THE EFFECT OF OCEANOGRAPHIC CONDITIONS ON DISTRIBUTION AND POPULATION
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DISTRIBUTION AND ABUNDANCE INDICES OF POSTLARVAL AND 0-GROUP COD

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ABSTRACT

Postlarvae surveys have been carried out in the southwestern part of the Barents Sea and the northeastern part of the Norwegian Sea in June/July since 1977. The aim of the investigations has been to study characteristic distributions of fish larvae and their relation to the distribution of water masses, and to establish abundance indices. It has been shown that mesoscale features of the larval distribution are very pronounced, and that they are connected to the current features. Therefore the survey strategies was changed in 1983, and emphasis was laid on the investigation of cod larvae. Postlarval cod is especially abundant at Tromsøflaket due to the reduced diffusion by the existence of the anti-cyclonic vortex above the bank. It is shown that the cod postlarvae tend to be larger in the western part. The postlarvae and 0-group distribution are discussed and compared, and similar features of the two stages are found. The postlarvae and 0-group indices are discussed and compared, and a correlation coefficient of 0.82 was found.

INTRODUCTION

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

The Institute of Marine Research has been sampling fish eggs and larvae since 1948 at different localities along the Norwegian coast (e.g. WIBORG 1960, HOGNESTAD 1969, DRAGESUND 1970, GJØSÆTER and SÆTRE 1974, ELLERTSEN et al. 1981, BJØRKE 1981, 1984, SUNDBY and SOLEMDAL 1984, SUNDBY and BRATLAND 1987). The sampling has taken place during the spring and summer seasons and has partly been aimed at the study of single species, such as herring and cod.

Offshore sampling of older larvae (postlarvae) started in 1977. The aim was to study the distribution of larvae in June/July and if possible calculate an abundance index of the different species. Results from the period 1977-1983 and a discussion of the sampling strategy are presented by BJØRKE and SUNDBY (1984).

The aim of this paper is to present some of the results of this work with the emphasis on the distribution of cod in the area Lofoten - Bear Island, and to compare the results with the 0-group indices.

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 KOKHLINA (1964), BARANENKOVA, SOROKINA and KOKHLINA (1973), MUKHINA (1980) and MUKHINA and DVININA (1983).

MATERIALS AND METHODS

The geographical distribution of larvae was found by fishing with a midwater trawl. A trawl with an effective opening of 4 x 10 m was used in 1977, and from 1978 until 1985 a trawl with an opening of 18 x 18 m was used. In 1985 a trawl with an opening of 29 x 29 m was introduced. The different types of trawls had diminishing mesh sizes towards the end and a 4 m long net with mesh size 4 mm (stretched) at the inner part of the cod end (wrongly described as 15 mm mesh size in BJØRKE and SUNDBY, 1984). Attempts made in 1985 to compare the fishing efficiency between the latter two kinds of trawls failed unfortunately, and the only way to compare the 1985 data with those of previous years was to regard the opening of the two trawls.

Regarding the reduced avoidance for larger gears we used the ratio 2.8:1 for fishing efficiency between the largest and smallest trawl.

During the period 1978-1981 two hauls were made at 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 of this haul was 30 minutes.

Only one kind of haul was made at each station from 1982 onwards. From 1982 until 1985 the depths and towing time were the same as the previous years, and five big floats were used on the headline during the haul. The same procedure was followed in 1985, but the towing time at each depth interval was halved.

Towing speed during all the years was 2-3 knots. The volume of the filtered water is not known. Therefore the computed index is based on the number of larvae caught per trawl hour. Hydrographic observations were made with a Neil Brown CTD microprofiler down to the bottom or to 500 m depth where bottom depths were more than 500 m.

All the fish larvae were identified, and a subsample of 50 larvae was taken to measure the length.

The results from the six years 1979-1981 and 1983-1985 are plotted on horizontal maps, and the indices were estimated by using a planimeter tracing the isolines. In 1977 a smaller trawl was used, and in 1978 and 1982 the station net was not dense enough to reveal the mesoscale features, and therefore the abundance indices for these years are not calculated. From 1983 the sampling program was stratified to map the mesoscale features more correctly.

The abundance index may be formulated

$$A = \iint_{x,y} N(x,y)\, dxdy$$

where A is the abundance index
N is the concentration of larvae expressed as number caught per trawl hour
x and y are the geographical coordinates.

The abundance index has the unit no.larvae per trawl hour $\cdot$ km^2 $\cdot$ 10^6.
The reason for using this index instead of absolute no. of postlarvae is that the exact opening of the trawl and the fishing efficiency is unknown.

When calculating the abundance of cod larvae in different subareas (Table 2) the same procedure was used.

KVENSETH (1983) measured a growth rate from 0.47 to 0.68 mm/day for cod larvae at an age of about 40 days. By assuming a growth rate of 0.5 mm/day for the postlarvae, synoptic maps can be made to show the length distribution of larvae with reference to the same day i.e. half way through the cruises.

RESULTS AND DISCUSSION

Distribution of postlarvae 1983-1985

Figs 1-6 show the distribution of postlarval cod in the six years 1979-81 and 1983-85. The results from the first four years were presented by BJØRKE and SUNDBY (1984). In 1983 the sampling program was revised based on the knowledge obtained during the previous years sampling program. Since then a more stratified sampling program was worked out, and this has lead to a more detailed mapping of the horizontal distribution of cod, and hence more correct abundance indices.

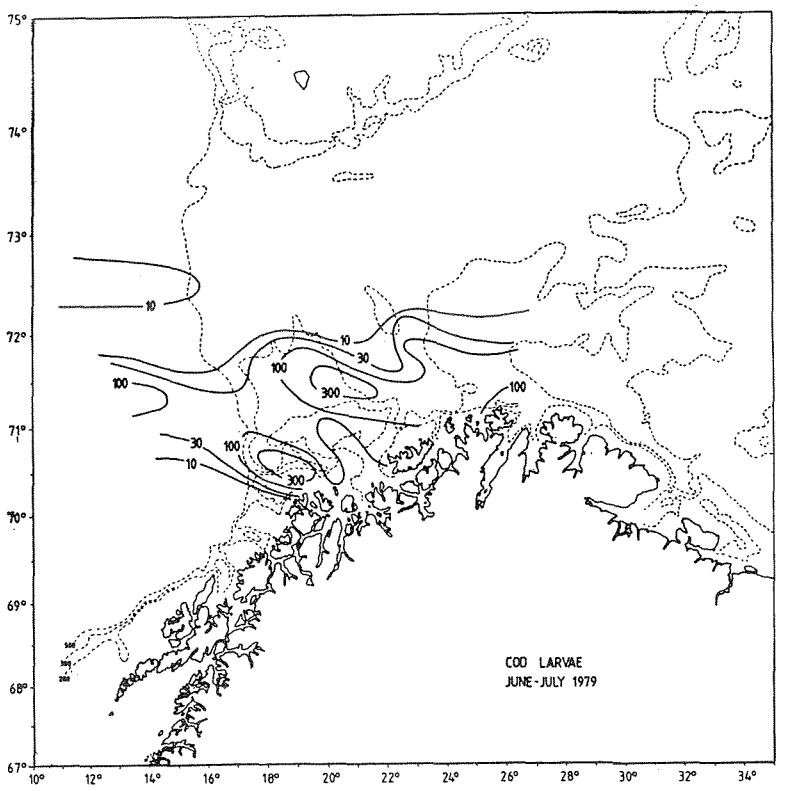

Fig. 1. Distribution of postlarval cod 20 June-10 July 1979.
Number per trawl hour.

