DISTRIBUTION AND ABUNDANCE OF POST LARVAL NORTHEAST ARCTIC COD AND HADDOCK

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ABSTRACT

From 1977 onwards an annual postlarvae survey has been carried out off northern Norway in June/July. The aim is to study the distribution of fish larvae, and to establish an index for the abundance of economically important fish species. A pelagic trawl is used for sampling, and depth for sampling is from 53m to surface.

In 1983 the station grid was designed to study mesoscale features of the larval distribution. It was found that cod larvae were mainly confined to coastal water masses and haddock larvae to the Atlantic water masses. The mesoscale circulation was found to influence the larval distribution. The same features were also found for the years 1980 and 1981. In 1979 the larval distribution was different, and the reason for this is discussed.

From 64 to 84% of the cod larvae were found in the upper 13 m. The vertical distribution indicates no diel migration, and no difference of the vertical distribution for the different length groups was found. The mean length of the cod larvae was highest in 1983, indicating good feeding conditions this year.

Indications of a high larval mortality from June to September in 1981 are discussed. The denser station grid introduced in 1983 gives probably a better quantitative index than the station grid used the previous years.

INTRODUCTION

The Norwegian shelf constitutes important spawning grounds for fishes of great economical interest such as Northeast Arctic cod, saithe, capelin and Norwegian spring spawning herring (Anon, 1979). Eggs and larvae of these species are transported northwards and eastwards by the residual currents.

The Institute of Marine Research has since 1948 been sampling fish eggs and larvae at different localities along the Norwegian coast (e.g. Hognestad, 1969; Wiborg, 1960; Dragesund, 1970; Gjøsæter and Sætre, 1974; Ellertsen et al. 1981 and Bjørke, 1981, 1983). The sampling has taken place during the spring and summer seasons and has partly been aimed at the study of single species, such as, for example, herring and cod.

After 1966 a closer sampling grid was introduced from Stad to Vestfjorden in April and the sampling was aimed at the study of the herring larvae only.

Findings of oil along the Norwegian coast and the subsequent oil spill contingency plans introduced the need for increased and updated knowledge about the occurrance and distribution of fish eggs and larvae. These younger stages, with strongly reduced ability to choose their surroundings, are more vulnerable to the effects of oil and oil dispersants than the older ones.

Therefore, utilizing the sampling schemes already working, it was decided from 1976 onwards to identify and record all fish eggs and larvae caught with zooplankton gears.

Sampling of older larvae (postlarvae) offshore started in 1977. The aim was to study the distribution of larvae in June/July, and if possible calculate an index for the abundance of the different species. In addition genetic investigations were made on cod and herring.

In June-July most of the larvae hatched on the Norwegian shelf are to be found north of Træna (66°N) and most of the sampling was made in this area. In 1982 the sampling grid was extended southwards and started at Stad.

Ellertsen et al. (1981) showed that the cod eggs were confined to certain coastal water masses in Vestfjorden. Sundby (1983) showed that the distribution of cod eggs further north, off the coast of Troms, is confined to the coastal water masses, and that the distribution is influenced by the mesoscale circulation. This circulation in turn was shown to be strongly influenced by the bottom topography. On this background the question arose whether such mesoscale current features also may influenced the distribution of larvae later on, and further north. In 1983 the larva survey was designed to study possible mesoscale features of larval distributions due to bottom topography.

The aim of the present paper is to present some of the results of this work with emphasis on the distribution of cod in the area Lofoten - Bear Island.

USSR has since 1959 been conducting egg- and larvae-surveys partly overlapping the area presented in this work. The sampling periods have been April-May and June-July, e.g. Baranenkova and Khokhlina (1964); Baranenkova, Sorokina and Khokhlina (1973), and Muchina (1980).

MATERIALS AND METHODS

The geographical distribution of larvae was found by fishing with a small meshed midwater trawl. A trawl with an effective opening of 4 x 10 m was used in 1977, and the following years a trawl with an effective opening of 13 x 13 m. Both gears had varying mesh sizes and a cod end with 15 mm meshes.

Two kind of hauls were made in 1977, one with the headline at 40, 20 and 10 m and a towing time of 20 minutes in each depth-interval. The other haul was made with five big floats on the headline and with a towing time of 60 minutes. The depth of the headline was checked with a depth measuring device.

From 1978 onwards a larger trawl was introduced. During the period 1978 - 1981 two hauls were made on each station, one with the headline in 40 and 20 m depth and a towing time of 15 minutes in each depth interval. The other haul was made at the surface with five big floats on the headline. Towing time was 30 minutes.

Only one kind of haul was made at each station in 1982 and 1983. Depths and towing time were the same as the previous year and five big floats were used on the headline during the haul.

Towing speed during all the years was 2-3 knots. The volume of filtrated water is not known. Therefore the computed index is based on the number of larvae caught per trawl haul. Oceanographic observations were made with a Neil Brown CTD-microprofiler down to 500 m depth.

Zooplankton hauls were made with a 180 micron Juday net, 36 cm in diameter, from 200 m to surface and from 20 m to surface.

All the fish larvae were identified, the length of 50 larva were measured when present, and the volume of the medusae recorded.

The results from the years 1979, 1980, 1981 and 1983 are plotted on horizontal maps, isolines drawn and the total number of larvae was estimated by using a planimeter on the isolines. Horizontal maps of the salinity distribution are also drawn to compare with the larval distribution. In 1978 and 1982 the station net was not dense enough to reveal meaningful mesoscale features, and therefore these data are not presented as isoline distribution. They are only shown as numbers of larvae sampled at each station (Fig. 18 and Fig. 19).

The abundance index may be formalized:

$$A = \int\int_{x,y} N(x,y)\,dx\,dy$$

where A is the abundance index

N is the concentration of larvae expressed as number caught per trawl haul.

x and y are the geographical coordinates.

Fig. 1 shows local names used in the text.

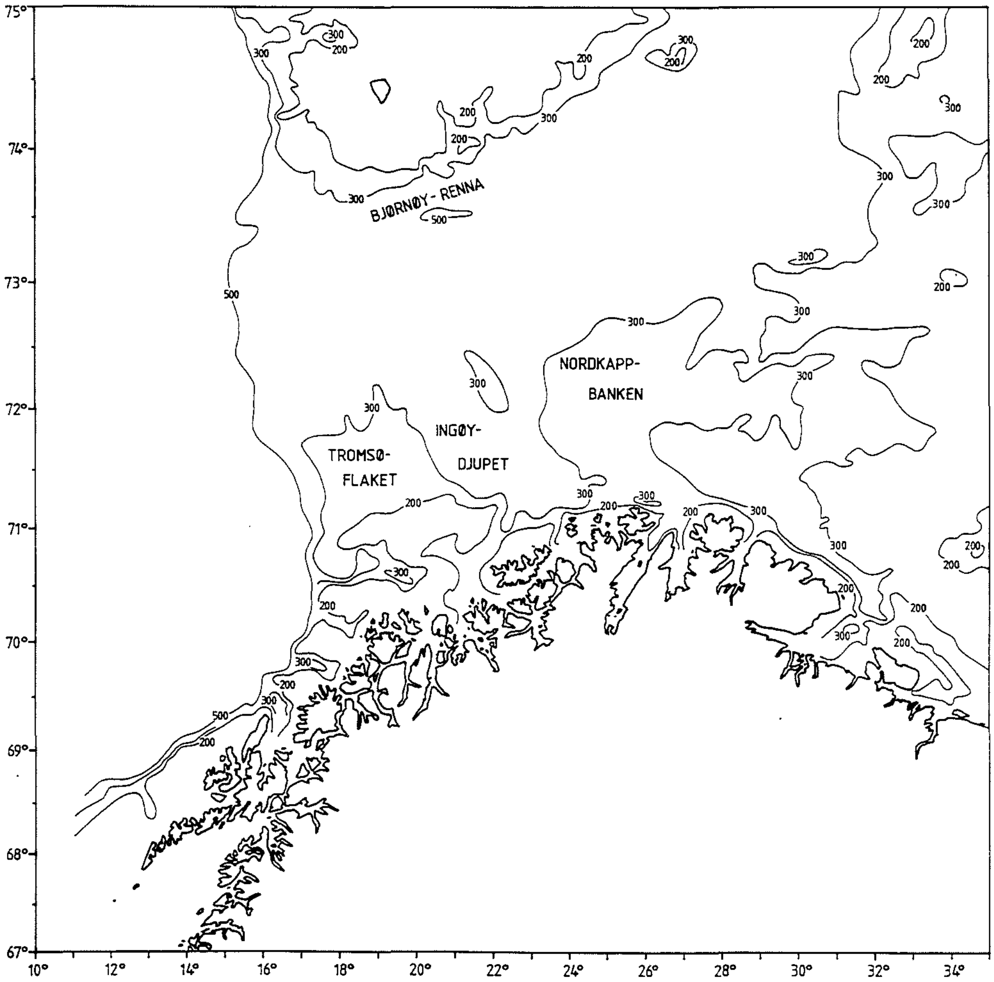

Fig. 1. Local names used in the text.

RESULTS AND DISCUSSION

HYDROGRAPHY AND DISTRIBUTION OF COD AND HADDOCK LARVAE

Figs. 2-6 show results from the survey in June/July 1983. Fig. 2 shows the distribution of cod larvae, Fig. 3 the distribution of haddock larvae, Fig. 4 the salinity at 20 m depth, Fig. 5 the temperature at 20 m depth, and Fig. 6 shows delta-D at the surface with respect to the 150 dbar surface. In Fig. 6 the trajectory of a satelite tracked drifting buoy drogued at 30 m depth is plotted. The buoy drifted for 22 days from 22 June to 7 July a distance of about 80 nautical miles, i.e. an average residual current of 7,8 cms^{-1}.

