Fol.41 H Not to be cited without prior reference to the authors

C.M.1986/H:54

International Council for
the Exploration of the Sea

Pelagic Fish Committee
Ref.Fish Capture and
Hydrography Committees

RELATIONSHIP IN DISTRIBUTION OF BLUE WHITING AND HYDROGRAPHIC CONDITIONS IN THE NORWEGIAN SEA DURING SUMMER, 1980-85

by

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ABSTRACT

During the summer period in the Norwegian Sea the stock of blue whiting was found to have decreased considerably from 1980 to 1983. Although the stock increased again, the adult part of it continued to decrease and in 1985 only 0.5 mill.tonnes of it were found. Particularly in the northern Norwegian Sea this was associated with an increasingly dispersed distribution and lack of fishable concentrations.

Blue whiting was found to feed in water of temperatures from 0^0 to 8^0C, with preference for 5-7^0C, i.e., Atlantic water. The change in distribution and abundance of blue whiting in the Norwegian Sea observed in this period may therefore not only result from a general decrease in the stock, but also from environmental fluctuations.

If the hydrographic conditions were important for these changes, they are not likely to be found in the Atlantic water. It is, however, more likely that the increasing extent of Artic water in the East Icelandic Current has been decisive.

INTRODUCTION

Commercial exploitation of blue whiting (Micromesistius potassou) increased during the 1970s from insignifcant quantities at the beginning of the decade to a total catch of 1.1×10^6 tonnes in 1980. From 1978 to 1981 the largest quantities were fished in the feeding areas , in the Norwegian Sea, but since 1981 landings from this area have decreased drastically (ANON.,1986).

The blue whiting in the feeding area have been surveyed in August every year since 1980. In 1980 and 1981 the survey work was done by Norwegian research vessels. Since 1982 the surveys have been coordinated by ICES and research vessels from The Faroes, GDR, Iceland, Norway and the USSR have participated (ANON., 1982-1984, Anon., 1985b). These assessments have indicated a steady decrease in the stock from 9.1 mill. tonnes measured in 1980 (MONSTAD, unpublished) to 2.8 mill. tonnes in 1983. Although the stock increased again, the adult part of it still continued to decline, from 4.1 mill.tonnes in 1982 to only 0.5 mill.tonnes in 1985 (ANON., 1986). Particularly in the northern Norwegian Sea, this has been associated with an increasingly dispersed distribution with lack of fishable concentrations.

Age and length compositions in the feeding area indicate that mainly adult fish migrate beyond the southern areas of the Norwegian Sea, the large fish moving furthest north (DRAGESUND and JAKUPSSTOVU, 1971; USHAKOV, 1972; ANON., 1982- 1984).

Although a stock decrease has been observed also in the spawning area during the same period, this decay has been considerably less pronounced than what has been observed in the feeding area. The assessments of adult blue whiting in the feeding area were considerably lower than in the spawning area, and give reason to believe that errors in the methodology may have been introduced. A workshop set up by ICES in 1985 therefore reviewed the results of the coordinated blue whiting surveys. A conclusion was that to obtain reliable estimates, the stock has to be above a certain level or distributed in a smaller area in

larger concentration than was the case in 1983 and 1984. This minimum size level has yet to be determined (ANON., 1985a).The reason for the changes in the Norwegian Sea may, however, not only result from a general stock decrease, but may also be due to environmental fluctuations. HANSEN et al.(1979), noted a change in the migration of post-spawners, shifting from a route west of the Faroes to the Faroe-Shetland Channel, which they ascribed to hydrographic fluctuations. This has since been confirmed and further described by SHEVCHENKO and ISAEV,(1983, 1985) and SHEVCHENKO,(1984), who connected the variations in migration and distribution to varying temperature conditions, particularly in the East Icelandic Current.

In the present paper the fish distribution observed during the blue whiting surveys in August 1980 - 1985 is compared with temperatures observed during the same periods.

DATA AND METHODS

During the surveys blue whiting was observed with echo sounders, and measurements of fish density were obtained by echo integration. Samples of blue whiting were collected with pelagic trawls. Abundance estimates were obtained from integrator readings and fish length in sub-areas, 1^0 latitude by $2,5^0$ longitude, as described for example in ANON.,(1982). Hydrographic observations were made with reversing thermometers and water bottles, or with CTD. Survey tracks and stations from August 1980 are shown in Fig. 1. The observation grid in 1981 was similar to Fig. 1, while courses and stations in the other years are shown in the survey reports (ANON., 1982-1984; ANON., 1985b).

Since 1982 when vessels from different institutes first participated, data have been exchanged between the vessels during the cruises. This included echo integrator readings, a summary of trawl catches and temperature observations at 0, 200 and 400 m depth.

Based on the length and age data from the surveys, a body length of 25 cm is here chosen to distinguish between the stocks of young and adult fish. At this length there is relatively little overlap of several year classes, and, generally, the 2-group and younger fish are

separated from the adult stock.

