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Vertical distribution and feeding of cod larvae in relation to occurrence and size of prey organisms

by

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Introduction

The 'critical period' concept for fish larval mortality, first put forward by Hjort (1914), is still being investigated. A large number of field investigations with traditional plankton gear have failed to demonstrate a drastic mortality at the end of the yolk sac stage. A thorough analysis of the data showed that the gear used were not precise or accurate enough to give a reliable answer to the question (May 1974).

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Extensive laboratory studies on fish larvae, and the development of equipment to study the degree of patchy distribution of the prey organisms, have largely refined the methods in the study of fish larvae dynamics.

The two main methods are:

1) Larval bioassay (Lasker, 1974), using laboratory reared larvae to test the 'food content' of the water masses. The method has been developed for Engraulis mordax, a phytoplankton feeder.

2) Particle rate meter, a submersible Coulter Counter. Providing data on prey density from small samples in situ. (Scura, in press)

Systematical investigations on the biology and mortality of cod larvae in Norwegian waters are lacking, though papers by Wiborg (1948a, 1960) and Dannevig and Dannevig (1960) give valuable information on the biology of these larvae.

In 1976 a combined laboratory, basin and field study was started (Ellertsen et al. 1976). The main conclusion from the field work last year was the need for improved sampling methods and gear. The field work in 1977, therefore, concentrated on introducing and adapting existing sampling methods for cod larvae, as the larval bioassay and particle rate meter. In addition, a commercial fish pump has been adapted to obtain larval samples from discrete depths.

MATERIALS AND METHODS

Measurements

1. Standard length

Standard length of the cod larvae was found by measuring the distance from the mouth (upper jaw) to the end of the notochord (Fig. 2 b).

Due to the poor condition of copepod nauplii found in the gut of the cod larvae the total length of the nauplii could not be measured.

However, the carapax was seldom damaged, so the standard length of the nauplii was found by measuring this. (Fig. 2 a).

A regression analysis based upon data from sea-caught nauplii shows that standard length (carapax) x 1.487 = total length.

2. Yolk sac stages

On the basis of laboratory-hatched larvae and larvae from the field, five categories of yolk sac stages are given, Fig. 1. Cod larvae are able to feed from stage 4.

3. Degree of digestion

The larvae were dissected and the gut contents analysed. The degree of digestion of the nauplii eaten by the cod larvae was assessed according to the following criteria: 1) no visible digestion, 2) a transparent zone between carapax and interior of the nauplii, and 3) the interior of the nauplii completely dissolved.

Laboratory experiments

Larvae from the experiments in 1976 were hatched from eggs of Arcto-Norwegian cod. Thirty larvae were fed newly hatched Artemia salina nauplii at densities of 1 nauplius/ml. The experiment lasted for 5 hours. The larvae were anaesthetized in MS 222 (1:20000), standard length measured to the nearest 0.1 mm, and the number of nauplii in the gut counted. The next day the experiment was repeated with larvae from the same stock population, which were not fed. These experiments were conducted on cod larvae in yolk sac stage 4, 4^+ and 5. The larvae were from 6 to 12 days old.

The experiments in 1975 were carried out on cod larvae 13 to 18 days old, all with the yolk absorbed (stage 4^+ and 5). The larvae were hatched from eggs from five different females. The larvae were fed continually during the experimental period.

Basin experiments

The cod larvae used in the basin experiments originated from cod eggs naturally spawned in a spawning pond. In 1976 the eggs were collected on March 9 and 10 and incubated at the laboratory at about 7° C. Simultaneous hatching of the two groups was arrived at by exposing the second group to a somewhat higher temperature. On March 25, four days after 50% hatching, about 200 000 yolk sac larvae were transferred to a 1 700 m^2 large basin situated on land, with a maximum depth of 4 $\frac{1}{2}$ m.

In 1977 the eggs were collected on April 1 and incubated at a mean temperature of 5.2° C. About 100 000 yolk sac larvae were transferred on April 22 to the basin, four days after 50 % hatching. Daily sampling of larvae with plankton nets gave information on larval growth and diet and on stomach filling and feeding success. Sampling with a centrifugal pump at seven depths gave information on density and composition of the plankton community from which the cod larvae took their food. In 1977 horizontal hauls were made at the depths of $\frac{1}{2}$ m, 1 m, 2 m and 3 m. Fish larvae and prey organisms were caught simultaneously in separate nets with different mesh size (375 µm and 90 µm respectively). Although the basin was 4 $\frac{1}{2}$ m deep it was not possible to sample deeper than 3 m, due to irregularities of the bottom. Biological data on the cod larval groups are given in Table I. The cod larvae had a mean length of 6.3 mm and were 15 days old at the diurnal station in 1977.

Table I. Biological data on the cod larvae used in laboratory and basin experiments.

	Laboratory		Basin experiment		
			1976		
	1975	1976	March 9	March 10	1977
Diameter of egg, mm	1.42-1.52	1.42	1.40	1.54	1.40
Incubation in days	19 - 22	18	12	11	17
Incubation mean temp.	4.0° C	5.0° C	7.5° C	7.9° C	5.2° C
Larval length at 50 % hatching	-	4.4	3.4	3.3	4.4

Lofoten area

1. Sampling of cod larvae

The material presented in this paper was collected from three diurnal stations: 2-3 May 1976 with R/V "H. U. Sverdrup", 10-11 May 1977 and 18-19 May 1977 with R/V "Johan Ruud". The sea was calm during the sampling periods. All sampling was carried out in Austnesfjorden.

In 1976 the larger proportion of the larvae was collected by a rectangular net, 40 x 60 cm, with 500 µm mesh size, in vertical hauls from 30-0 m. The monopump (200 l/min) was used for sampling cod larvae from the following depths: 0, 3, 5, 10, 15, 20, 25 and 30 m. The volume filtered, 1 m^3, was too small to give reliable values.

In 1977 cod larvae were sampled with the Bongo-60, (375 µm mesh size) without closing device, a commercial fish pump (U 230, Rapp Fabrikker, Bodø, Norway) and a Juday net, 80 cm opening, 375 µm mesh size.

The 24-hour station sampled by Bongo-60 was worked at three depths: 0, 15 and 25 m. To eliminate disturbances due to propeller during surface hauls, hydrographic wire was used and the haul was carried out in a curve. The speed was always kept within 1.5 - 2.0 knots. A TSK-flowmeter was attached to the Bongo-60.

The commercial fish pump has a theorethical capacity of about 10 tons/min. with a lifting height of 3.5 metres above sea level.

The rotor is worked hydraulicly, with the water being pumped through a 8" soft rubber hose. The length of the hose was 30 m and was used at full length at all sample depths: 0 (1), 2, 5, 10, 15 and 20 metres. The pump could also be operated at greater depths.

The filtration of large water volumes was difficult. The hose was fitted to one end of a U-shaped metal pipe, and a plastic pipe was connected via a short flexible hose to the other end. Initially filtration was carried out through a Juday net, 80 cm Ø, 375 µm mesh size,

kept at surface level along the side of the ship. The plastic pipe was lowered into the net and the pump started; then, to record water volumes, a simple flowmeter (nautical log) was installed in the U-shaped pipe.

This flowmeter proved to be unstable. Therefore the numbers of cod larvae in the profiles given in Fig. 13 are somewhat uncertain until 0430 hrs. From this time on, the filtration was performed on deck by filtering the water through a Juday net, 40 cm Ø, 180 µm mesh size, into a 400 litre plastic jar. At certain intervals the water flow was tested by filling the jar. The most stable water flow was obtained at about 2000 l/min.

During testing of the pump it was found that the mesh size of 375 µm was too large, resulting in damaged larvae.

The use of the fish pump was a success for the project purposes. Technically, the method can be considerably improved, especially the regulation of speed and hose fittings.

In future surveys it would be desireable to filtrate even larger water volumes.

2. Sampling of prey organisms

The vertical distribution of food organisms was studied by sampling 20 litres of seawater with a monopump from the following depths: 0, 2, 5, 10, 15, 20, 25, 30 and 40 metres. The samples were filtered through a 40 µm mesh gauze. The nauplii profiles were sampled in connection with cod larvae profiles.

3. Other parameters recorded

Detailed surveys on the hydrographic situation, the vertical distribution of chlorophyll, and the surface currents (drift experiments with plastic pellets) were carried out in Austnesfjorden during the cruise.

4. Field strategy

As in 1976, the decisions for positioning of stations were taken on the basis of current information obtained from Austnesfjorden. The decisions for time and place for the 24-hour stations were the result of a series of Juday surveys in the fjord, not discussed in this paper.