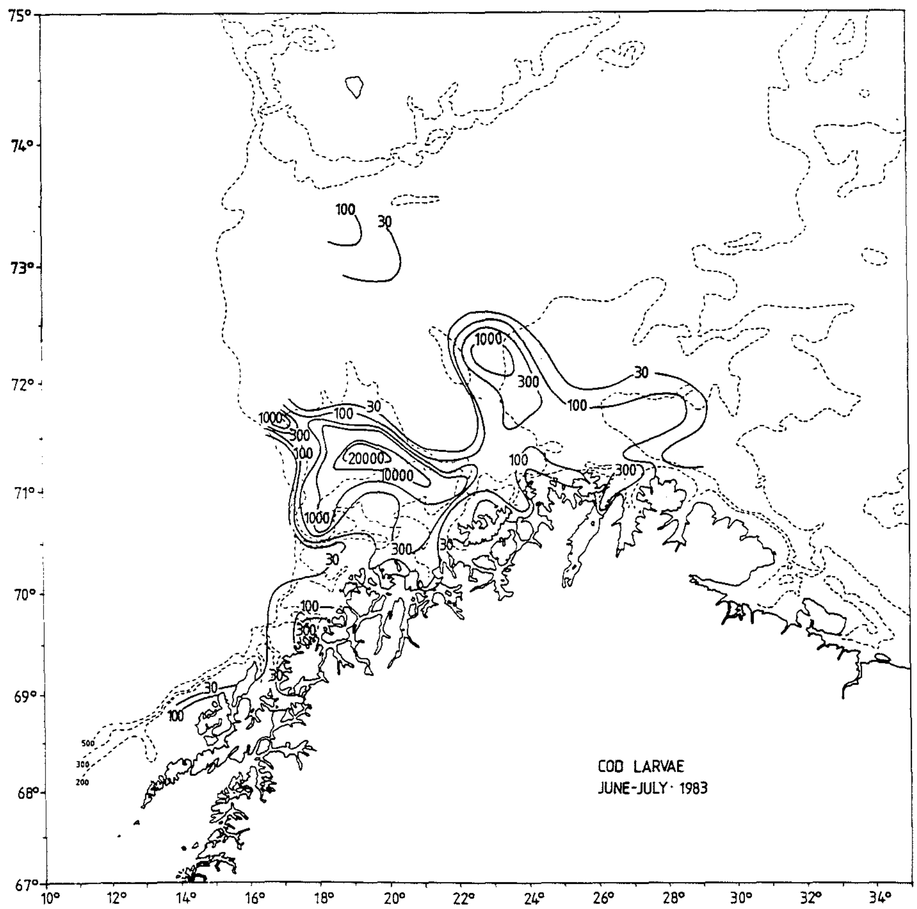

Fig. 2. Distribution of cod larvae. 24 June to 17 July 1983.

Very high concentrations of cod larvae are found at Tromsø-flaket and relatively high concentration are found at the north-western part of Nordkappbanken. More than 95% of the

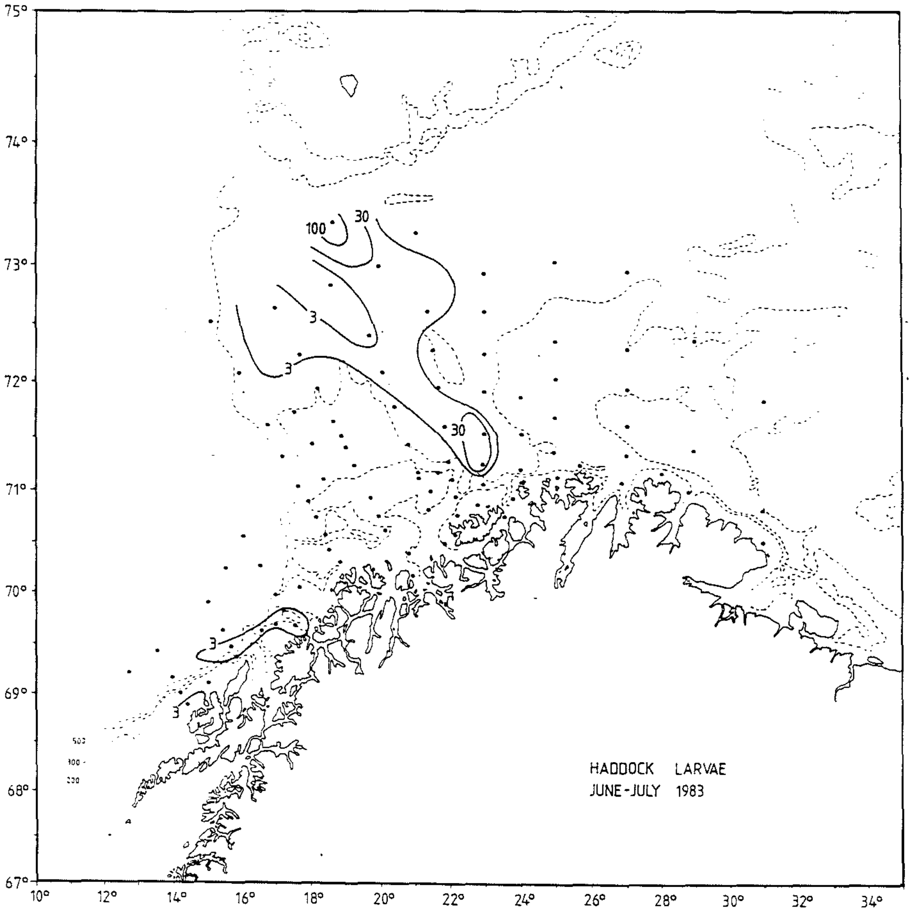

Fig. 3. Distribution of haddock larvae, and station net. 24 June to 17 July 1983.

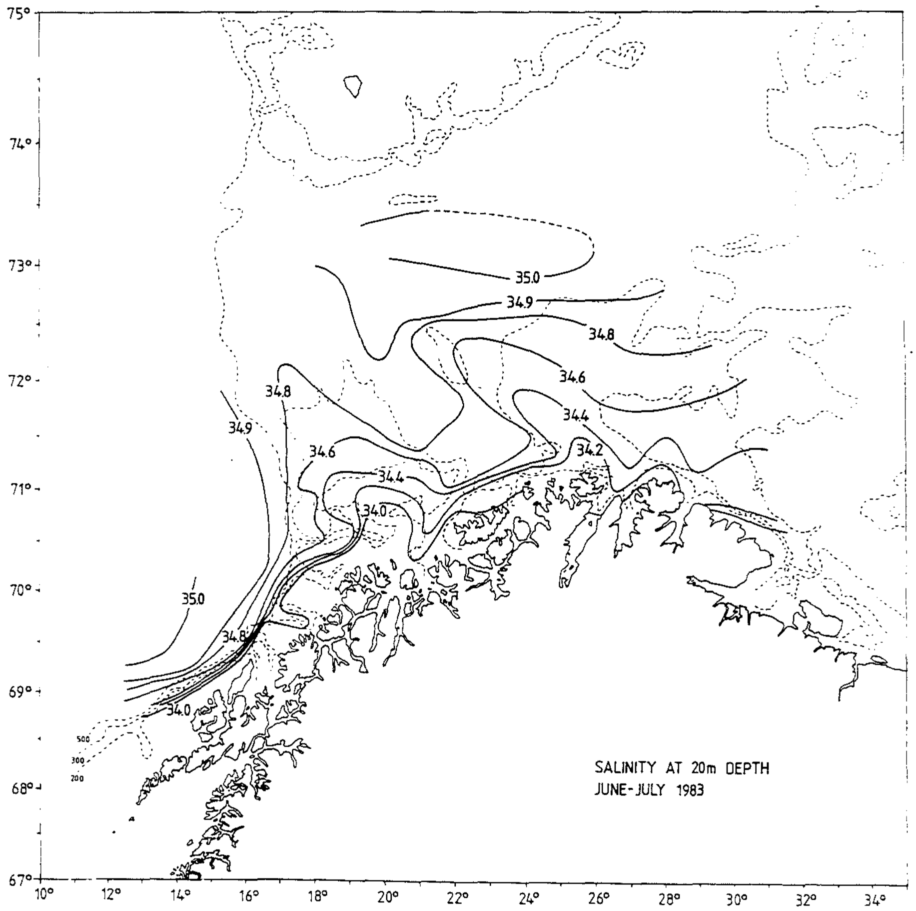

Fig. 4. Salinity at 20 m depth. 24 June to 17 July 1983.

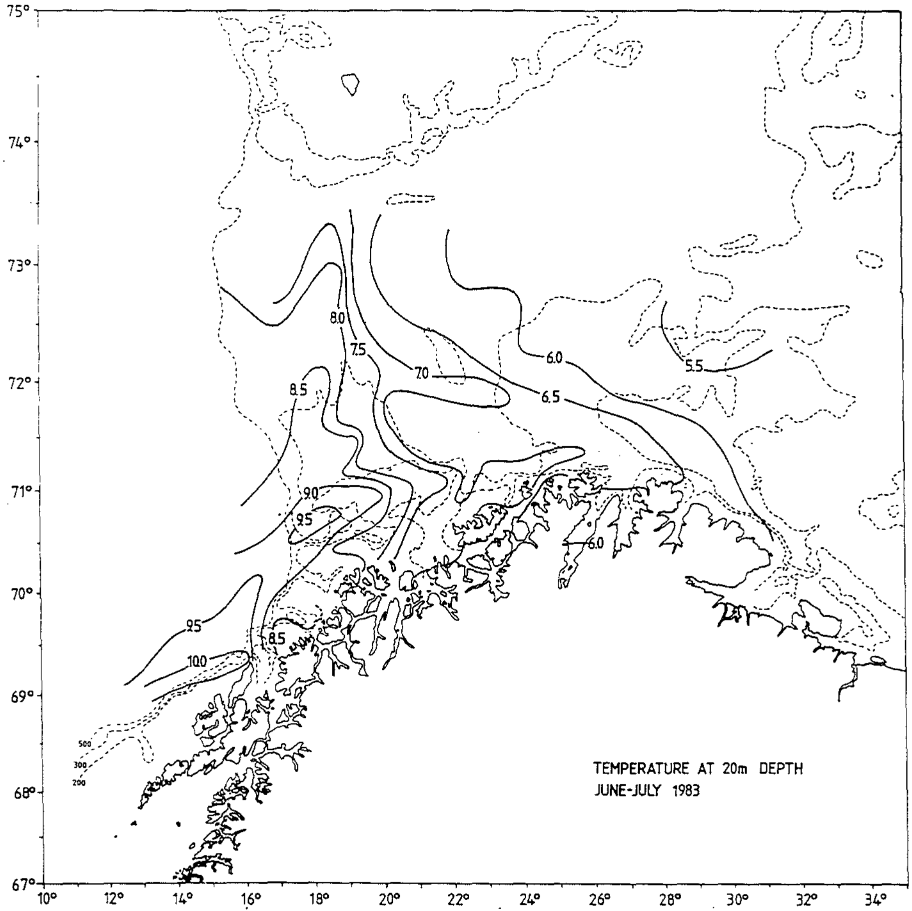

Fig. 5. Temperature at 20 m depth. 24 June to 17 July 1983.

larvae were found at these two banks (Table 1). The highest concentrations are found in coastal water at salinities of 34,3-34,6^{o}/oo S. This salinity interval also covers the banks of Tromsøflaket and Nordkappbanken where anticyclonic gyres are found. These gyres are indicated in Fig. 6, which shows geostrophic stream lines in the area. At Ingøydjupet, where highly saline Atlantic water intrudes from the northwest, very small concentrations of cod larvae are found. Also off the shelf break to the west of Tromsøflaket small concentrations are found. However, cod larvae are found in a small area in Bjørnøyrenna, in the atlantic water mass.