DISTRIBUTION IN THE FEEDING AREA

The distribution of adult blue whiting in August 1980 - 1985 is shown in Fig. 2. In 1980 it covered the entire Norwegian Sea, the eastern Iceland Sea and the Bear Island Channel in the Barents Sea. Dense concentrations were observed more or less continually northward from the Shetlands to the area east of Jan Mayen, and further along the Arctic front to about 74^0N. The most western extent was observed off north-eastern Iceland, between 66 and 67^0N. To the east there were dense concentrations along the shelf off mid-Norway.

In 1981 the general distribution area was similar to that in 1980, but the total abundance had decreased. Dense concentrations were found further to the south, with highest abundances off east Iceland and, to some extent,in the central Norwegian Sea.

In 1982 there was a further decrease in total abundance. The main concentrations were now limited to the area south of 65^0N, extending in a zone from east Iceland towards Norway at about 63^0N. Only very scattered recordings were found further north. The distribution area was reduced in relation to the previous years.

In 1983 dense concentrations were found in one sub-area off east Iceland while only scattered recordings were made in the rest of the feeding area. The total abundance was reduced to less than a third of its level in 1982.

In 1984 the distribution area was considerably reduced and only scattered concentrations were observed except to the north and east of the Faroes. Here the rich 1982 year class now contributed to the stock. This contribution gave rise to an estimated increase which more than compensated for the decay of older year classes.

In 1985 the stock size increased further, but its major portion was found far to the south. Most of the dense concentrations remained around the Faroes and along the Norwegian shelf. This year the

northern Norwegian Sea was not surveyed, but notable quantities of large blue whiting were reported from bottom trawl catches on the Svalbard shelf (ANON., 1985b) These observations are indicated separately in the distribution chart for 1985 (Fig. 2).

Fig. 3 shows the distribution of young blue whiting of length less than 25 cm. In 1980, young fish were recorded in abundance along the southern slope of the Faroe-Shetland Channel. Further north, young fish were scattered up to about 72^0N.

In 1981 young blue whiting were widely distributed, but abundant concentrations were not observed.

In 1982 observations of young fish were confined to the southern Norwegian Sea, but there were now abundant concentrations off southeast Iceland and to the northeast of the Shetlands.

In 1983 the abundance of young fish had increased considerably and the young year-classes accounted for the major part of the total stock. South of 64^0N, dense concentrations were recorded from off southwestern Iceland , across the southern Norwegian Sea to the coast of Norway. Along the Norwegian coast there were also dense concentrations in several areas from the Norwegian Trench to the Lofoten area.

In 1984 the total distribution area was not much different from 1983, but the abundance south of 65^0N had increased due to the very large year class from 1983.

In 1985 the distribution area expanded northeastwards, but the assessed stock of young blue whiting was less than in 1984. Densest concentrations were found off eastern Iceland and around the Faroes.

DEPTH DISTRIBUTION AND TEMPERATURE PREFERENCE

The vertical distribution of blue whiting shows considerable geographical and seasonal variations. Generally, diel vertical migrations vary with the latitude, in accordance with the amplitude of the diel light cycle. Geographical variations may further depend on the vertical temperature distribution. In the area of the East Icelandic Current and along the Arctic front, the temperature is the decisive factor. This is for example demonstrated in Fig. 4 which shows a section across the Arctic front to the northeast of Jan Mayen in August 1976 (BLINDHEIM and JAKUPSSTOVU, 1976). Echo sounder recordings of blue whiting along the section are also indicated in the figure. In the relatively high temperatures on the warm side of the front, blue whiting was recorded to approximately 300 m depth. In the frontal zone the distribution was mainly limited by temperatures between 1 and 2^0C, but with occasional recordings in water with temperature below 1^0C. In the cold water behind the front, there were no recordings except in the warmed surface layer.

Fig. 5 shows the distribution of blue whiting in relation to the temperature in August 1982 - 1984. In the sub-areas used for the acoustic assessments, blue whiting biomass is apportioned in temperature intervals of 1^0C according to the temperatures at 200 m depth. All three years show a peak in the temperature range 6 - 7^0C. This may be interpreted as the preferred temperature in the regime of the Norwegian-Atlantic current. Fig. 5 is hardly relevant in areas influenced by the East Icelandic Current and along the Arctic front where the blue whiting may be distributed shallower than 200 m. In conclusion, Figs.4 and 5 show that blue whiting are feeding in waters with a temperature range from 0 to 8^0C, with preference for 5 - 7^0C. In 1982 - 1984 about 70 % of the total biomass was distributed in areas with temperature above 3^0C at 200 m depth. In the Iceland and Norwegian seas, a temperature of 3^0C is often used to distinguish between Atlantic and Arctic water (STEFANSSON, 1962; MEINCKE, 1978). In general it may be concluded that blue whiting prefers Atlantic waters. A similar temperature preference has been described previously, for example by ZILANOV (1968).

TEMPERATURE DISTRIBUTION

The temperature distribution at 200 m depth in August 1980-1985 is shown in Fig. 6. The charts for 1982-85 are copied from the reports of the blue whiting surveys (ANON., 1982 - 1984, ANON., 1985b), while those for 1980 and 1981 are previously unpublished. For a study of temperature influence on distribution of blue whiting, the 200 m level may not be the most representative in all parts of the Norwegian Sea. This level is chosen because all data from the surveys are available at this depth.