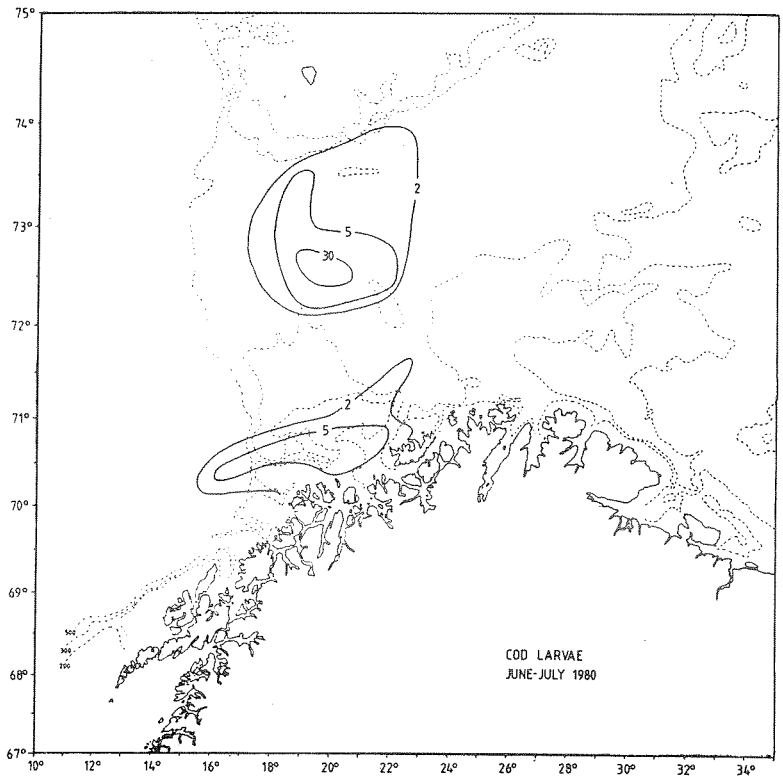

Fig. 2. Distribution of postlarval cod 24 June-10 July 1980. Number per trawl hour.

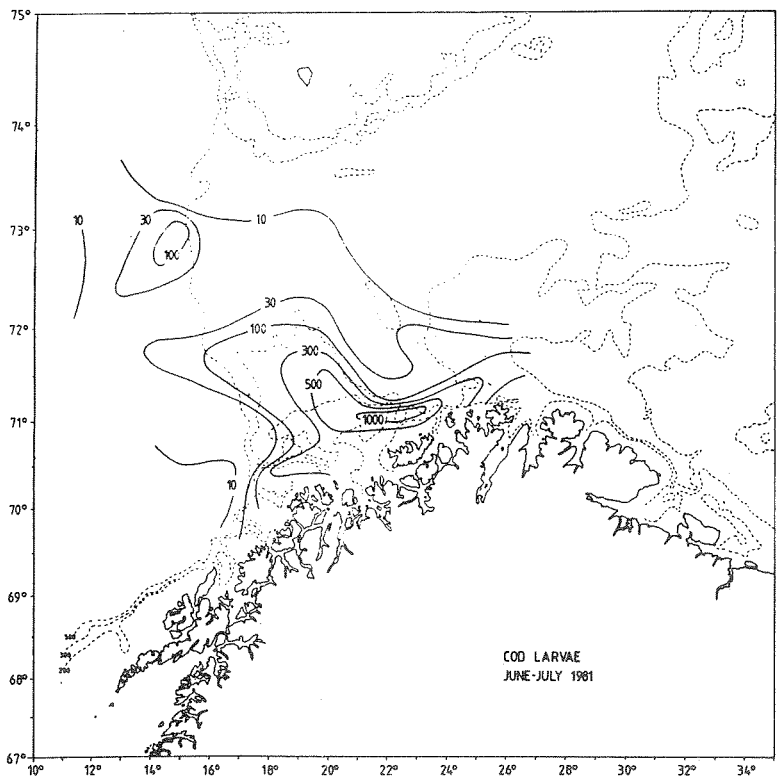

Fig. 3. Distribution of postlarval cod 29 June-23 July 1981. Number per trawl hour.

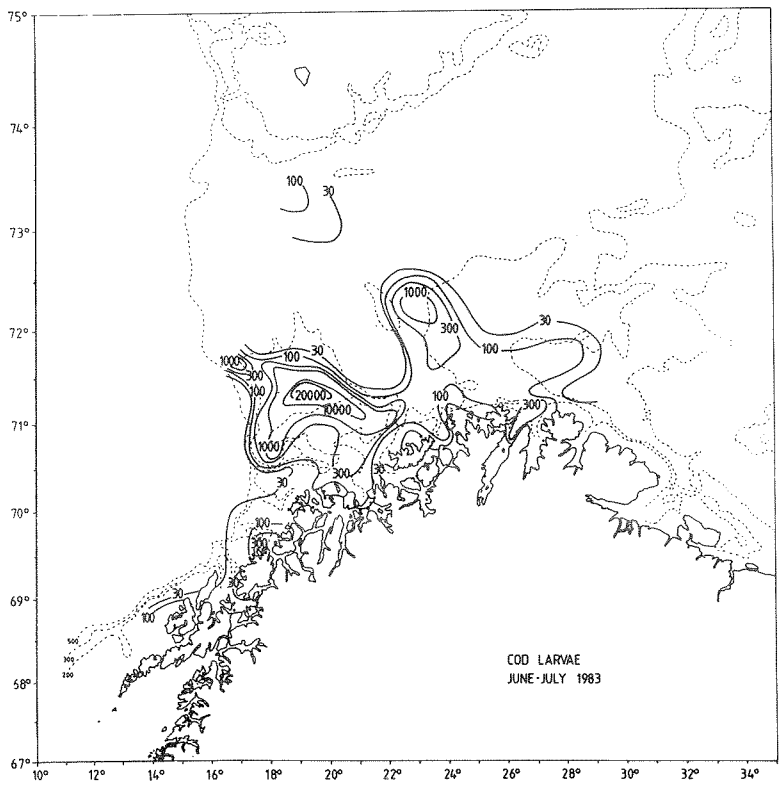

Fig. 4. Distribution of postlarval cod 24 June-17 July 1983. Number per trawl hour.