While cod larvae occupy the coastal water on the banks, the haddock larvae are distributed in the highly saline Atlantic water masses, partly at Ingøydjupet, but mainly at Bjørnøydjupet.

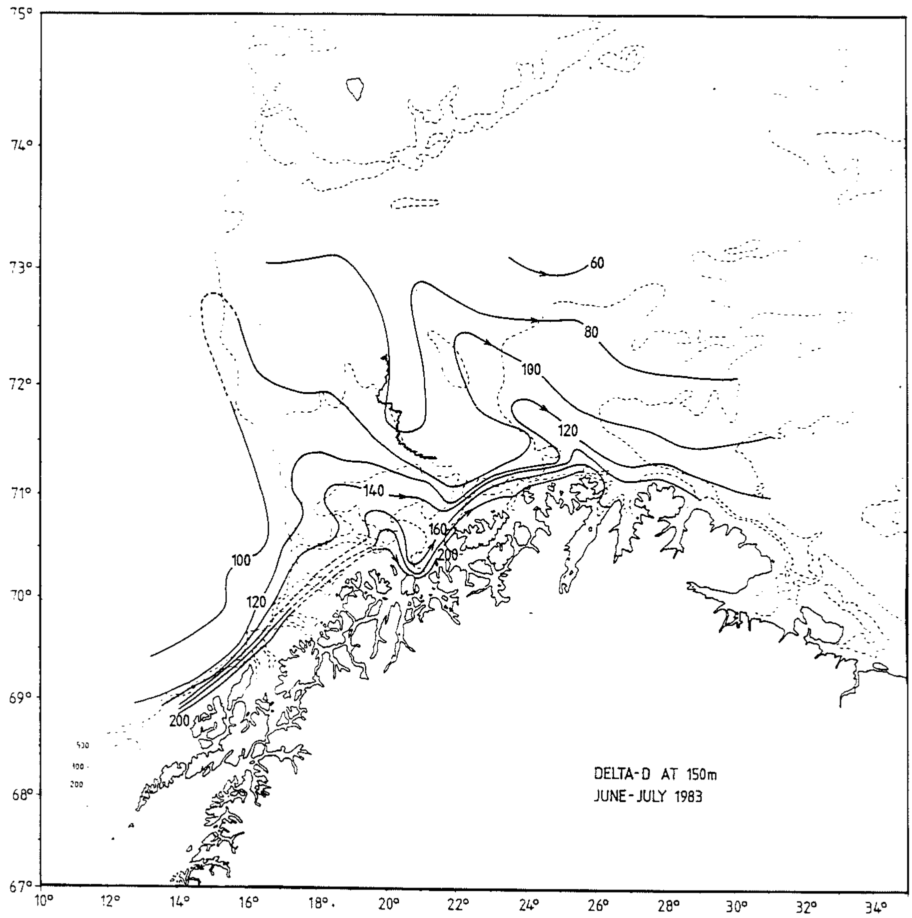

Fig. 6. Delta-D at the surface relative to the 150 dbar surface. 24 June to 17 July 1983. Trajectory of satellite tracked drfiting buoy draugued at 30 m depth. 15 June to 7 July 1983.

Table 1. Frequency distribution (in percent) of cod larvae in the different geographical areas. 23 June - 14 July 1983.

	The continental shelf Andøya-Tromsøflaket	Tromsø-flaket	Ingøy-djupet	Coastal area Tromsøflaket Nordkapp	Northwestern Nordkappbanken and Hjelensøy-banken	Porsanger fjord	Bjørnøy Trench	SUM
Frequency in percent	1,2	87,7	1,2	1,1	7,7	0,6	0,5	100
Area in km^2	12.900	22.900	14.000	6.400	21.500	2.300	9.400	91.000

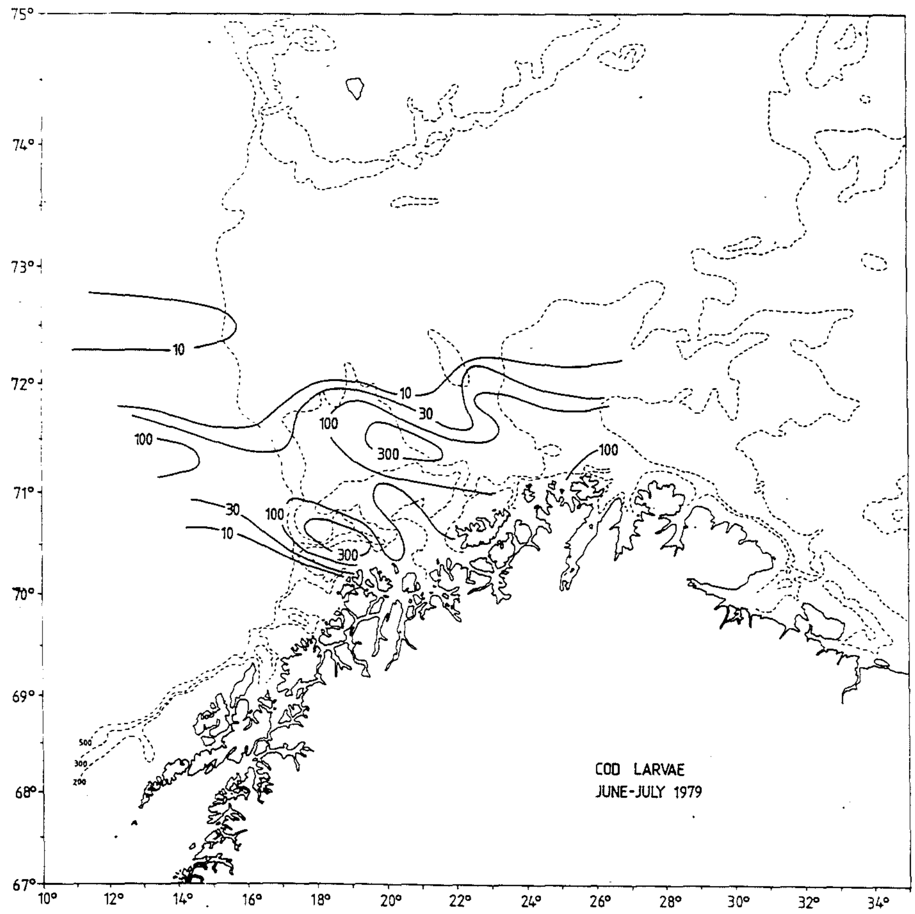

Fig. 7. Distribution of cod larvae. 20 June to 10 July 1979.

The features of watermasses and larval distribution in 1983 are rather detailed because the station grid was specially designed to reveal such mesoscale features. In the years 1979, 1980, and 1981 the station grid net was more dispersed. However, these data can still be used to show some rough mesoscale features. Figs. 7, 8 and 9 show the 1979 data of cod larvae, haddock larvae, and salinity at 20 m depth respectively, Figs. 10, 11, 12 the 1980 data, Figs. 13, 14, 15 the 1981 data. Fig. 9 reveals the same structures of the watermasses: coastal water extends above Tromsøflaket and Nordkappbanken, while Atlantic water intrudes into Ingøydjupet. These features were not that clear in 1980 (Fig. 12). However, these features of the water masses are reproduced in 1981 (Fig. 15).

In 1981 the larval distribution had the same general features as in 1983: the cod larvae are mainly found in the coastal water above the banks, and the haddock are found in Atlantic

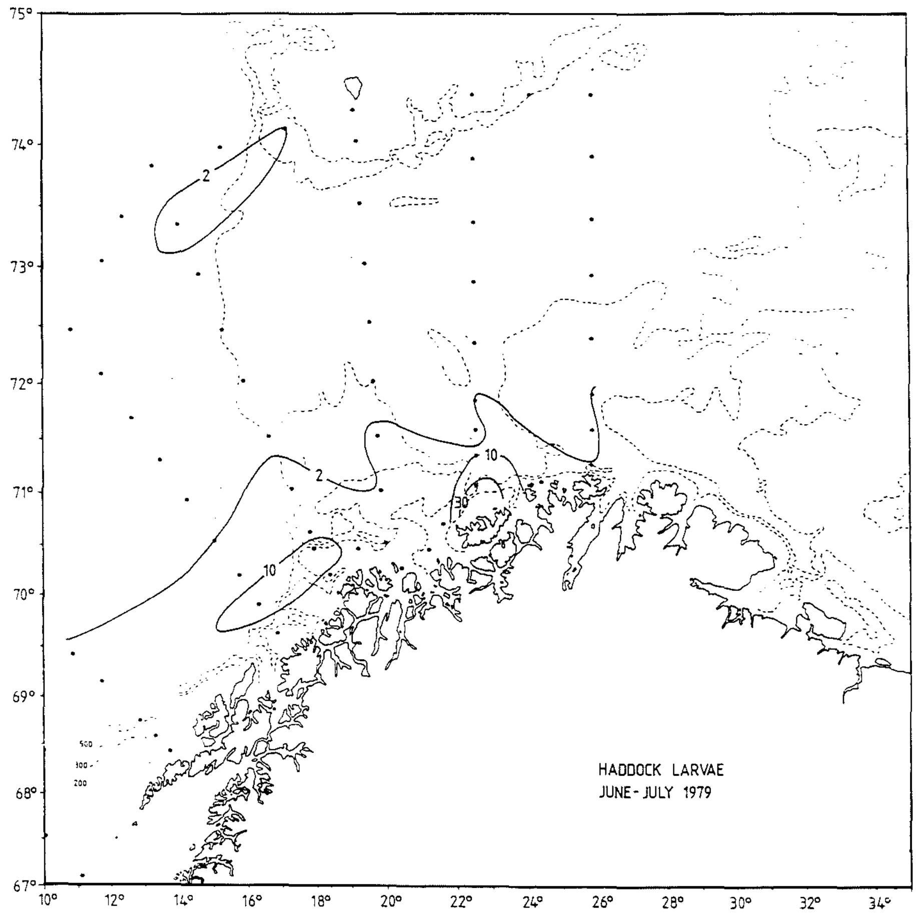

Fig. 8. Distribution of haddock larvae, and station grid net. 20 June to 10 July 1979.

water at Bjørnøyrenna. In 1981 the abundance of both haddock larvae and cod larvae was very poor (Table 3). However, also this year the haddock larvae are found in the Atlantic water masses.

