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The detection of larval fish food particles by an *in situ* particle counter, and monitoring of the particle density and distribution in first feeding areas.

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ABSTRACT

An *in situ* particle analyser system adapted to the particle size ranges most frequently captured by first feeding cod (*Gadus morhua* L) larvae is described. The results achieved by the instrument compared to the results from plankton pump samples is presented. The effect of a sudden change in wind direction and velocity on the hydrography in the Austnesfjord (Lofoten area), the vertical distribution of cod larvae, food particles and the consequences on the larval feeding incidence is demonstrated.

INTRODUCTION

Johan Hjorts (1914) hypothesis for fish larval mortality is based on variable feeding conditions at a critical stage which can cause extreme variations in the year class strength. It has been difficult to test this simple attractive hypothesis in field surveys (May, 1974). The main reason for this has been the inadequacy of the sampling gear currently in use (pumps and nets) to establish whether any body of water can or cannot support fish larval survival.

During the last few years fishery scientists have done a great deal of work on the behaviour of fish larvae and their energy requirement for growth and survival (Hunter, 1972, Houde, 1978). The results of this research have without almost any exceptions showed the great differences between the required density of nutrient particles for first feeding larvae to survive and to the densities found in the sea (Hunter 1972, Lasker, 1975). However, pelagic fish has success in their environment and it has been recognized that there have to be patches of suitable concentrations of food organisms for first feeding larvae (Lasker and Zwaifel, 1977).

There has consequently been a need in fisheries research today to detect and describe these patches, and to study the biological and physical mechanisms affecting the formation of patches.

To do this one has to design and make new sampling systems adapted to particle sizes important to first feeding fish larvae. The solution to this problem seems to be *in situ* particle analysis.

Boyd (1973) adapted the Coulter counter principle to an *in situ* towed system where the sensor was connected to the cod end of a plankton net. The system counted particles within the size range of 0.5-2.5 mm. Pugh (1977) and Tungata and Raynolds (1980) adapted the Hiac-PC 320 Particle Analyser to a shipboard on line sampling system.

The present paper describes and presents some of the results achieved by an *in situ* instrument system designed to sample, count and size analyse particles within the size range 150-600 µm. The size range of food particles most frequently captured by cod larvae (Ellertsen, *et al.*, 1977).

MATERIALS AND METHODS

The Particle Analyser

The in situ particle analyser system is schematically presented in Fig. 1. The system is based on a Hiac-PC 320 Particle Analyser (works on the principle of light blockage).

The sensor (E-2500, dynamic range 80-2500 µm) is installed in a pressure-proof box together with a depth detector. A pump is connected to the sensor. The sensors and the pump is lowered in the sea by a special winch. Sea water is sampled by the pump through a 60 cm 30 mm in diameter hose and pumped through the sensor at a flow rate of 6.15 liter per minute.

Particles are counted by the Hiac PC-320 Particle Analyser, depth sensed by the separate depth detector unit. The Microcount datalogger unit contains an input-output interface to take care of the incoming data, a large internal data storage area to hold the accumulated data, operator communication via a small CRT display, a keypad, and a microprocessor with program to controll the system. Finally, a Silen 733 terminal is connected to the micro-computer. This terminal contains a full text keyboard and a page printer, used for initial operator communication, and later for printout of data tables. Two cassette tape stations are included in the terminal.

The system operates from 0-50 m of depth and the registration of particles are presented on the TV monitor as the sensors are lowered in the sea. The vertical distribution of particles can be presented on the monitor per meter, per 2 meters or per 5 meters depending on the selected depth intervals one wants to monitor.

When a profile is made the data are printed out in two tables, as particles per meter in 6 size ranges, the time spent by the sensor at each depth interval, and as particles/liter per meter of depth in 6 size ranges. At the same time the data are stored on cassette tape.

Field investigations

The instrument system was tested, and the biological samples were collected on two cruises to the Austnesfjord (Fig. 2) in the main spawning area of the Arcto-Norwegian cod stock in Lofoten, Northern Norway in May 1980 and in May 1981. In 1981 tests was also made in the open ocean waters off the Lofoten island (Fig. 3).

Cod larvae were sampled by Juday net (80 cm, 180 µm mesh size) and by a submersible electric pump (Flygt B 2125, 3.4 m^3/min) at 5, 10, 15, 20, 25, 30 and 35 m depth, 15 m^3 were sampled at each depth. The sea water was pumped through a 15 cm hose and filtered through a small Juday net (180 µm mesh size) in a big tank on deck. Zooplankton was also sampled by a submersible electric pump (Flygt 2051, 250 l/min) and pumped on deck through a 5 cm hose. The sea water was collected in calibrated tanks (23.7 l) and the zooplankton filtered on 90 µm mesh size plankton net. Samples were collected at 0, 2.5, 5, 2.7, 10, 15, 20, 25, 30 and 40 m depth. As a rule zooplankton were sampled at the same time as the in situ particle profiles were made during 24 hours stations, and on every second station when a section was made.

During the cruise in May 1980 a Wolfe wind recorder was placed on land in the Austnesfjord, measuring wind velocity and direction continuously during the cruise. Temperature and salinity were measured by a CTD sonde.

RESULTS

The Hiac Particle Analyser measures the size of irregular particles, such as a nauplii, as ratio of its areas. Artemia nauplii were measured by the microscope in the same way and their size distribution divided in four 50 µm size groups from 200-400 µm. Four of the Hiac Particle Analyser channels were set according to the sensor calibration diagram in the same size groups. The result of this comparison is presented in Fig. 4.

A test at sea was also made. The in situ particle analyser was submerged to 5 meters depth. The concentration of particles, 300-500 µm size range was calculated in ten samples (total volume 25 l) and the particle density at 5 meter was estimated. At the same time sea water from the same depth was pumped on deck by the electric submersible pump, two 23.7 liter were filtered on 90 µm plankton net and zooplankton within the size range 300-500 µm were counted. The results from the two methods are presented in table 1.

Table 1. The particle density (300-500 µm) at 5 m of depth at position 5 in the Austnesfjorden (Fig. 3). The result from the in situ particle analyzer is compared to that from the plankton pump.

	In situ P.A.	Plankton pump
Particle cons.	16(liter (SD±2.1)	19/liter
Samples	10 x 2.5 liter	2 x 23.5 liter
Total no. of particles	381	1692

Both the size calibration on Artemia nauplii and the counting experiments at sea turned out satisfactory.

In Fig. 2 (see also Fig. 3 for general view) is presented a map with sections of the Austnesfjord where most of the in situ particle analyser tests took place. The figure also shows the increase in the number of cod larvae in the fjord during the survey.

In Fig. 5A is presented the vertical particle (150-600 µm) distribution in a 24 hours station at position 5 on the 22-23.4.81 in the Austnesfjord. The maximum observed particle concentration was a small patch of 50 particles pr. liter at about 15 m. The particle isolines in the upper 20 meters tend to ascend to the surface at midnight, indicating diurnal vertical migration. Fig. 5B shows the distribution of copepod nauplii

(all sizes) during the same 24 hours station. The figures 5A and 54B resemble fairly well each other, the nauplii isolines in the upper 20 meters indicate the diurnal vertical migration of the nauplii.

Another 24 hours station was made 6 days later at the same position (Fig. 6 A and B). The particle concentration had increased markedly during that period. More than 50 particles per liter were found at 25-35 m on every profile during the 24 hours station. A very dense surface patch was found at midnight with more than 500 particles pr. liter. In Fig. 6B the distribution of nauplii only, during the very same 24 hours station. This Figure is the result of samples taken by the submersible plankton pump. Figs. 6A and B show about the same particle/nauplii isopleth diagram and particle/nauplii distributions. However, Fig. 6B shows more clearly the diurnal vertical migration of the nauplii. This was investigated more closely to see what sizes of nauplii which made vertical diurnal migration. In Fig 7 is presented the size frequency distribution of nauplii at 30 m at 13 hours, 23 hours and 09 hours, and 0 m at 23 hours during the 24 hours station on the 28-29.4.81. It appears from the figure that it is only the bigger nauplii (200-350 µm carapax-length) which make vertical diurnal migration. The hydrographic situation during that 24 hours station was perfect for this type of observation. There was no wind in the fjord and consequently no vertical turbulence. The temperature distribution in the upper 60 meters during the experiment is presented in Fig. 8. Cooling of the surface water took place during the 24 hours station and one can see cores of cold water (2.4-2.6^{o}C) in the upper few meters. Between 5 to 15 meters a layer of warmer water (2.7-2.8^{o}C) was observed. An intermediate layer of colder water (2.6^{o}C) was found between 15-50 meters, above the transition layer (Coastal water-Atlantic water), with rapidly increasing temperature with depth.

Figs 9A and B presents the particle (150-600 µm) distribution in 0-40 meters depth through a section of the Austnesfjord. The section was made by night on the 27/4-28/4-81 from 21^{30} hours

to 04^{20} hours. There was very little to no wind in the fjord when the section was made. Patches of more than 100 particles per liter were found in the surface water of the outer parts of the fjord. A minimum layer was observed at 10 m of depth in the middle of the fjord where the particle density was less than 10 particles per liter. In the bottom of the fjord three patches of more than 50 particles per liter were found at different depths. Fig. 9B shows the naupliar distribution on the same section. Highest concentrations were observed in the bottom of the fjord at intermediate depths and in the surface water of the outer parts of the fjords, and thereby resemble the distribution of particles.

The very same section through the fjord was made 24 hours later by day time (Fig. 10A and B). Within that short period of time the particle distribution in the fjord had changed completely. A particle minimum layer (> 10 particles/liter) was found from the surface down to about 20 m through almost the entire fjord and the surface patches in the outer parts of the fjord had disappeared. Only one big patch with more than 50 particles per liter was observed between 20-40 meters at the bottom of the fjord.

The in situ particle analyser gives a fairly good picture of the nauplii distribution, the main cod larval food organisms, in the Austnesfjord. This is shown by comparison of the results found by the in situ instrument with the results from the plankton pump samples examined microscopically (Figs. 6A and B, 98A and B, and Figs. 10A and B). The same particle/nauplii distribution patterns were found by both methods.