4 a) Field hatchery

An incubator system for pelagic fish eggs, of the same design as described by TILSETH and STRØMME (1976), was installed on land at Austnesfjorden, Lofoten. Seawater was pumped from 20 m depth and filtered through 50 and 10 µm Fulflo filters before entering the system, as cod larvae do not actively feed on particles less than 10 µm (Ellertsen et al., 1976).

Eggs from Arcto-Norwegian cod were artificially fertilized and incubated on 2, 5, 11 and 22 April 1977.

4 b) Bioassay experiments

The experiments were conducted according to the method described by LASKER (1975). First feeding cod larvae were sorted out from the field hatchery and transferred to a thermostaticly controlled room at 5° C on board R/V "Johan Ruud". Cod larvae at yolk sac stage 4 and 4^+ are considered as first feeding larvae (Ellertsen et al., 1976). Samples of seawater were brought on deck via the hose of a "particle rate meter" pump (see below). Samples of seawater containing different particle concentrations were collected. Twelve samples were collected in black plastic jars to test whether the samples of seawater contained suitable food particles for cod larvae. A 2 l subsample was taken from each jar for nauplii counting. The remaining 10 l were transferred to the thermostaticly controlled room for larval bioassay experiments. Thirty cod larvae in the first feeding stage were gently added to each jar. The jars were covered with two 20 % neutral filters, in order to reduce the light intensity (Ellertsen, et al., 1976).

The authors did not have a suitable cultured food organism to run control experiments to determine if the particular catch of cod larvae was in good condition and would feed. As a control experiment they concentrated the number of nauplii in one jar.

The larvae were permitted to feed for 5 hours, then MS 222 (1 : 200 000) was added to the seawater and they were collected after 2 minutes. The larvae were preserved in 4 % formaline in 10 o/oo seawater for later examinations.

4 c) The particle rate meter

Essential for the application of the larval bioassay method is the detection and sampling of food particles edible for first feeding cod larvae. This consists mainly of copepod nauplii. An instrument suitable for this purpose has been developed by Dr. Edward Scura at the National Marine Fisheries Service, Southwest Fisheries Center, La Jolla Laboratory, USA. The instrument works on the coulter counter principle. The sensor with an aperture of 1 mm is mounted in the mouthpiece of a 30 m submersible hose which is connected to a membrane pump on deck. The time from detection of a patc until sampling on deck is 60 seconds. For further information about this instrument see Scura (in press.).

The instrument was also used to study the vertical distribution of nauplii. A 20 l sample was brought on deck and concentrated by filtering through 40 um plankton gauze, and examined under a microscope.

RESULTS

Feeding of cod larvae in relation to larval length and nauplii size

Laboratory experiments

Cod larvae start active feeding about five days after hatching (Ellertsen et al. 1976). Two experiments were carried out with cod larvae 10 to 18 days old feeding on Artemia salina.

The results presented in Fig. 3 show that the same effect is observed

in both experiments, longer larvae being able to catch more nauplii than smaller larvae. The different lengths of larvae is not due to feeding or to various degrees of yolk absorbed as they have all passed yolk sac stage 4. The size range of O. salina nauplii in these experiments was from 360 to 410 µm total length.

Field observations

a. Basin experiment

The larvae were released in the basin 25 March 1976, four days after hatching, and first feeding started 28 March 1976. Larvae were sampled during the first 4 days when the larvae first started feeding, 7 to 10 days after hatching. The increase in length due to feeding in this period was insignificant. The mean number of nauplii in the gut as a function of larval length is shown in Fig. 4. The length-frequency distribution of larvae presented in Fig. 5 shows considerable differences in larval length at first feeding. The mean number of nauplii in the gut is seen to increase with increasing length. The size range of the pelagic nauplii in the basin was 100-300 um total length, being within the size range taken by the cod larvae in the Lofoten area.

b. Lofoten area

It is not yet possible to determine the exact age of larvae in the field. The larvae older than yolk sac stage 3 with lengths less than or equal to 5.2 mm were taken to be first feeding larvae (See Fig. 1). With regard to age it is possible to compare these larvae with those sampled in the basin and laboratory experiments. In Fig. 6 the mean number of copepod nauplii in the gut of larvae at three different 24 hour-stations is shown as a function of larval length. The mean number of nauplii per larvae is seen to increase with increasing larval length in all observations. The observed size range of nauplii ranged from 120 to 420 um in the larval guts and from 50 to 540 um in the sea. Figs. 7 and 8 show the mean size, standard deviation and the smallest and largest nauplii observed in the guts of larvae in different length groups for two 24-hour stations. The 24-hour station taken 3 May 1976 included Juday net hauls from

30-0 m, so vertical differences are not shown here. The size range of nauplii eaten by cod larvae is seemingly uncorrelated with larval length in the length range 3.8 to 5.2 mm. Therefore nauplii measured in the larval stomachs are grouped together and compared with the size range of nauplii observed in the sea. Fig. 9 shows the results from the 24-hour station 3 May 1976. Fig. 10 shows the size ranges for the 24-hour station 10-11 May 1977, where larvae and nauplii data are based on samples from 15 m depth.

Diurnal vertical distribution of nauplii density and size, and density of cod larvae

Basin experiment

Diurnal sampling was carried out on 3 May 1977 on cod larvae and their main prey organism, a rotifer species. Assuming a constant standing stock during this period, the catchability changed diurnally, giving a maximum stock estimate of cod larvae at 0300 hrs. in the morning. At that time the population had a predominantly pelagic distribution. Fig. 11 illustrates the percentage of the standing stock observed at different depths. As can be seen (Fig. 11), the catches were low during daytime and the larvae were mainly distributed close to the bottom. This was clearly demonstrated at 1500 hrs. when all larvae were taken at 3 m depth. During dusk, dawn and night sampling, the catches were usually higher and the larvae had a more pelagic distribution. At 2100 hrs. no larvae were caught at 3 m depth.

The mean number of rotifers in different depths is also illustrated in Fig. 11, with maximum occurrence being observed at 1900 hrs. The mean density of nauplii, which was of minor importance in the diet, was about 0.1 nauplii/l.

Lofoten area

The vertical distribution of cod larvae (sampled by a Bongo-60) and nauplii in the uppper 25 m during the 24-hour station 10-11 May 1977 is shown in Fig. 12.

A high density of nauplii was observed and the maximum was found between 5 and 10 metres. The highest concentrations of cod larvae were observed at 15 and 25 m, and the density of cod larvae was considerably lower at 0 m.

Fig. 13 gives vertical profiles of cod larvae taken with the commercial fish pump in the upper 20 m of the water column, with nauplii profiles included. The nauplii values are still high, note especially the figure at the surface at 1900 hrs.

As in Fig. 12, the nauplii maximum is never found below 10 m. Low densities of cod larvae were always found at the surface. The larvae maxima obtained by pump were more pronounced than those from the Bongo samples (Fig. 12).

A comparison with the Bongo-60 at 1000-1200 hrs. (Fig. 13) shows a distinctly lower number of larvae sampled and also a less pronounced maximum compared to the fish pump samples at 1000 and 1350 hrs.

The vertical distribution of nauplii seems not to be homogeneous with regard to nauplii size, Fig. 16. Measuring the carapax length of nauplii from the 24-hour stations, it was found that the nauplii size decreases with increasing depth at the first 24-hour station. A more complex distribution was found in the next 24-hour station, where the largest nauplii were found close to the surface and at about 30 m depth, while the smallest nauplii was found at 10-20 m depths.

A minimum mean length (about 150 um), found at greater depths 10-11 May was due to the presence of some very small nauplii (60-100 μm), while these nauplii were seldom observed at the next 24-hour station.

Bioassay and particle rate meter experiments

Bioassay experiment

The results from an incidental chosen bioassay test are shown in this paper, Table II. In this specific test the rate meter showed patches at depths of 13 and 23 m. Water was sampled from these depths, and as a control experiment on the feeding ability of cod larvae, particles from 13 m were concentrated.

All larvae were in yolk sac stage 4 and seemed to be in good condition. The results are presented in Table II and indicate that first feeding cod larvae are efficient feeders. The densities of particles edible for cod larvae were calculated to be 0.001-, 0.005- and 0.03 nauplii/ml and the feeding incidence at the end of the 4-hour experiment revealed that 13, 27 and 40% of the cod larvae had eaten one or more nauplii. It is of significance to note that 85% of the nauplii eaten were completely digested. This shows that cod larvae at yolk sac stage 4 are able to digest nauplii. The analysis of the stomach contents also showed that most of the cod larvae had eaten particles which could not be identified with certainty. Some of these contents had a green colour and are suspected to have been fecal pellets from copepods present in the experimental jars.