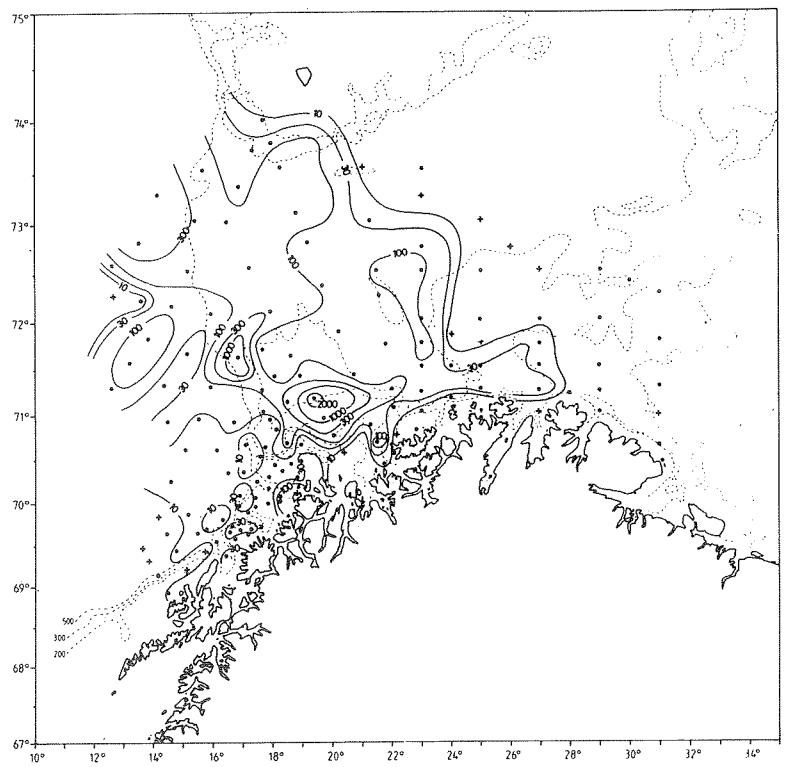

Fig. 5. Distribution of postlarval cod 24 June- 20 July 1984. Number per trawl hour.

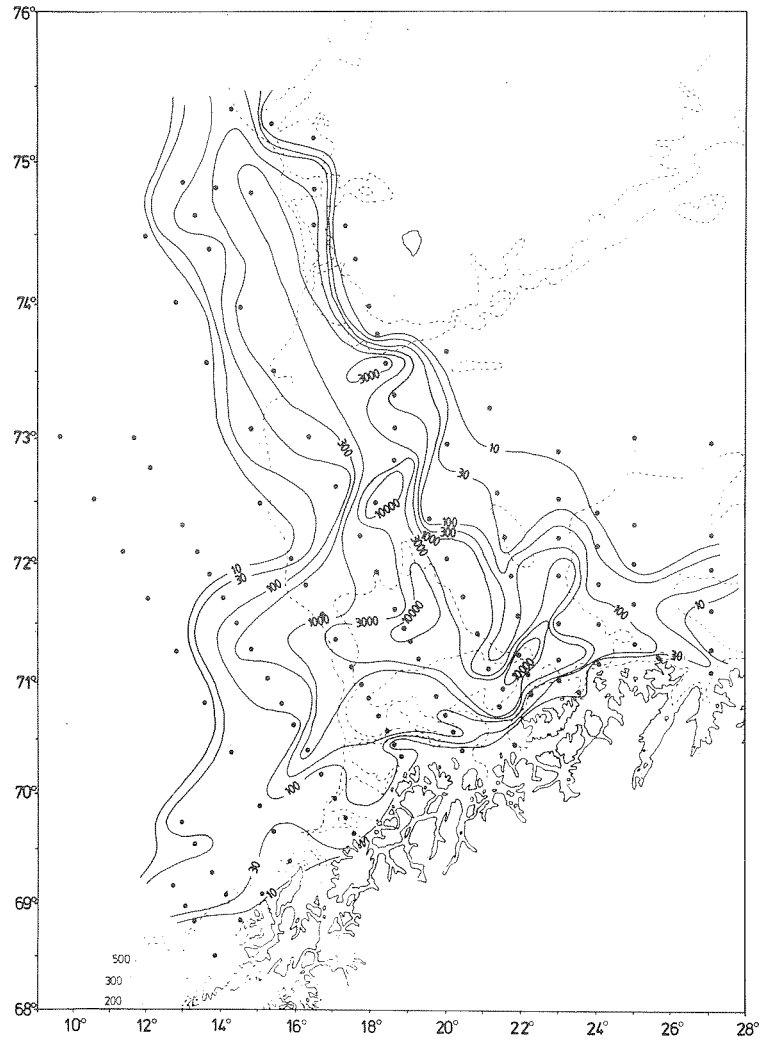

Fig. 6. Distribution of postlarval cod 21 June-15 July 1985. Number per trawl hour.

A general feature common for all the six years is the high concentrations found at Tromsøflaket (Fig. 17). Another is that postlarval cod is mainly found in the coastal waters of salinity less than 34.9‰. However, there are also certain features that are specific for each year: In 1983 extremely high concentrations were found at Tromsøflaket. This year 88 percent of the larvae was found within the 300 m isobath at Tromsøflaket. This coincided with the area of salinity 34.4-34.6‰ S. The distribution in 1984 and 1985 differed to some extent from the 1983 distribution. Both years a fairly large fraction of the total larval number was found in the western and northern areas. Nevertheless, also these years a large fraction of the larvae was found at Tromsøflaket, 45 percent and 57 percent respectively. The large fraction of cod larvae found at Tromsøflaket is due to anti-cyclonic circulation above the bank which greatly reduces the diffusion of the larvae confined to the upper layer.

Fig. 7 shows the fraction of cod larvae at different salinity regimes (A), the geographical extent (in 1000 km^2) of the different salinity regimes where cod larvae are found (B), and the mean concentration of cod larvae in the different salinity regimes (C). From the figure it is clear that the distribution in 1983 was special in the way that a large fraction of the larvae was confined to the salinity 34.4-34.6‰ S. This coincided with the area of Tromsøflaket.

