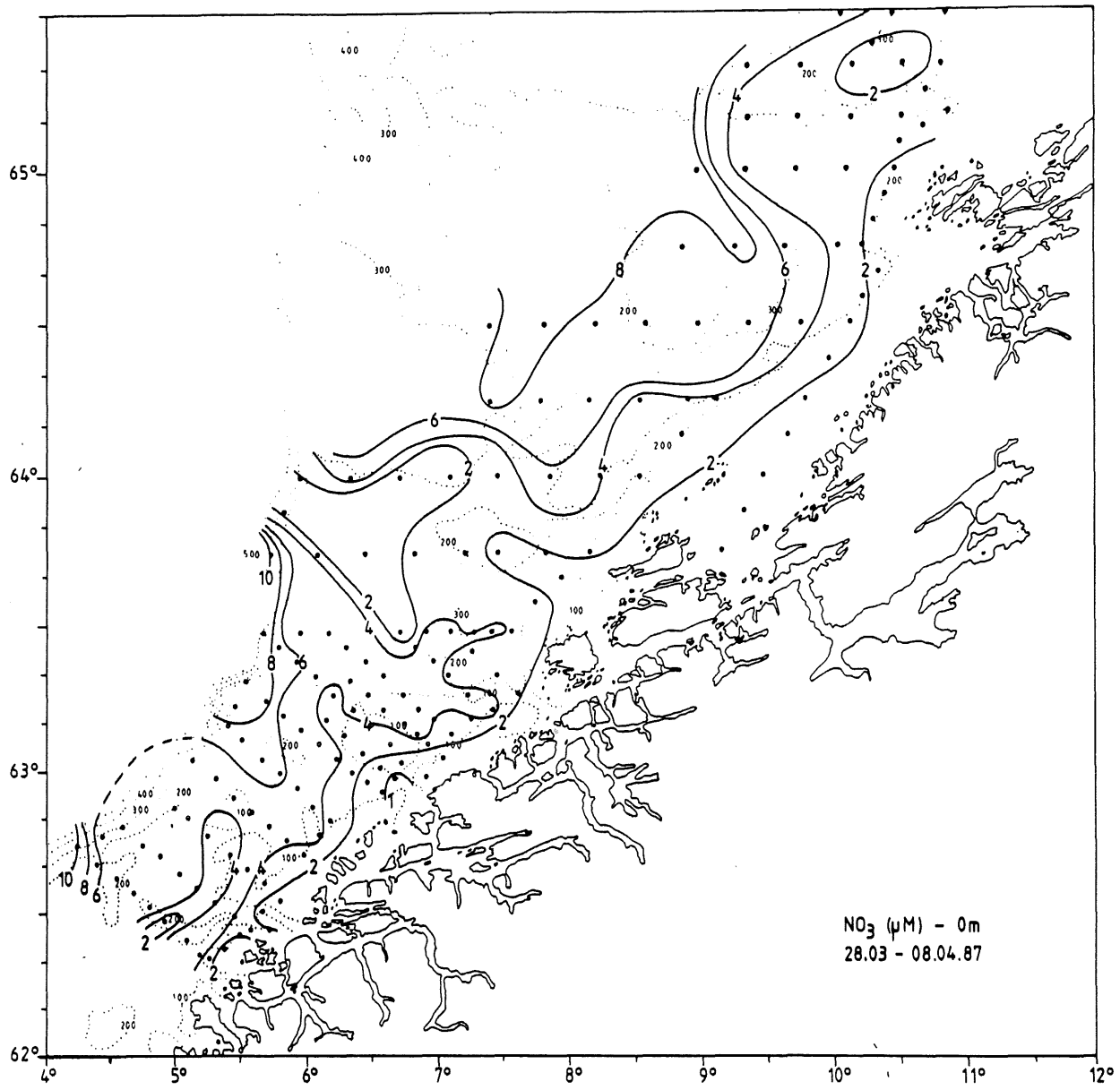


Fig. 4. Surface values of nitrate, 28 March - 8 April 1987.

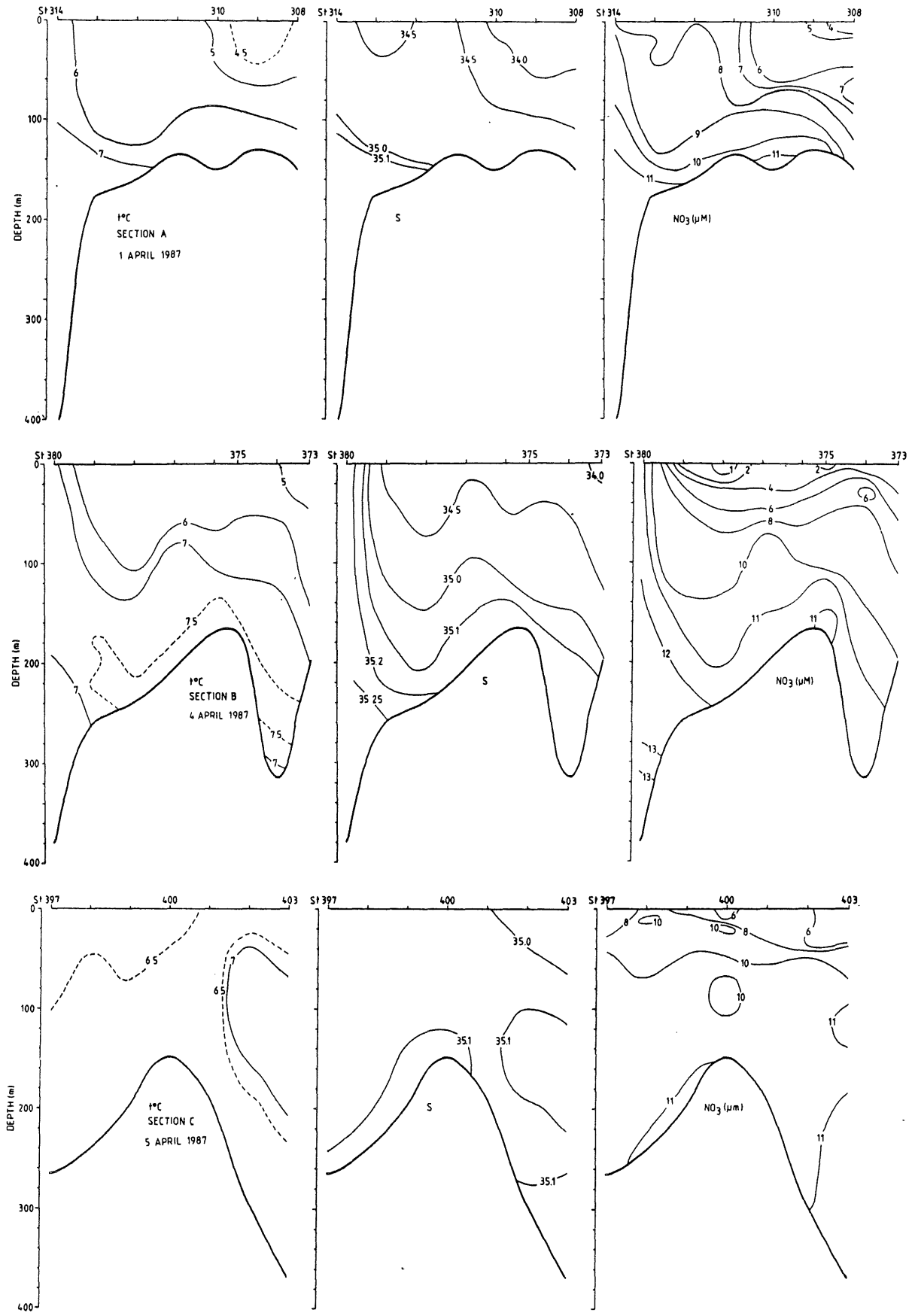


Fig. 5. Hydrographic sections A, B and C. The location of these is indicated in Fig. 1.