The effect of wind stress or turbulence on vertically migrating particles is presented in Figs. 11A, B, C, and D. The figures present continuous measurements of wind velocity and direction (11A) from 9/5-15/5-80, temperature distribution (0-90 m, 11B) particle (300-500 µm) distribution (0-40 m, 11C) and "the integrated particle density" (0-40 m, 11D). The observations were made from an experiment in 1980 at position 5 in the Austnesfjord (see Fig. 2). From the 9/5 to 12/5 the wind was

blowing down-fjord with varying velocity. On the 12th of May the wind changed direction 180^{O} and was blowing up-fjord with a velocity of 5-10 m/sec (Fig. 11A). Unfortunately observation of temperature and particle distribution were not made from the 10th to the 12th of May. However one 24 hour station was made on the 9th of May during the period when the wind was blowing down-fjord. During that period the upper 10 m of the water column showed tendencies of mixing and colder intermediate watermasses were observed between 15 to 55 meters above the transition layer with rapidly increasing temperatures with depth (Fig. 11B). Within the cold intermediate watermasses a particle maximum layer was found (Fig. 11C), and the particle density was increasing during the period (Fig. 11D). The wind was blowing the surface water down-fjord and this was compensated by the intermediate watermasses moving in the opposite direction. What we observed during the 24 hours station on the 9th of May, was a patch of particle rich intermediate water moving in from the outer part of the fjord. The particle isolines in the upper 10 meters followed the isoterms (Fig. 10B and C). When the wind direction reversed and increased in velocity on the 12th of May the current system also reversed. The surface water moved up-fjord and became completely mixed within 24 hours. The intermediate watermasses moved in the opposite direction and the transition layer (bottom water of the fjord) moved in the same direction as the surface layers. This is shown in Fig. 11B where the isoterms of the transition layer ascends from 60-70 m to 30-40 m from the 12th to the 15th of May.

No particle diurnal vertical migration was observed during that period (Fig. 11C). The particle density decreased (Fig. 11D) and became almost homogeneous from the surface down to 40 meters and no particle patches were observed.

The effect of wind on the vertical distribution of first feeding cod larvae, larval feeding incidence (% larvae with gut content) and larval "feeding index" (number of nauplii in gut per larvae with gut content) is presented in Figs. 12A and B. These observations were made during the 24 hours station on the

13th to 14th of May 1980, when the effect of surface wind stress on the hydrographic situation in the upper 10 to 20 meters, became obvious.

The density of larvae dropped from a maximum of 15 larvae/m^3 at 20 meters at 22-23 hours to a maximum of 4 larvae/m^3 at 15 meter at 01-02 hours. The larval feeding incidence varied from a minimum of 73% at 10 meters to a maximum of 100% at 30 meters at 22-23 hours, and decreased to a minimum of 4% at 25 meters and a maximum of 45% at 10 meter at 01-02 hours. The feeding index varied from 1.9 nauplii/larvae at 10 meters to 3.4 nauplii/larvae at 30 m at 22-23 hour, and from 0.3 nauplii/larvae at 5 meters to 0.5 nauplii/larvae at 10 meters.

The feeding incidence increased again during the early morning hours, but the feeding index showed only a minor increase (Fig. 12B), indicating a more difficult food accessebility.

In Fig. 13 a map of the Lofoten area is presented. The main spawning area of the Arcto-Norwegian cod stock is located at Henningsvær, Hølla and the Austnesfjord. Some of the cod eggs are being trapped in the Austnesfjord. However, the main amount is transported by the Coastal current along the Lofoten islands. Most of the eggs will hatch in the waters outside the islands, and the main first feeding area is thought to be in this area and in the open ocean bay of the Vesterålsfjord.

The particle distribution in the waters off the Lofoten islands and in the Vesterålsfjord was monitored at the time when the cod eggs were hatching. In the present paper only a few of the particle vertical sections will be presented.

Fig. 13A and B show the particle distribution on the north-east section in the Vesterålsfjord, Fig. A presents the in situ particle analyser results and Fig. B the plankton pump results. Plankton pump samples were only taken at every second station on the section. The two figures show the same particle distribution picture. However, due to the more frequent samples taken

by the particle analyser, a more accurate distribution of the particles on the section was achieved. This is clearly seen by comparing the extent of the surface patch in the two figures, observed at about 3 nautical miles off land. This is an example of how important it is to make frequent samples when looking for particle/nauplii patches.

The following sections were made in the open ocean water off the Lofoten islands: Eggum (Fig. 14), Myrland (Fig. 15), Fuglehuk (Fig. 16) and Skiva (Fig. 17) (see Fig. 3). The Skiva section was surveyed at three different periods during the cruise.

The Eggum and Myrland sections were surveyed by day and only on the Myrland section a surface patch (>50 particles/liter) was observed at about 8 nautical miles off land. On the Eggum section a patch of more than 50 particles per liter was found at 10 meters depth at the same distance off land as on the Myrland section. Common for both of the two sections were the low particle densities (10-30 particles/liter) in the surrounding watermasses. The particle distribution was a little more different on the next section where we found a high density patch (50-100 particles/liter) close to the shore extending to about 2 nautical miles off land from the surface down to 15 meters. On the same section at about 8 nautical miles off land a surface patch (>50 particles/liter) was observed. The section was surveyed by night. There are good reason to believe that the observed patch on all three sections (Eggum, Myrland and Fuglehuk) constitute a coherent watermass with higher particle density than the surrounding watermasses, this can be seen on the isolines at this position on these three sections. On the southernmost section there was observed a more complicated particle distribution picture. The section was survey on the 24/4-81 by day and two patches were observed at about 4 nautical miles off land, one at about 5-10 meters depth (>100 particles/liter) and another at about 20-25 meters (>50 particles/liter). Further off land along the section the particle density decreased. Three days later (27/4-28/4) the

same section was surveyed by night (Fig. 16B). Two surface patches were found. One smaller at about 8 nautical miles off land and the other at about 14 nautical miles off land extending from the surface down to 20 meters. The last survey of the Skiva section was made by night on the 6/5-7/5-81 (Fig. 16C). The particle density on the section had increased substantially in 8 days. On the outer half of the section in the upper 10 meters of water the particle concentration was between 100 and more than 200 particles pr. liter. The naupliar distribution at the Skiva section was investigated on the 6.-7.5. (Fig. 16A-D). The nauplii density ranged from less than 10 to more than 40 nauplii per liter (160). This means the particles outnumbers the copepod nauplii. A closer investigation of the plankton pump samples reveals no considerable numbers of organisms other than copepod nauplii. The discrepancy between the two counting methods in this case is not fully understood.

DISCUSSION

The significance of food aggregations in the sea on the survival of first feeding fish larvae has been pointed out by Lasker (1975) and by Lasker and Zweifel (1977). The need to detect, count and size analyse pelagic fish larval food organisms *in situ* has been demonstrated by the model of Vlymen (1977).

The results presented in the present paper show some of the dynamic in the formation and distribution in time and space of particles - microzooplankton patches. Due to differences in diurnal vertical migration patterns of different sizes of copepod nauplii (Fig. 7) the vertical distribution and density of nauplii changes during 24 hours (Figs. 5A, B, and 6A, B). Surface patches of particles within the size range 150-600 microns, the particle size range most frequently captured by first feeding cod larvae (Ellertsen *et al.*, 1977) formed in the upper 2 meters at midnight with particle densities of 100-500 particles/liter. The concentration of particles in the patch was quite clearly dependent on the hydrographic situation (discussed later) and on the mean distribution and density of microzooplankton in the water column (Fig. 5 and 6). The 24

hours station made on the 22-23/4-81 (Fig. 5) and on the 28-29/4-81 (Fig. 6) in the Austnesfjord, were made during conditions with no or very little wind. There was consequently no mixing of the surface layers (demonstrated in Fig. 8). The difference in the vertical distribution pattern of particles-nauplii observed during the period of one week, could be due to an increase in the secondary production and the number of bigger size nauplii. Marshall and Orr (1972) showed that nauplii of Calanus finmarchicus (the most dominant species in the area) is able to grow from nauplii stage III-IV within one week, which implies an increase in length from 200-400 µm (Wiborg 1948), the size group demonstrated to make diurnal vertical migration (Fig. 7).

Consequently the vertical distribution of particles - nauplii on a section, would be dependent on factors such as the hydrographic conditions, size distribution of nauplii and the time of the day when the section is made. This is demonstrated by the vertical distribution of particles - nauplii on two sections through the Austnesfjord which were made at night on the 27-28/4-81 and by day on the 29/4-81. There was no wind during the observation. The vertical migration of particles is clearly demonstrated, showing a minimum density layer from the surface down to about 20 meters and a big patch of more than 50 particles/liter at 20 to 40 meters of depth in the central part of the fjord by day. During night a dense surface patche (>100 particles/liter was observed close to the surface in the utter part of the fjord and the big patch in the central part of the fjord was split in three separate patches at different depth positions, most probably representing nauplii of different sizes migrating down in the water column as the light intensity increased in the early morning hours.

The effect of wind stress, causing mixing of the surface layers, on the distribution of particles and cod larvae, larval feeding incidence and "feeding index" is demonstrated in Figs 11A, B, C and D, and Figs 12A and B. The observations were made in the Austnesfjord on the 12th to the 15th of May in 1980.