In 1979 the larval distribution was somewhat different from the other years. Again, cod larvae were mainly found in the coastal water, but a larger part was also found in the Atlantic water to the west of the shelf break. The distribution of haddock larvae was even more anomalous with the main concentrations found close to the coast.

As shown above, the cod larvae seem mainly to be distributed in the coastal water masses and the haddock larvae in the Atlantic water masses. This is partly to be expected because the cod spawns in coastal water masses close to the coast and the

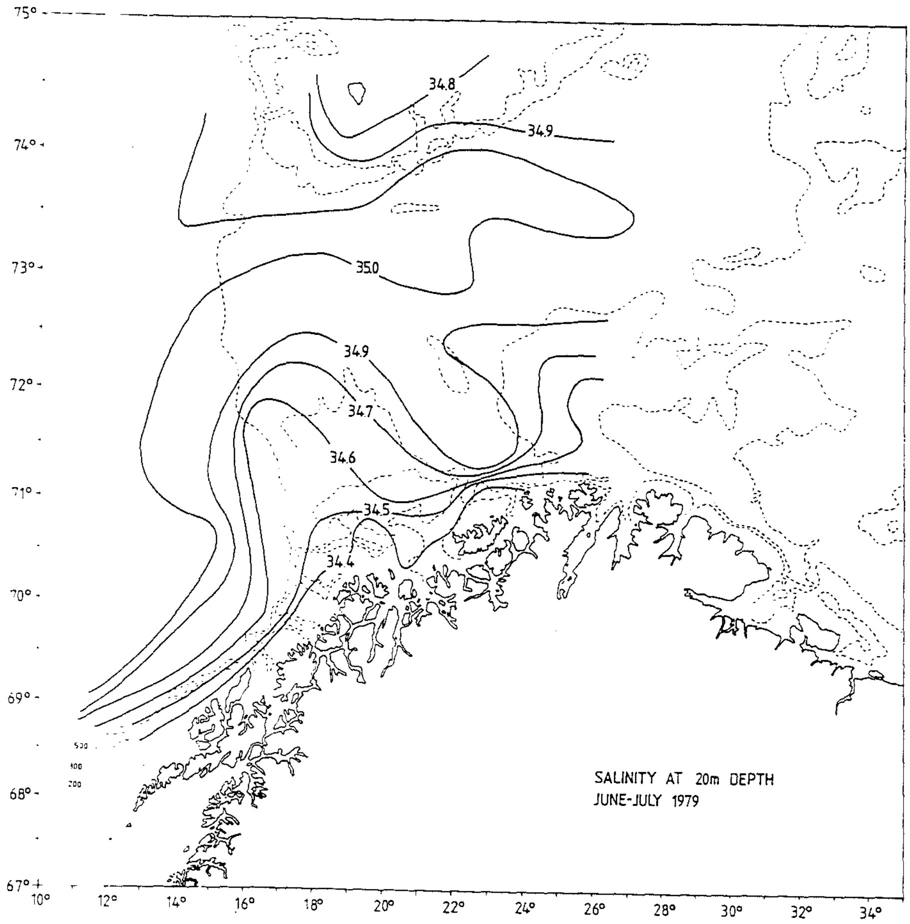

Fig. 9. Salinity at 20 m depth. 20 June to 10 July 1979.

haddock spawns in the Atlantic water masses at the shelf break (Anon, 1979). The cod eggs are then transported and spread northwards in the coastal water and the haddock eggs are transported and spread northwards in the Atlantic water as shown by Sundby (1983). Turbulent mixing is expected to gradually diminish these features, but the present data indicate that the features are still present in June/July. In 1979 the characteristic larval distributions were somewhat different. The haddock larvae were then distributed in the coastal water masses, and the cod larvae were partly distributed in the Atlantic water masses in the Norwegian Sea. This indicates that a large exchange of the Atlantic and coastal water masses had occurred after spawning. This is also indicated by the salinity distributions which show high values close to the coast.

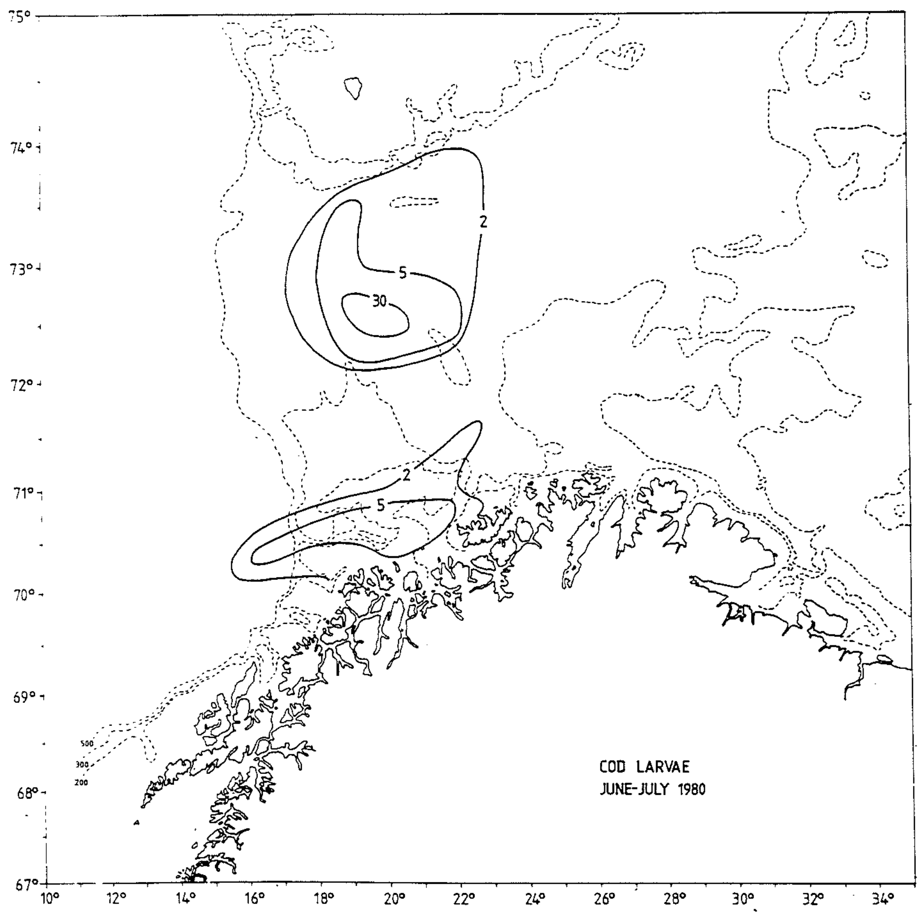

Fig. 10. Distribution of cod larvae. 24 June to 10 July 1980.

The hydrographic data from all the years indicate that anticyclonic gyres exist above Tromsøflaket and the Northwestern part of Nordkappbanken, and that the Atlantic water flows cyclonically in Ingøydjupet. This will consequently influence the distribution of larvae whose residence time is most probable largest at the banks. This is confirmed at Tromsøflaket by satellite tracked drifting buoy. Fig. 16 shows a drifting buoy that was trapped into anticyclonic whirls at Tromsøflaket for a period of approximately three weeks before it was released into Atlantic water.

Also the extremely high concentrations of cod larvae in 1983 indicate gyres at Tromsøflaket and Nordkappbanken. These two banks include about 49 percent of the total area where cod larvae were found, but contain more than 95% of the total number of cod larvae found.

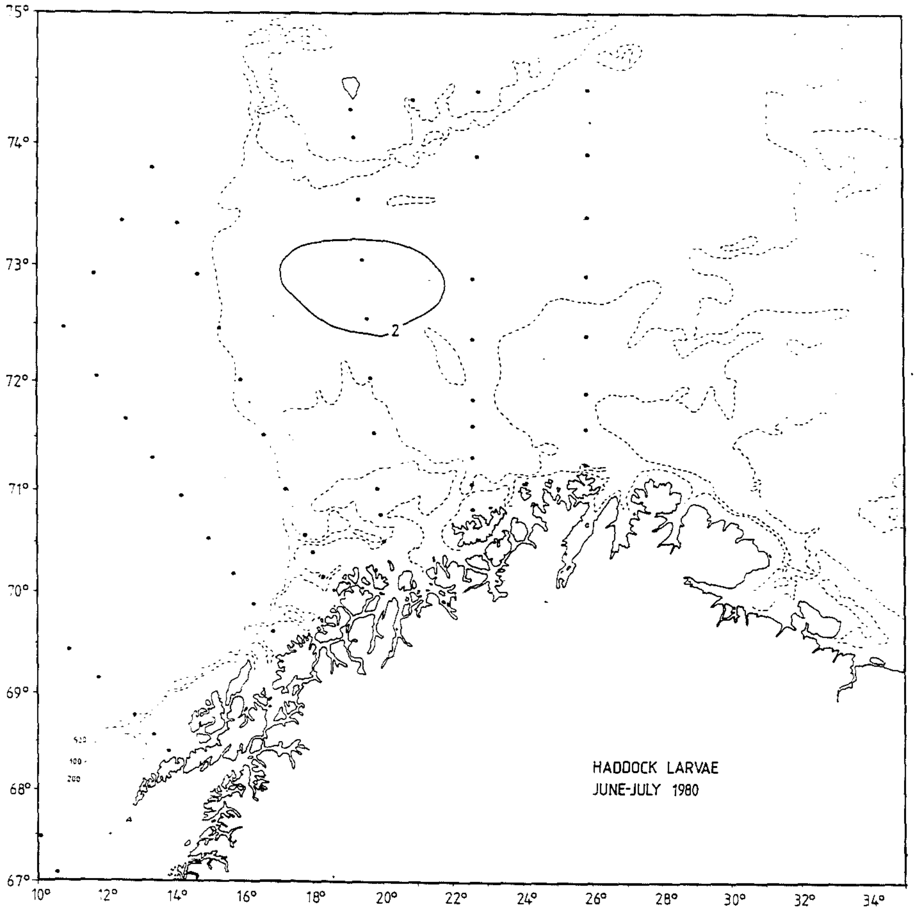

Fig. 11. Distribution of haddock larvae, and station grid net. 24 June to 10 July 1980.