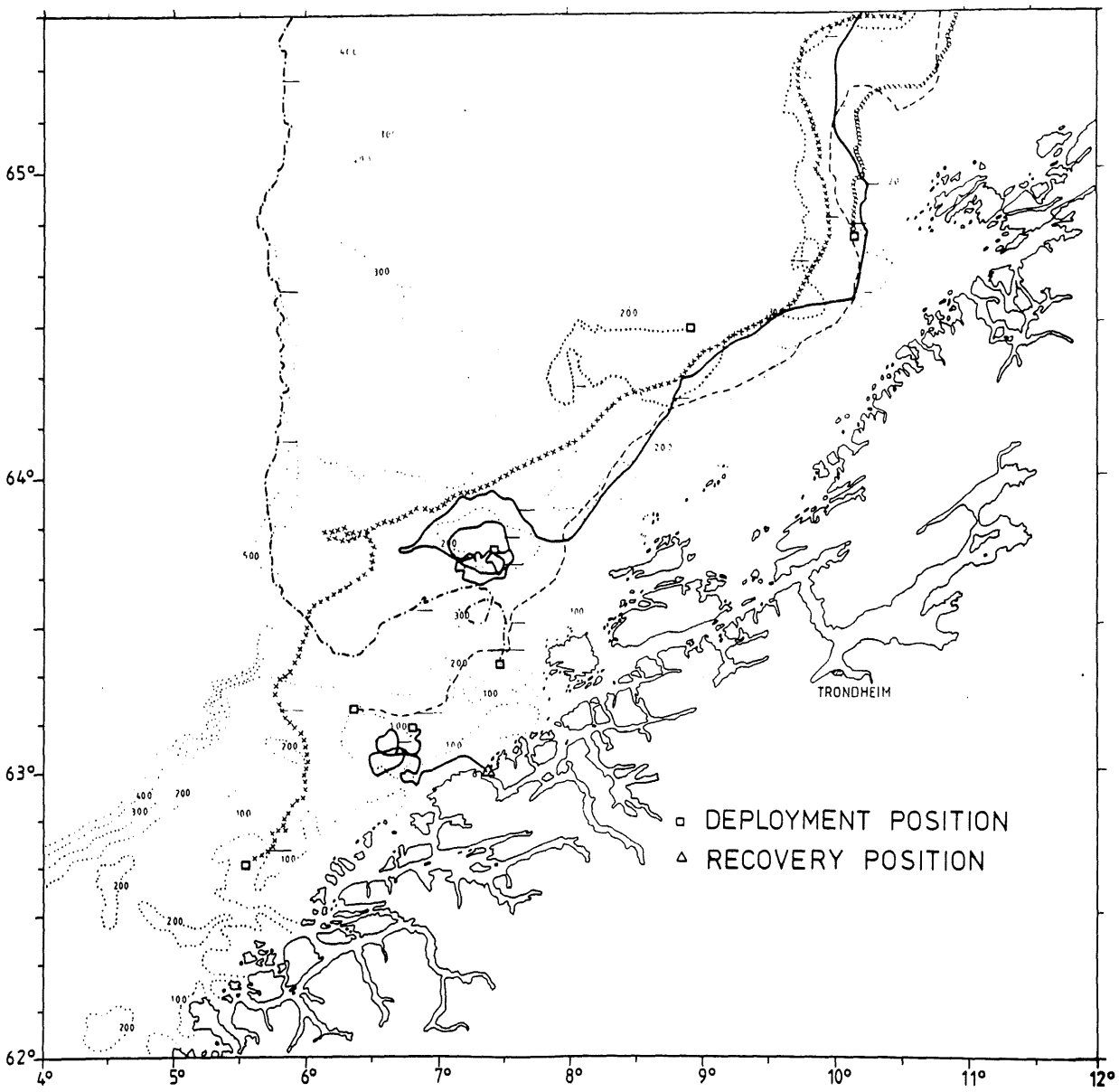


Fig. 6. Tracks of the drifting Argos buoys within the investigation area drogued at 60 m depth.

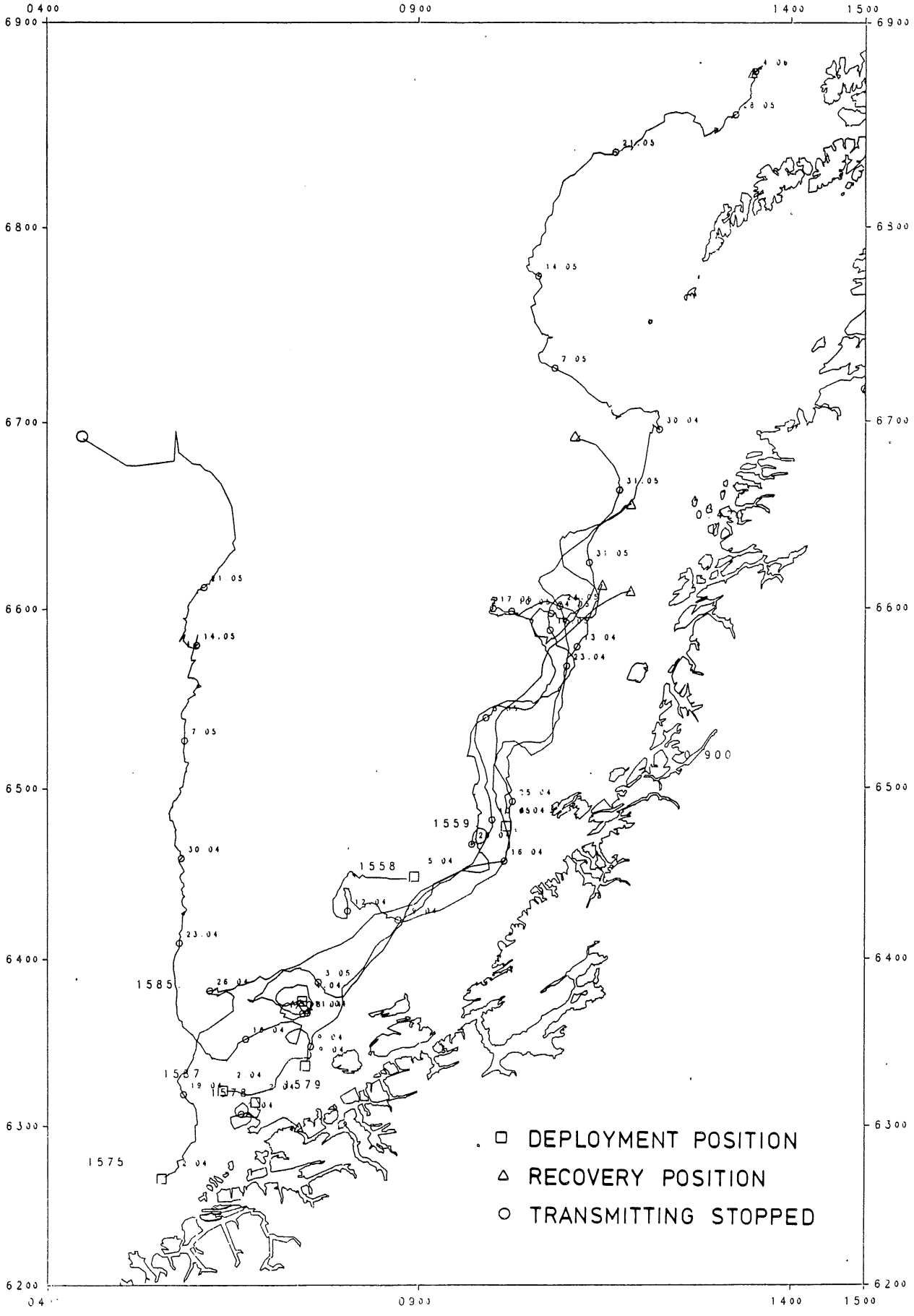


Fig. 7. The total tracks of the drifting Argos buoys.

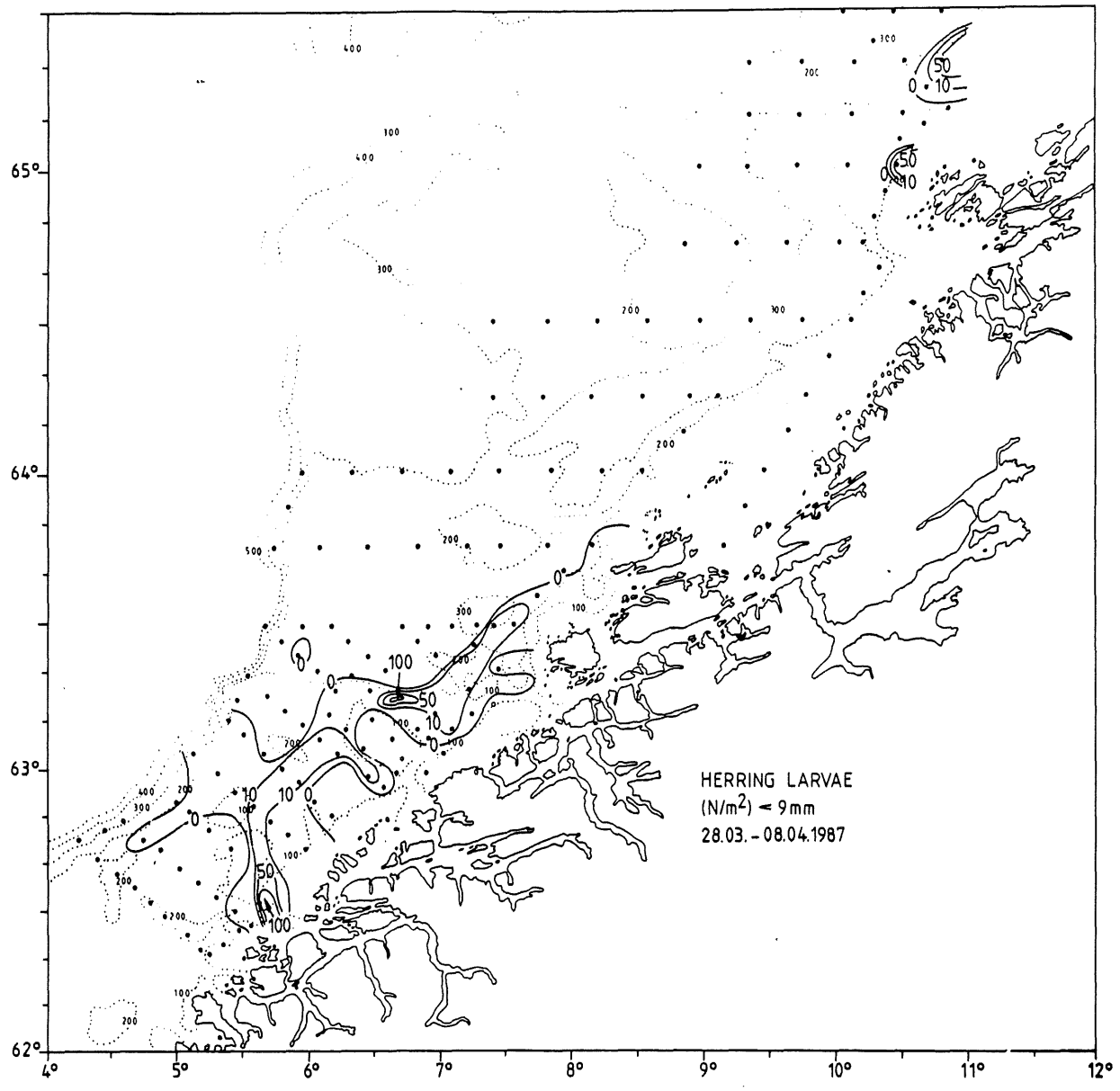


Fig. 8. Distribution of herring larvae < 9mm (N/m^2), 28 March - 8 April 1987.