Particle rate meter profiles

Figs. 14 and 15 show the particle rate meter profiles at two different locations. Fig. 14 shows an extremely high density of particles close to the surface at night. The rate meter was set to record the rate of particles within the size range of about 100-800 μm. A subsample was collected from some patches and the particles within the size range edible to cod larvae were counted under a microscope, and calculated to be 0.6 nauplii/ml or 6×10^5 nauplii/m^3. This is, as far as is known, the highest density of nauplii ever recorded in a patch at sea. Fig. 15 shows the particle rate meter profile at the same locality 2 days later at about noon. This profile indicates that the particles withdraw from the surface at mid-day. Both profiles show that small particles are patchy distributed vertically.

Table II. Results of a 5-hour feeding experiment with first feeding cod larvae. All larvae came from the same female, and all were in yolk sack stage 4.

Depth of water sample	Cons.of particles acceptable to cod larvae	No.of larvae	Mean larval length	Percentage of larvae with nauplii in gut			No.of nauplii ingested and degree of digestion				Percentage of larvae with unindentified gut contents
				1 nauplii	1	Total	1	2	3	Σ	
13	0.00[illegible]/ml	31	4.7 mm	6.5	6.5	13	-	-	8	8	64
23	0.005/ml	29	4.7 mm	17.0	10.0	27	-	5	6	11	76
Control	0.03/ml	30	4.8 mm	20.0	20.0	40	-	1	22	23	87

DISCUSSION

1. Number of size of prey organisms in first-feeding larvae of different size.

The material from the laboratory and basin (Fig. 3 and 4), are of known age, and though the basin material is grouped for a 4-day period the length distribution reflects true intraspecific variation.

As regard to the age distribution in the field material this is unknown. A comparison between larvae from the basin, laboratory and field was based upon yolk-sac criteria (see page 3 and fig. 1).

The causes of intraspecific variation in length of first feeding larvae has been investigated by several authors, and a positive correlation between egg size and larval length has been found (BLAXTER & HEMPEL 1963, SOLEMDAL 1970, FOWLER 1972).

The negative correlation between temperature during incubation and length of larvae at hatching is shown in several laboratory studies (summarized in BLAXTER 1967 p. 213. See also SOLEMDAL 1970, STRØMME 1977).

The variation in larval length at hatching at different temperatures seems to be an effect of variation in degree of development at hatching, as the ontogenetic stage at hatching seems to be negatively correlated with temperature (LILLELUND 1967).

Comparing larvae at a given developmental stage (for example time for first feeding), the effect of temperature seems to be reduced (STRØMME 1977).

The average number of food items increased with increasing larval length at a given age (Fig. 3, 4 and 6). This may be due to increased seeking potential of the larvae (ROSENTHAL & HEMPEL 1970, herring). A higher viability of large larvae has also been emphasized by VLADIMIROV (1973)

Gut clearance rate of cod larvae of different length has not been investigated, and may influence the number of food items observed in the gut of the larvae at a given time.

The ultimate fate of small first feeders are not fully investigated, though the results from the basin experiments in 1976 indicate a higher mortality for this group (unpublished data).

Fig. 7 and 8 shows that all sizes of first feeding cod larvae eat nauplii of the same size. The same effect is also shown by Berner (1959) working on anchovy larvae (Engraulis mordax). The data on the nauplii sizes found in the gut of larvae of all lengths was grouped together and compared to the nauplii size range observed in the sea (Fig. 9 and 10).
The smallest nauplii sizes seems to be ommitted by the larvae.

2. Vertical distribution of cod larvae and prey organisms.

The 24-hrs stations taken 10 - 11 May and 18 - 19 May 1977 was located at the same place. They show a similar vertical distribution of the nauplii (Fig. 12 and 13).

Looking at vertical distribution of nauplii densities the maxima was never found below 10 metres as also found by ELLERTSEN et al., 1976.

The density range of nauplii observed in 1976 was from 4 to 80 nauplii per litre, this is significantly lower than in 1977.

A density maximum of 600 nauplii per litre has been observed close to the surface in the evening 15 May, as shown in rate meter profiles (Fig. 14), while low densities was observed in the middle of the day (Fig. 15).

The occurrence of the smallest nauplii at about 25 - 30 meter depth 10-11 May is probably due to a previous spawning of small copepods in the area. Copepod egg spawned close to the surface may hatch at greater depths due to the slow sinking of the eggs (MARSHALL & ORR 1972).

The growth of copepod nauplii is rather fast, the nauplii of Calanus finmarchicus is able to grow from nauplius stage I to stage III-IV within 8 days (MARSHALL & ORR 1972), which implies an increase in total length from about 200 to 400 µm (WIBORG 1948b). The larger mean length in the nauplii in the last 24 hrs station may be due to a development and growth within the nauplii stock, probably consisting of several copepod species.

The vertical distribution of cod larvae in the upper 25 meters is shown in Fig. 12 and 13. Low densities of cod larvae is always found at the surface. The maximum densities was observed at 5 to 10 metres depth. The observations does not indicate any pronounced vertical migration of the larvae.

The vertical distribution found is also demonstrated by Wiborg (1948a) within the same size range of cod larvae. However, in the basin a diurnal vertical migration was observed on larvae with mean length 6.3 mm. The cod larvae were distributed close to the bottom during daytime and pelagically at night (Fig. 11). As emphasized above this was not observed in the Lofoten area. This could be due to differences in diurnal variations in light intensities in southern Norway (where the basin is located) and in the Lofoten area. The diurnal differences in light intensity in the Lofoten area is minor at this time of the year. In the laboratory investigations (ELLERTSEN et al. 1976) it is shown that cod larvae has a response to variations in light intensity at yolk sac stage 4, 4^+ and 5. The stable vertical distribution of cod larvae observed in Austnesfjorden could also be due to other environmental factors. Miller et al. (1963) showed that the periodic change in larval depth distribution was correlated to the fluctuations in depth of the thermocline.

The low number of cod larvae taken with the Bongo-60 compared to the values obtained with the fish pump 8 days later (Fig. 12 and 13), truly reflects the trend of decreasing larval density in Austnesfjorden, documented by several Juday-net surveys through the whole period, not shown in this paper. However, during the 24-hrs station with the fish pump, Fig. 13, the Bongo net was used as a comparison.

As can be seen the densities observed with the Bongo net is significantly lower than those obtained by the fish pump at the same time. The differences in density observed using the two gears is probably due to the difference in fishing efficiency of the two gears. The possibility of a too large mesh size used (375 µm) cannot be neglected.

3. Effect of density of nauplii on the feeding of cod larvae.

Fig. 17 shows that there is no correlation with nauplii density and mean number of nauplii in the gut of the cod larvae at the observed density range of nauplii.

Larval bioassay performed at a nauplii density of 30 nauplii per litre resulted in a mean number of two nauplii per larval gut during four hour feeding period (Table II).

In Fig. 18 the feeding incidence is seen not to be correlated with nauplii density, this observation seems to be in contrast to the findings of Ellertsen et al.. 1976, where it was a positive correlation between nauplii density and feeding incidence.

This is probably due to a satiation phenomena at high densities of nauplii (IVLEV 1961, LISIVNENKO 1961, HOUDE 1976 and LAURENCE 1974).

Summary

1) Investigations were carried out on the distribution and feeding of cod larvae and on their main prey organisms in the laboratory, in a large outdoor basin and in the Lofoten area, Northern Norway.

2) A field hatchery in Lofoten was established to supply cod larvae for bioassay experiments.

3) A particle rate meter was applied to detect and investigate the vertical density of nauplii at sea.

4) In addition to Bongo-and Juday net sampling a commersial fish pump, (capacity 10 m^3/min), was used with success to investigate the vertical density of cod larvae in the field and a monopump (capacity 200 l/min) to investigate the vertical distribution of nauplii.

5. Maximum density of nauplii was observed at or above 10 m.

6. The main density of nauplii based on vertical profiles was significantly higher in 1977 than in 1976. An extreme maximum of 600 nauplii/litre was detected by the particle rate meter.

7. In early May relatively high densities of small nauplii were observed at the deepest sampling depths (25 - 30 m). This was not observed in last part of May.

8. The maximum density of cod larvae was observed at 5-10 m depth throughout the 24-hour station. No clear indication on diurnal vertical migration was detected at sea in contrast to the situation in the basin.

9. The number of food items in the gut of first feeding larvae increased with larval size. Difference in size of first feeding larvae seems to be caused by intraspecific variation.