VERTICAL DISTRIBUTION OF COD LARVAE

Table 2 shows the number of cod larvae caught in the upper and lower hauls at stations where both hauls were made. Only offshore stations are included. From 61 to 84% of the larvae were found in the upper haul showing that the majority of the cod larvae are to be found in the upper 13 m. In 1977, when a smaller trawl was used, 69% of the larvae were found in the upper 4m.

There is no indication of a diel migration of the cod larvae in the present material. Ellertsen et al. (1980) found a light intensity of 0.1 - 0.4 lux as a treshold for feeding for young cod larvae. Gjøsæter and Tilseth (1982) measured light intensity at various depths in the middle of May in the Lofoten area. They found enough light for feeding throughout 24 hours

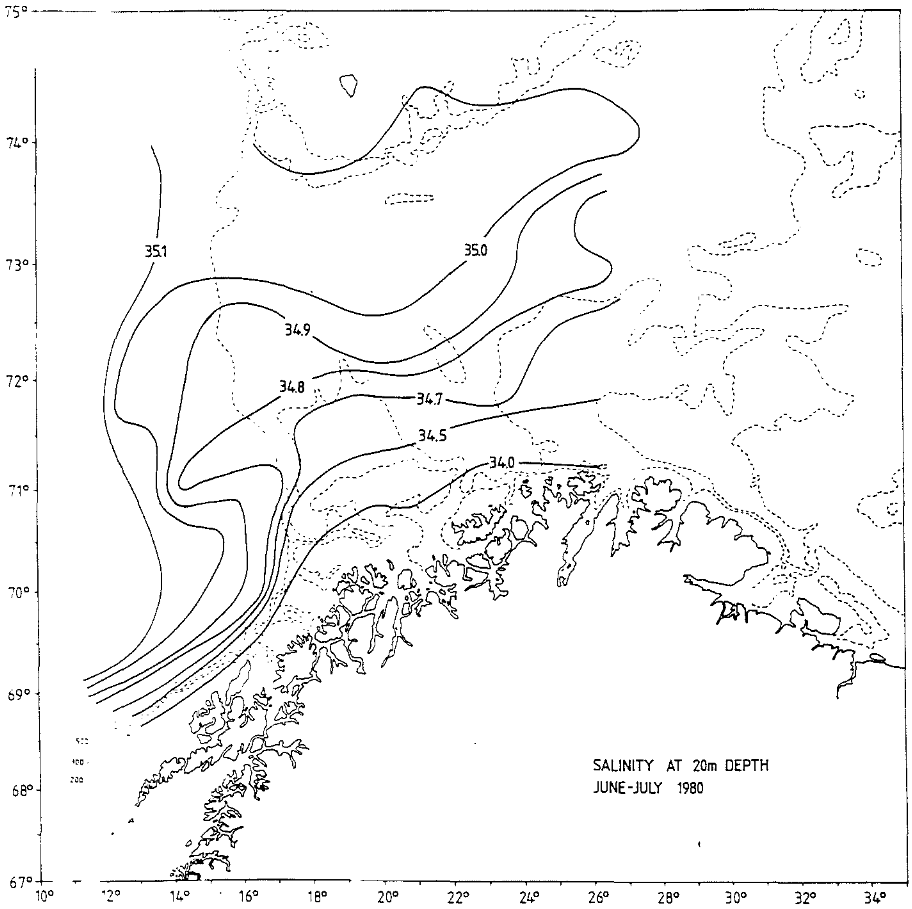

Fig. 12. Salinity at 20 m depth. 24 June to 10 July 1980.

a day at depths were the larvae was found, i.e. down to 30 m. It is thus conceivable that enough light for feeding are to be found in all sampling depths in the present material. Bogorov (1946) studied the vertical distribution of zooplankton organisms in the Barents and White Sea and found no diel vertical migration during summer. This could explain why no diel migration was observed in the present material.

Table 3 shows the mean length of the larvae from the upper and lower hauls. There are small differences in mean length of the larvae from the two kind of hauls, they are, however, significant at a 5% level. Fig. 17 shows the percentage distribution of cod larvae within length groups in the upper and lower hauls. No clear trend can be interpreted although the percentage of larvae in the deeper hauls seems to increase with length in 1979 and 1980.

Table 2. The percentage of cod larvae caught in the upper and lower hauls at stations where both kind of hauls were made.

Year / Depth m	1977	1978	1979	1980	1981
0-4	69%				
0-13		81%	84%	71%	61%
40-10	31%				
40-20		19%	16%	29%	39%
No. of larvae	1153	3139	3659	118	5866

Table 3. Mean length and standard deviation of cod larvae from the upper and lower trawl hauls.

Year	1977		1978		1979		1981	
	Upper hauls	Lower hauls	Upper hauls	Lower hauls	Upper hauls	Lower hauls	Upper hauls	Lower hauls
No.of larvae measured	362	393	737	380	981	362	673	865
Mean length	40.43	40.68	29.95	28.84	22.93	23.21	25.46	26.40
Standard deviation	10.39	11.43	6.17	5.14	4.21	4.17	6.11	6.01

It thus seems that the differences in the vertical distribution shown in Table 2 are due to other factors than time of day and length of the larvae.

LENGTH DISTRIBUTION OF COD LARVAE

Fig. 18 shows the length distribution of the cod larvae sampled in the period 1977-1983. The dates indicate the period when the larvae were sampled. The mean length of the cod larvae was highest in 1977, and, in decreasing order; 1983, 1978, 1982, 1981, 1979 and 1980. In 1977 the survey was made nearly one month later than the following years, and this year have to be

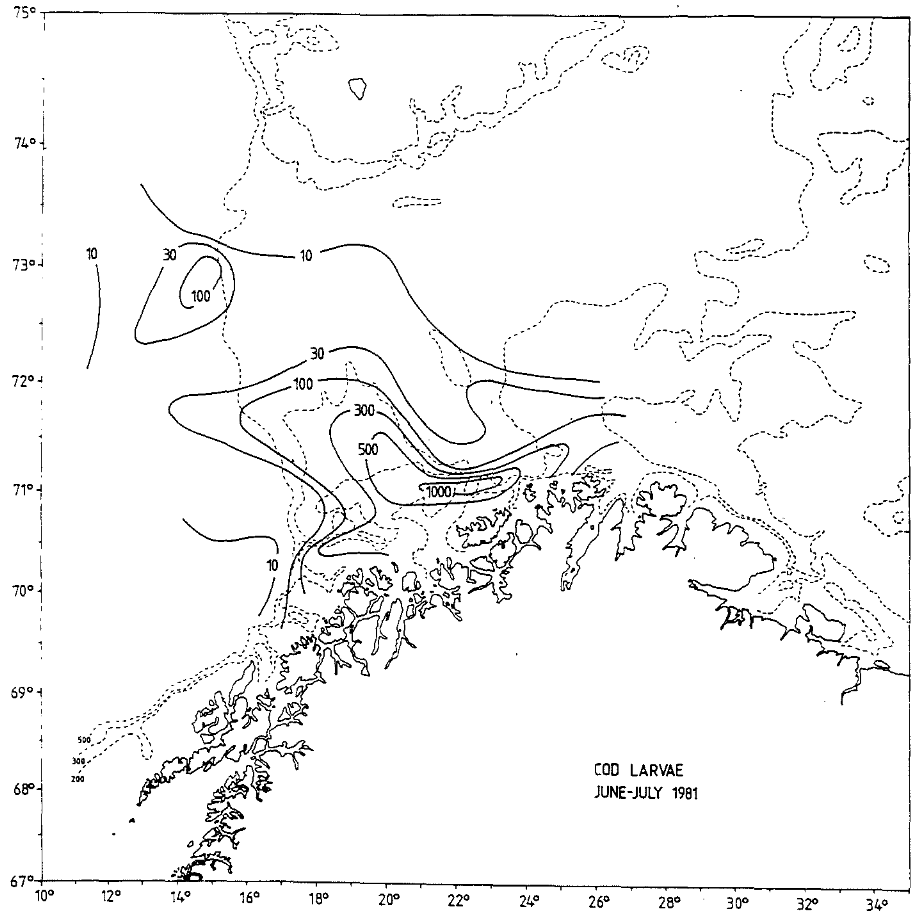

Fig. 13. Distribution of cod larvae. 5 June to 23 July 1981.

omitted when comparing the length distribution for the different years. Of the other years the majority of the larvae were caught before July 10 in 1979, 1980 and 1983, and later than July 10 in 1978 1981 and 1982. Kvenseth (1983) measured the growth rate of free-living cod larvae and found a growth-rate from 0.47 to 0.68 mm/day at an age of about 40 days. If a similar growth rate is to be found for the postlarvae, this results in a length increment of about 5 mm in 10 days. This is probably reflected in the high mean length for 1978, 1981 and 1982 when the majority of the larvae were sampled after July 10. Early sampling is probably reflected in the mean lengths for 1979 and 1980. However, in 1983, when nearly all the larvae were sampled before July 10, the mean length was high and the length range of the larvae wide. Solemdal _et al._ (this meeting) found small differences in spawning period and peak of spawning for different years in Vestfjorden. Vest-