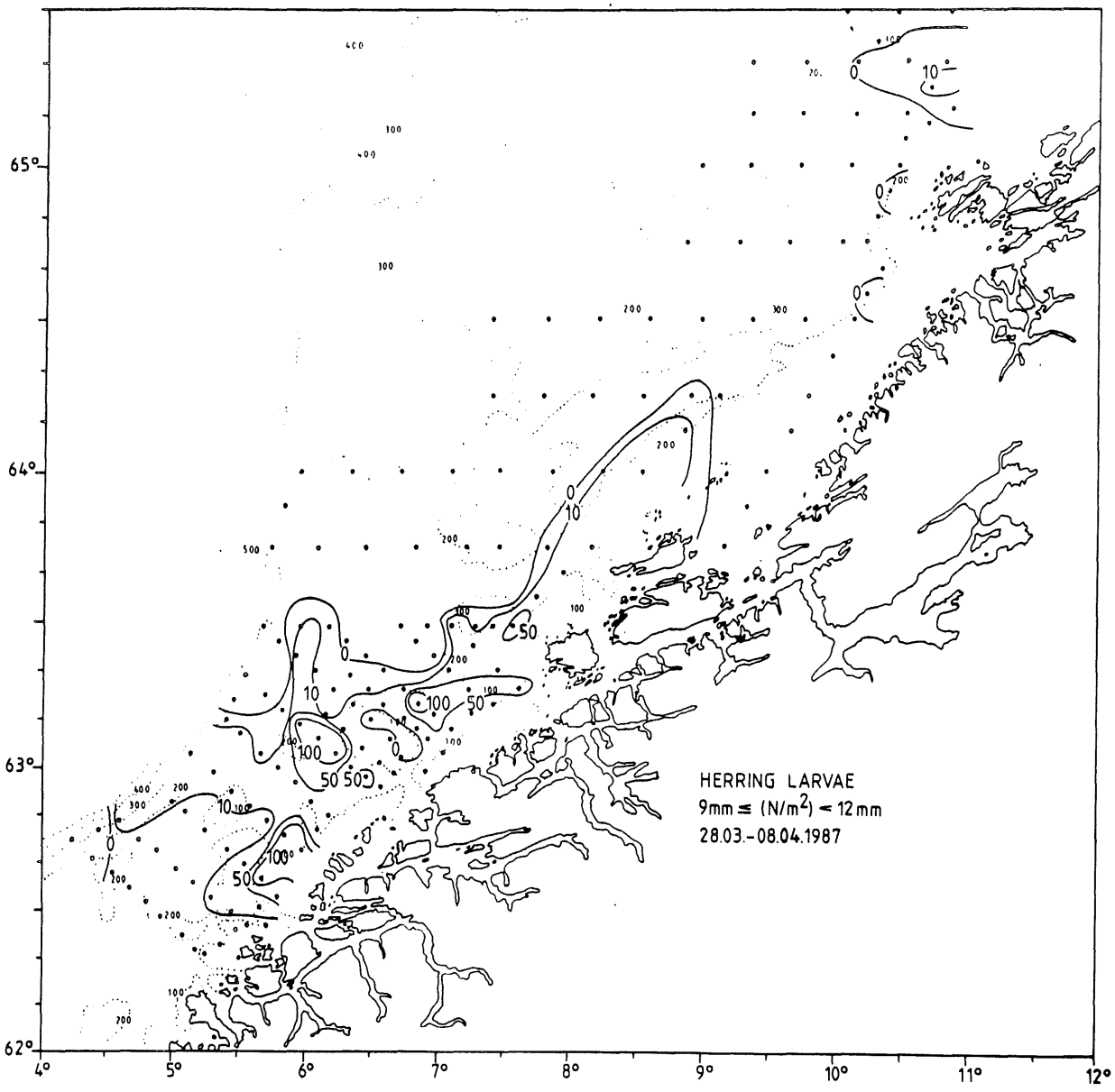


Fig. 9. Distribution of herring larvae between 9 and 11mm (N/m^2), 28 March - 8 April 1987.

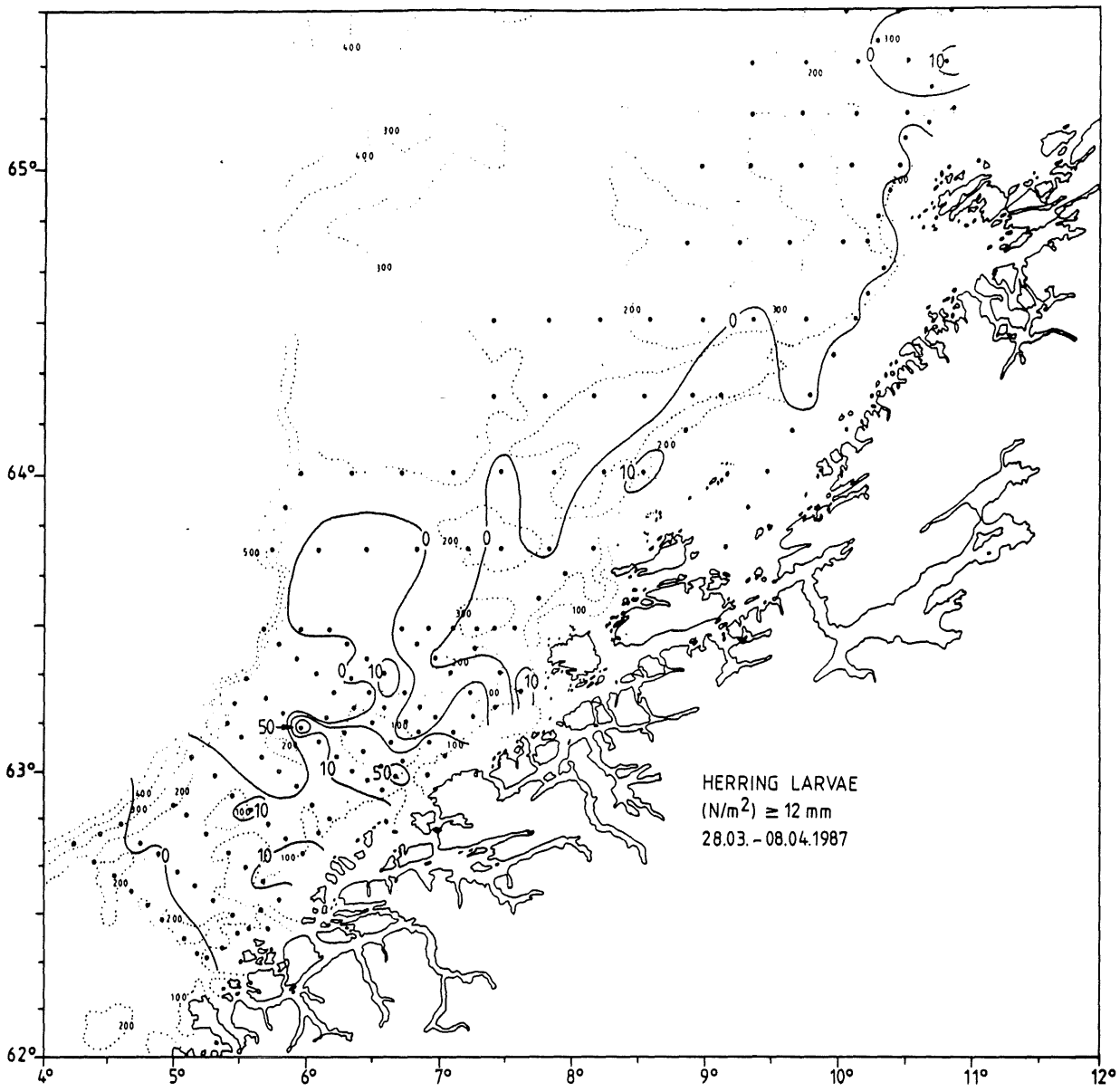


Fig. 10. Distribution of herring larvae >11mm (N/m^2), 28 March - 8 April 1987.