Within 36 hours after the wind had changed direction and velocity (Fig. 11A) the upper 10 to 18 meters became completely mixed (Fig. 11B) and the vertical particle distribution became almost homogenous, no surface patch was observed at night (Fig. 11C) and the mean particle density in the water column dropped steadily during the period of observation (Fig. 11D). The decrease in water stability and particle concentration caused a lowered feeding incidence and feeding index, in first feeding cod larvae during the first few hours following the breakdown of the water stability. During the following hours the larval feeding incidence increased again, most rapidly in larvae sampled at 15-30 meters depth, indicating that the food particle density did not become critial (Fig. 11C). (Note that the particle concentrations in Fig. 11B only represents particles within 300-500 microns size range. Due to technical problems, we were not able to count particle sizes in situ smaller than 300 µm in 1980). However, the feeding index (number of particles/larvae with gut content) did not increase significantly, indicating a more difficult accessibility of food particles, most probably due to increased vertical turbulence and increased movements of the watermasses (see page 7-8). A similar observation was made by Lasker (1975, 78), where the stability of the water column in the upper 30 meters of the water column was observed to be the key conditions required for food organisms of larval anchovy to aggregate in densities high enough to exceed the threshould for the feeding stimulus of first feeding Northern anchovy larvae.

The most important first feeding area of cod larvae is thought to be in the open ocean waters off the Lofoten islands and in the open ocean bay of the Vesterålsfjord. Figs. 13-17 presents the particle-nauplii distributions on 5 of the sections made in the area. On every section, patches with particle densities of more than 50 to 100 particles/liter were observed. The importance of frequent sampling on a section in the detection of the horisontal and vertical distribution of patches is demonstrated (Figs. 12-14A and B). The mean density in the watermasses down to 40 meters in the area seemed to be within the

order of >10-20 nauplii/liter of the size range 150-600 microns. This density was 10 times higher than the mean density in the same area and period of time (plankton pump samples) in 1980 (Ellertsen et al., 1980), and the 1980 0-group survey gave a small index indicating a poor 1980-yearclass. The cod larval food condition seemed improved in 1981 compared to 1980.

However, the critical food concentrations for first feeding cod larvae is not exactly known, but is thought to be in the order of 100-200 nauplii/liter (average size 200 µm) based on studies on swimming activity, larval search volume and oxygen requirement of first feeding cod larvae (Solberg and Tilseth, unpublished data). Under laboratory conditions Houde (1978) demonstrated for three subtropical marine species that food concentrations within the order of 10-100 per liter appeared to define critical food levels. However, to obtain substanti al survival the food concentration had to be raised to the order of 200-2000 nauplii/liter. This food concentrations was thought to be critical only during the first 3-4 days of active feeding (Houde, 1978). Ellertsen et al., (1976) demonstrated heavy mass mortality of cod larvae within a period of 8 days starting 3 days past the PNR, under poor feeding conditions. Most marine fish larvae is thought to pass through a period where food concentrations are critical for first feeding. However, the mean food concentrations suitable for fish larvae which have passed through this first critical period are frequently found in the sea. However, food concentrations leading to substantial survival is to be found in sheltered areas such as fjords and estuarys (Hargrave and Green 1970, Heinle and Flemer, 1875). In the open ocean this concentrations is only found in patches (Lasker 1975, Ellertsen et al., 1977) and that the life of this patches are limited in time both as a result of vertical migration of the nauplii and the hydrographic conditions of the watermasses.

The mechanisms of recruitment to the oceanic fish stocks are not only dependent on suitable food concentrations at a critical time during the early larval development, other factors such as the nutritive value, size, digestibility and food

selection by the larvae are important in this context. The effect of predation is another major cause of fish larval mortality. However, this is, as pointed out by Cushing (1976) inversly related to the growth rate of the larvae, under good feeding conditions larvae are likely to grow fast and avoid predators. The effect of predation on the degree of survival of fish larval populations have been difficult to observe, mainly due to the difficulties of identifying predators and observing the distribution in space and time between fish larvae and their predators. Further laboratory and field studies on the effect of food supply and predation during the early first feeding stages of fish larvae is needed in the understanding of the mechanisms regulating the recruitment of the ocean fish stocks.

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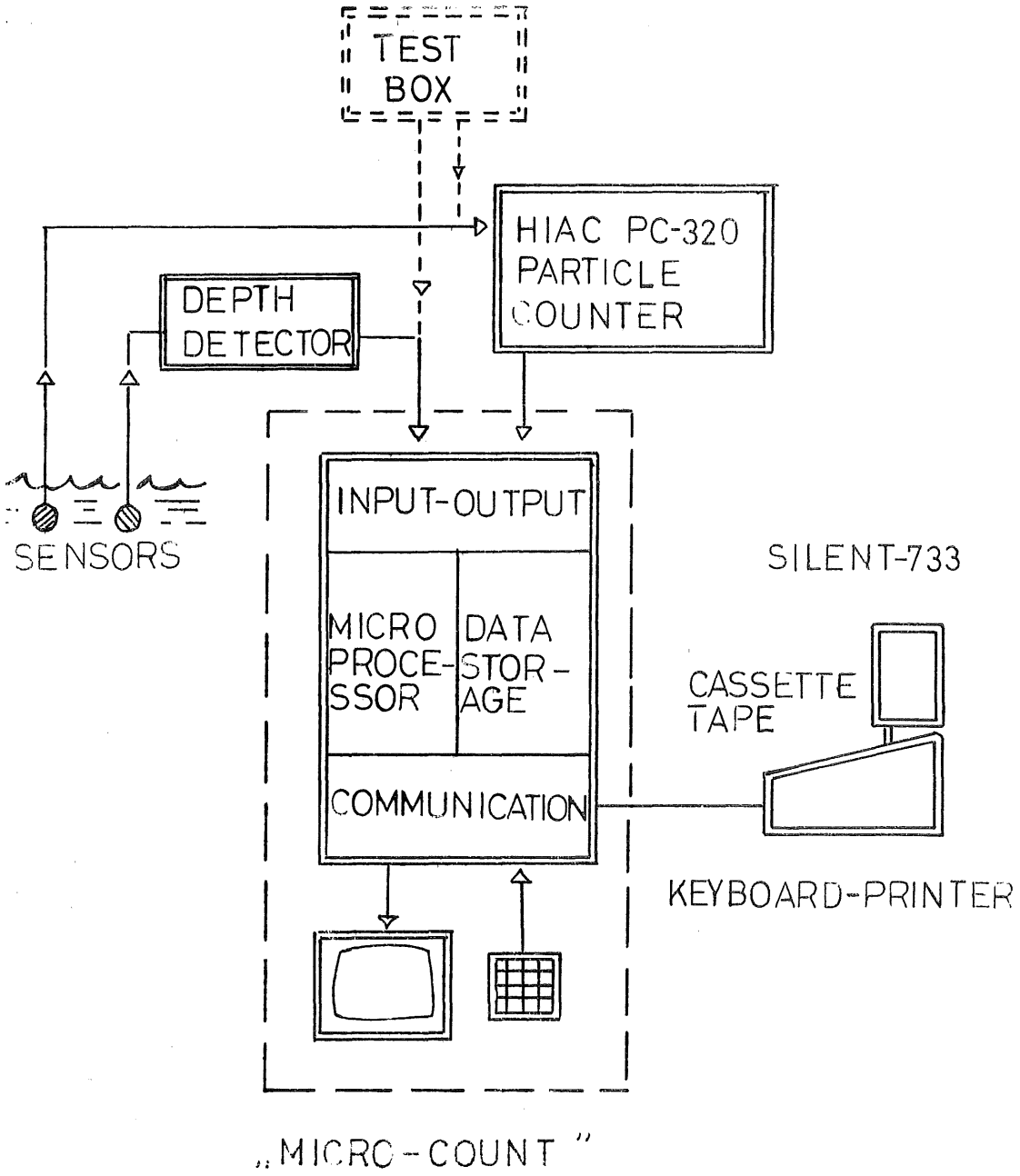

Fig. 1 The particle analyser system.