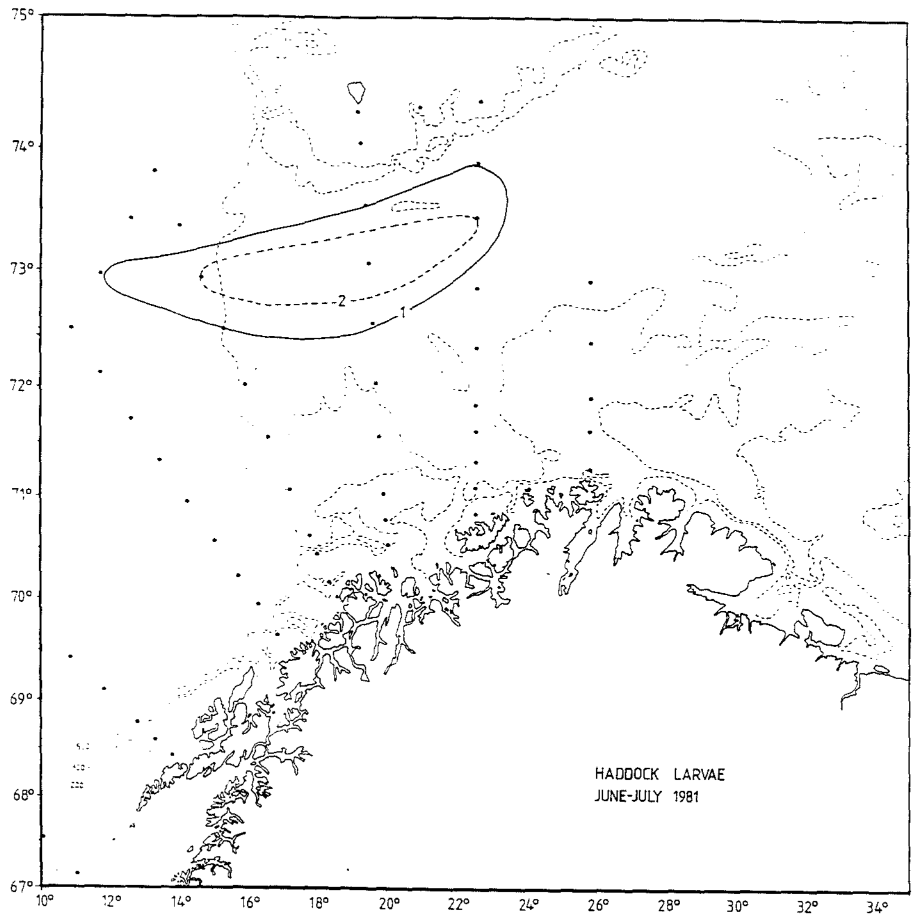

Fig. 14. Distribution of haddock larvae, and station grid net. 5 June to 23 July 1981.

fjorden is regarded as the main spawning area of the Northeast Arctic cod (Anon, 1979). This means that finding a high mean length early in July and a wide length range indicate good feeding conditions throughout the hatching period until the time of the postlarvae survey in 1983.

ABUNDANCE INDICES

Table 4 shows the abundance indices from the postlarvae survey. In addition the table shows the 0-group indices from the international 0-group survey in August-September (Randa, this meeting). From the present material three indices are omitted; the 1977 index due to sampling with different gear than the other years, and the indices for 1978 and 1982 due to inadequate coverage of the area. Figs. 19 and 20 show the distribution of cod larvae in 1978 and 1982.

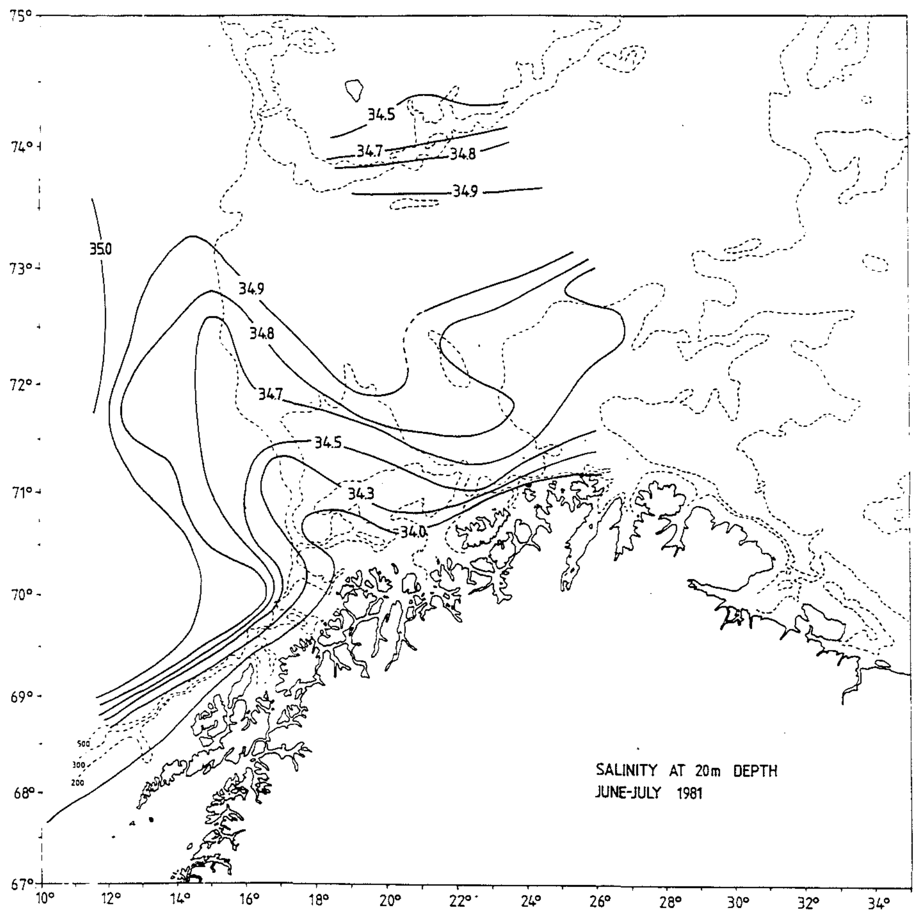

Fig. 15. Salinity at 20 m depth. 5 June to 23 July 1981.

Table 4. Abundance indices from the postlarvae and 0-group surveys.

Year	1979	1980	1981	1982	1983
Postlarvae index	7,16	0,37	15,42		74,66
0-group index (logaritmic)	0,40	0,13	0,10	0,59	1,69

The indices for the 0-group investigations show that the index for 1983 was highest and that the indices for 1980 and 1981 were nearly at the same level and lowest. The postlarvae indices show a high index for 1983 followed by that of 1981 and a low for 1980.

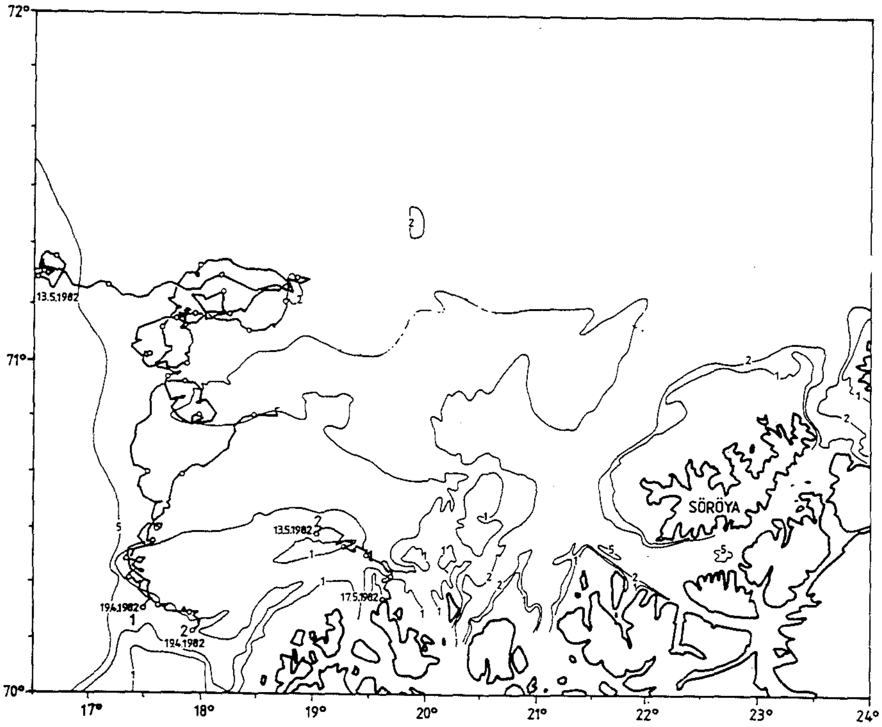

Fig. 16. Trajectories of satelitte tracked drifting buoys drougued at 30 m depth, at Tromsøflaket. 14 April to 17 May 1982.

It is evident that the postlarvae index for 1981 is not in correspondance with the 0-group index for this year. While the 0-group indices for 1980 and 1981 are at the same level, the postlarvae indices are quite different.

Somehow this is not reflected in the 0-group indices. Three explanations are suggested:

1) Incorrect 0-group indices.

2) Incorrect postlarvae indices.

3) Hign mortality among the cod larvae between the two investigations.

Randa (1981 and this meeting) studied the 0-group indices and the abundance of the same year class at age 3. He found a close relation between the two estimates.