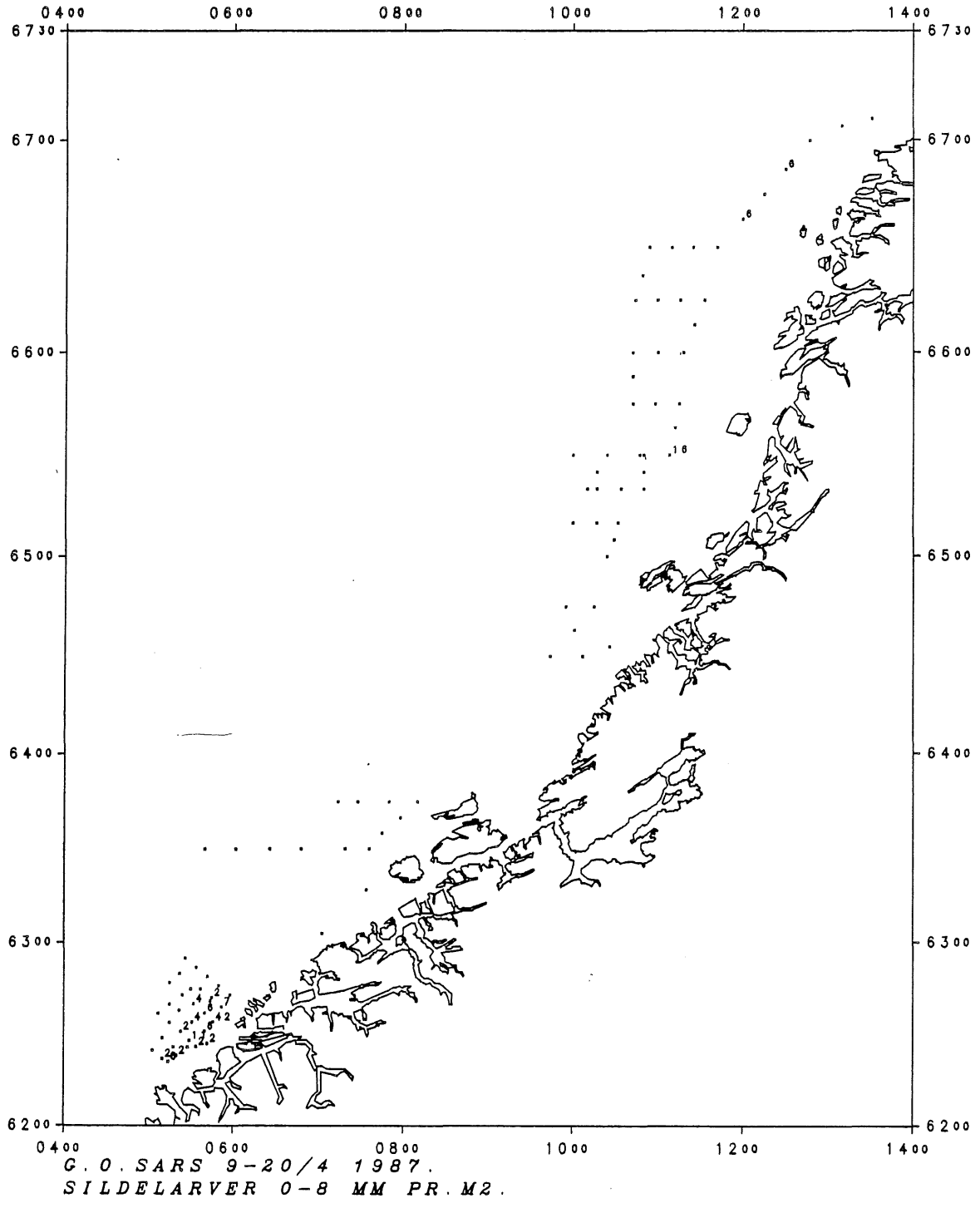
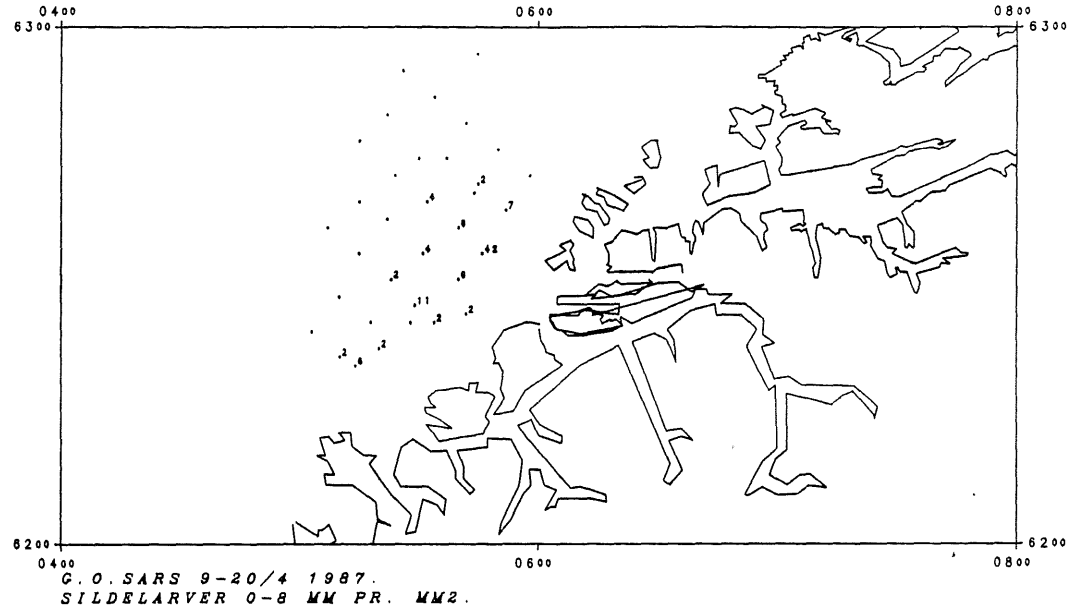
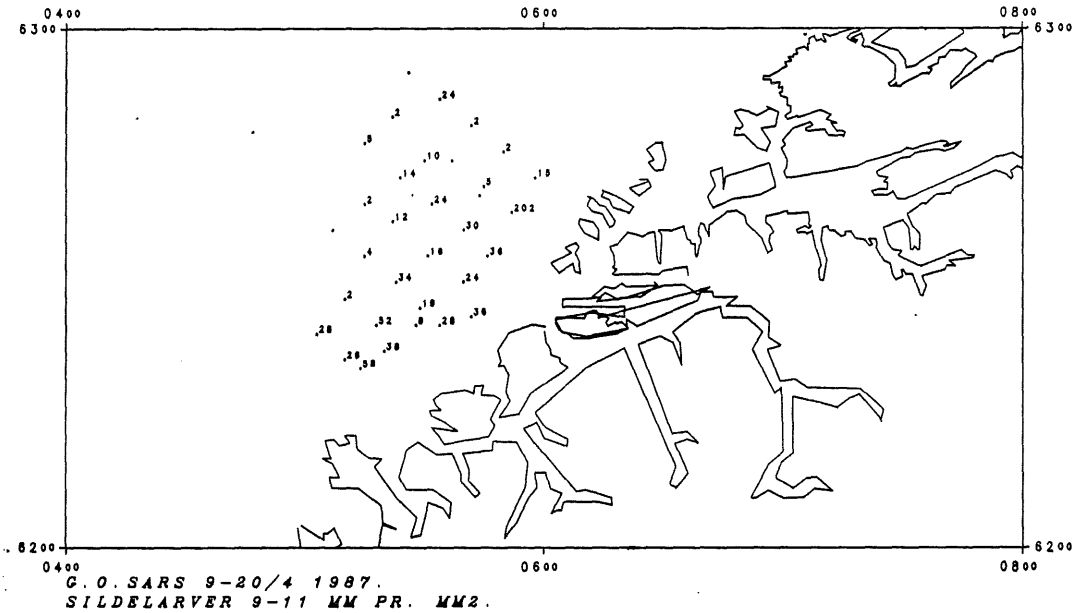


Fig. 11. Distribution of herring larvae <9 mm (N/m^2), 9-20 April 1987.





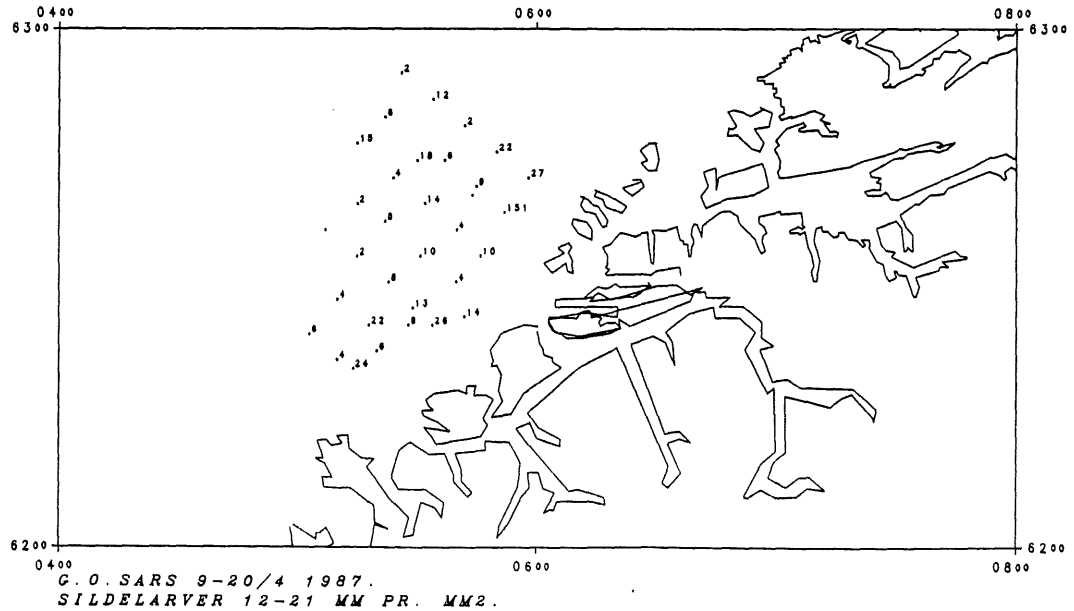


Fig. 12. Distribution of herring larvae in three length groups south of 63°N (N/m^2), 9-20 April 1987.