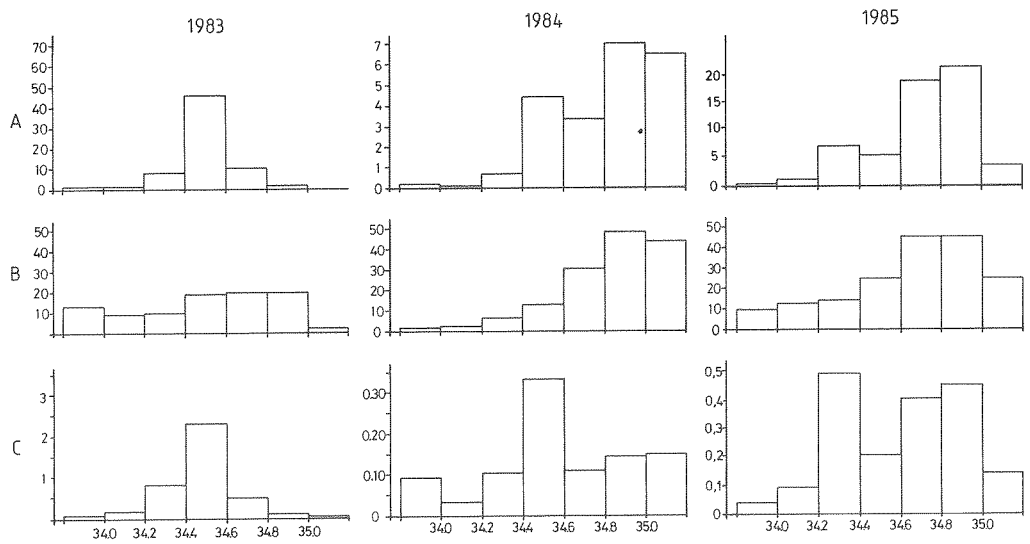

Fig. 7. (A) Abundance indices of postlarval cod at different salinities in 20 m depth. (B) Area (in 1000 km^2) of different salinity regimes where postlarval cod where found. (C) Mean concentration of postlarval cod in the different salinity regimes (A/B, abundance index per 1000 km^2).

In 1984 and 1985 the salinity within the area of the postlarvae was considerably higher, which can be seen from Fig. 7 (B). In 1984 about 8 percent of the area where cod larvae were found had a salinity less than 34.4‰ S, and in 1985 about 25 percent. These two years the postlarval cod were also more widely spread. Especially in 1984 large numbers of larvae were found in the northwestern part, in the Norwegian Sea and towards Spitsbergen. Fig. 5 also shows that the Spitsbergen area was not sufficiently covered. Also in 1985 a relative large fraction of the larvae was found in the northwestern parts towards Spitsbergen. However, this year the northwestern parts were more completely covered. The relative large fraction of larvae in the northwestern parts in 1984 and 1985 may be due to the increased spawning observed at the Vesterålen banks in these years (SUNDBY and BRATLAND 1987). Transport of larvae from these spawning sites tend to have more westerly drift patterns.

Figs. 8-16 show distribution of the cod larvae in three length groups, <30 mm, 30-40 mm, and >40 mm for the years 1983, 1984, and 1985. The lengths refer to the same point of time. A growth rate of 0.5 mm/day was used to adjust for the time lag between the stations. The figures show that the larger larvae are found more frequent in the southern and western parts, while the smallest larvae tend to have a more easterly distribution. This is also shown in Table 1 where the fractions of postlarvae in four subareas are listed for each length group. The four subareas are shown in Fig. 17.

The table shows that the smallest larvae are more abundant in the northern (1) and the eastern (4) areas, whereas the largest larvae are more abundant in the western area (2).

Assuming that the larvae in the eastern parts have been subjected to a longer driftroute from the spawning grounds, and hence are older larvae, one should expect that they should be larger than the larvae closer to the spawning grounds. However, when the results here show that the larger larvae tend to

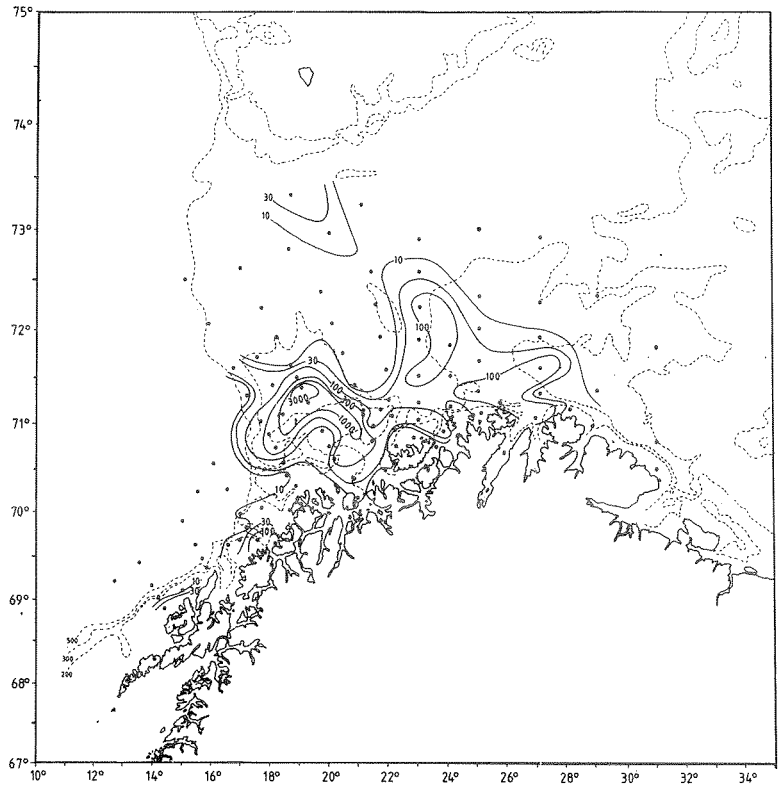

Fig. 8. Distribution of postlarval cod of lengths <30 mm. 1983. (See text).

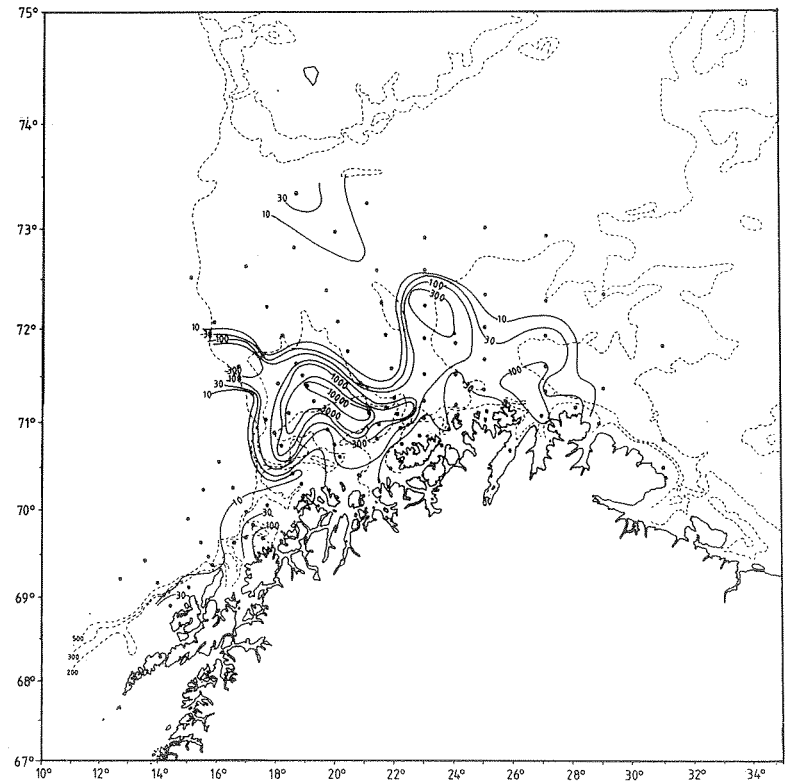

Fig. 9. Distribution of postlarval cod of lengths 30-40 mm. 1983. (See text).