10. First feeding cod larvae did not seem to be selective on a specific size group of nauplii. However, the smallest nauplii (< 100 µm) was not found in the gut content, regardless of larval length.

11. The number of nauplii in the gut and the feeding incidence for first feeding larvae was higher in Lofoten 1977 compared to 1976. Related to nauplii densities at the sea the results from the 2 year are in good agreements.

Acknowledgements.

During the visit of Dr. Reuben Lasker to Bergen in September 1976, the plans for field work in 1977 were discussed. As a result it was decided to introduce the larval bioassay and the submersible Coulter Counter with the assistance of Dr. Edward Scura from the same Institute, (Southwest Fisheries Center, La Jolla, California). Dr.

Edward Scura participated in the cruise with R/V "Johan Ruud" in the Lofoten area in April-May 1977, and was largely responsible for the success of that cruise. We are greatly indepted to both him and Dr. Lasker for their assistance in this project.

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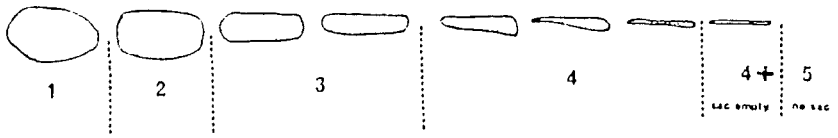


Fig. 1. Yolk-sac of cod larvae from hatching (stage 1) to absorbtion (stage 5)

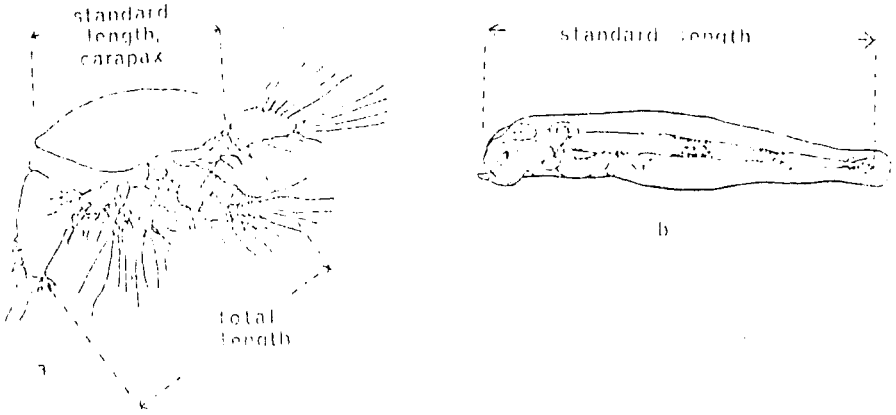


Fig. 2. Standard measurements of a, copepod nauplii and b, cod larvae

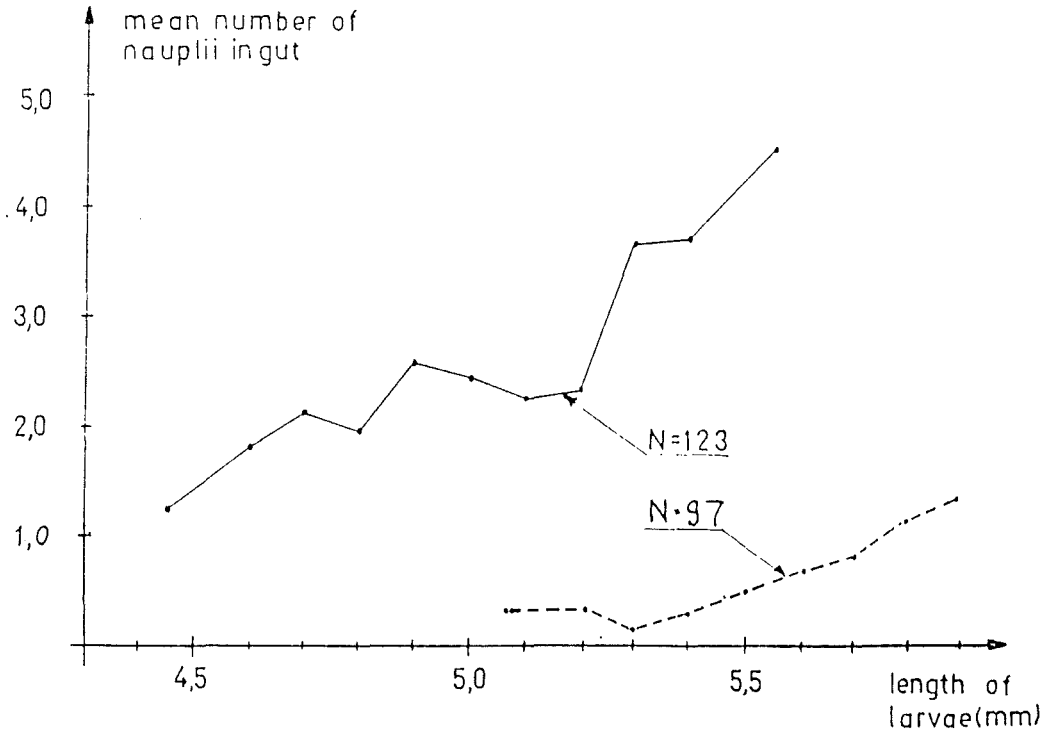


Fig. 3. Mean number of nauplii in gut of cod larvae feeding on artemia salina in two experiment series carried out in 1975 (---)

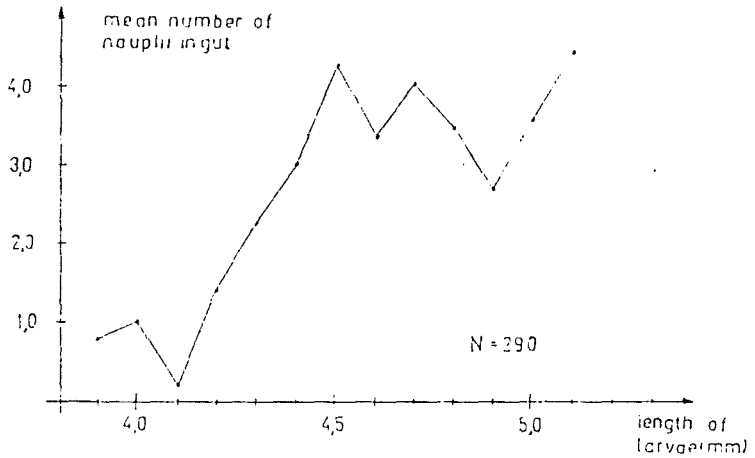


Fig. 4. Mean number of nauplii in the gut of cod larvae at different length of larvae observed in the basin at "Statens Biologiske Stasjon Flødevigen" in 1976.

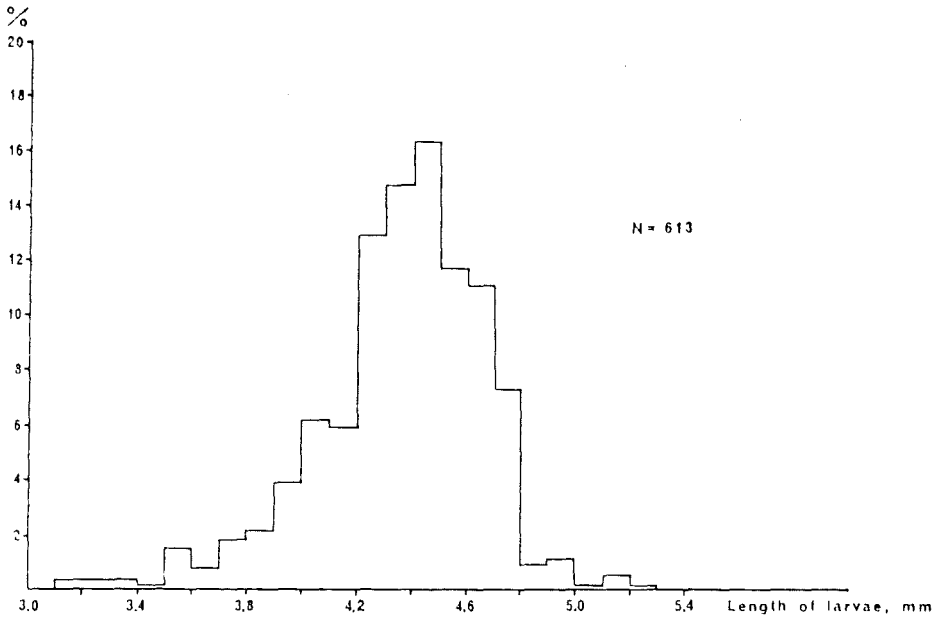


Fig. 5. Length-frequency distribution of cod larvae from the basin experiment on 30 March 1976.