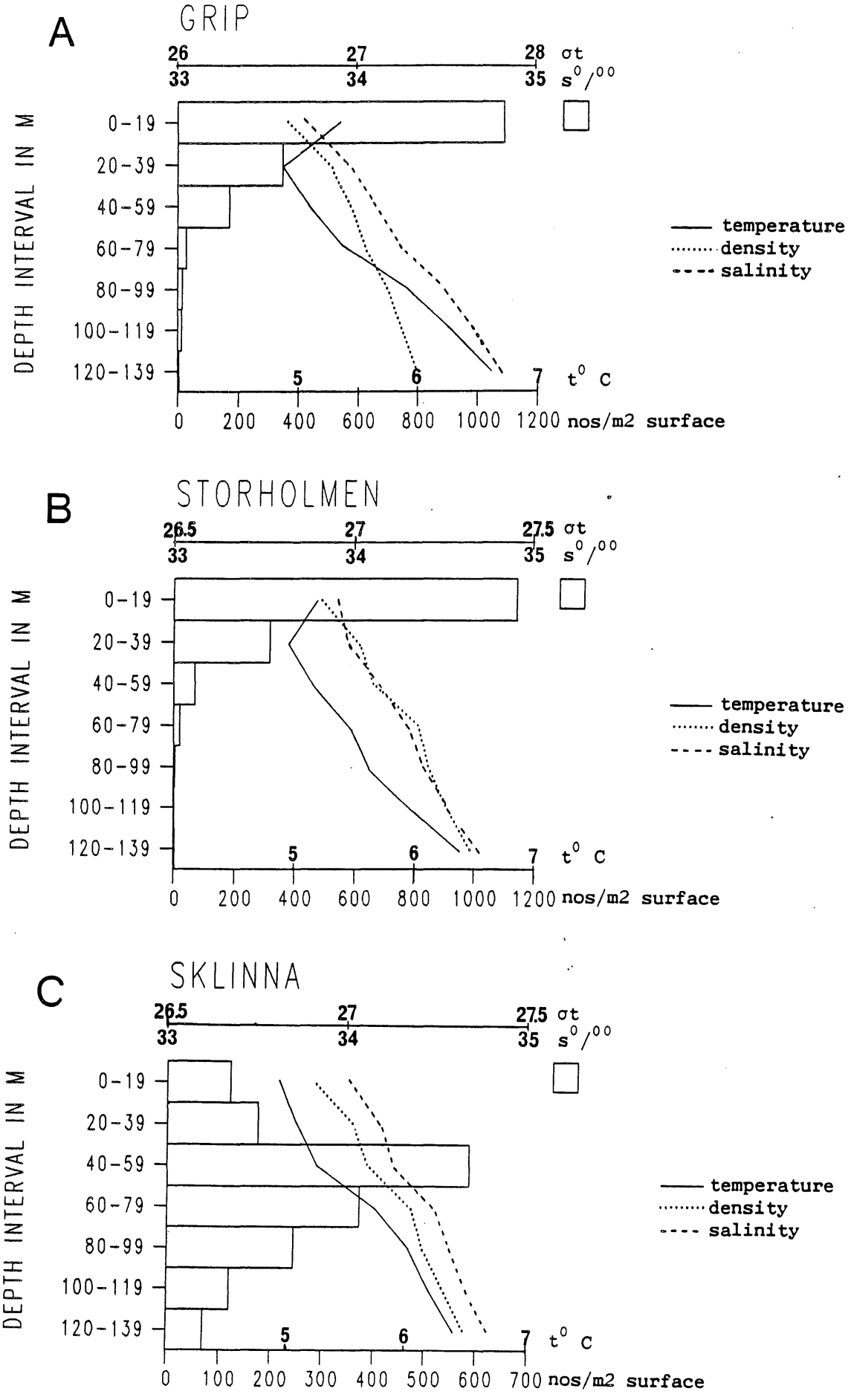


FIG. 13. Vertical distribution of herring larvae, temperature, salinity and density at the stations near Grip, Storholmen and Sklinna.

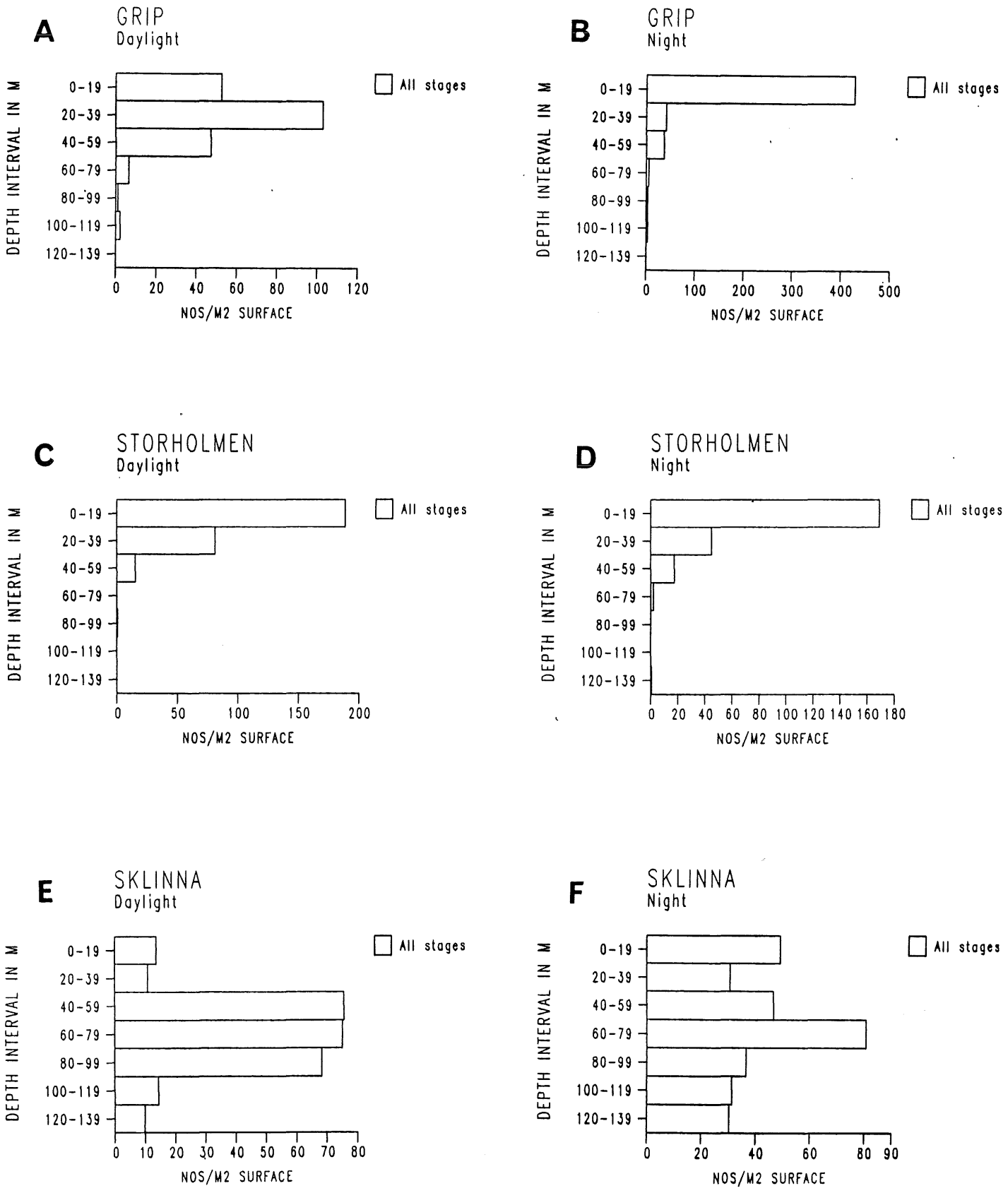


FIG. 14. Vertical distribution of larvae in all stages at the three stations during the day and the night.

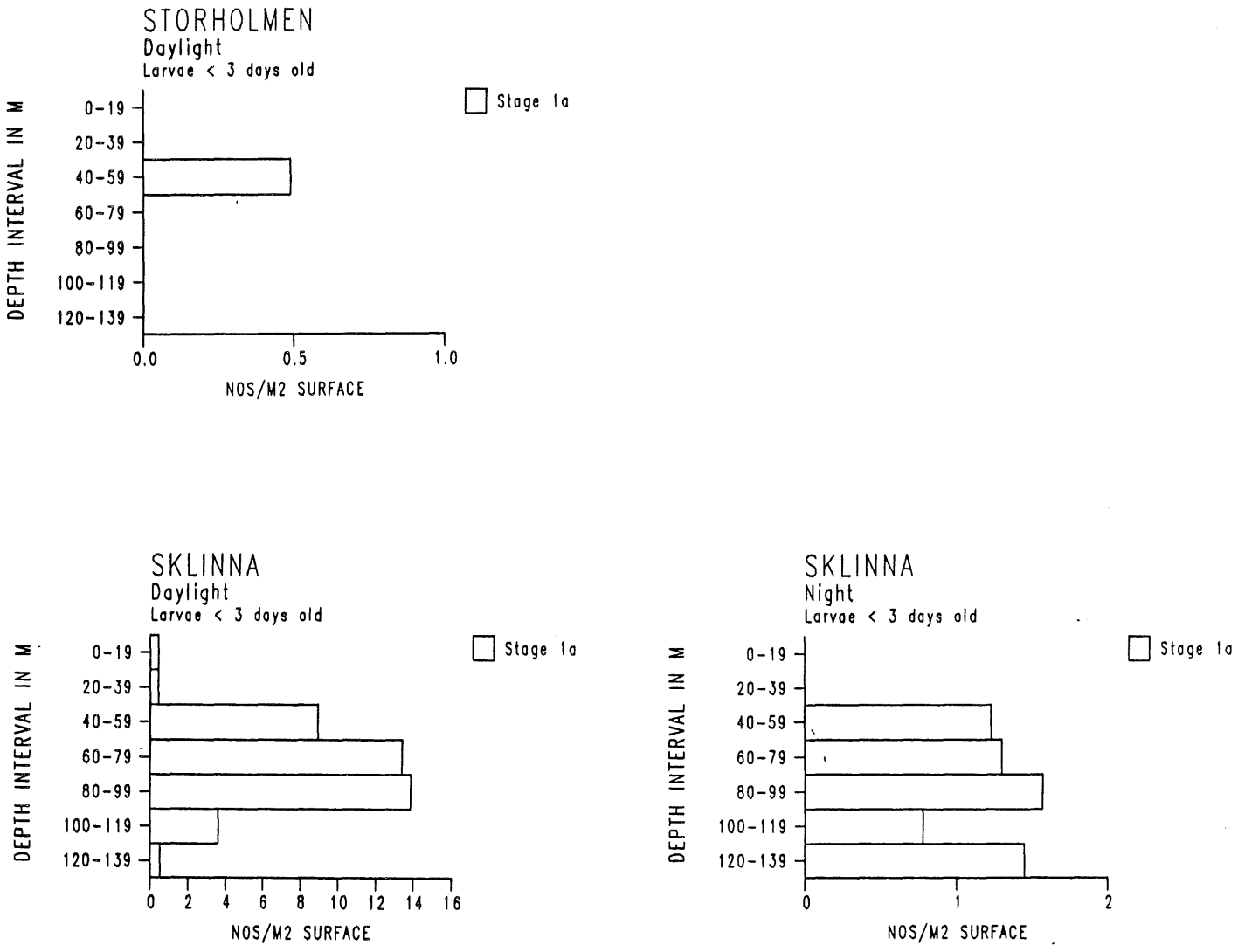


FIG. 15. Vertical distribution of larvae in stage 1a at the three stations during the day and the night.