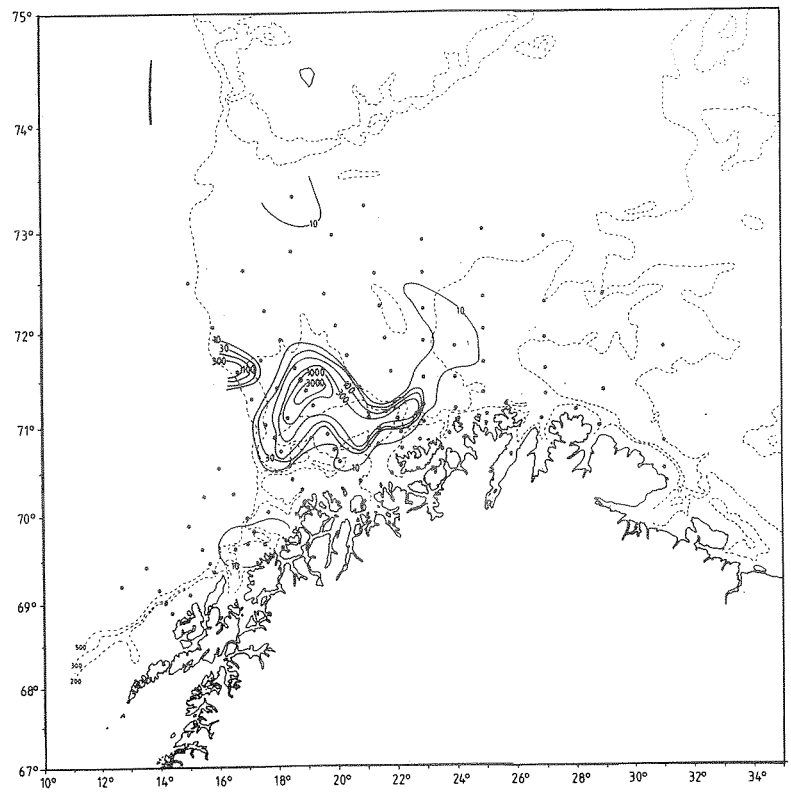

Fig. 10. Distribution of postlarval cod of lengths >40 mm. 1983. (See text).

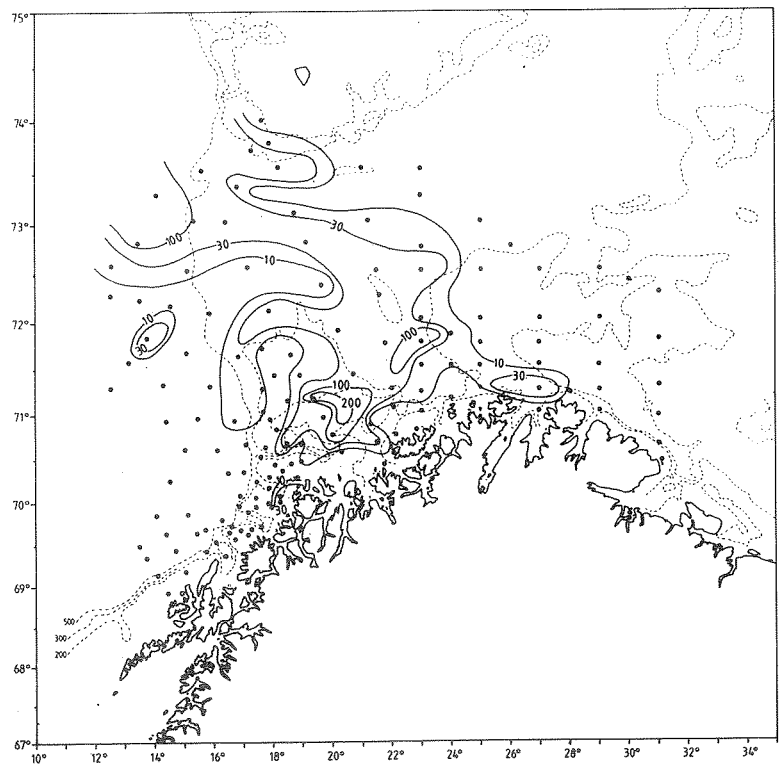

Fig. 11. Distribution of postlarval cod of lengths <30 mm. 1984. (See text).

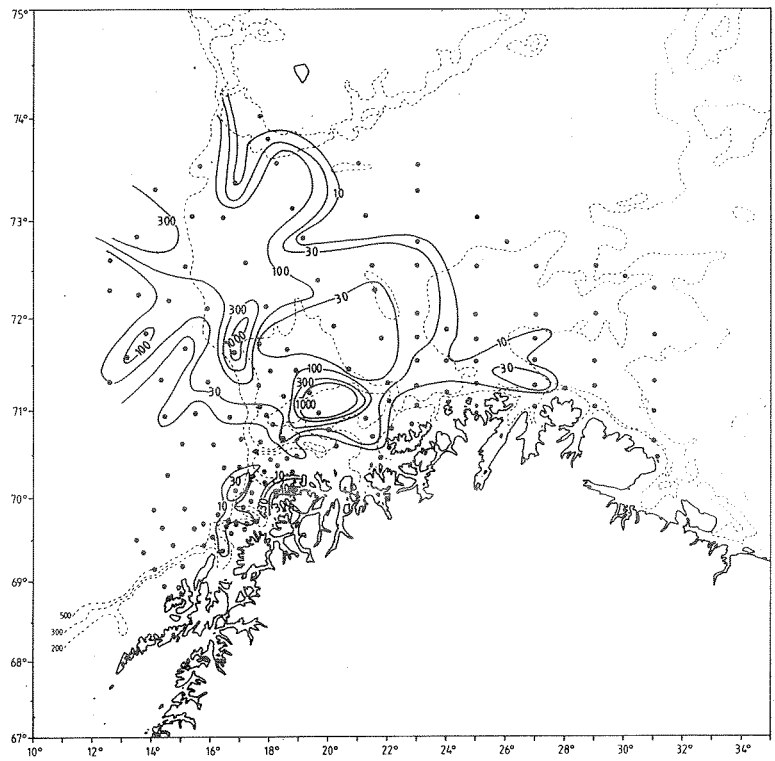

Fig. 12. Distribution of postlarval cod of lengths 30-40 mm. 1984. (See text).