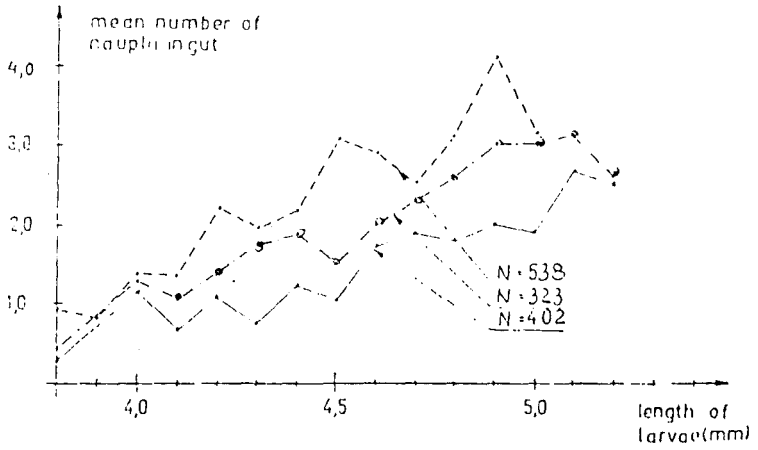


Fig. 6. The mean number of nauplii in gut of larvae at three 24 hour

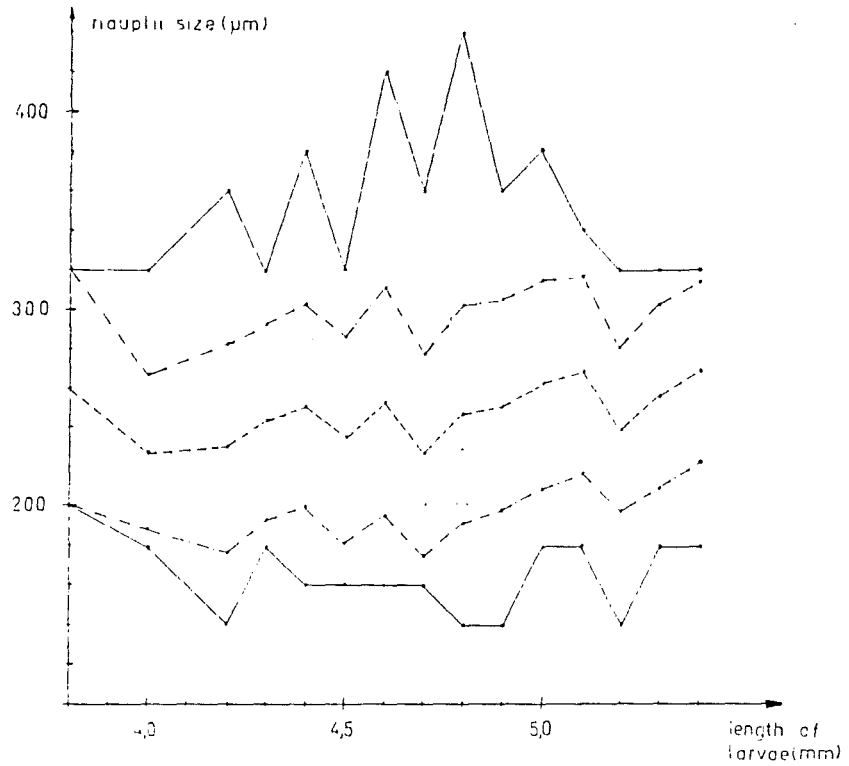


Fig. 7. Mean (---), upper and lower standard deviation (—·—·—) and smallest and biggest (———) nauplii size observed at different length of larvae, in a 24 hour station 3 May 1976.

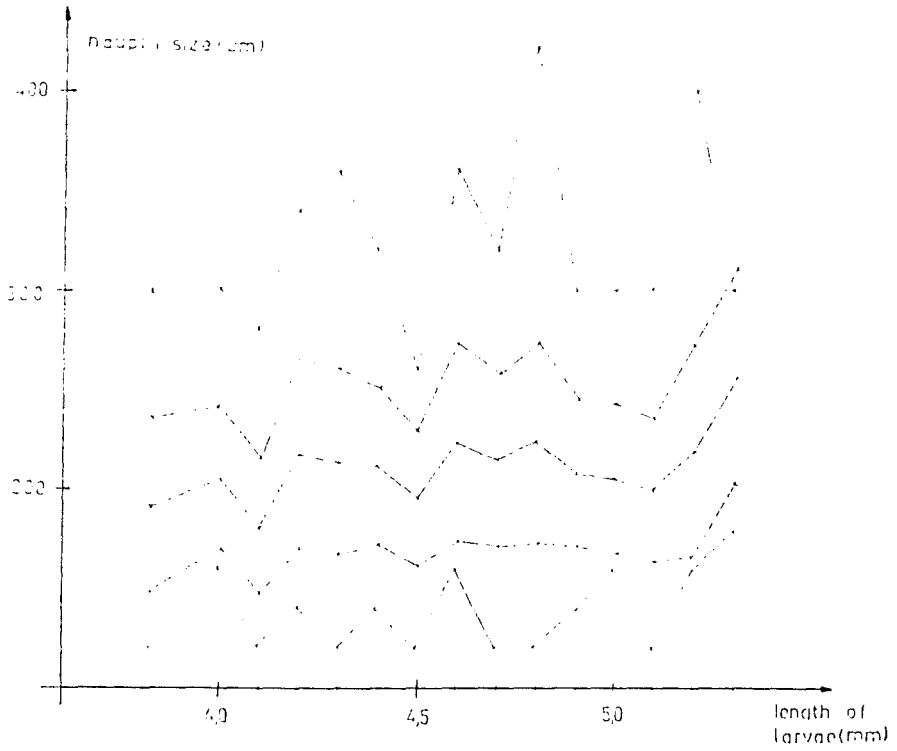


Fig. 8. Mean (-----), upper and lower standard deviation (—·—·—) and smallest and biggest (———) nauplii size observed in gut of larvae at different length. The larvae was caught at 15 m depth 10 - 11 May 1977.

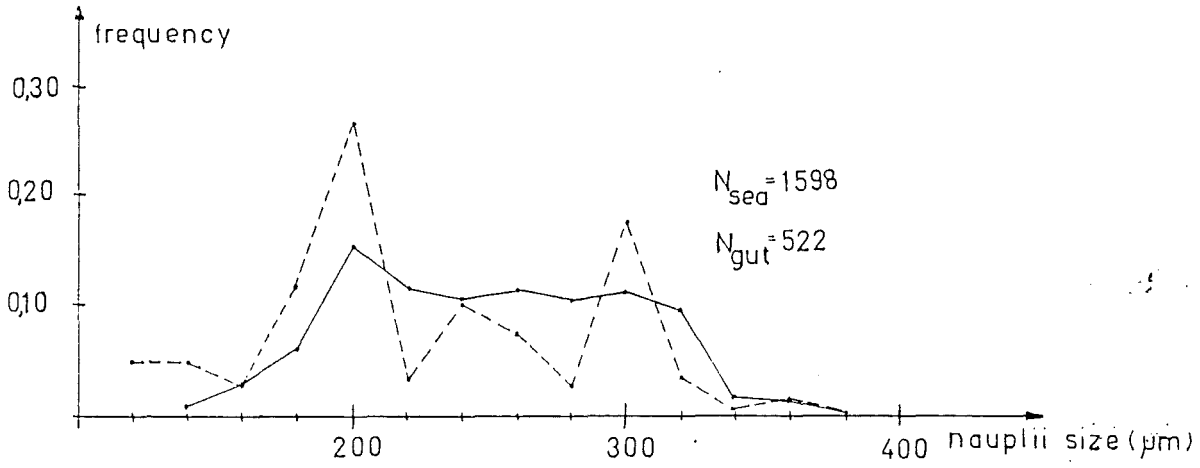


Fig. 9. Carapax-length distribution of copepod nauplii observed in the sea (---) and gut of larvae (——) at a 24 hour station in the Lofoten area 3 May 1976.