South of a line between Jan Mayen and Norway, at about 65^0N, the temperature field is more or less dominated by the East Icelandic current. During the period, the domain of the East Icelandic current varied considerably with an uninterrupted increase from 1980 to 1984. In 1980 its waters were generally warmer than 0^0C at 200 m depth. The temperature increased gradually from 1^0C at about 9^0W to approximately 7^0C in the Atlantic water off the coast of Norway. In the following years the area between northeast Iceland and Jan Mayen, west of about 9^0W, was colder than 0^0C. Cold water from the East Icelandic current intruded into the Norwegian Sea in 1981-1982 along the northern slope of the Faroe-Iceland ridge. In addition the volume of Arctic water with temperature below 3^0C expanded, and the front between Arctic and Atlantic waters became sharper. When this event culminated in 1984, there was a distinct front along the Faroe-Iceland ridge which turned north near 1^0E, to the northeast of the Shetlands. The variation of the area with temperatures below 3^0C, east of 3^0W and south of 66^0N is shown in Fig. 7. In 1980 the most eastern position of the isotherm for 3^0C was at 3^0W while it enveloped an increasing area until 1984. Although there was some decrease in the extent of Arctic water from 1984 to 1985, the East Icelandic current was still more developed in 1985 than in 1980 (Fig. 6).

To the north of the domain of the East Icelandic current the temperatures ranged between 3^0C along the Arctic front and, roughly, $6\text{-}8^0$C along the coast of Norway. In 1980 and 1985 the front was less distinct at 200 m depth than in the other years. Although there were differences from year to year in the northern Norwegian Sea, there was no

clear trend during the period.

Fig. 8A shows temperatures at 200 m depth in some positions along 71^0N during the period 1980 - 1985, at 6^0E, 0^0, 2^0W and 6^0W. At the 0^0-meridian and at 6^0E there was an increasing trend during the period, but observations further to the east, at $70^0$24'N, $08^0$12'E, shown in Fig. 8C, indicated different patterns.

Fig. 8B shows minimum temperatures at 200 m depth in the East Icelandic current at the longitudes 0^0, 3^0W and 10^0W. The eastern position, 65^0N, 04^0E, is situated east of the Arctic front in Atlantic water. The three localities in the East Icelandic current showed similar trends, with a marked cooling from 1980 to 1981 and lowest temperature in 1983. During the two latest years in the period there was a rise in temperature. This was far more pronounced at the 0^0-meridian than further to the west. Although the coldest conditions in the East Icelandic current were observed in 1983, its volume was largest in 1984 as shown in Figs 6 and 7.

The Atlantic water flowing into the Norwegian Sea, was colder in 1980 -1981 than during the three following years. This is indicated both by the conditions at 4^0E, in Fig 8B, and by the similar trends at a station in the core of the Norwegian Atlantic current ($63^0$04'N, $03^0$40'E) which are shown in Fig. 8D.

The stations shown in Fig 8C (70^0,24'N, 08^0,12'E) and 8D were repeated in the same positions during the period. Observations at 50, 100, 200 and 400 m at these stations, indicate that fluctuations in the upper layers of the Atlantic domain in the Norwegian Sea are fairly well reflected by the temperatures at 200 m depth.

DISCUSSION

There may be several reasons for the rather abrupt decay in abundance and distribution of blue whiting in the Norwegian Sea during the period 1980-1984. Although there was a general stock decrease, assessments in the spawning area did not agree with the more drastic reduction in the feeding area. Even if the stock was reduced, it is not evident

that this should bring about a change in migration pattern and feeding distribution if the conditions were otherwise favourable.

The distribution in the feeding area will depend on the availabilty of food. PLEKHANOVA and SOBOLEVA (1982) concluded that in 1980, when the biomass of copepods was low, blue whiting was concentrated in the zones where the plankton development was highest. In years with high production, as in 1979 and 1981, it was widely dispersed. The diet of blue whiting is, however, diversified, and euphausids, as well as mesopelagic fish and 0-group redfish, are important food items. It is therefore unlikely that the availability of food in the Norwegian Sea was reduced to such a low level that this should result in a drastic change in distribution.

If the change in distribution and abundance is due to fluctuations in the temperature conditions, it is not likely that these are found in the Atlantic water. The northern Norwegian Sea was not warmer in 1980-1981 than in the following years. In the southern area, the temperatures in the Atlantic water were higher in 1982-1984 than in 1980-1981 It seems more likely that the increased extent of Arctic water with temperatures below 3^0C in the East Icelandic Current may have been of some importance. At 200 m depth the Arctic front was shifted about 300 km eastward from 1980 to 1984. This may have acted as a barrier which forced the migration route to move eastward. The reduction of post-spawners migrating northward to the west of the Faroes may support this assumption (HANSEN et al., 1979). Instead, the migration route to the Norwegian Sea followed the southern slope of the Faroe--Shetland Channel as described by SHEVCHENKO and ISAEV (1983, 1985). It seems, however, not evident that this would bring about a reduced migration to the feeding areas further north. Still, if the hydrographic conditions have been of importance for the observed changes, it seems likely that the increasing extent of the East Icelandic Current has been the decisive event. The observations made during the surveys in August, therefore, support SHEVCHENKO and ISAEV's conclusions.