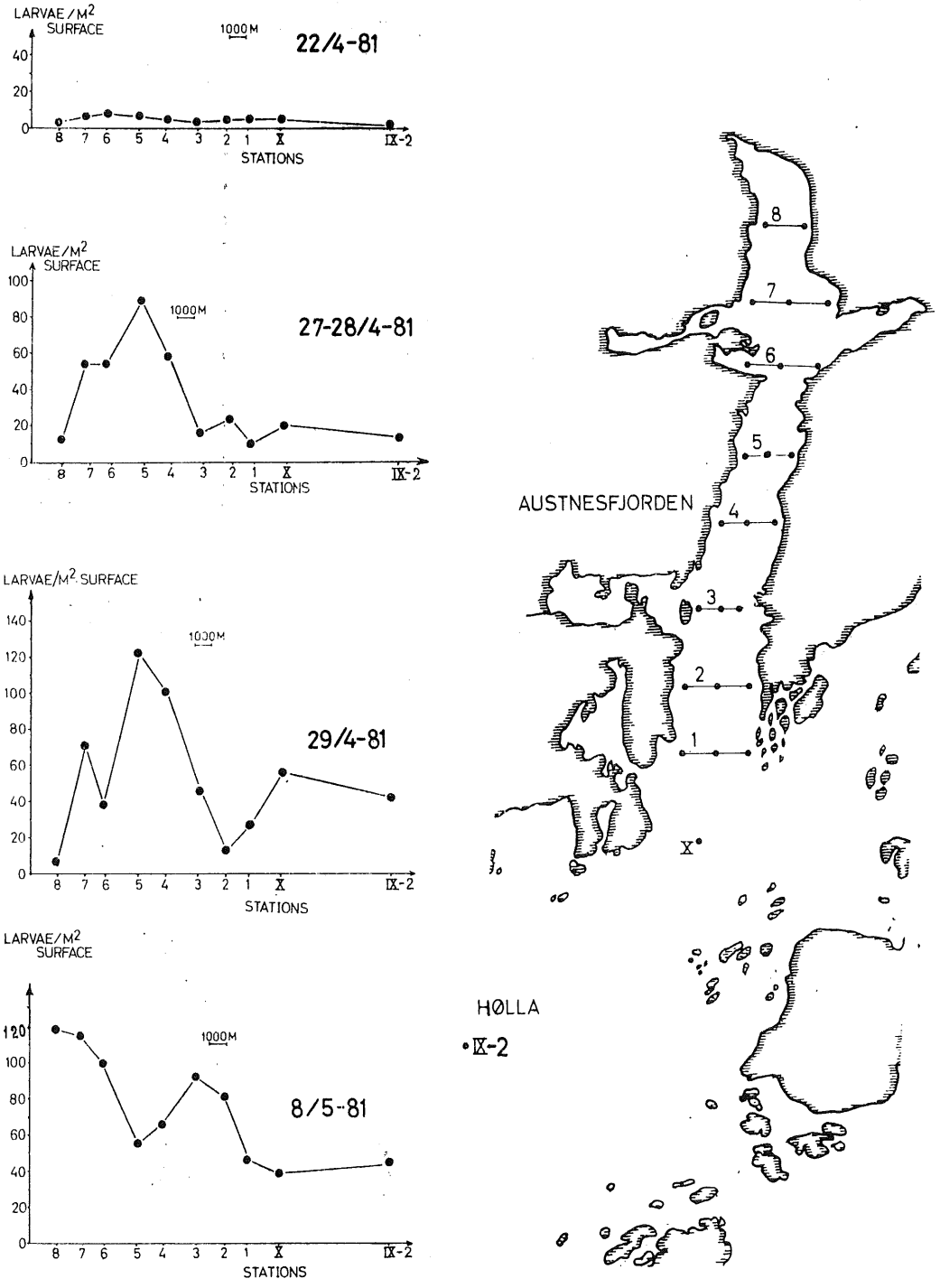

Fig. 2. Map of the Ausnesfjord with stations, sections and figures of the cod larval distribution pr. m^2 surface 22/4-8/5-81.

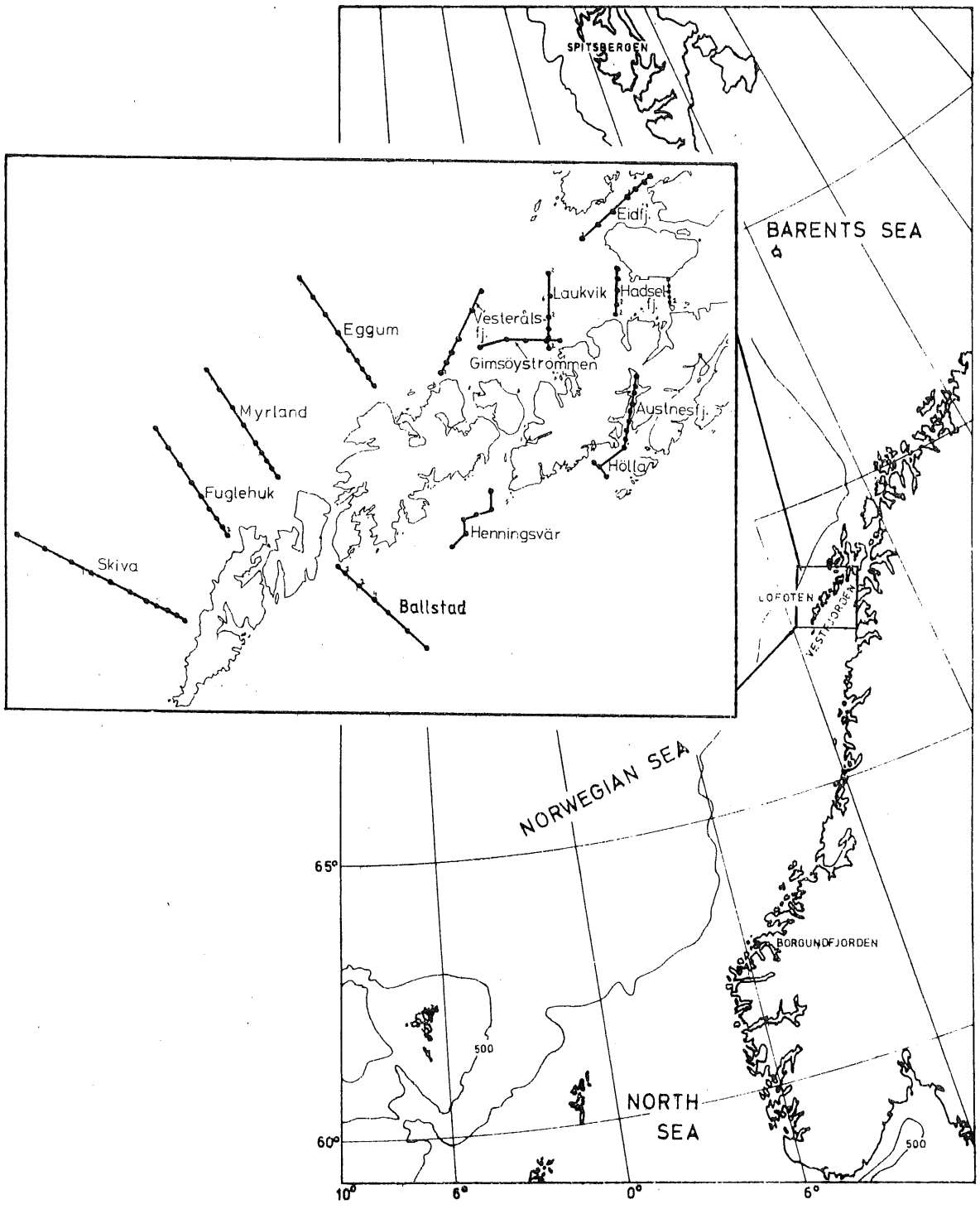

Fig. 3. Map of the Lofoten area with station and sections 21/4-8/5-81.

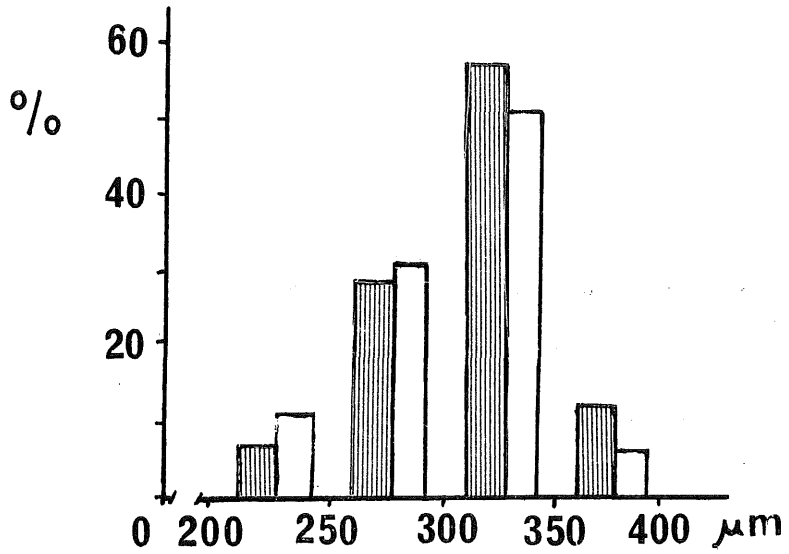

Fig. 4. Length distribution of Artemia nauplii analysed by the Hiac Particle Analyser ▨ (n=1542) compared to measurements made by the microscope ⬚ (n=45).

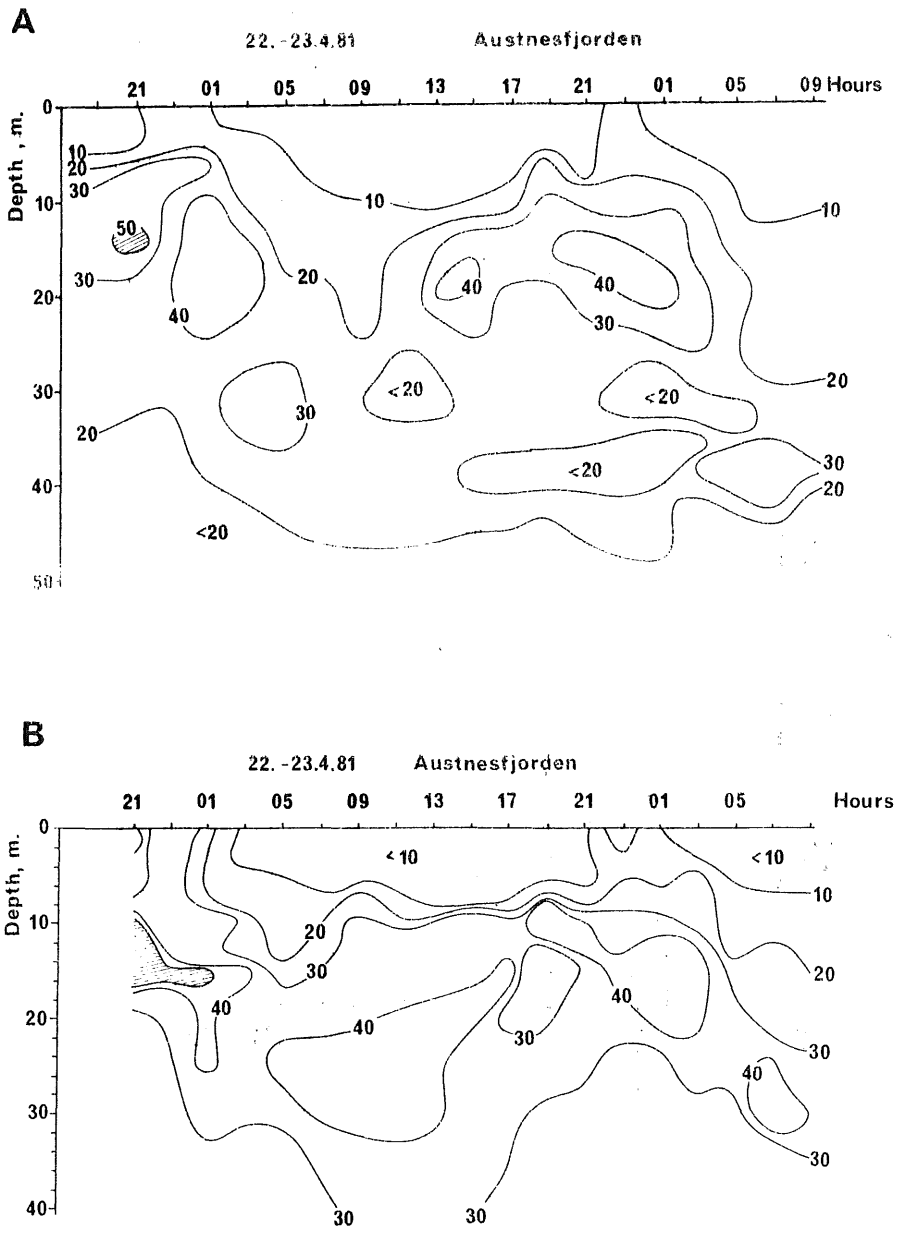

Fig. 5A and B. Isopleth diagrams of the particle concentrations (per liter) A, and nauplii (per liter) B, center station, Section 5 in the Austnesfjord 22-23/4-1981.