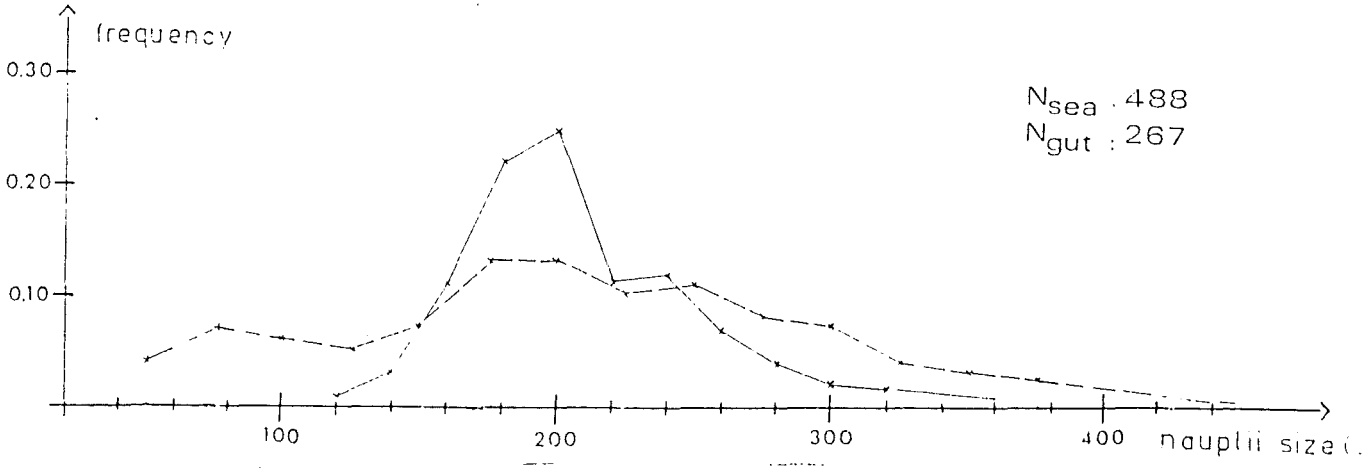


Fig. 10. Carapax-length distribution of copepod nauplii observed in the sea (---) and gut of larvae (——) at a 24 hour station in the Lofoten area 18-19 May 1977.

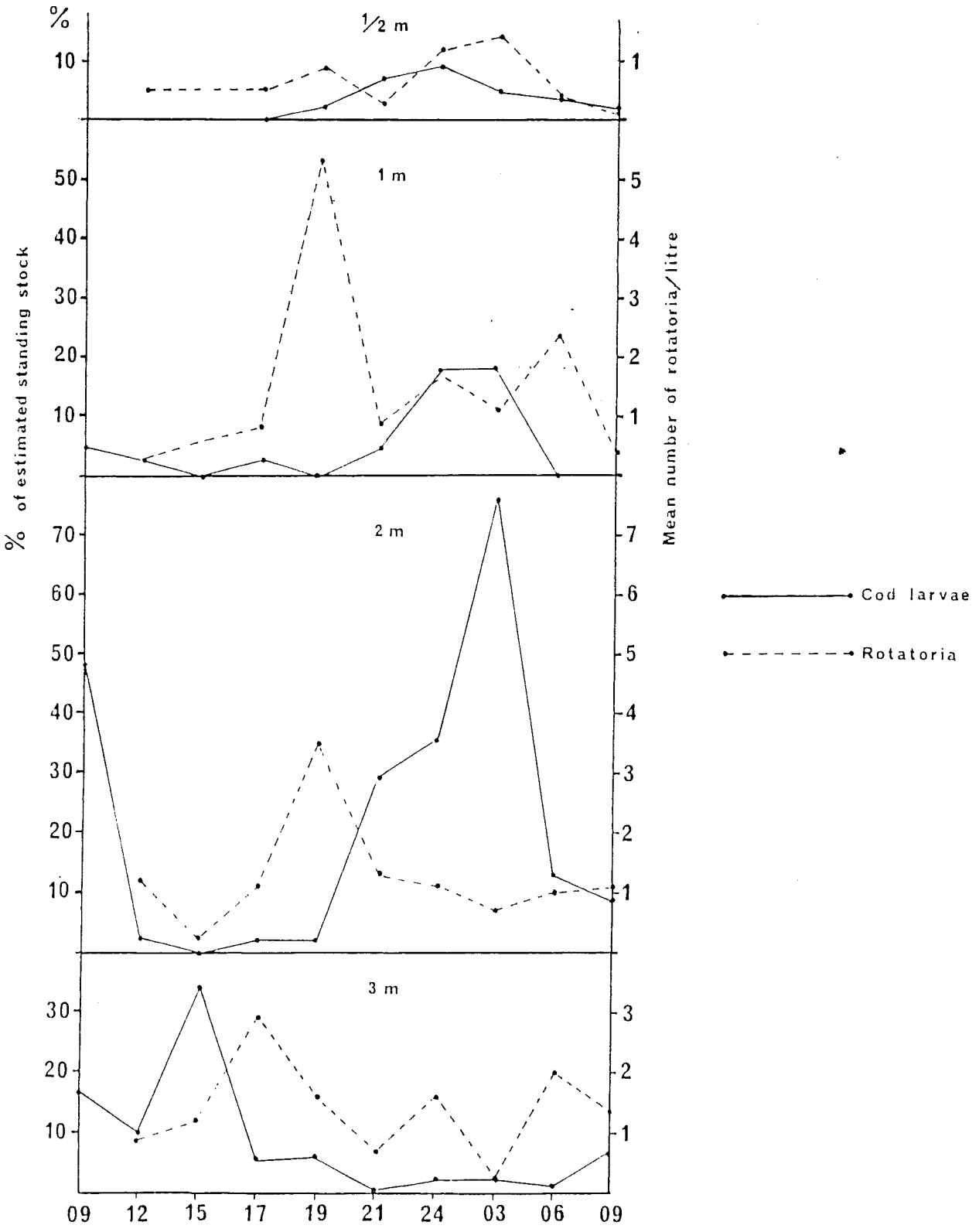


Fig. 11. Diurnal occurrence of cod larvae in four depths' presented as percentage of estimated standing stock (——) and of rotatories as mean number per litre (----). From the basin ex-