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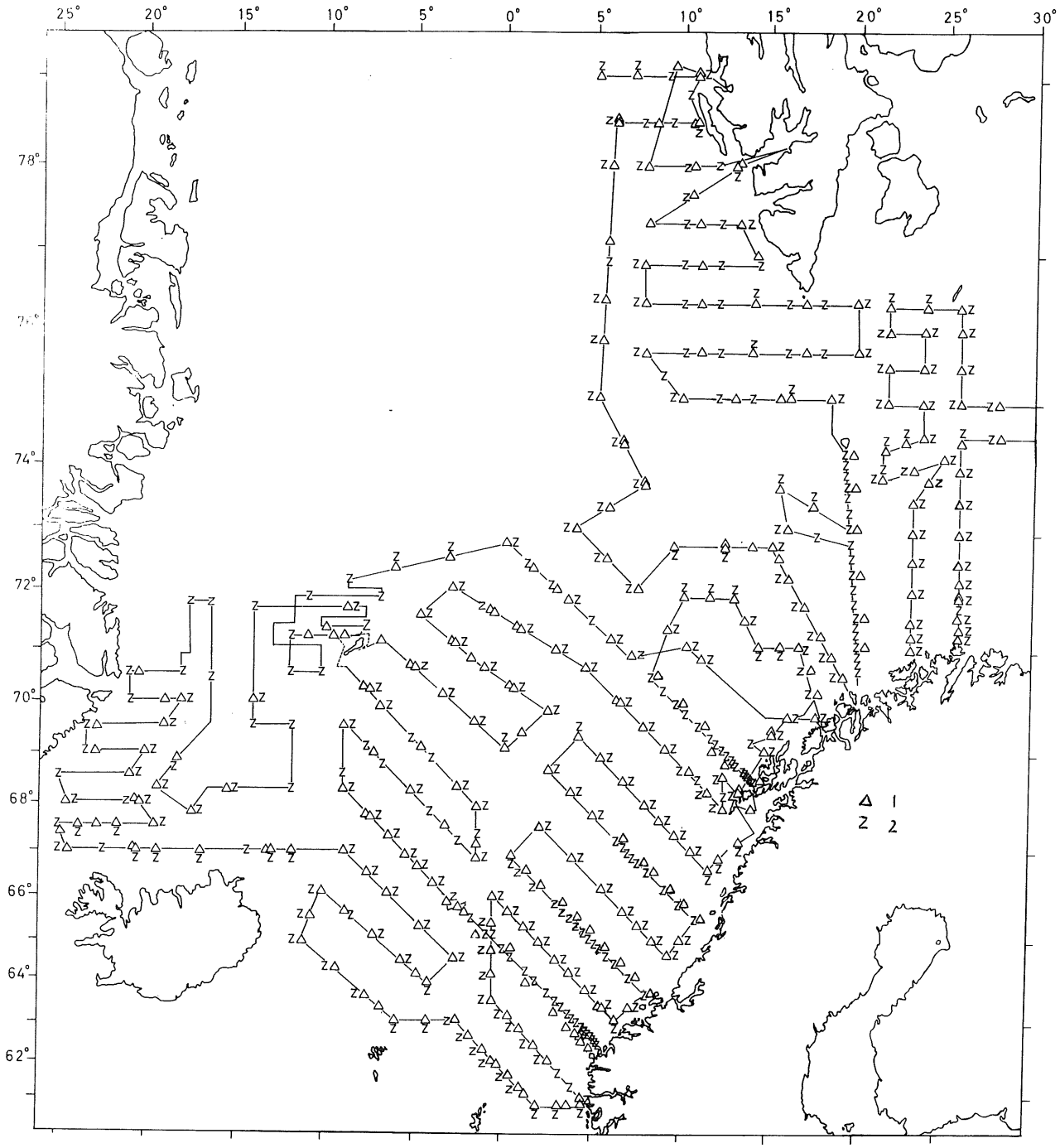

Fig. 1. Survey tracks and stations 1980. 1) Pelagic trawl, 2) CTD.