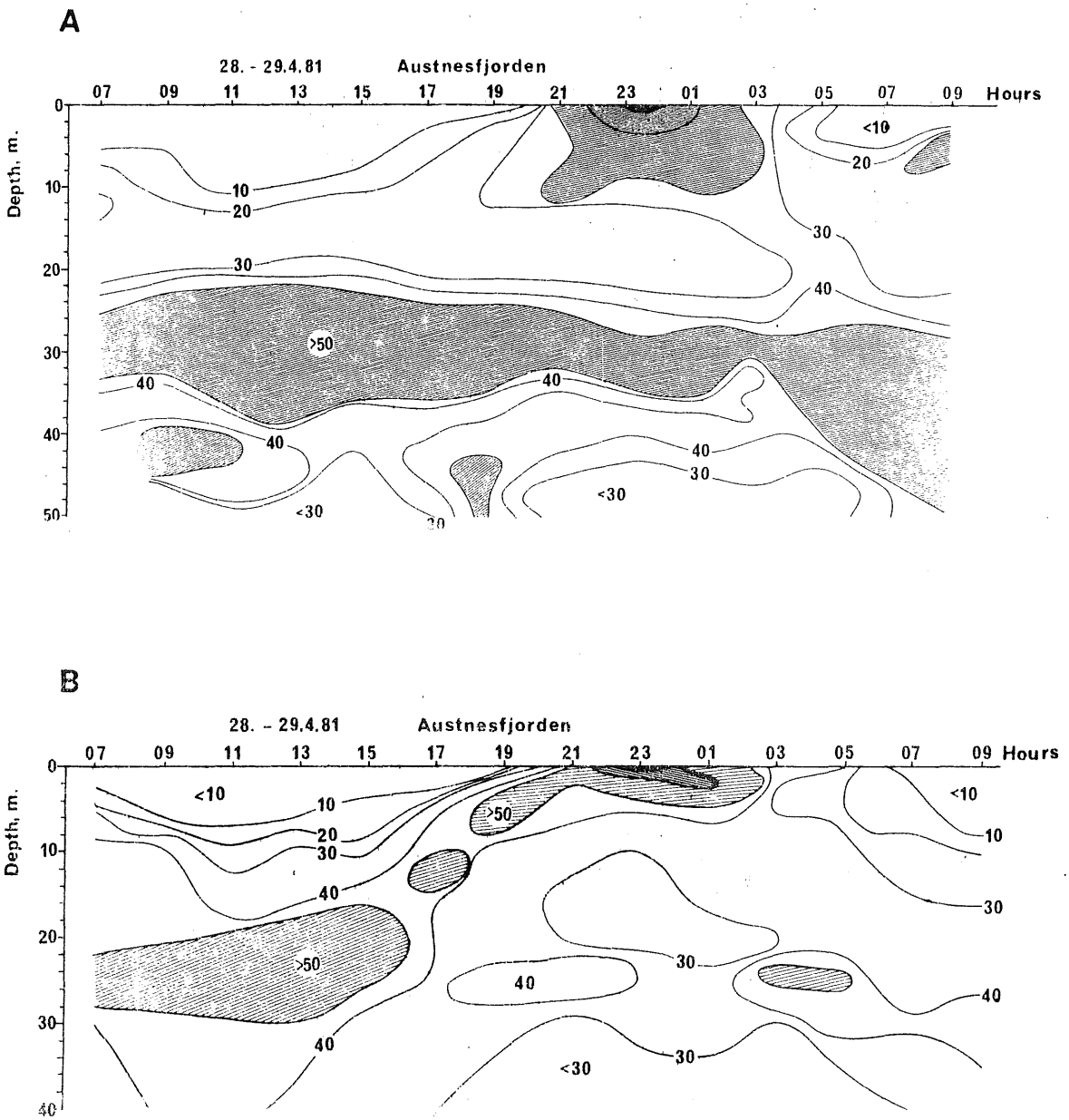

Fig. 6A and B. Isopleth diagrams of the particle concentrations (per liter) A, and nauplii (per liter) B, center station, Section 5 in the Austnesfjord 28-29/4-1981.

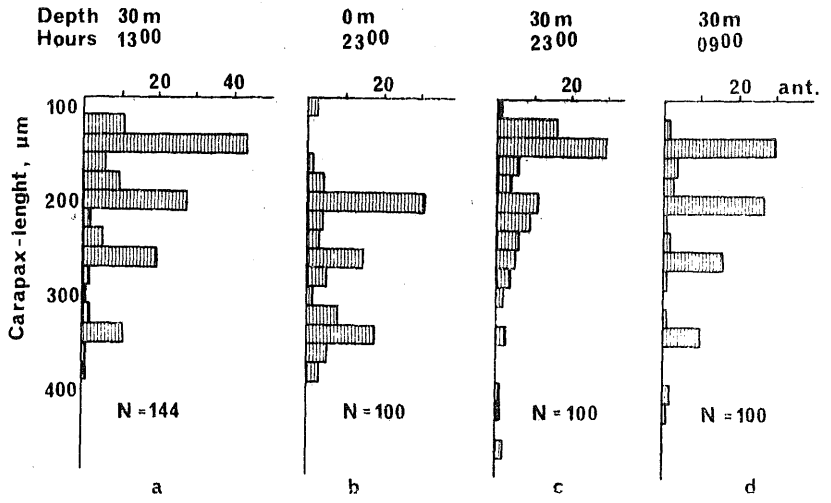

Fig. 7. Nauplii carapax-length (µm) distribution at 30 m at 13, 23 and 9 hour and at 0 m at 23 m, center station, section 5 in the Austnesfjord 28-29/4-81.

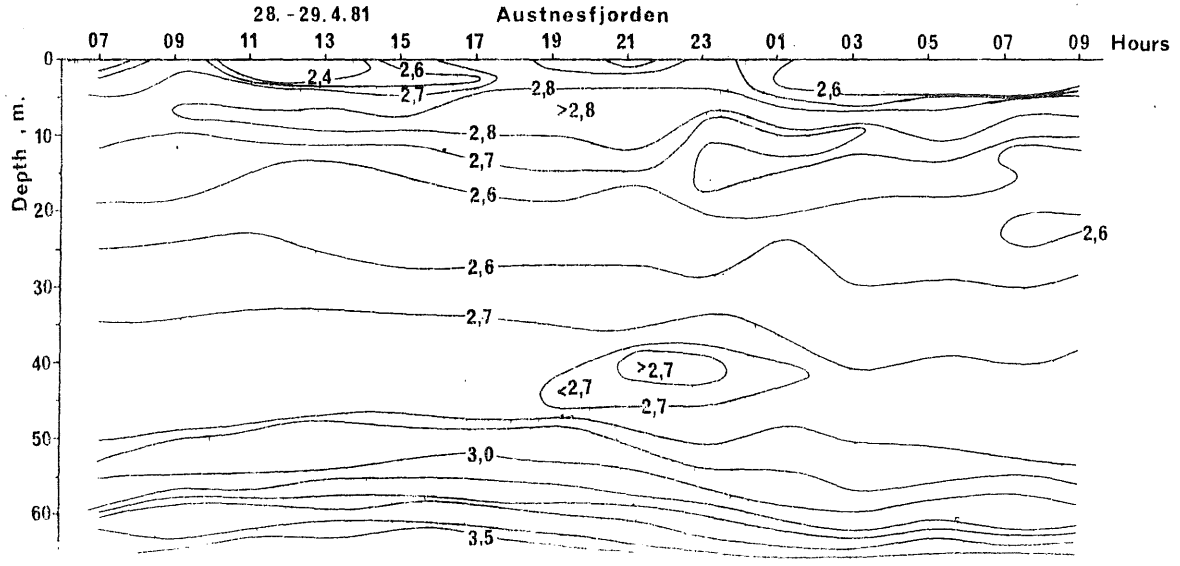

Fig. 8. Isopleth diagram of the temperature distribution, center station, section 5 in the Austnesfjord 28-29/4-81.