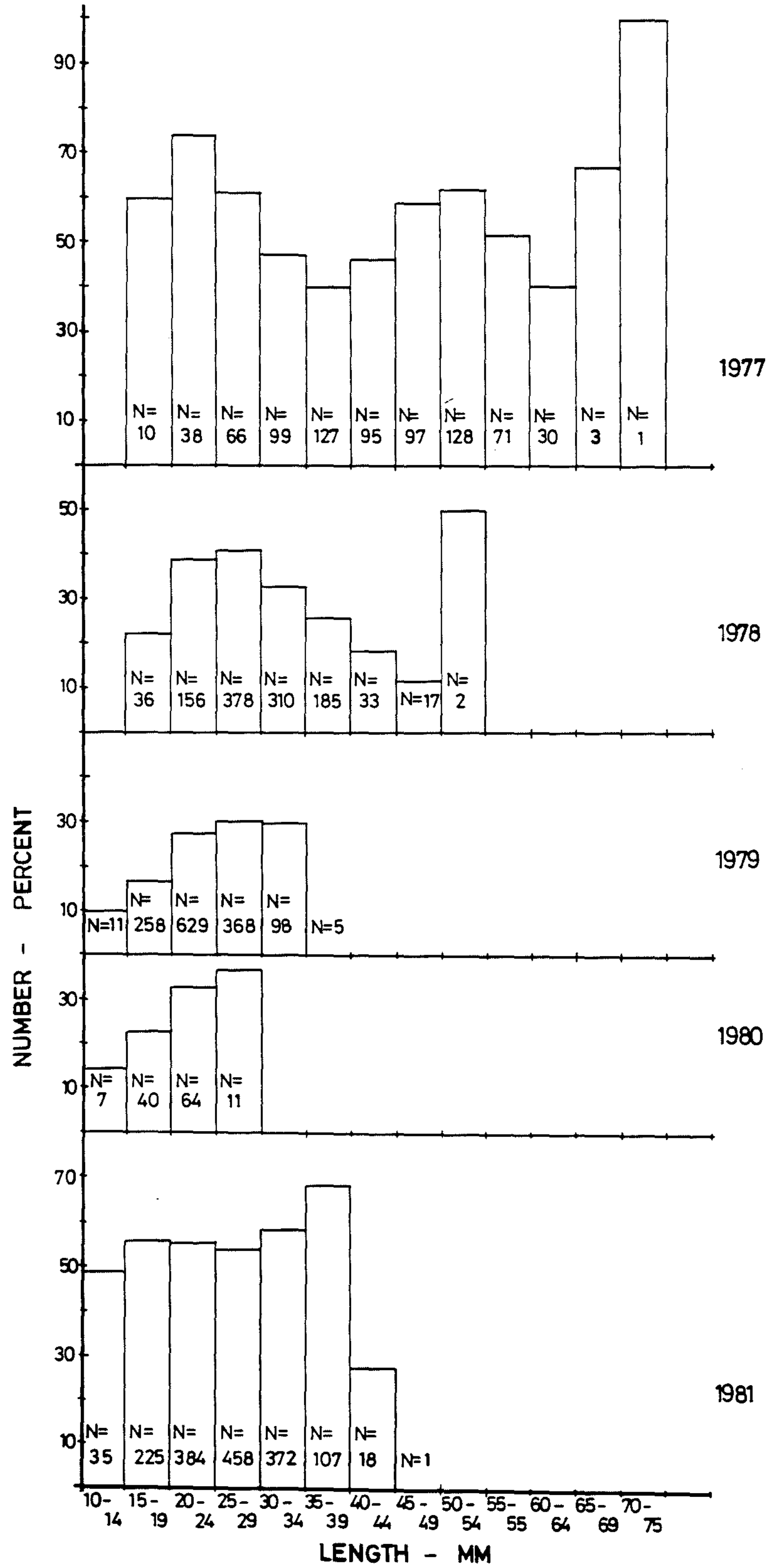

Fig. 17. Percentage distribution of cod larvae in the upper and lower hauls at different lengths. Percentage in lower hauls is indicated by histogram.

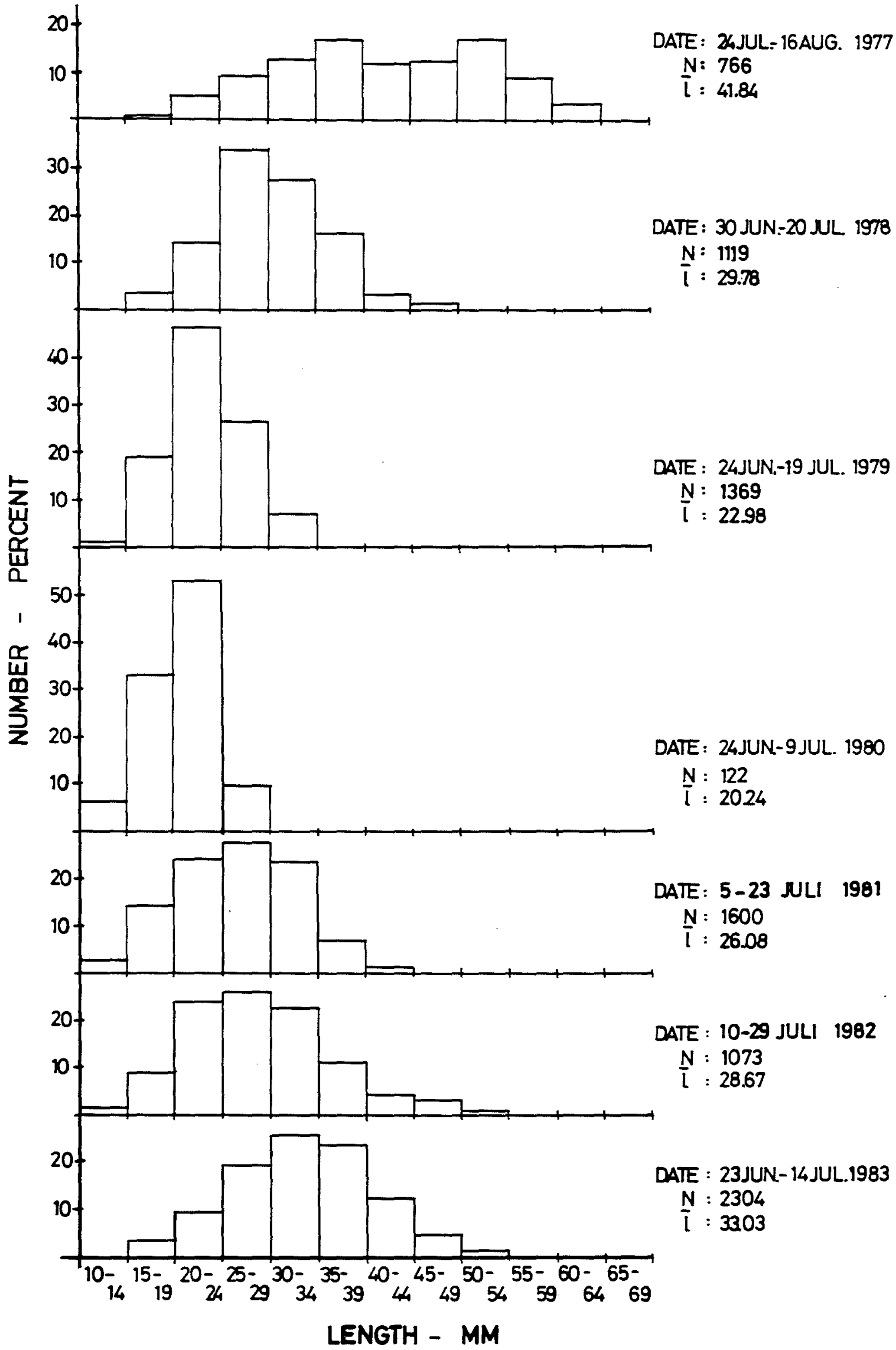

Fig. 18. Length distribution of cod larvae sampled in the period 1977-1983. Dates indicate period when larvae were sampled.

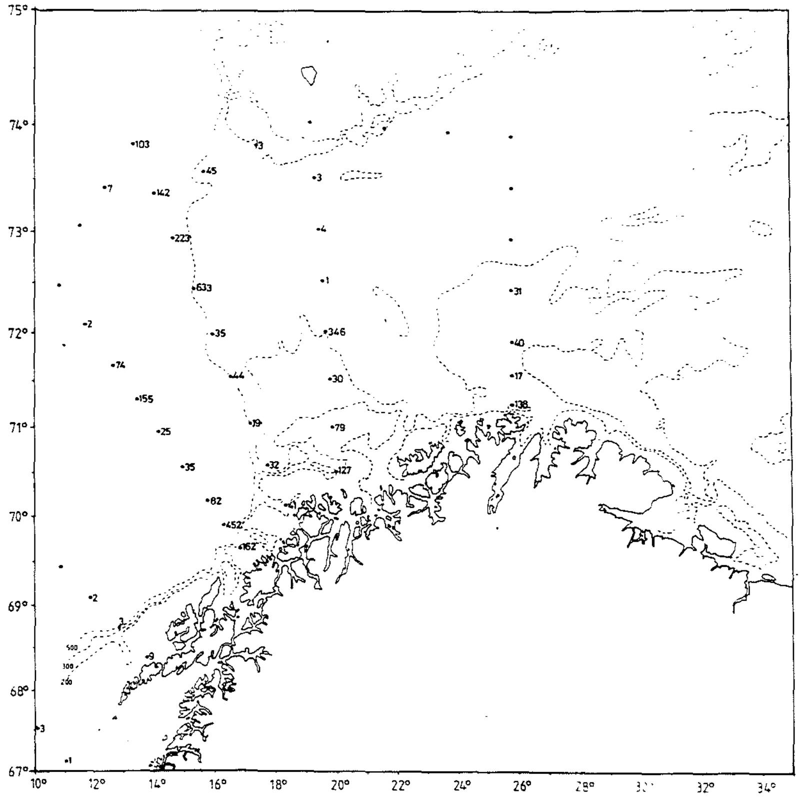

Fig. 19. Number of cod larvae caught per hour in 1978.

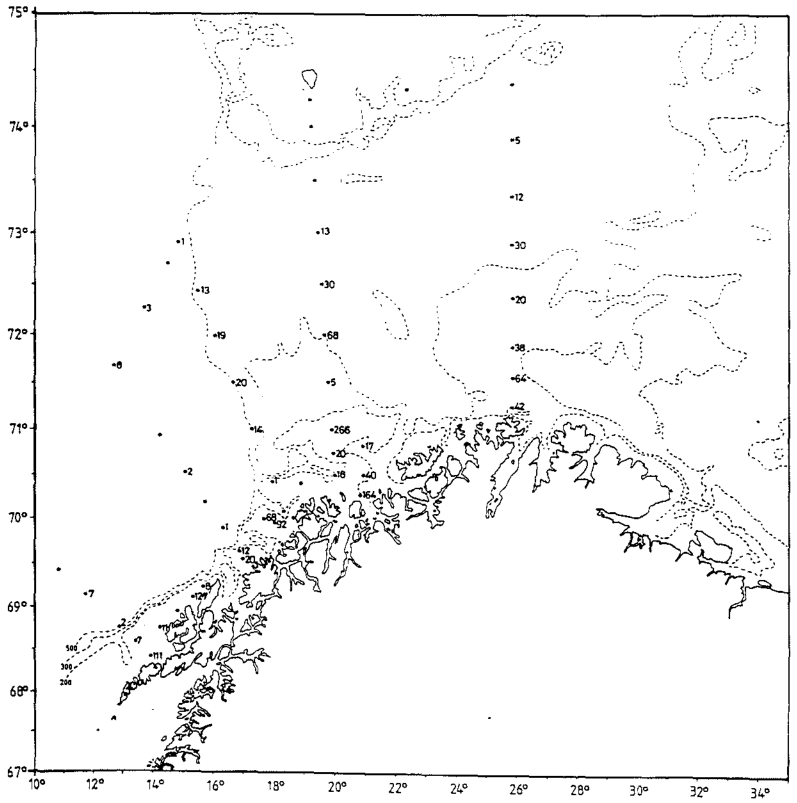

Fig. 20. Number of cod larvae caught per hour in 1982.