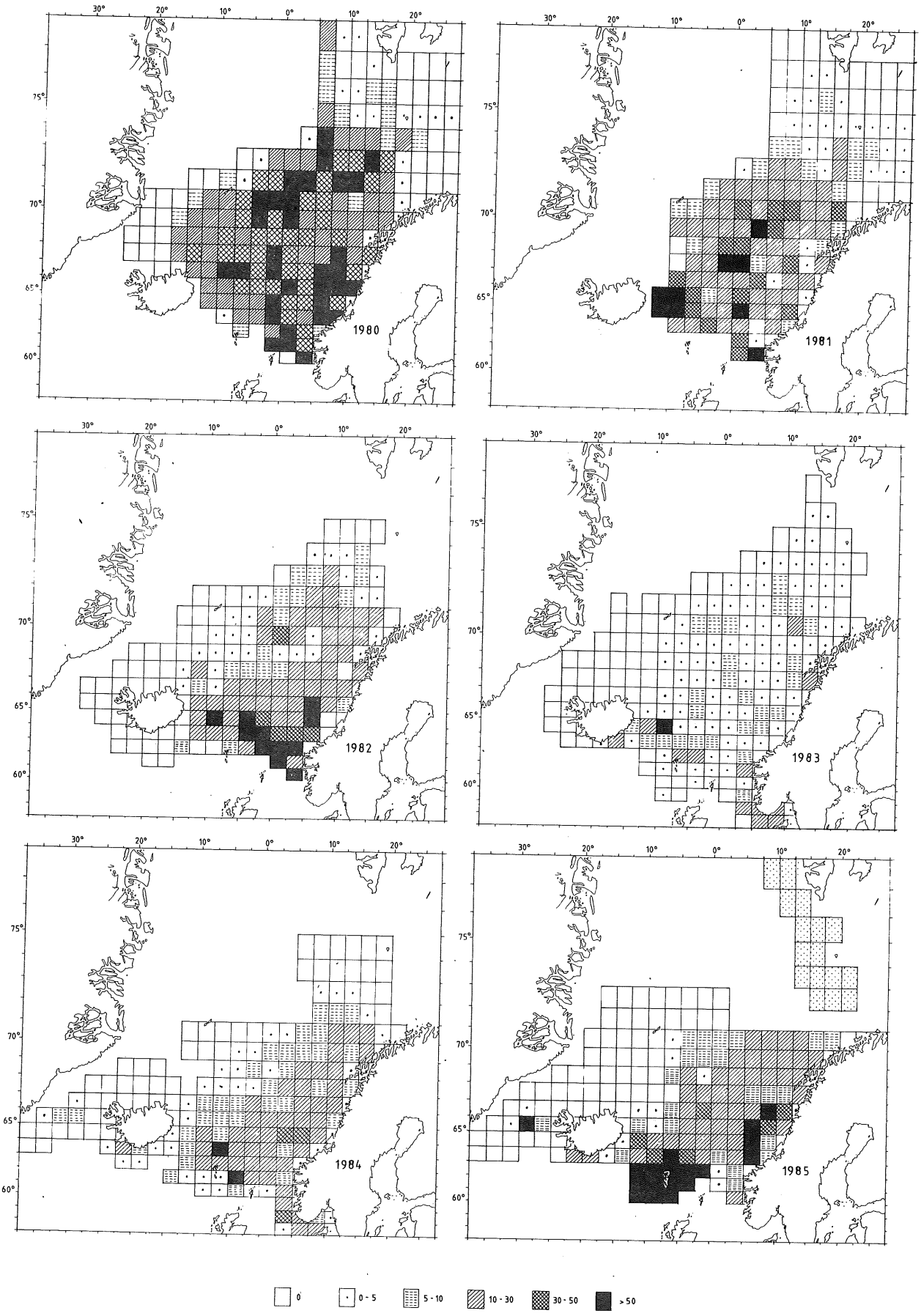

Fig. 2. Distribution and abundance of adult blue whiting, August 1980 - 1985. N x 10^{-7}.