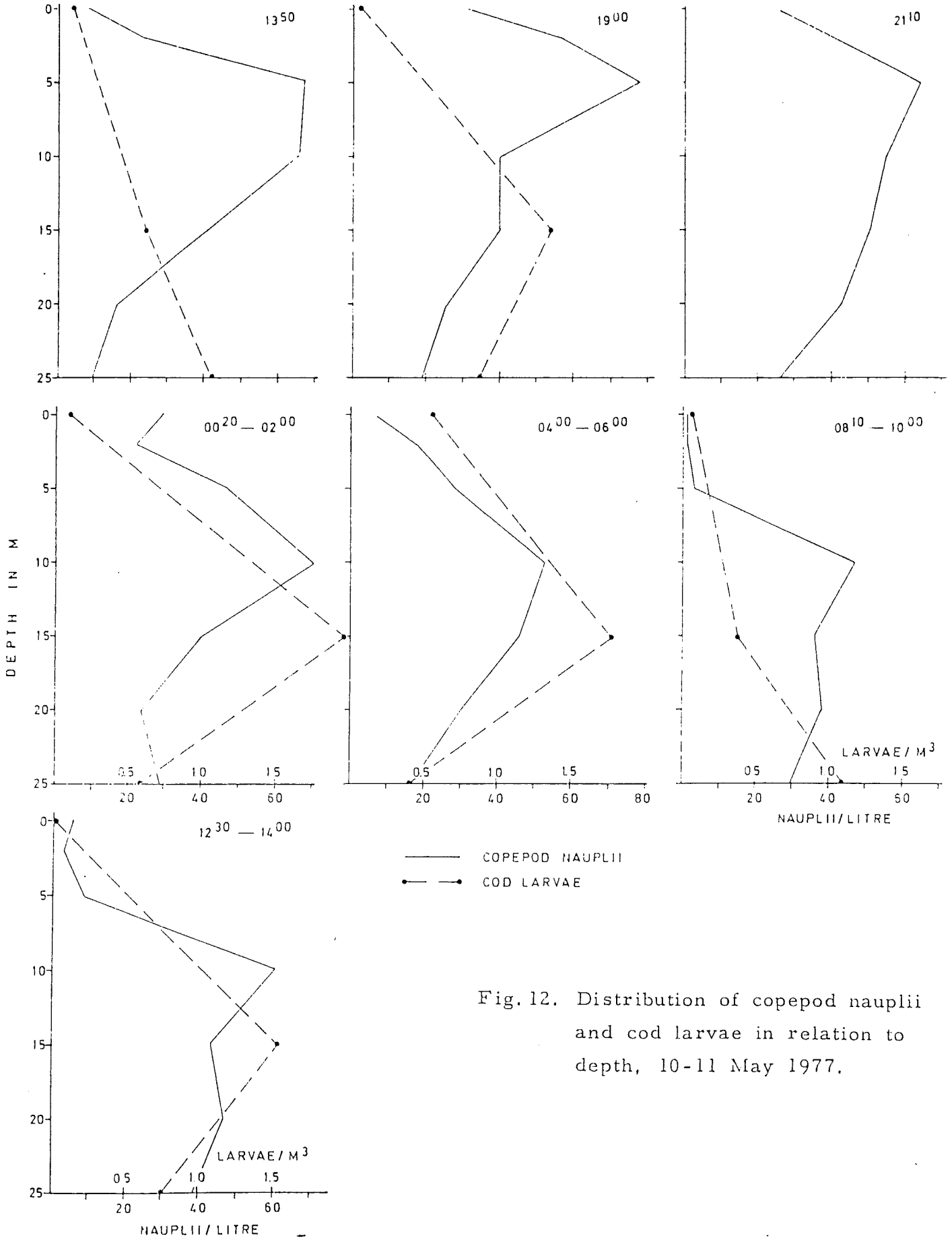
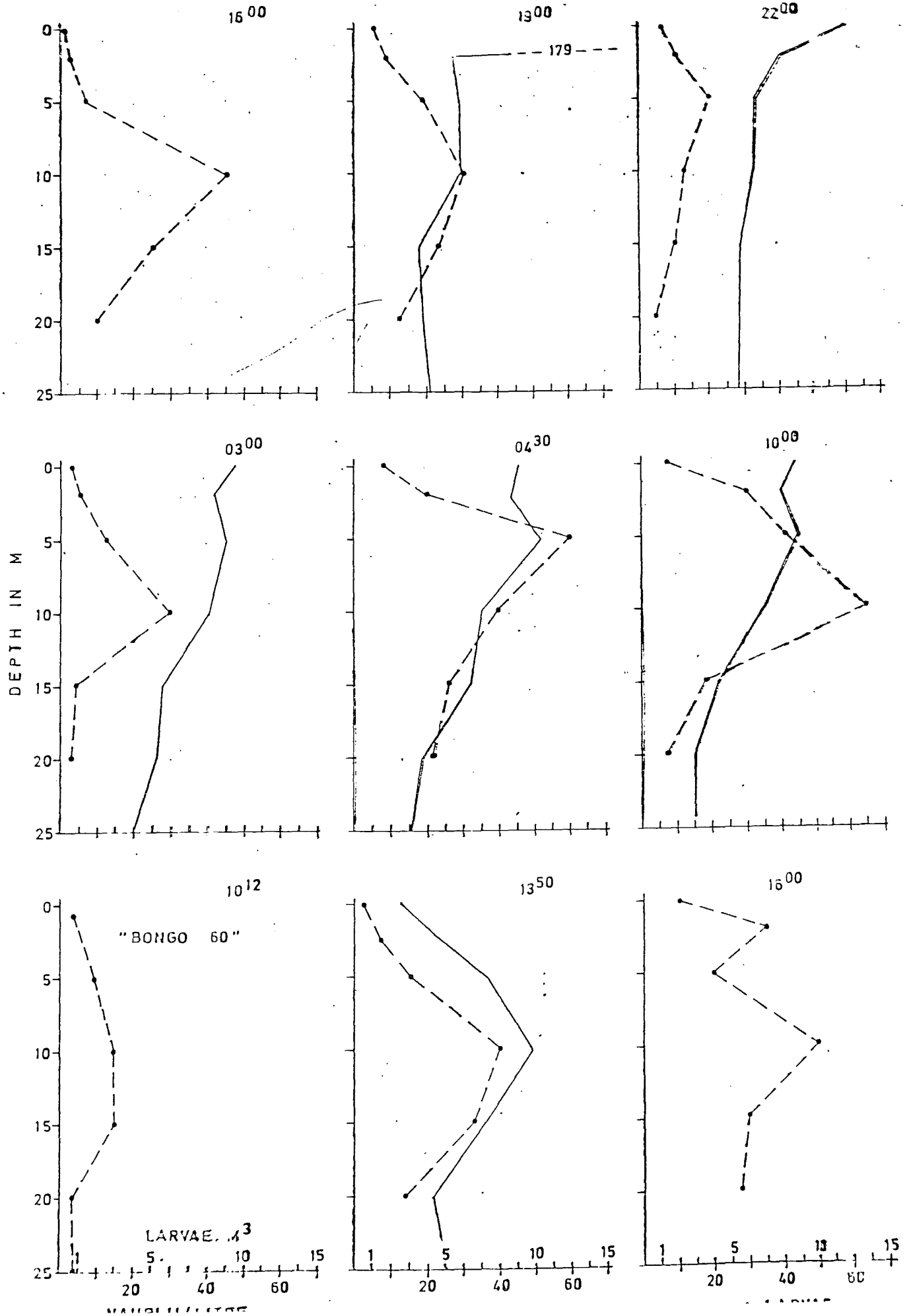


Fig. 12. Distribution of copepod nauplii and cod larvae in relation to depth, 10-11 May 1977.


16 00
19 00
22 00
179
03 00
04 30
10 00
10 12
13 50
16 00
DEPTH IN M
"BONGO 60"
LARVAE. M3
0
5
10
15
20
25
1
5
10
15
20
40
60

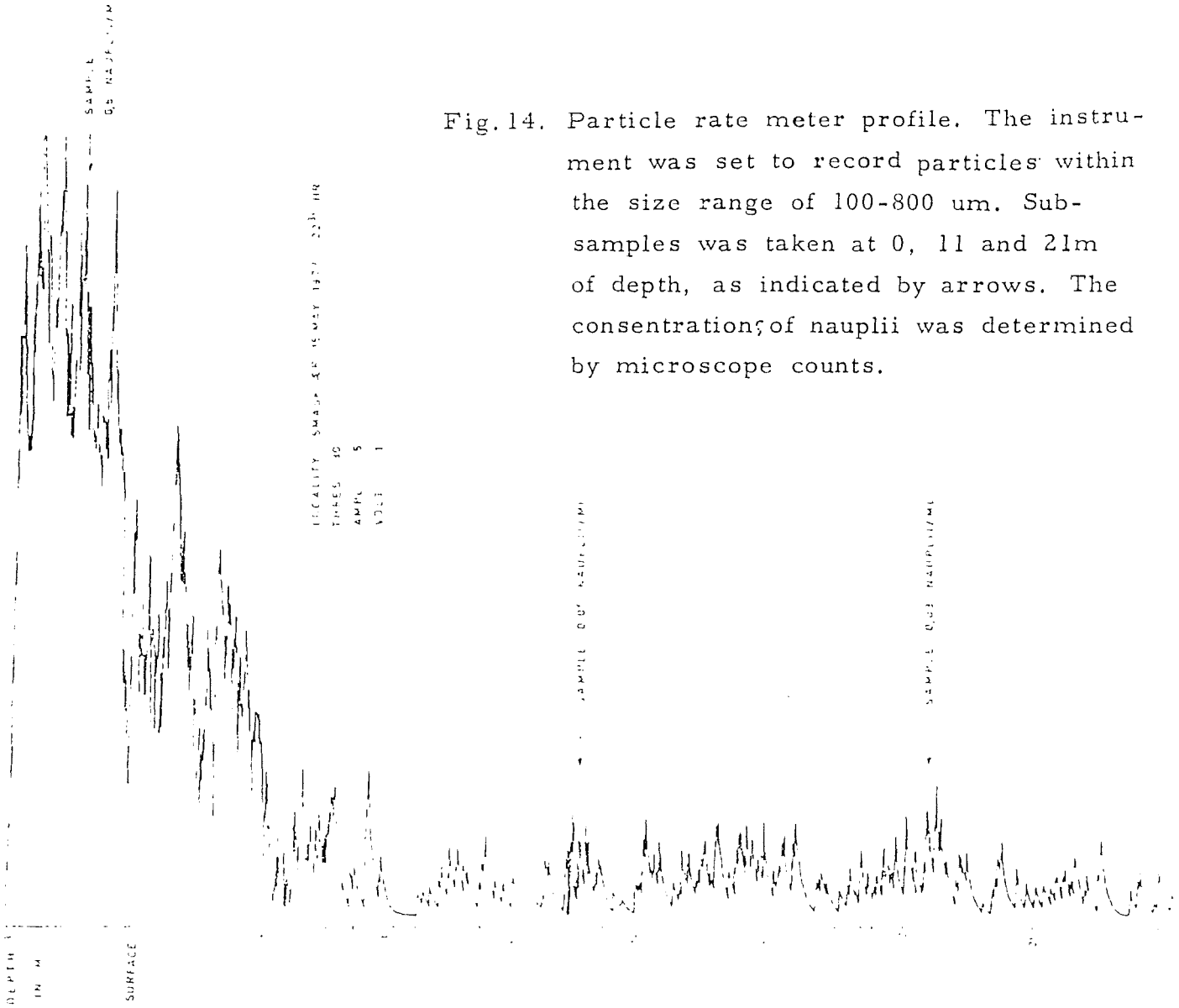


Fig. 14. Particle rate meter profile. The instrument was set to record particles within the size range of 100-800 um. Subsamples was taken at 0, 11 and 21m of depth, as indicated by arrows. The consentrations of nauplii was determined by microscope counts.