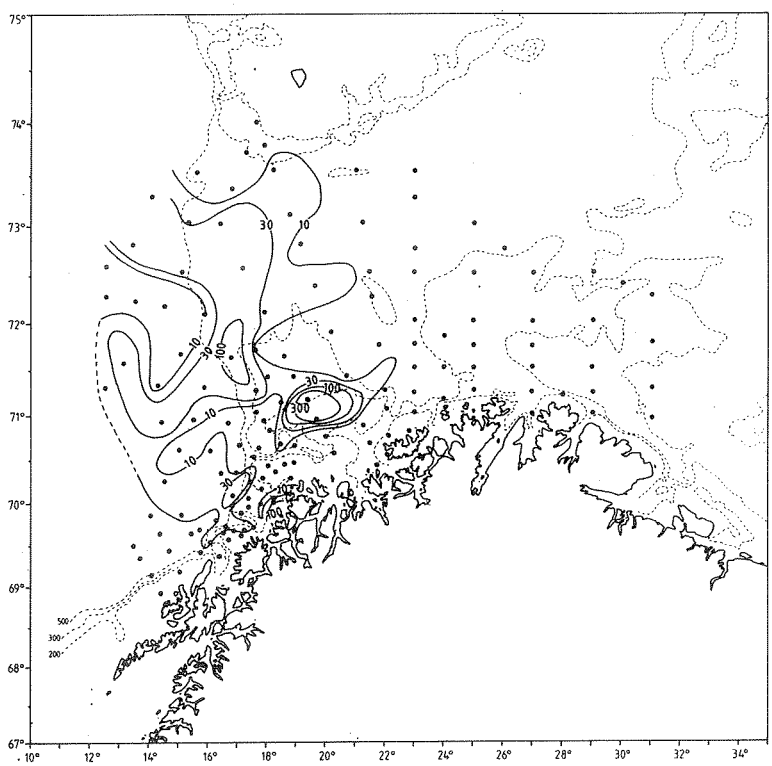

Fig. 13. Distribution of postlarval cod of lengths >40 mm. 1984. (See text).

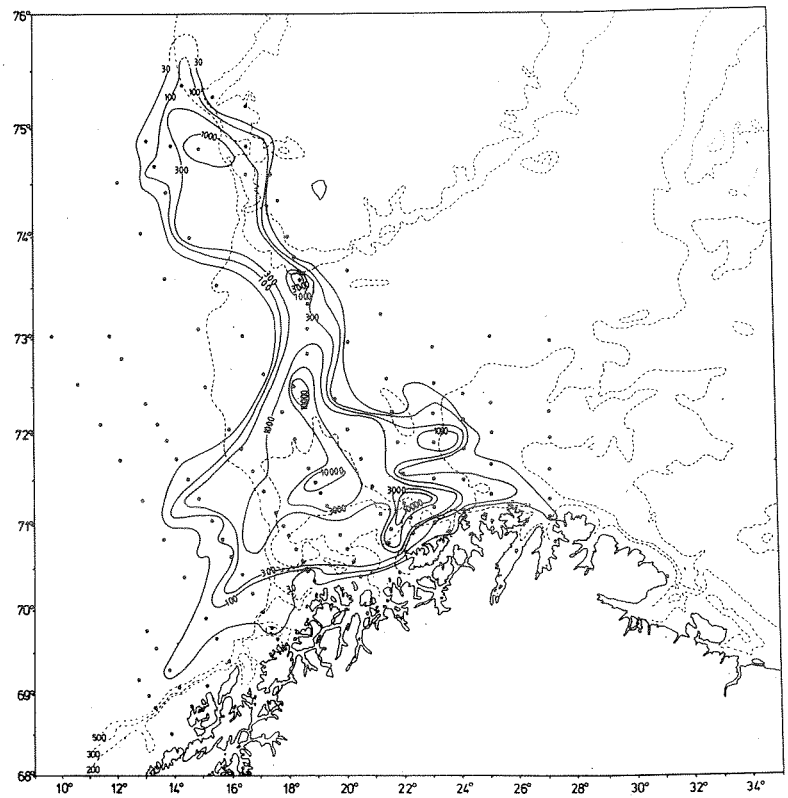

Fig. 14. Distribution of postlarval cod of lengths <30 mm. 1985. (See text).

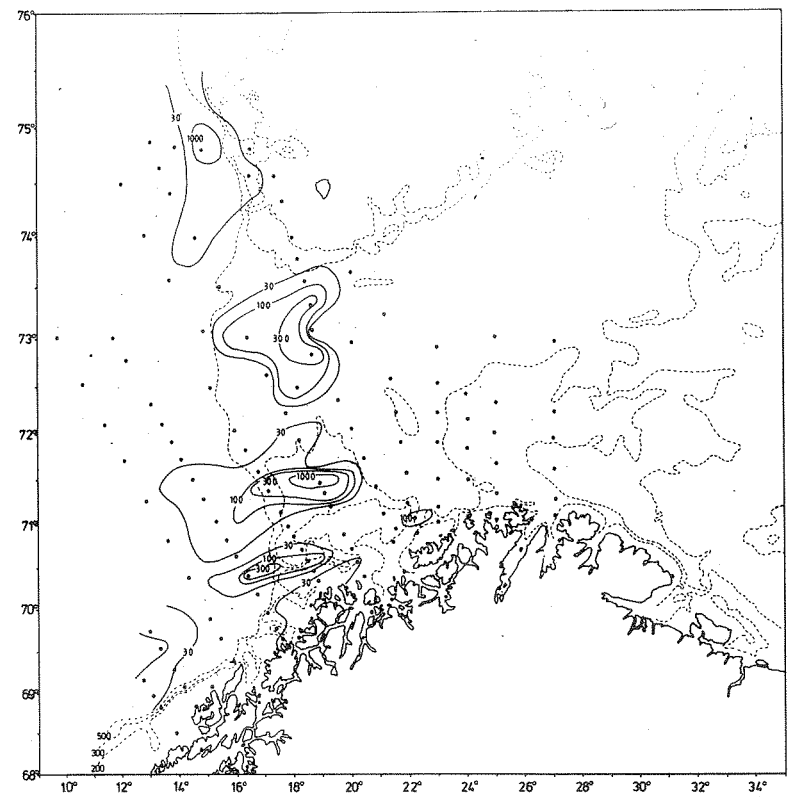

Fig. 15. Distribution of postlarval cod of lengths 30-40 mm. 1985. (See text).