Confidence limits are not calculated for the postlarvae indices. It is, however, clear that the abundance of cod larvae were higher in 1981 than in 1980 (Fig. 13 and 10).

The third possibility, high mortality of the cod larvae, could be an explanation of the discrepancies between the two sets of indices. This mortality could theoretically be due to lack of food for the 1981 year-class. Randa (this meeting) considered the 1982 year class as medium in size. Fig. 21 show the volume of the zooplankton biomass of this year. Compared to the biomass in 1981 (Fig. 22), it may be concluded that the biomass in 1981 were at least equal or even larger than in 1982. Therefore it may be concluded that at the time of the postlarvae sampling no indication of lack of food for the fish larvae could be shown. Another source of mortality could be predation of the cod larvae. Unfortunately, data to confirm this are not available.

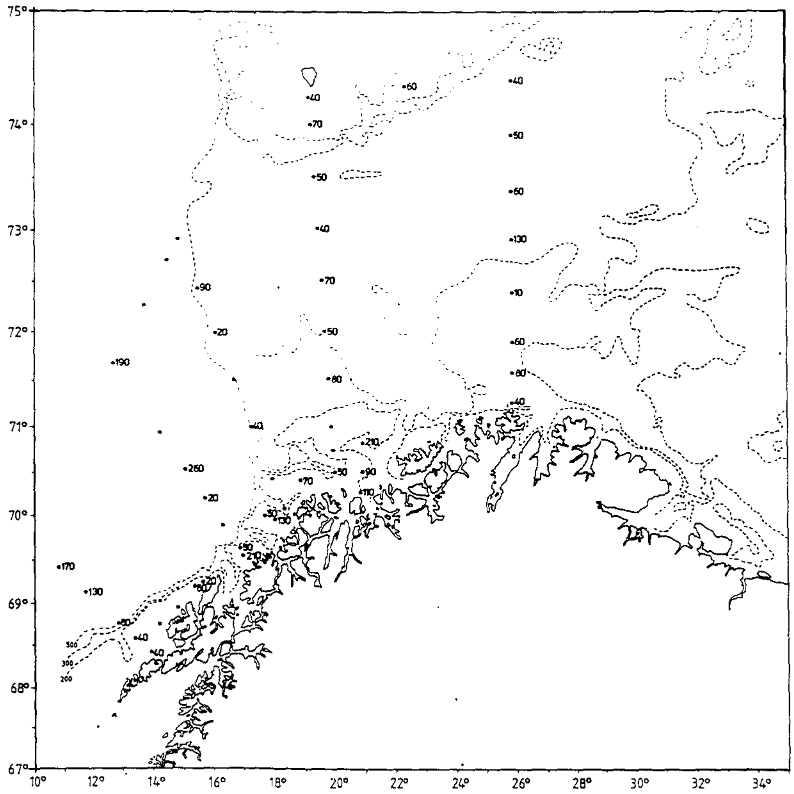

Fig. 21. Zooplankton volume in ml per m^2 surface in 1982. 200-0 m.

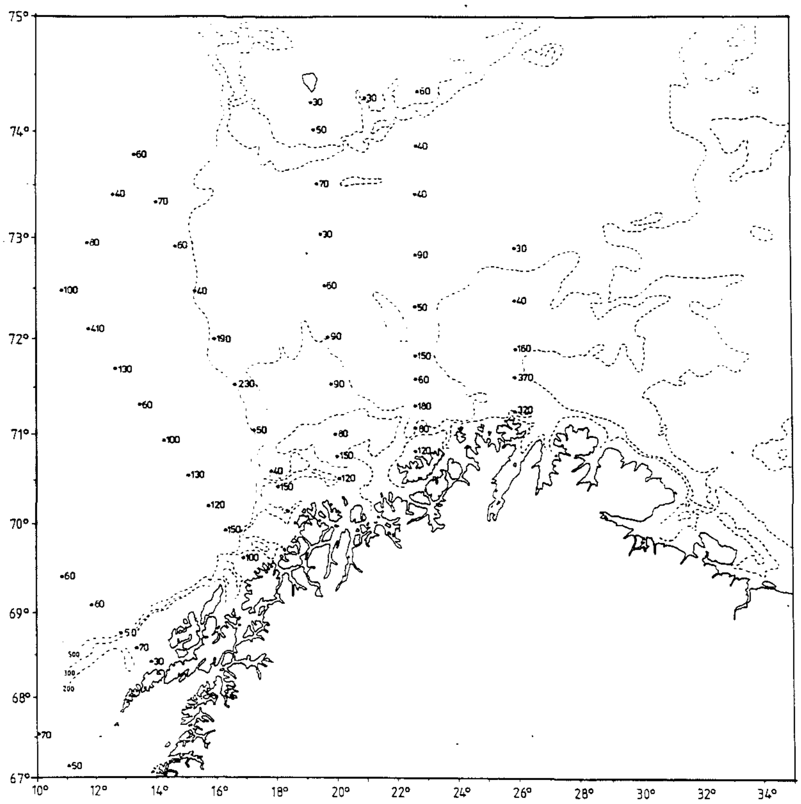

Fig. 22. Zooplankton volume in ml per m^2 surface in 1981. 200-0 m.

The 1983 index for cod was highest both in the postlarvae and 0-group surveys. This year the station grid was much closer during the postlarvae survey than the previous years and was planned to cover the distribution of the cod larvae only. This closer station grid revealed great differences from one station to another, and gave reasons to believe that a similar station grid is necessary to give a quantitative index for the abundance of postlarval cod in June-July.

REFERENCES

Anon., 1979. The biology, distribution and state of exploitation of fish stocks in the ICES area. Part II. Int. Coun. Explor. Sea Coop. Res. Rep., 1977(86): 1-202.

Anon., 1983. Preliminary report of the international 0-group fish survey in the Barents Sea and adjacent waters in

August-September 1983. Coun. Meet. int. Coun. Explor. Sea, 1983 (G:35): 1-28.

Baranenkova, A.S. and Khokhlina, N.S., 1964. On the condition of formation of the Arcto-Norwegian cod stock in the 1956, 1960 and 1961 year classes during the first year of their life. Trudy PINRO, Vyp. 16: 195-214.

Baranenkova, A.S., Sorokina, G.B., Khokhlina, N.S., 1973. Distribution and abundance of eggs and larvae of main commercial fishes of the Barents Sea on drift routes from spawning areas in April-July 1969. Trudy PINRO, vyp. 33: 34-81. (in Russion, with English abstract).

Bjørke, H., 1981. Distribution of fish eggs and larvae from Stad to Lofoten during April 1976-80. pp 583-603 in The Norwegian Coastal Current. Roald Sætre and Martin Mork (Eds). University of Bergen 1981.

Bjørke, H., 1983. Spawning of blue whiting (Micromesistius poutassou) in Norwegian waters. Coun. Meet. Int. Coun. Explor. Sea, 1983(H:35): 1-8.

Bogorov, B.G., 1946. Peculiarities of diurnal vertical migration of zooplankton in polar seas. J. Mar. Res. 6(1): 25-32.

Dragesund, O., 1970. Factors influencing year-class strength of Norwegian spring spawning herring. FiskDir. Skr. Ser. HavUnders., 15: 381-450.

Ellertsen. B., Moksness, E., Solemdal, P., Strømme, T., Tilseth, S., Westgård, T. and Øiestad, V., 1980. Some biological aspects of cod larvae (Gadus morhua L.). FiskDir. Skr. Ser. HavUnders., 17: 29-47.

Ellertsen, B., Solemdal, P., Strømme, T., Sundby, S., Tilseth, S., Westgård, T., and Øiestad, V., 1981. Spawning period, transport and dispersal of eggs from the spawning area of Arcto-Norwegian cod (Gadus morhua L.). Rapp. P.-v. Réun. cons. int. Explor. Mer, 178: 260-267.

Gjøsæter, J. and Sætre, R., 1974. The use of data on eggs and larvae for estimating spawning stock of fish populations with demersal eggs. P. 139-149 in Blaxter, J.H.S. ed. The early life history of fish. Springer-Verlag, Berlin, Heidelberg, New York: 765 pp.

Gjøsæter, H. and Tilseth, S., 1982. Primary growth increments in otoliths of cod larvae (Gadus morhua L.) of the Arcto-Norwegian cod stock. FiskDir. Skr. Ser. HavUnders., 17: 287-295.

Hognestad, P.T., 1969. Forekomst av fiskelarver i nord-norsk kyst- og bank farvann våren 1969. Fiskets Gang 55: 58-61 (in Norwegian).

Kvenseth, P.G., 1983. Metode for produksjon av torskeyngel (Gadus morhua L.) i poll. Thesis. University of Bergen. (Unpublished).

Mukhina, N.V., 1980(1983). Distribution and abundance of early stages of cod, haddock and deepwater redfish in April-June 1980. Annls. Biol., Copenh., 37: 256-259.

Randa, K., 1981. Rekrutteringsindekser for Norsk-Arktisk torsk basert på materiale på dei internasjonale 0-gruppe undersøkingane i Barentshavet. Thesis. University of Bergen. (Unpublished).

Sundby, S., 1983. Influence of bottom topography on the circulation at the continental shelf of northern Norway. Rapport fra Havforskningsinstituttet. FO 8303.

Wiborg, K.F., 1960. Forekomst av egg og yngel av fisk i vestnorske kyst- og bankfarvann og ved Skrova i Lofoten våren 1962. Fiskets Gang 48: 689-690 (in Norwegian).