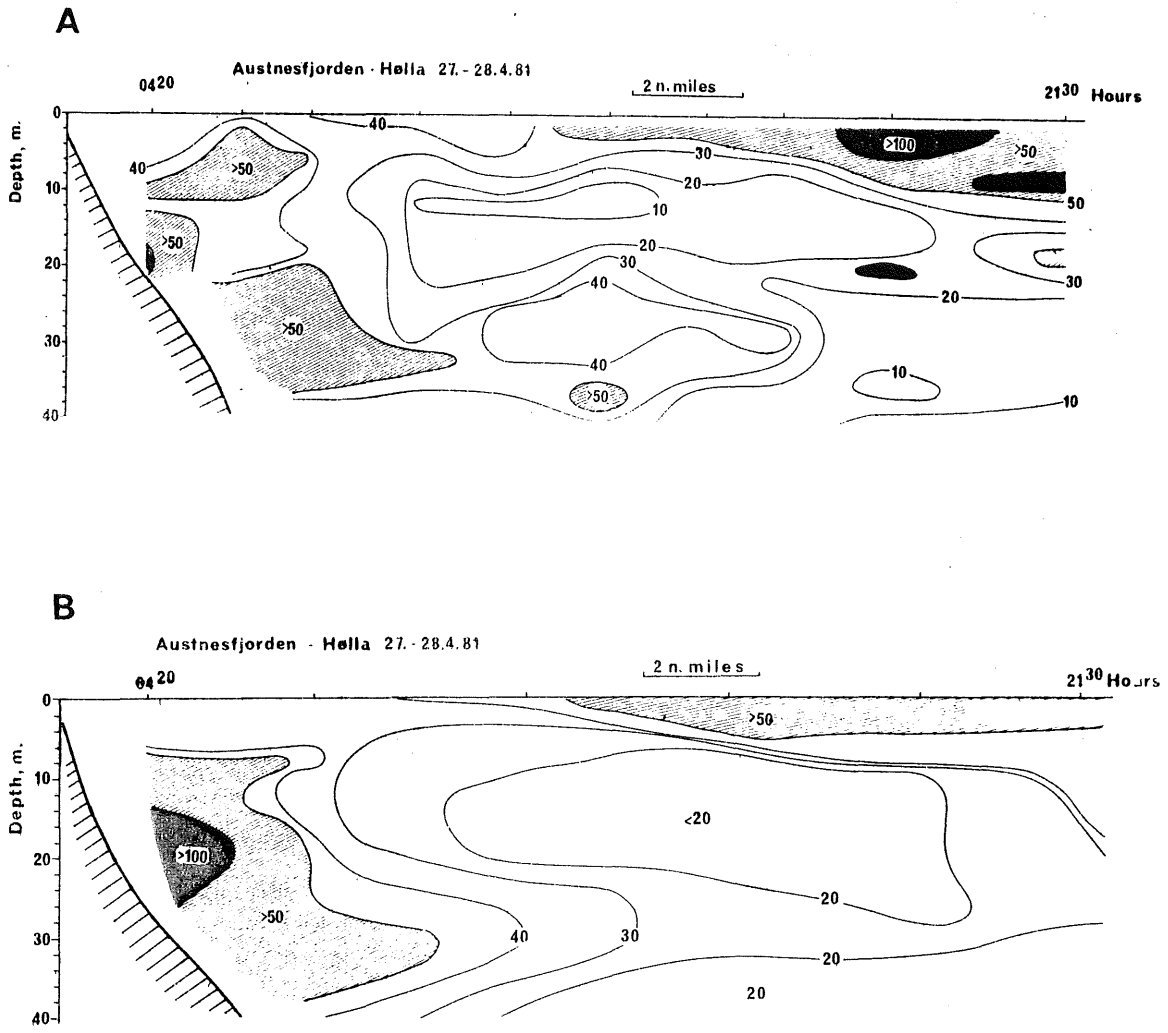

Fig. 9A and B. The particle (A) and nauplii (B) distributions (per liter) in the upper 40 meters of the Austnesfjord on the 27-28/4-81 at 2130 hours to 0420 hours. (Particle size range 150-600 µm, nauplii all sizes).

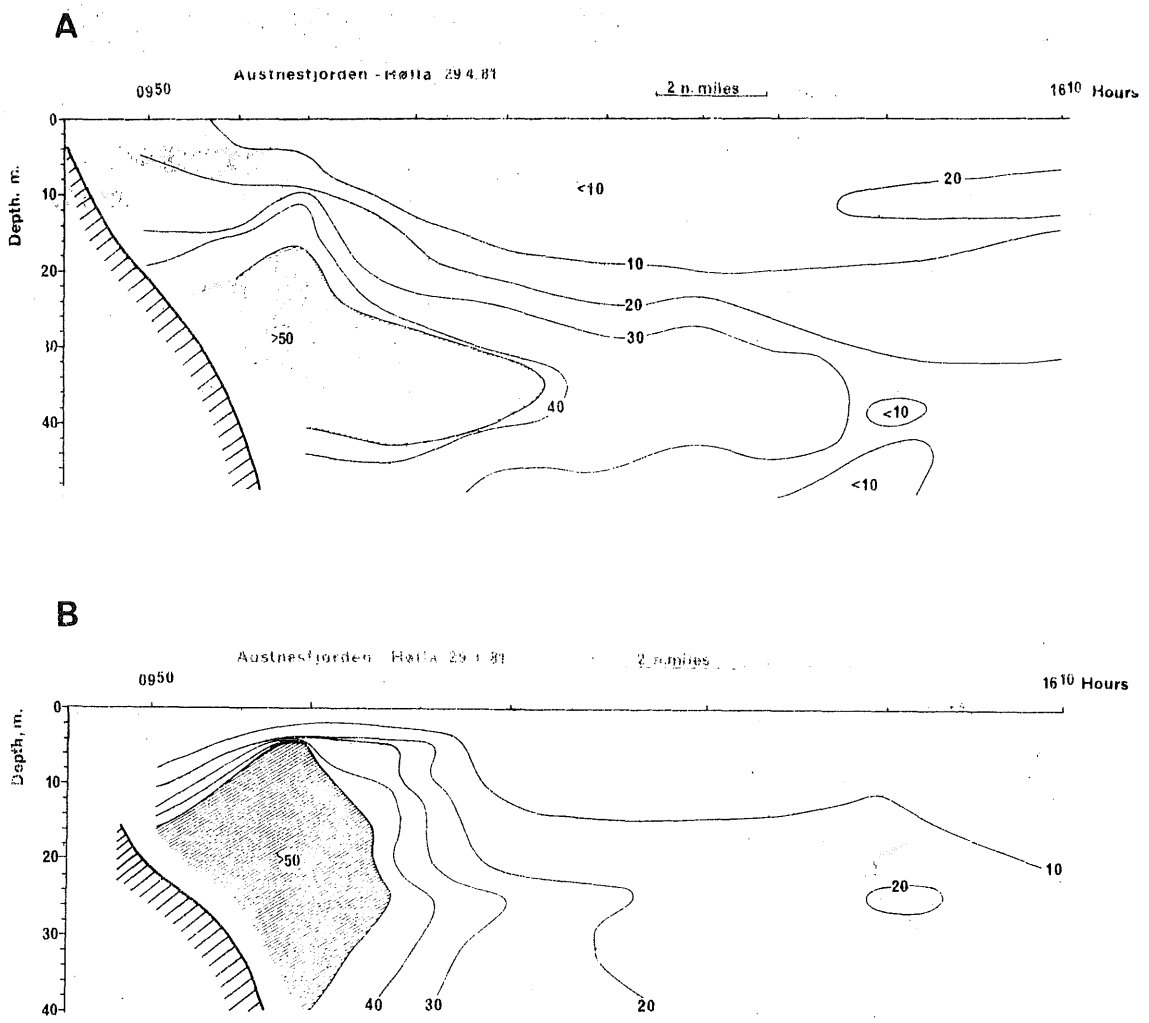

Fig. 10A and B. The particle (A) and nauplii (B) distributions (per liter) in the upper 40 meters of the Austnesfjord on the 29/4-81 at 0950 hours to 1610 hours.

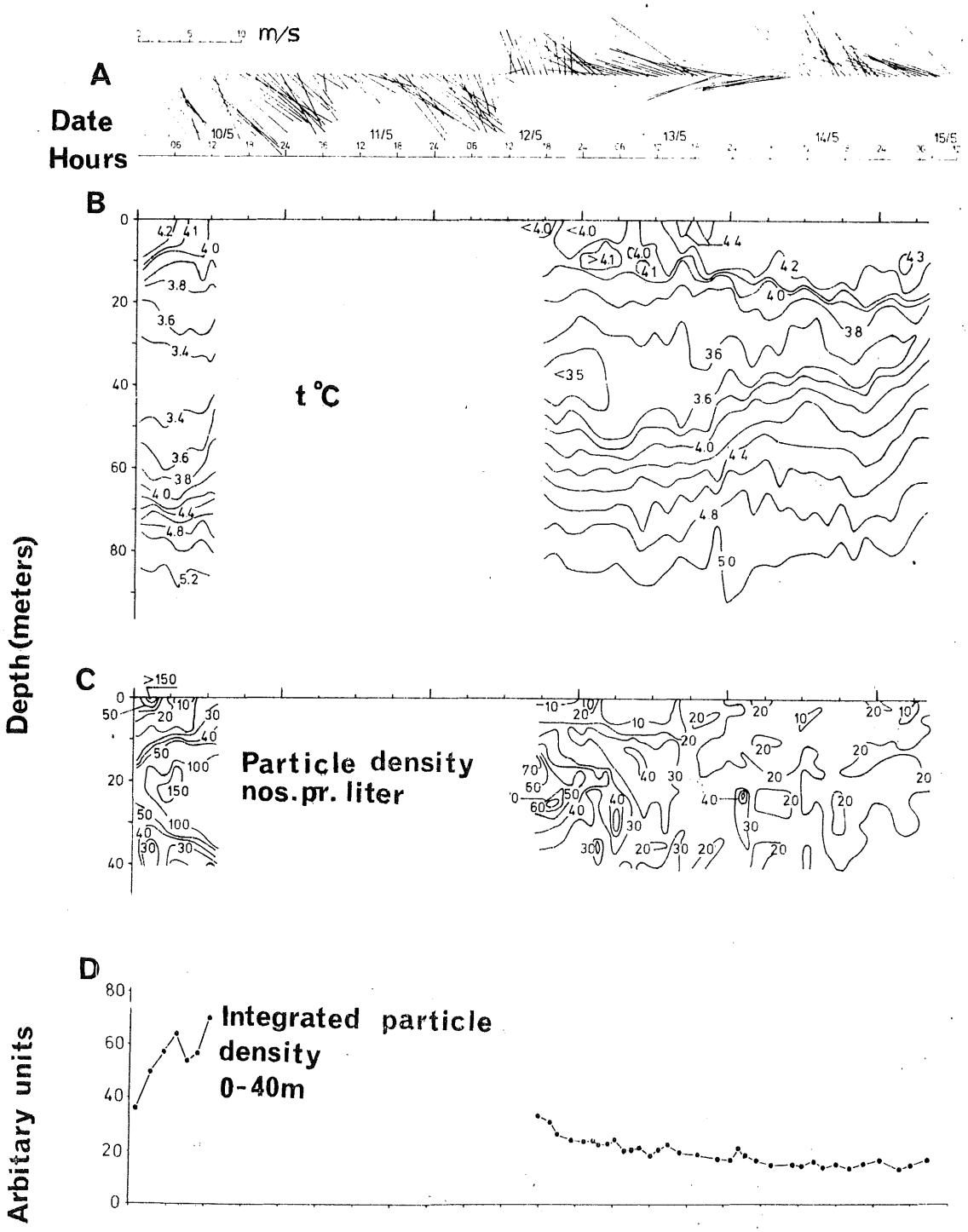

Fig. 11A. B. C and D. Presenting A; wind velocity and direction, B; isopleth diagrams of the temperature and C; particle concentration (300-500 µm) distribution and D; integrated particle density, at the center station on section 5 in the Austnesfjord 9/5-15/5-81.