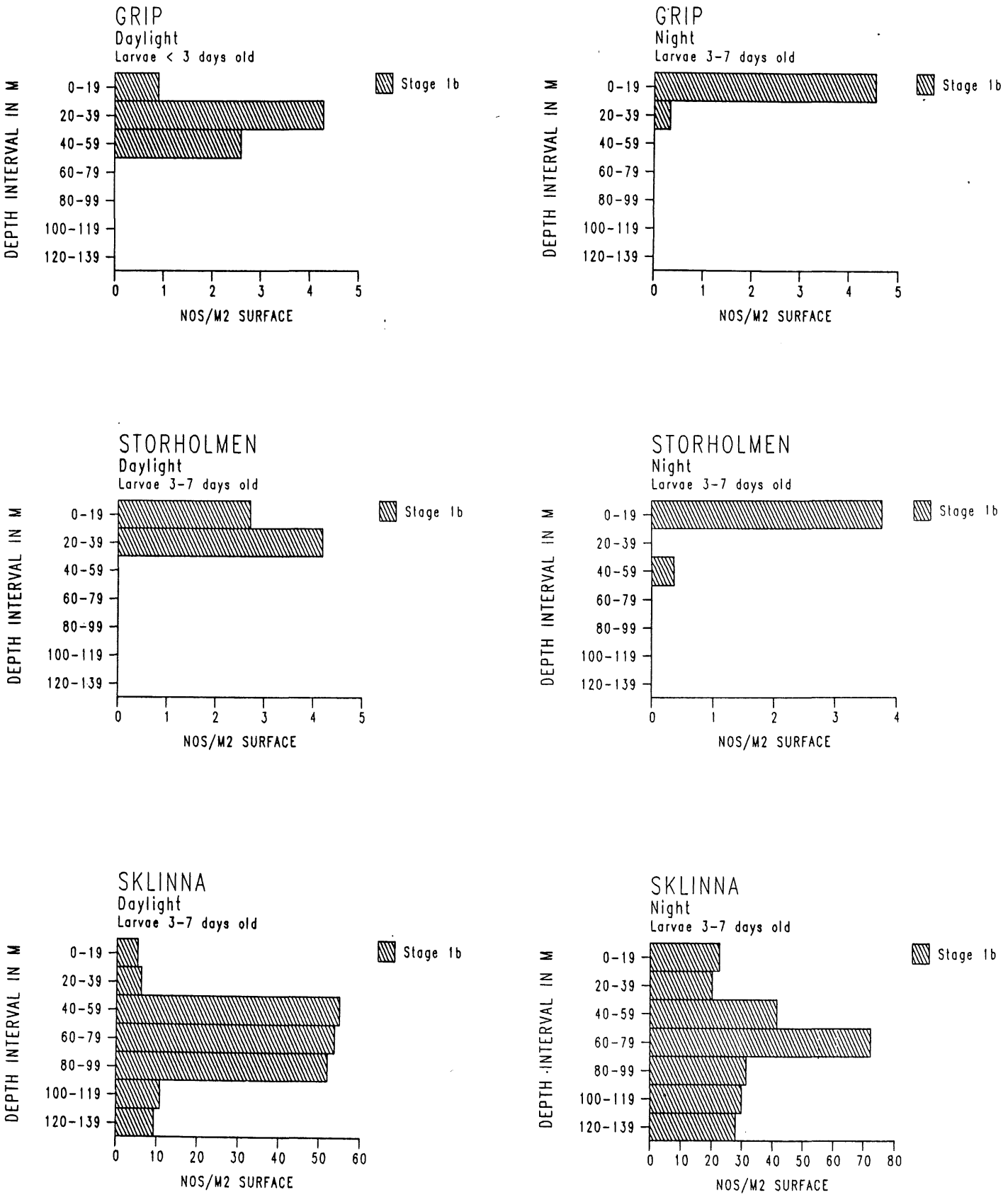


FIG. 16. Vertical distribution of larvae in stage 1b at the three stations during the day and the night.

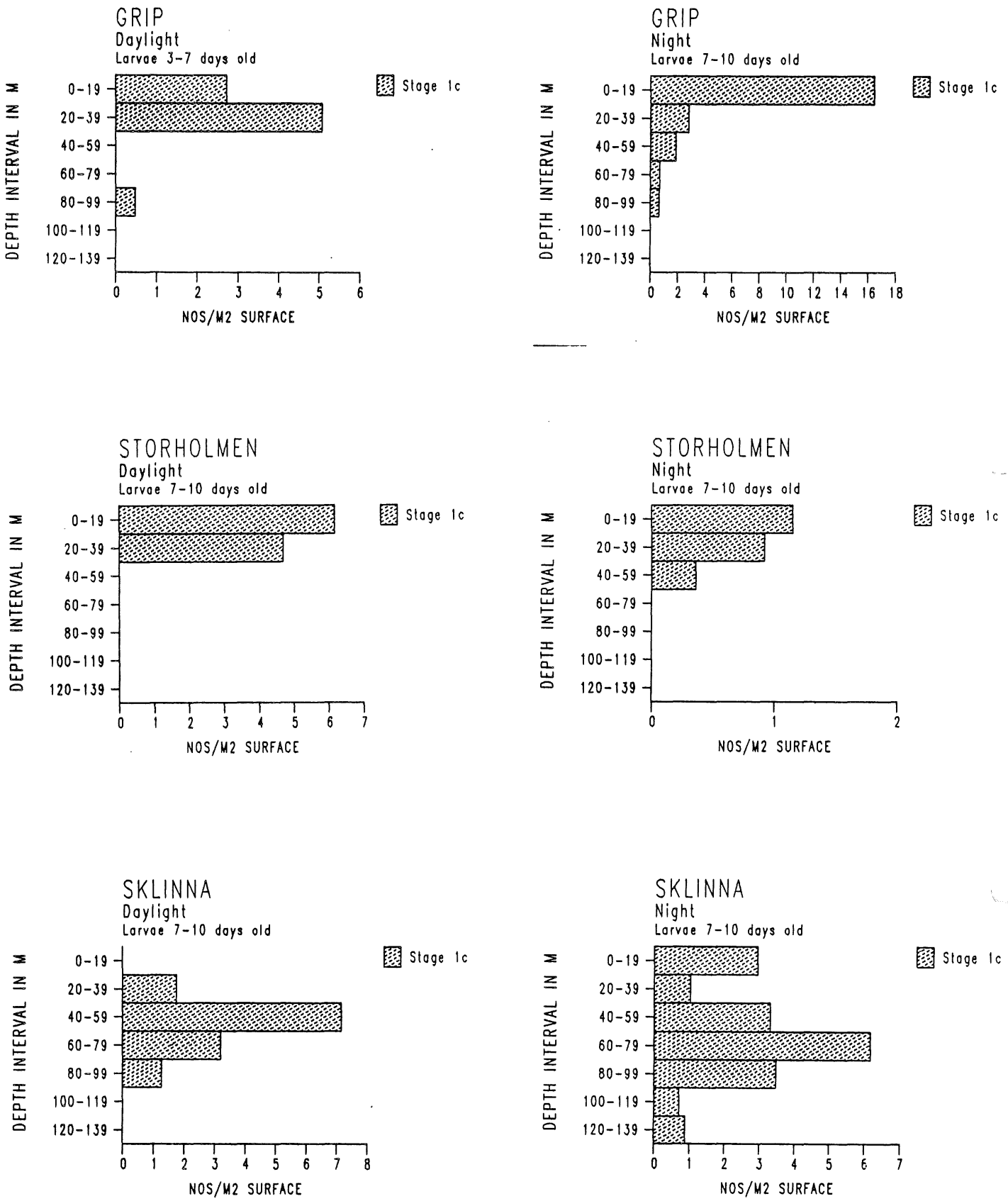


FIG. 17. Vertical distribution of larvae in stage 1c at the three stations during the day and the night.