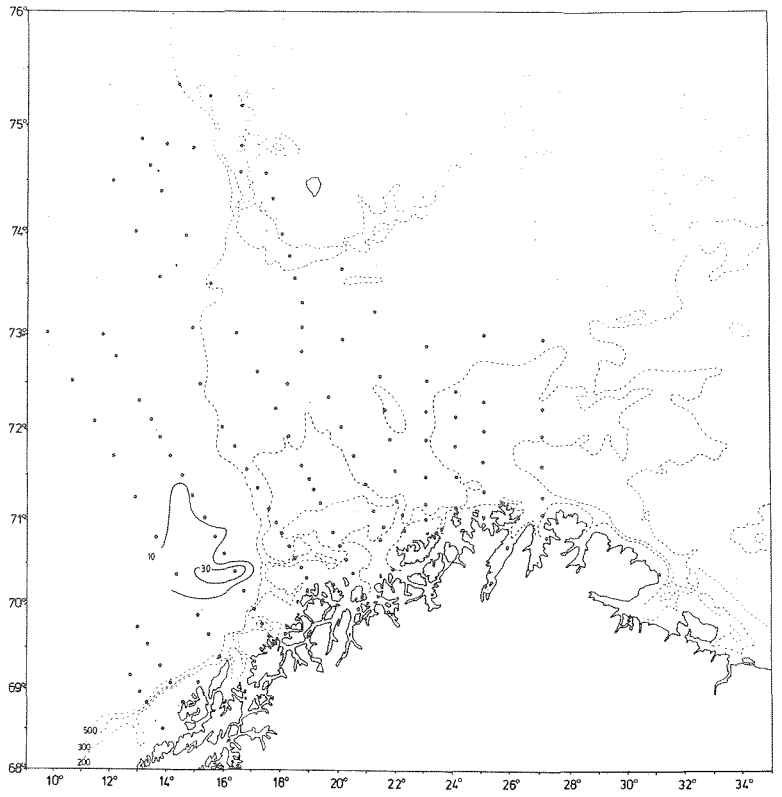

Fig. 16. Distribution of postlarval cod of lengths >40 mm. 1985. (See text).

have a more westernly distribution, it is more likely to believe that they have experienced a warmer life history, and hence subjected to a higher growth rate.

Comparison of the postlarval cod and 0-group cod horizontal distributions 1979-1981 and 1983-1985

During the six years 1979-1981 and 1983-1985 the first three years period had typical weak year classes while the second period had strong year classes. Fig. 18, showing the 0-group distributions, originates from the international 0-group surveys (ANON. 1979b, 1980, 1981, 1983, 1984a, and 1985). The 0-group distribution in 1979 (Fig. 18) must be considered as typical westernly. A very large fraction of the 0-group was then distributed to the west of the shelf edge of the Barents Sea and at the western coast of Spitsbergen. Also in 1984 and 1985 large numbers of 0-group cod were found at the western coast of Spitsbergen, but these years high concentrations were also found in the central parts of the Barents Sea.

Table 1. Percent of postlarval cod in four subareas for three length groups. The sub-areas are shown in Fig. 17.

Length	1983 Subarea				1984 Subarea				1985 Subarea			
(mm)	1	2	3	4	1	2	3	4	1	2	3	4
<30	0	3	82	15	7	28	40	25	7	11	77	5
30-40	0	3	90	7	2	38	50	10	7	29	61	3
>40	0	3	96	1	0	51	47	2	0	100	0	0

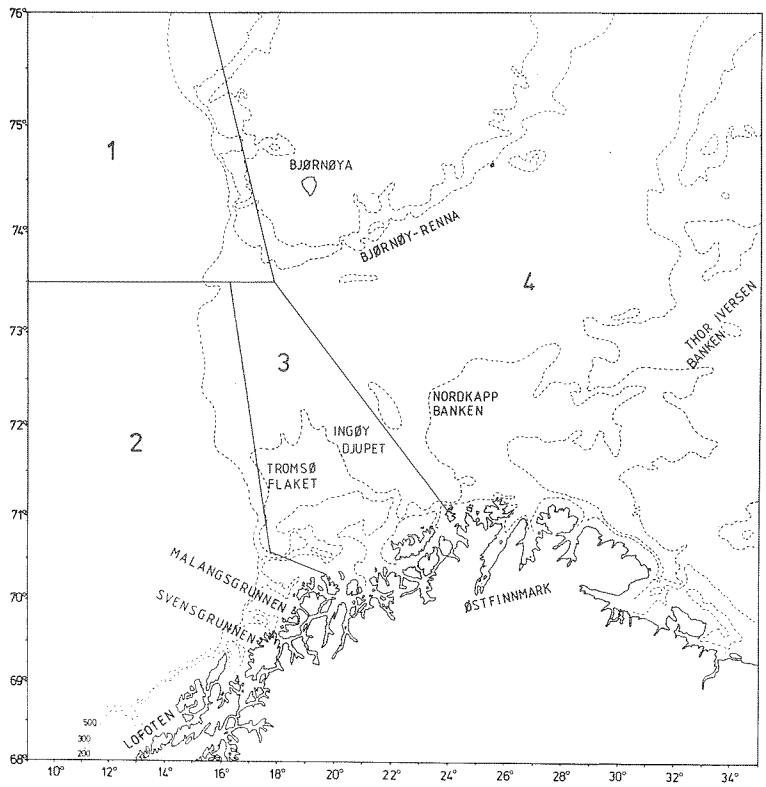

Fig. 17. Four subareas where the abundance of the different length groups are computed (see Table 1) and local names used in the text.

The westernly distribution of 0-group cod in 1979 was even more pronounced during the postlarvae survey showing large numbers of larvae at the southwestern parts of Tromsøflaket and in the Norwegian Sea to the west of the shelf edge. The large numbers of 0-group cod at the western coast of Spitsbergen in 1984 and 1985 can also be predicted from the postlarval distribution which shows high concentrations in the western part of the Bjørnøyrenna and to the west of Bjørnøya.

The very weak 1980 year class had also similar features of distribution during the postlarval and 0-group stages in the way that both stages show a separated northerly and southerly distribution. The postlarvae at the southern parts of Tromsøflaket were advected eastwards showing a distribution from Nordkappbanken and eastwards at the 0-group stage, while the postlarvae in the Bjørnøyrenna were advected northwards showing a distribution along the west coast of Spitsbergen during the 0-group stage.

Abundance indices

Table 2 shows the abundance indices for cod from the postlarvae surveys in June/July and from the 0-group surveys in August/September (ANON. 1985). The latter indices are logarithmic and calculated according to RANDA (1984). Fig. 19 shows the two sets of indices and the regression line.

Assuming that logarithmic transformation normalize the 0-group indices, a Pearson correlation coefficient can be calculated from the data in Table 2. The computed coefficient equals 0.82, significant at the 5 percent level.