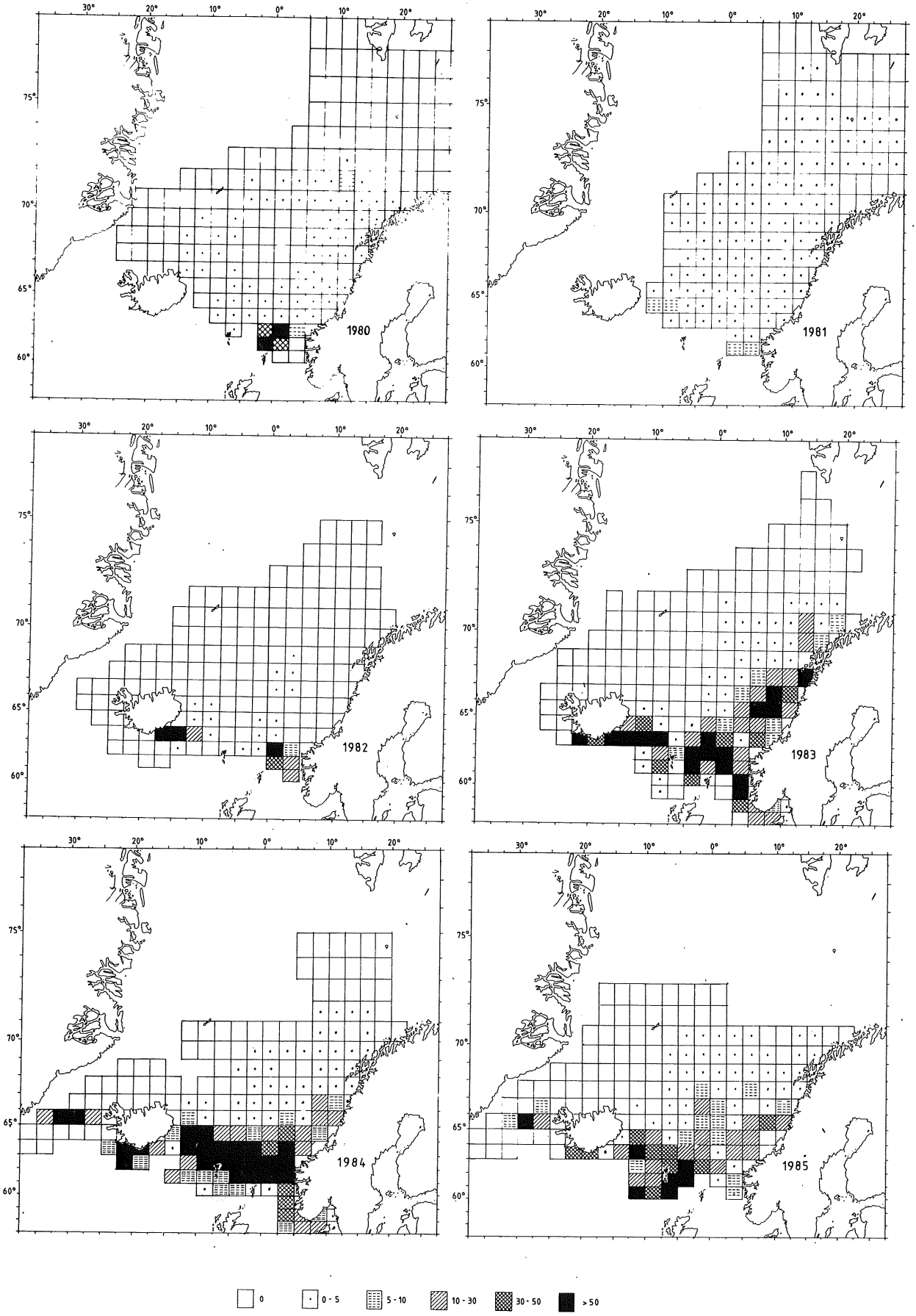

Fig. 3. Distribution and abundance of young blue whiting, August 1980 - 1985. N x 10^{-7}.

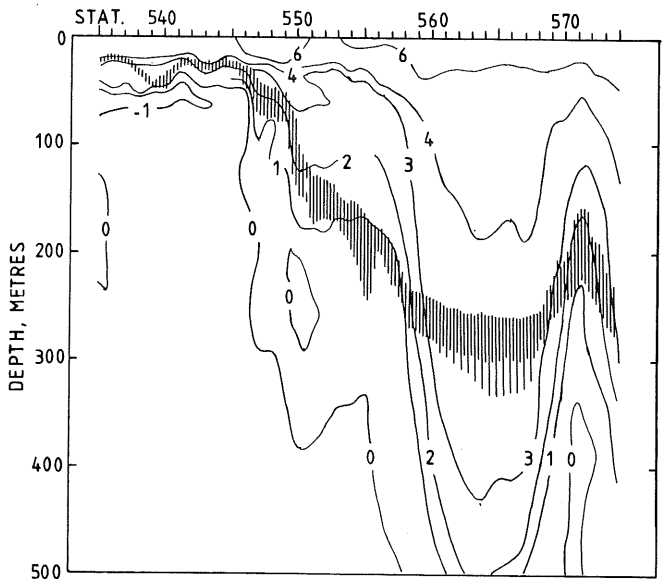

Fig. 4. Distribution of blue whiting in relation to the temperature across the Arctic front (71^0 52'N,02^0,35'E - 72^0 52'N,00^0,20'W) in August 1976.

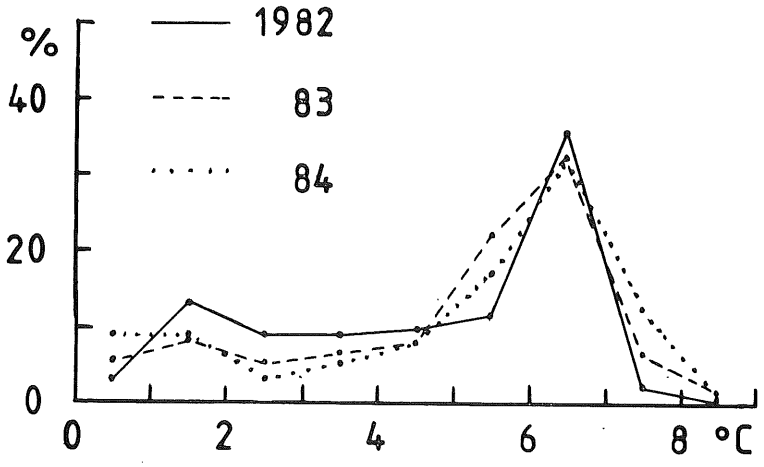

Fig. 5. Distribution of blue whiting in relation to the temperature at 200 m depth, August 1982 - 1984.