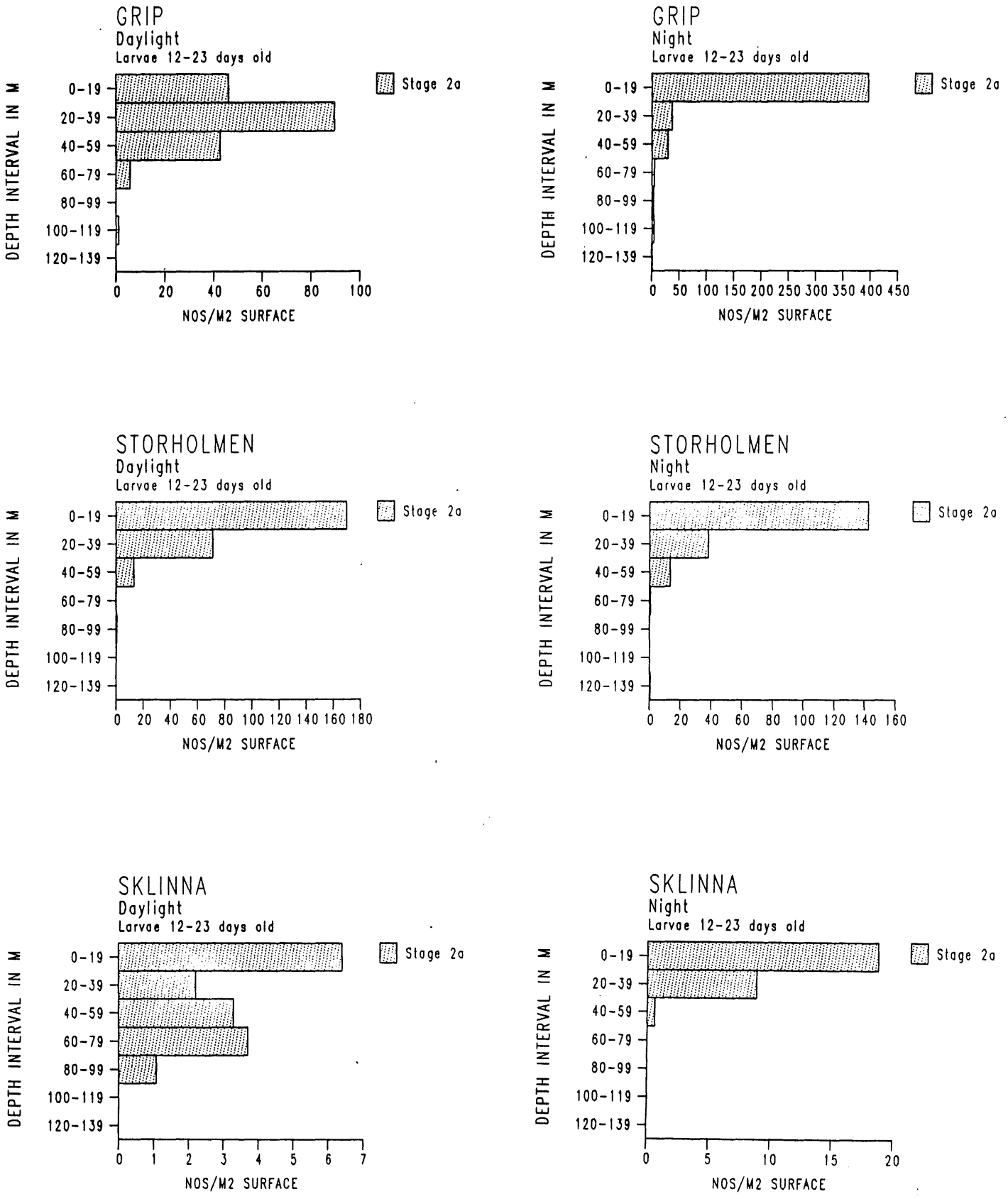


FIG. 18. Vertical distribution of larvae in stage 2a at the three stations during the day and the night.

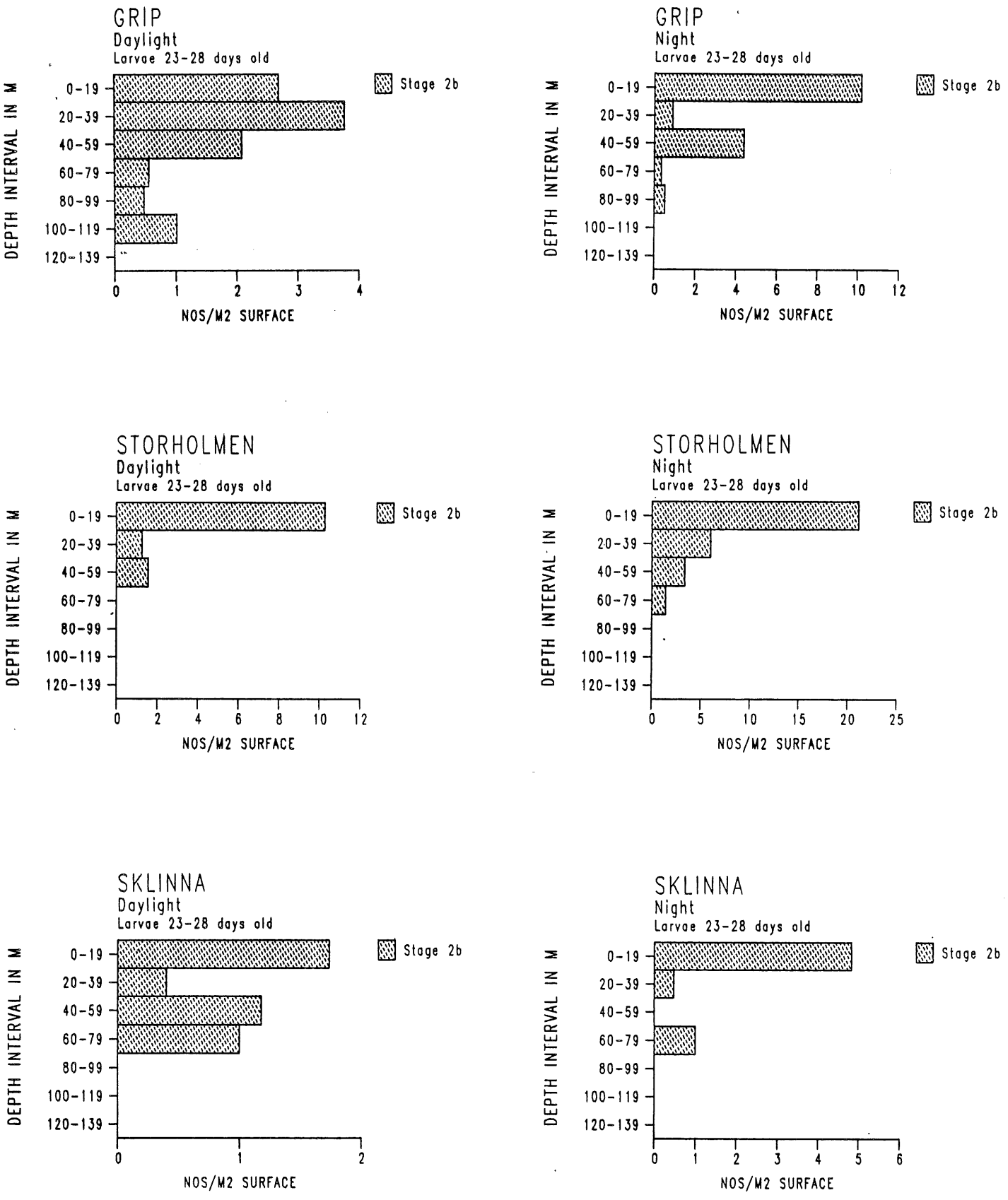


FIG. 19. Vertical distribution of larvae in stage 2b at the three stations during the day and the night.

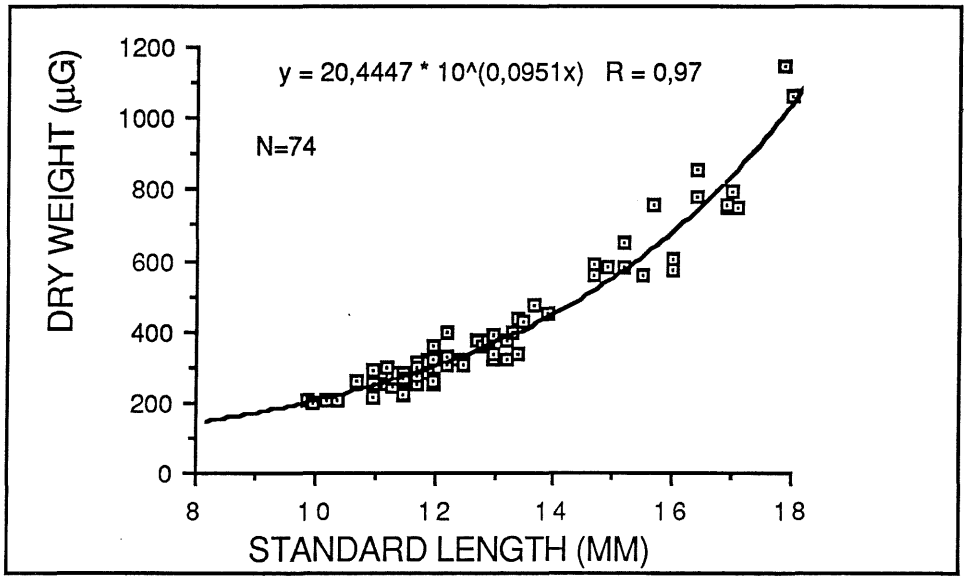


Fig.20. The standard length/ dry weight plot of the larvae not exposed to formalin fixation.

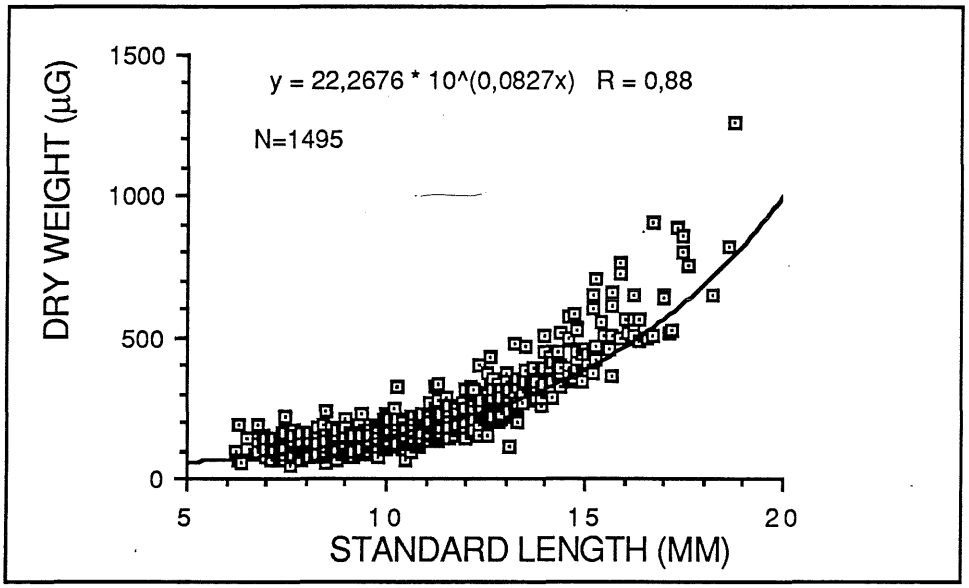


Fig.21. Length/dry weight plot of the total formalin preserved material sampled in 1987.