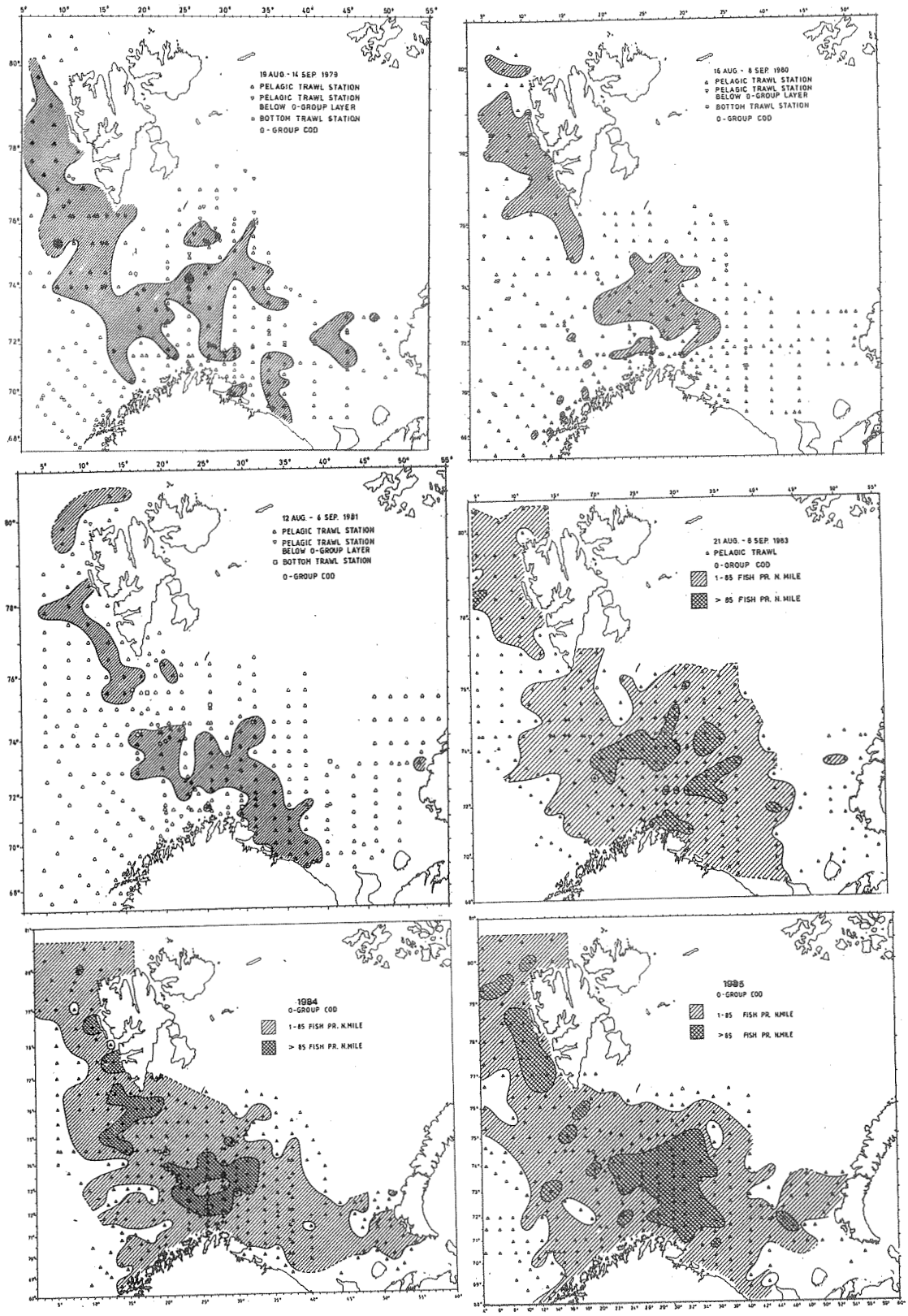

Fig. 18. Distribution of 0-group cod from the international 0-group surveys 1979-81 and 1983-85.

Table 2. Abundance indices for cod from the postlarvae surveys in June/July and from the 0-group surveys in August/September.

Year	1979	1980	1981	1983	1984	1985
Postlarve	7.2	0.4	15.4	74.7	23.5	56.5
0-group (logarithmic)	0.40	0.13	0.10	1.69	1.55	2.46

Both in 1981 and 1983 a very large fraction of the postlarvae index results from the abundance of larvae at Tromsøflaket. Both years the 0-group indices are low compared to the postlarvae indices. The abundance estimates of both these years have been adjusted upwards during the last years (ANON. 1982, 1984b and 1986) and recent estimates from acoustic surveys indicate that the 1981 year class is 1/5 of the 1983 year class. (HYLEN, JAKOBSEN, NAKKEN and SUNNANÅ 1985). This could indicate that the 0-group station grid may fail to record very patchy distributions.

The postlarvae index for the 1984 year class is obviously an underestimate since the northernmost area of distribution was not examined. The direction of these adjustments are indicated in Fig. 19. In view of these factors it is likely that the correlation between the two surveys is better than indicated in Fig. 19. Bearing in mind the improved coverage of the cod larvae distribution since 1983, it seems reasonable to believe that the postlarvae indices produced in July gives a fairly good indication for the year class strength of cod as 0-group.

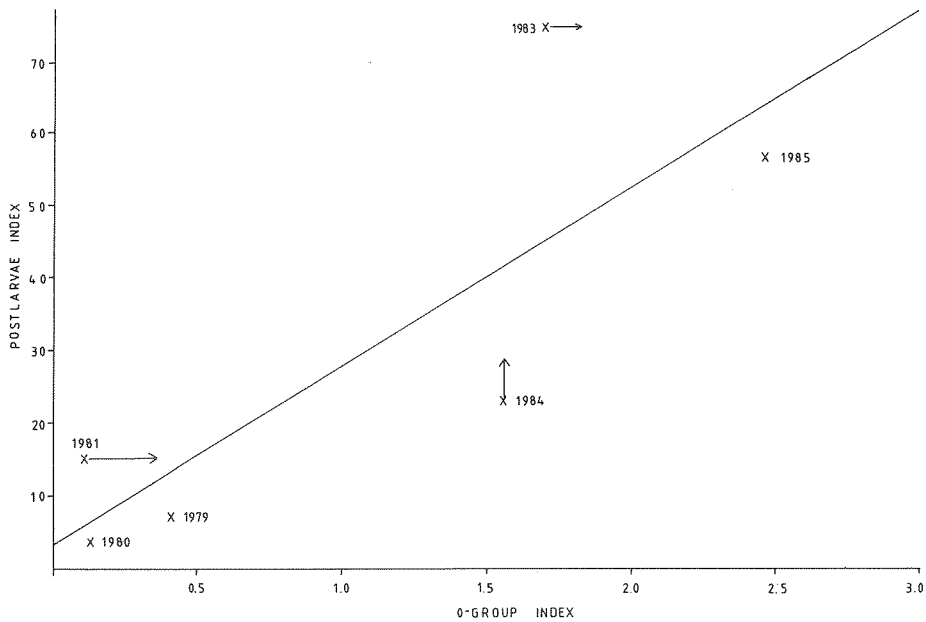

Fig. 19. The regression line between the cod postlarvae and the 0-group indices. Arrows indicate direction of adjustments.

CONCLUSIONS

In June/July a large fraction (45-90 percent) of the year class of cod was found at Tromsøflaket. This was caused by the presence of an anti-cyclonic circulation above the bank that greatly reduces the diffusion of postlarval cod which is confined to the upper layer.

The postlarvae are most years found in coastal water masses of intermediate salinities (34.4-34.8^{o}/oo S).

The relative large fraction of larvae in the western parts and in the Spitsbergen area in 1984 and 1985 may be due to heavy spawning activity at the more offshore spawning fields Moskenesgrunnen and Eggagrunnen.

There are similar features of the distributions of postlarval and 0-group cod with respect to westernly/easternly distributions.

The postlarvae indices produced in July seem to give a reasonable good indication for the year class strength as 0-group cod in September.

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