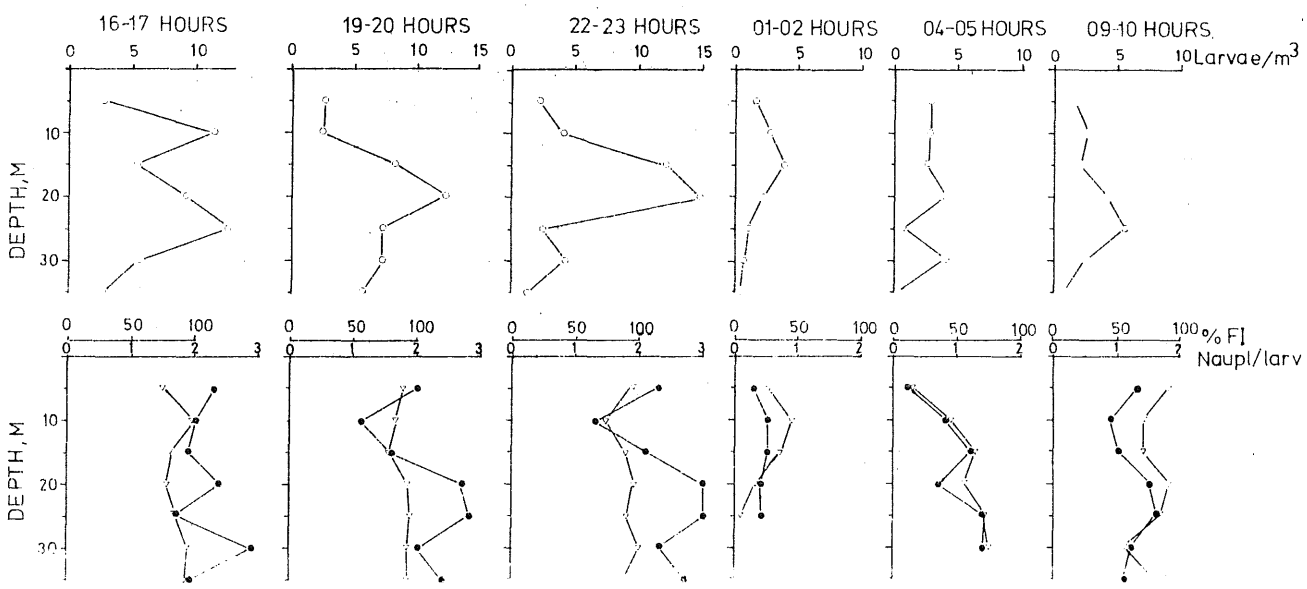

Fig. 12A and B. The density distribution of first feeding cod larvae (per m^3) A, and the larval feeding incidence (% larvae with gut content) and larval feeding index (nauplii/larval gut) B, during the 24 hours sampling station on the 13th to 14th of May 1981, on center station, section 5 in the Austre fjord.

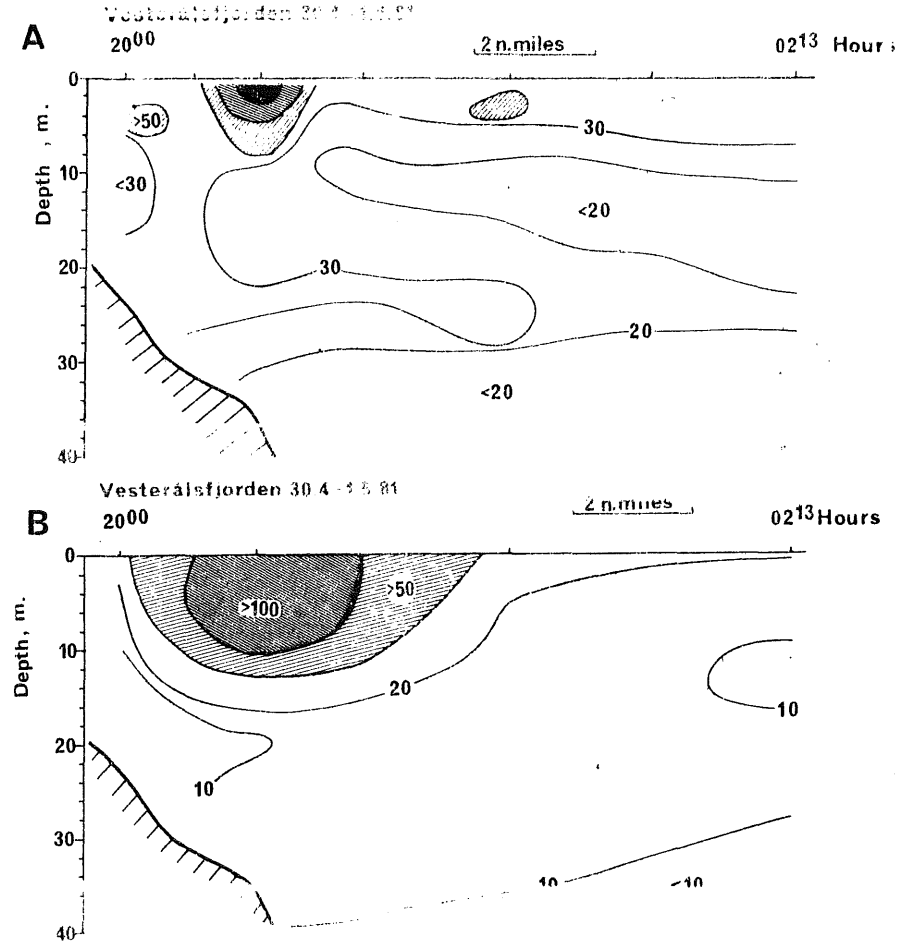

Fig. 13A and B. The particle (A) and nauplii (B) distribution (per liter) in the upper 4 meters on the section in the Vesterålsfjord 30/4-1/5-81.

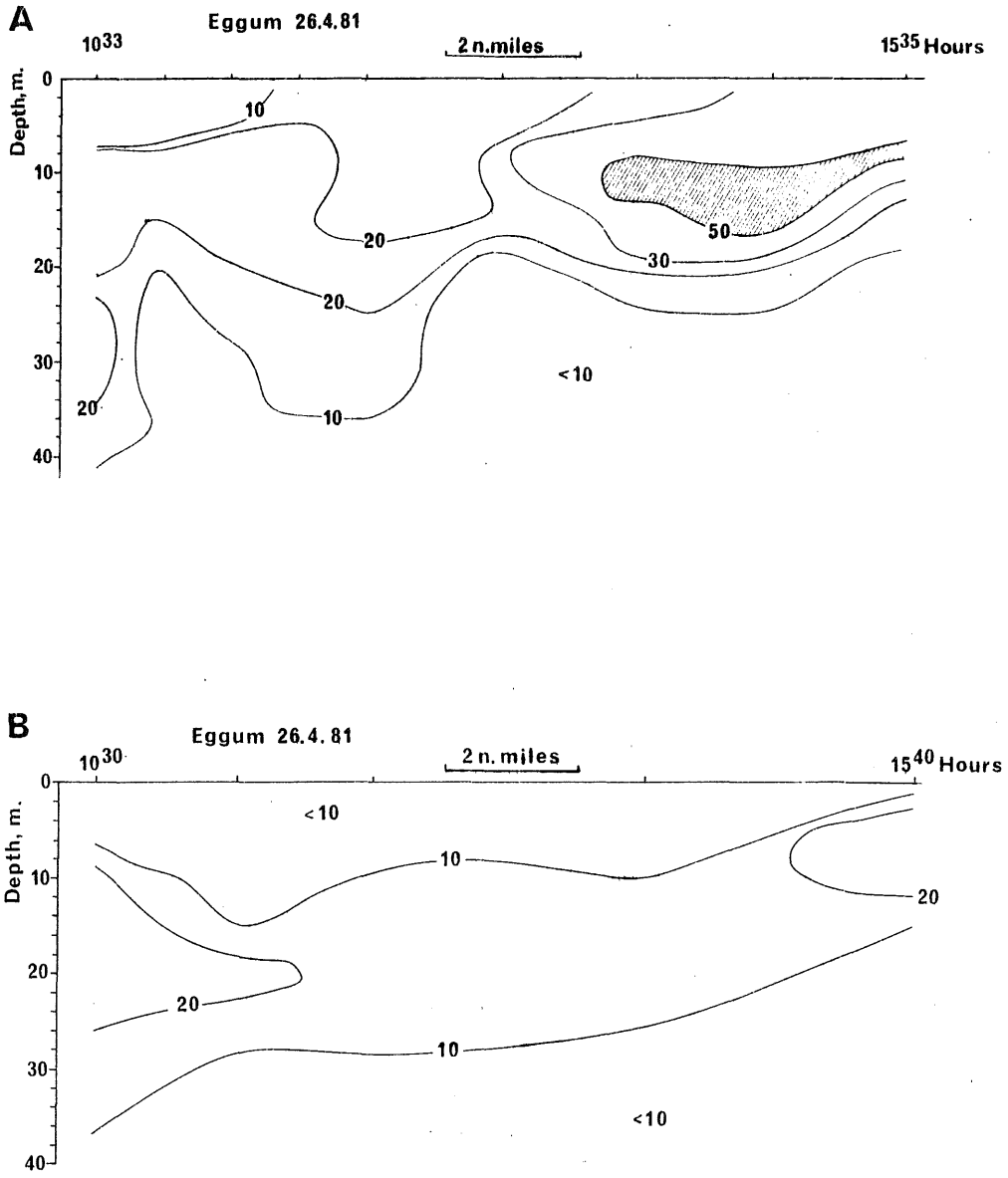

Fig. 14A and B. The particle (A) and nauplii (B) distributions (per liter) in the upper 40 meters on the Eggum section, 26/4-81.