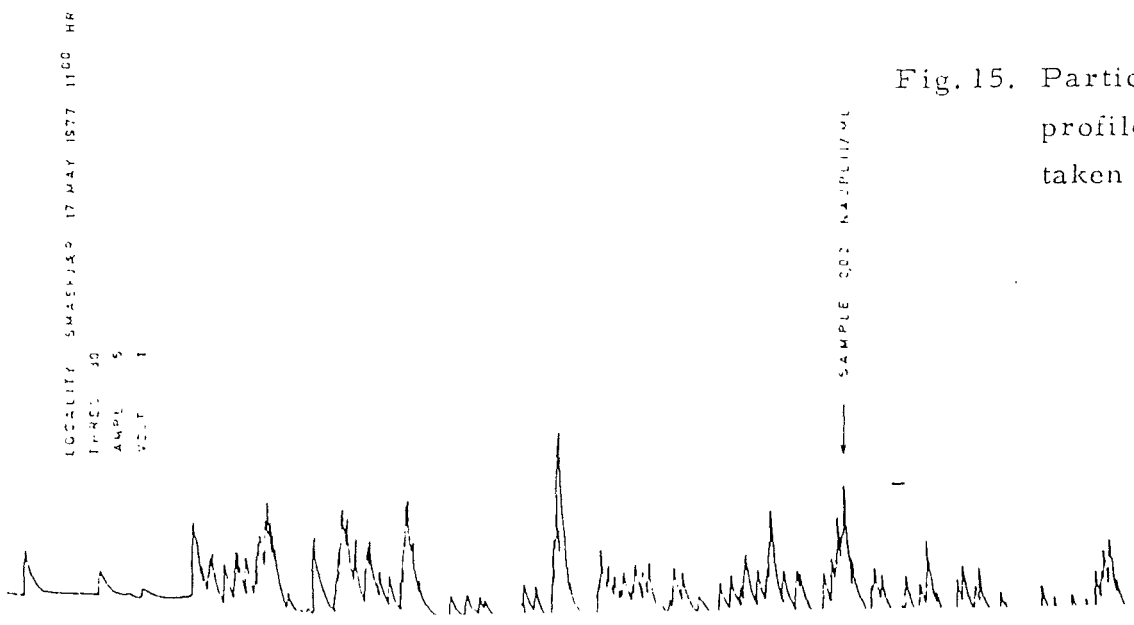


Fig. 15. Particle rate meter profile. Subsample taken at 23m depth.

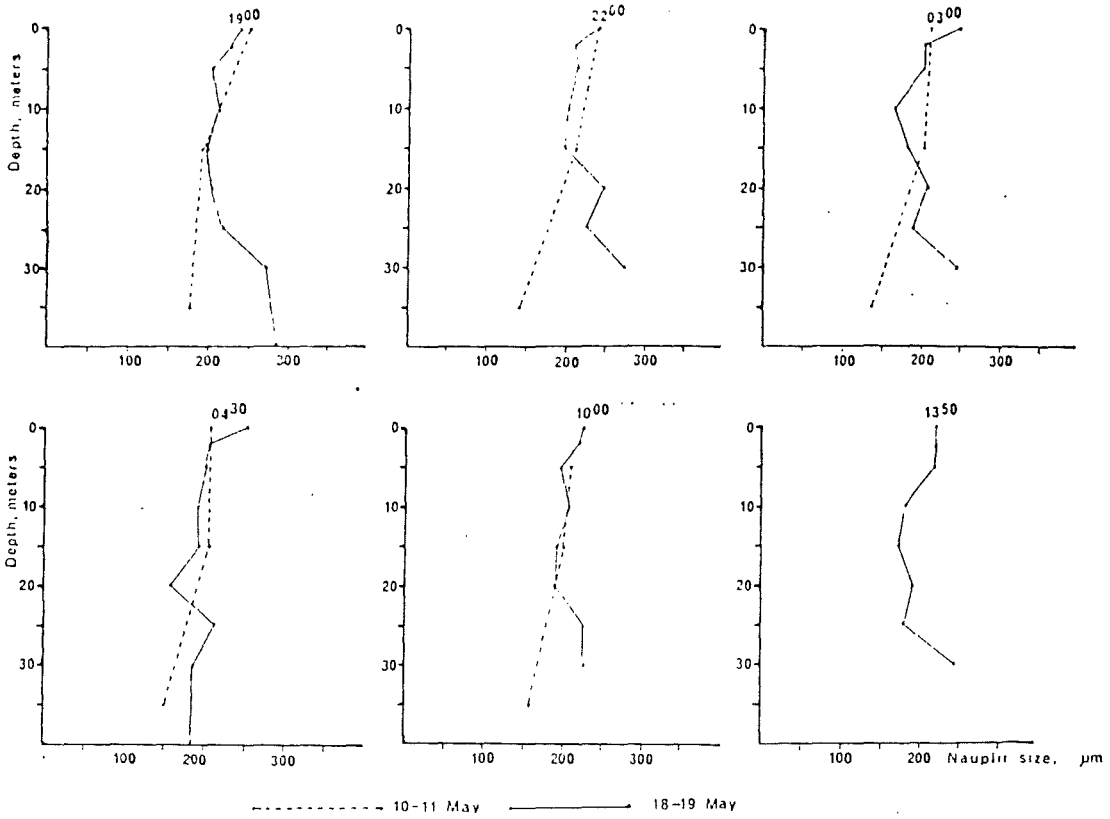


Fig. 16. Distribution of mean nauplii size (Carapax) in relation to depth.

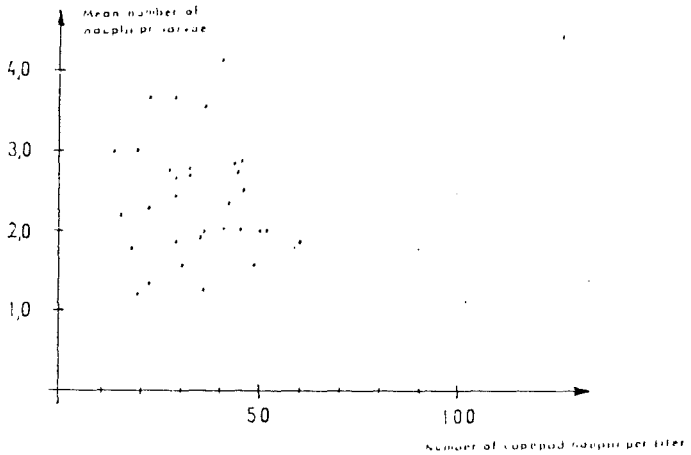


Fig. 17. Mean number of nauplii pr. larvae in relation to number of nauplii pr. liter observed at the 24 hour station 18-19 May 1977.

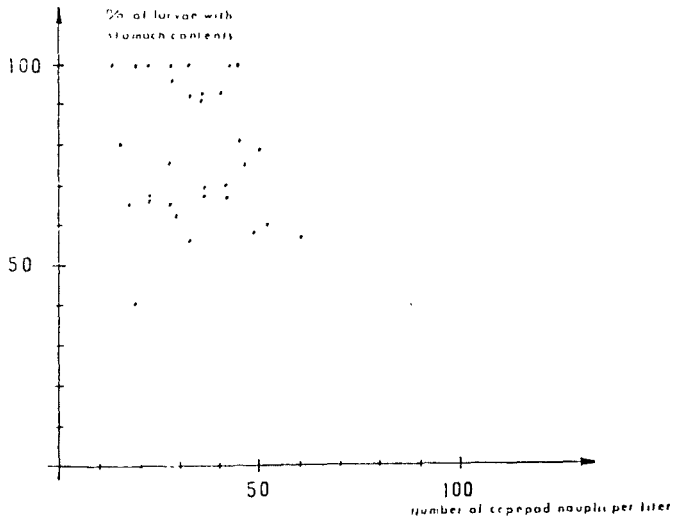


Fig. 18. Feeding incidence of larvae observed at the 24 hour station