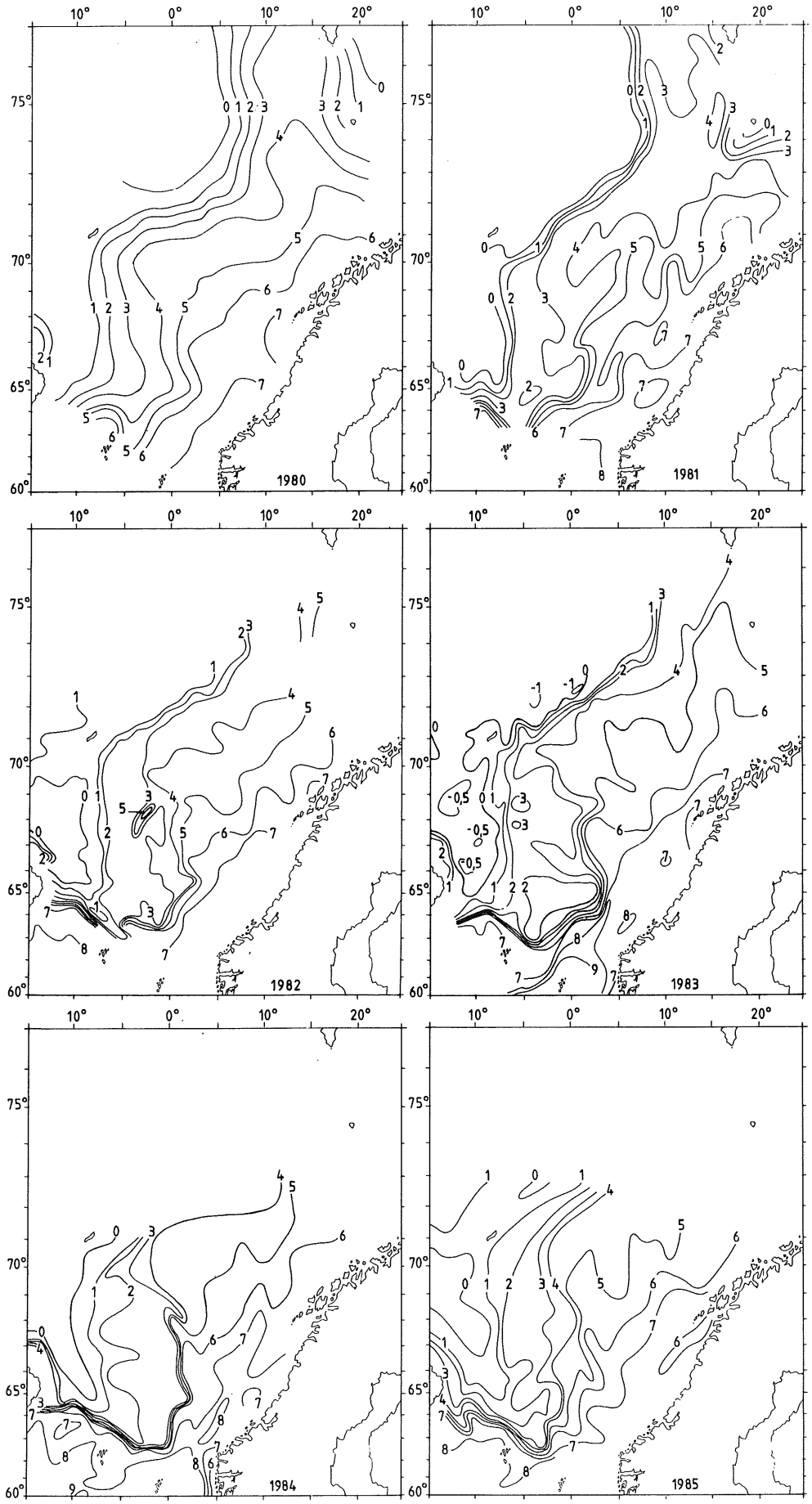

Fig. 6. Temperature at 200 m depth, August 1980 - 1985.

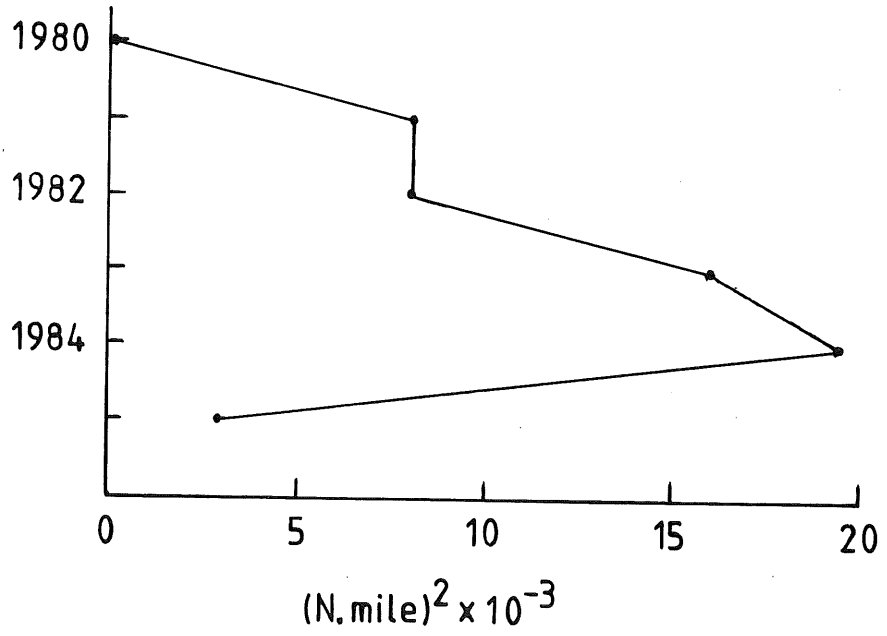

Fig. 7. Area to the east of 3^0W and south of 66^0N with temperature below 3^0C at 200 m depth, August 1980-1985.