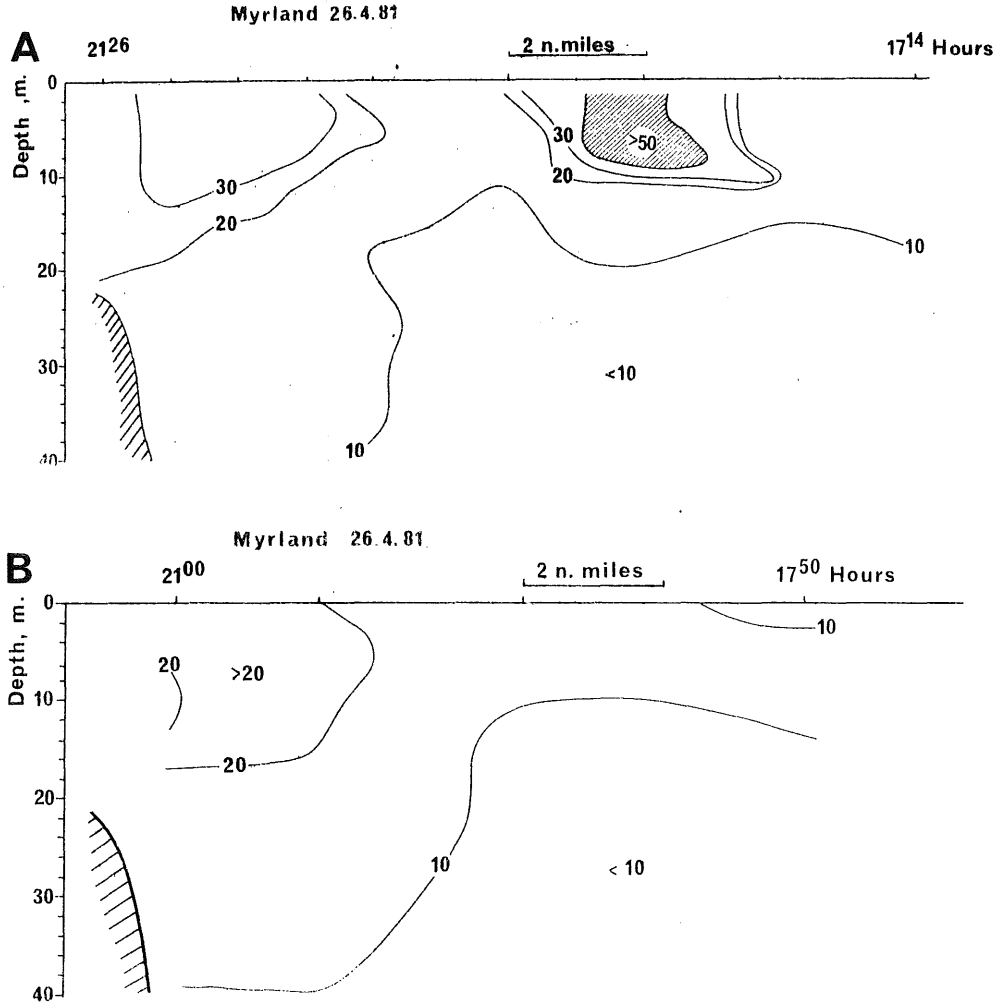

Fig. 15A and B. The particle (A) and nauplii (B) dis tions (per liter) in the upper 40 meters on the Myrland se , 24/4-81.

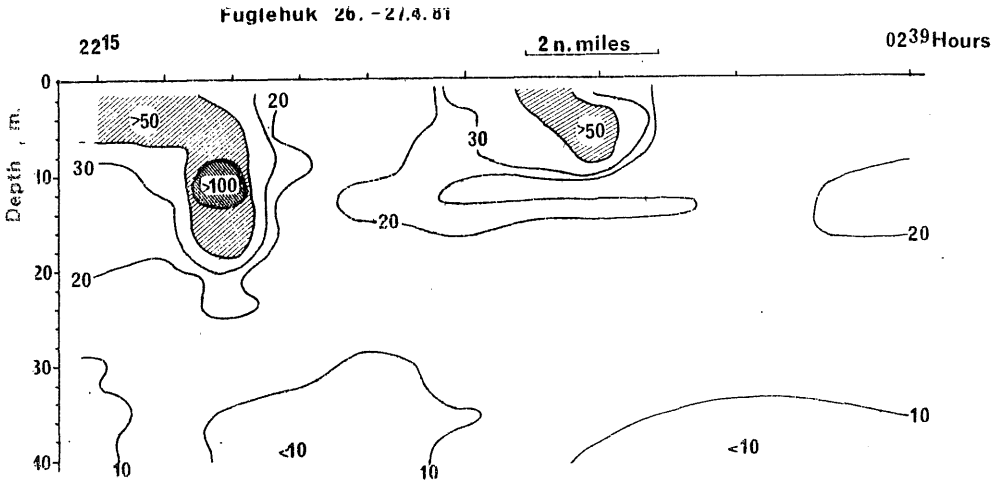

Fig. 16. The particle distribution (per liter) in the upper 40 meters on the Fuglehuk section, 26-27/4-81.

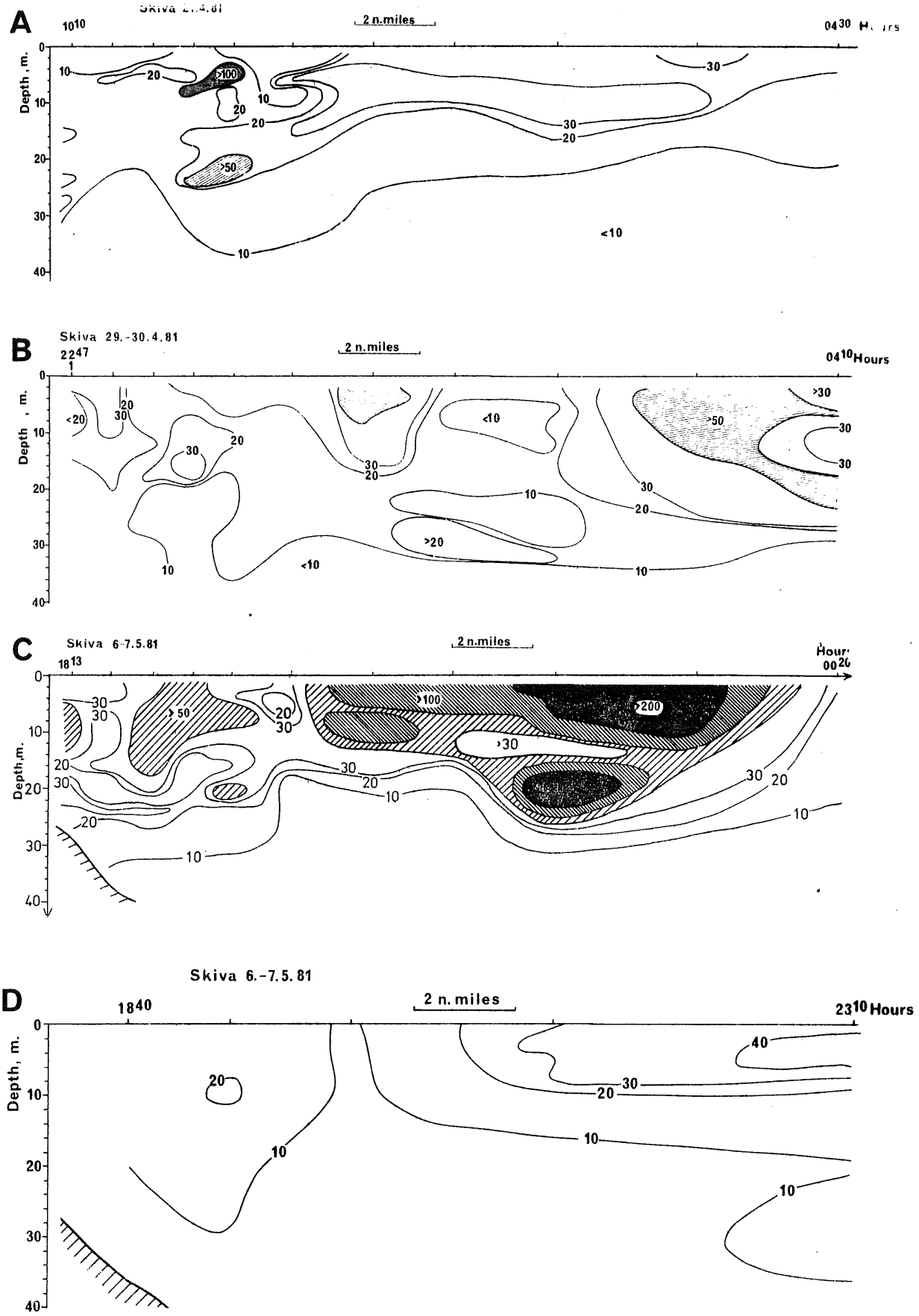

Fig. 17A, B, C and D. The particle distribution (per liter) in the upper 40 meters on the Skiva section on the 27/4, 29-30/4 (A, B) and the particle and nauplii distribution on the 6-7/5-81.