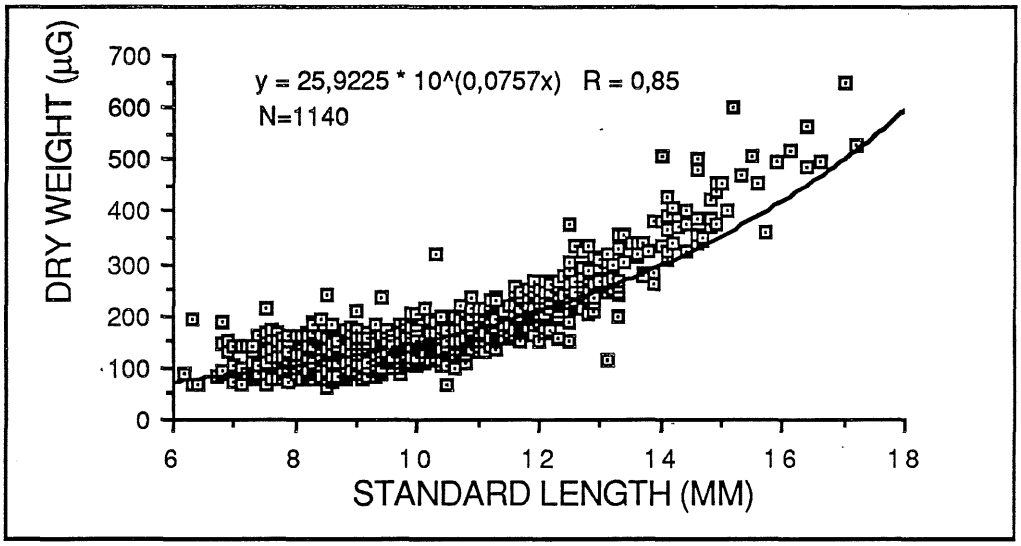


Fig.22. Length/dry weight plot of the larvae sampled on the first coverage.

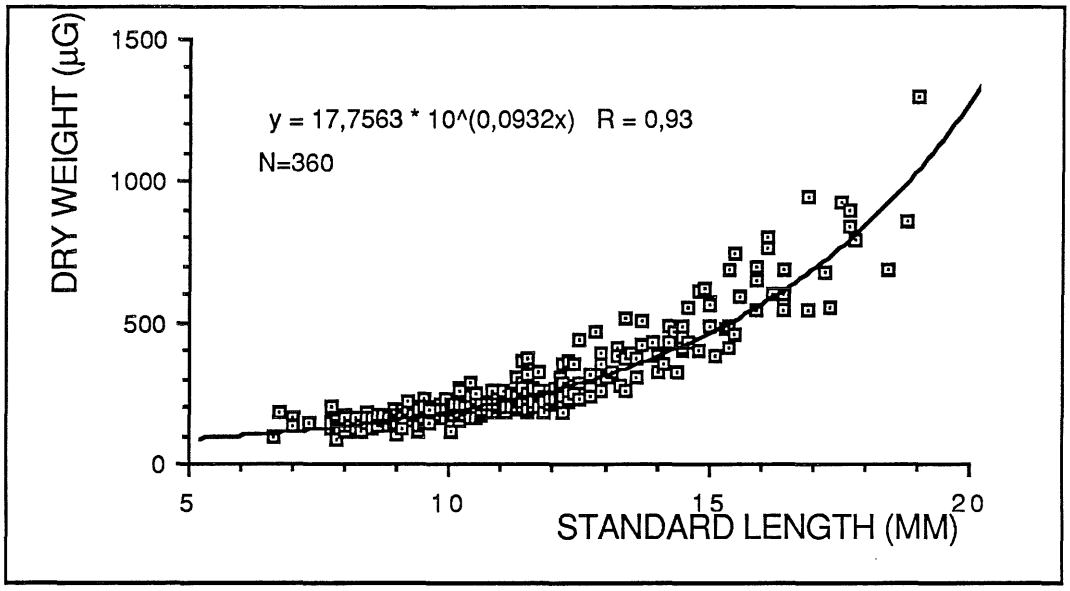


Fig.23. Length dry weight plot of the larvae sampled on the second coverage.

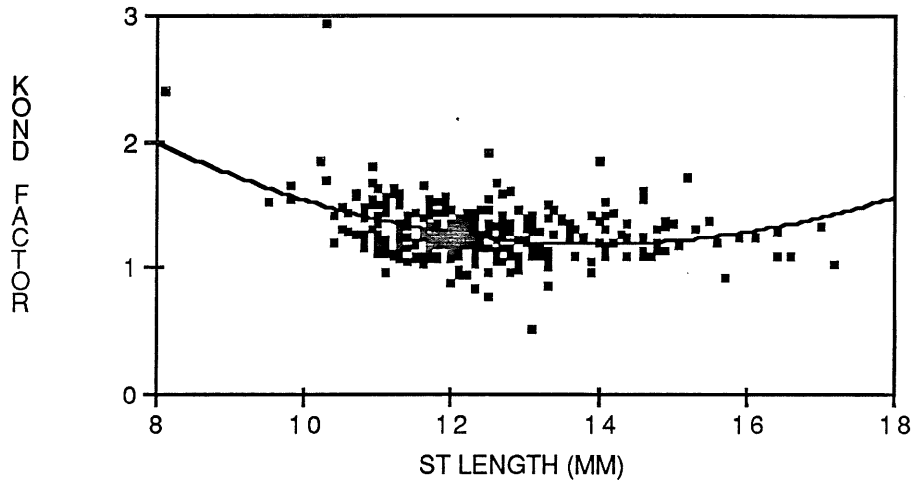


Fig.24. Length versus condition of the larvae sampled on the first coverage.

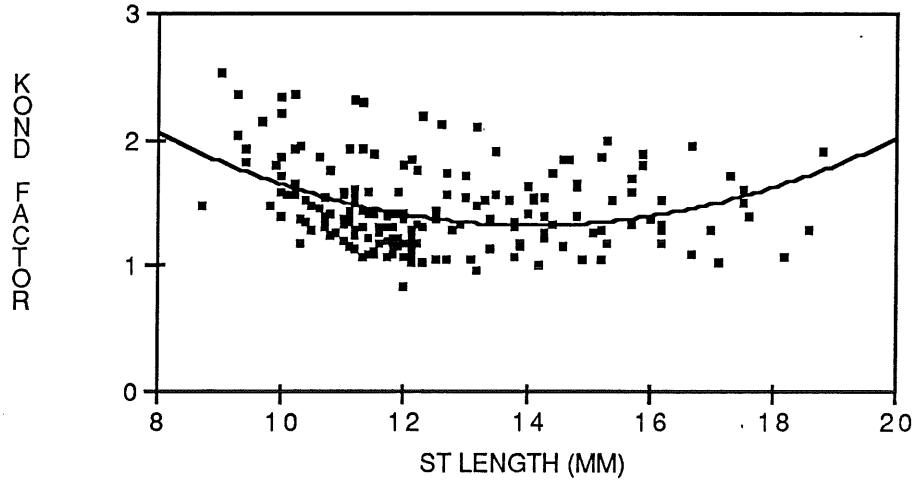


Fig.25. Length versus condition of the larvae sampled on the second coverage.

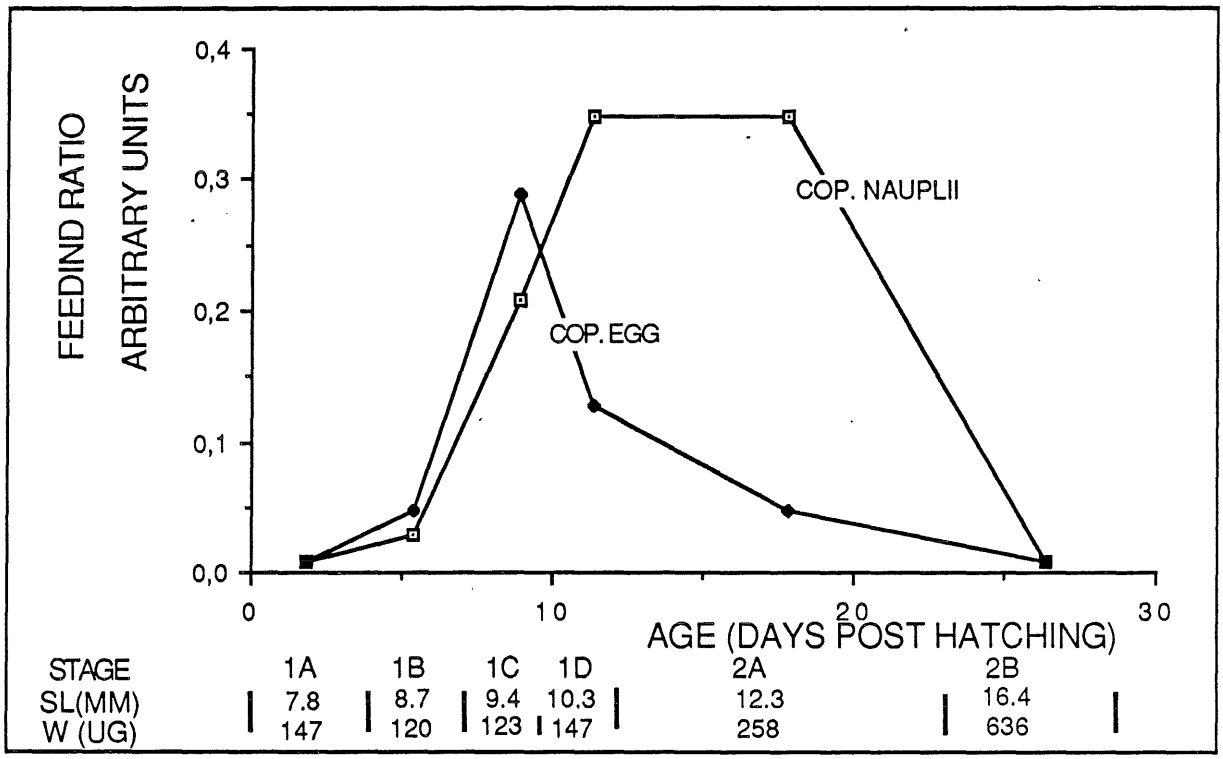


Fig.26 The diet of the herring larvae in the period 0-28 days post hatching.