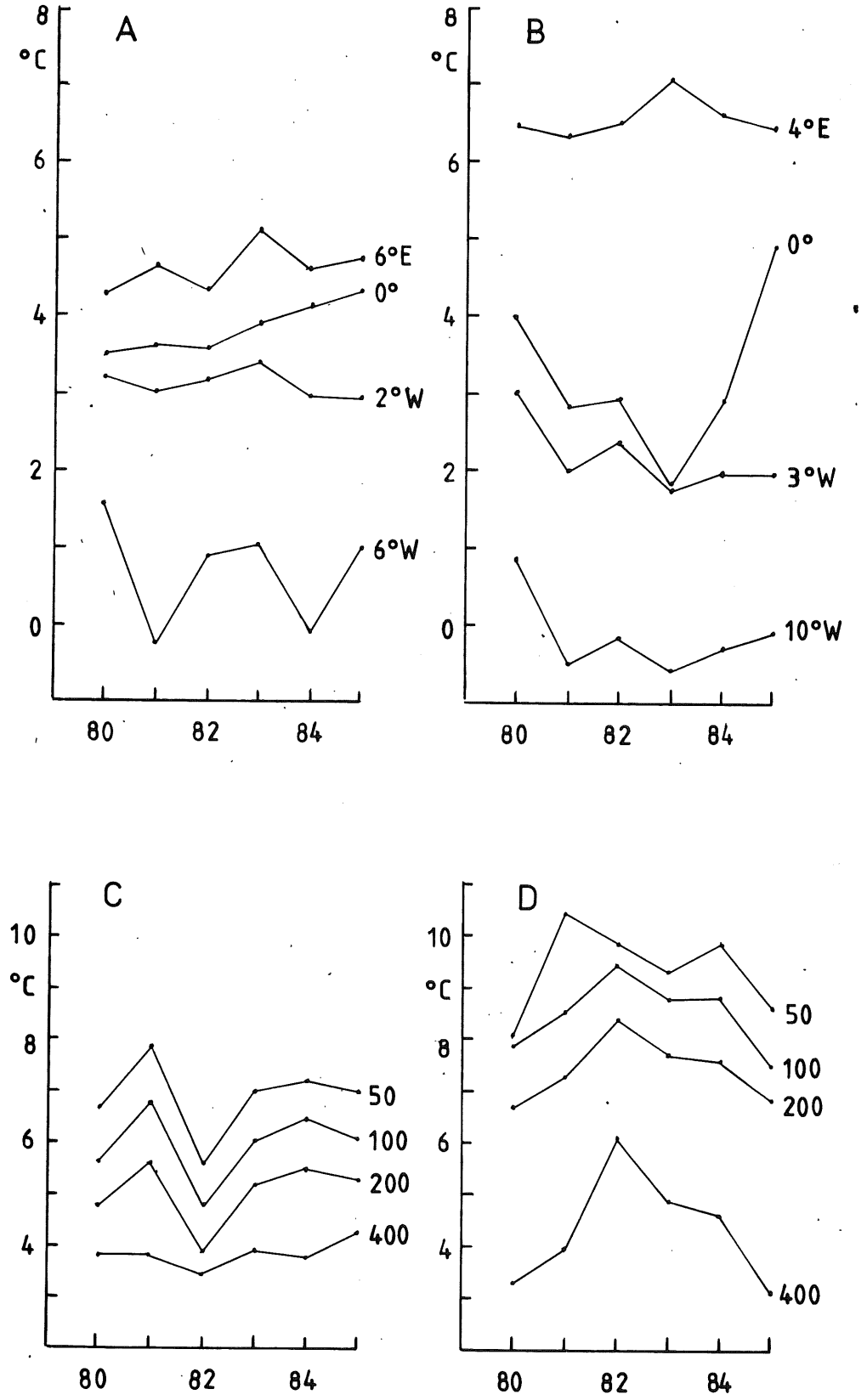

Fig. 8. Temperature trends for August during the period 1980 - 1985. A) At 200 m depth in four positions along 71^0N. B) Minimum temperature at 200 m depth in the area of the East Icelandic current, at 4^0E, 0^0, 3^0W and 10^0W. C) At 50, 100, 200 and 400 m depth at $70^0$24'N, $08^0$12'E. D) At 50, 100, 200 and 400 m depth at $63^0$04'N, $03^0$40'E.