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The migration of Norwegian herring to Icelandic waters and the environmental conditions in May - June 1961 - 1964

by

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Introduction

Since 1949, the migrations of herring in the Norwegian Sea has been intensively studied. Devold (1951) has then shown that the time and place for the immigration of the Norwegian herring to the spawning grounds along the west coast of Norway are closely related to hydrographic conditions, particularly temperature. During the feeding migration in the summer the hydrographical conditions are also important for the distribution and formation of the herring shoals (Devold 1963, Jakobsson 1963).

Several authors have, however, shown that there is a connection between the plankton conditions and the migration pattern of feeding herring. Review of works on plankton herring relationship has been given by Pavshtiks (1956) and by Jakobsson (1959, 1962).

The most extensive work on the migration of Norwegian herring in the Norwegian Sea in relation to plankton has been given by Pavshtiks (1956). She found that the older age groups of the Norwegian herring were after spawning feeding mainly on the overwintering stock of Calanus finmarchicus in the coastal or Atlantic waters continuing in waters of the East Icelandic Arctic Current; they thus followed the shift in spawning time of C. finmarchicus. The observations showed that the migration routes of the herring are related most closely to the seasonal changes in the plankton production and its distribution. Annual fluctuations in time of the biological spring may, therefore, cause a change in the feeding migration of the herring.

The Norwegian investigations on herring migration in the Norwegian Sea during May and June have been conducted since 1951 in coloboration with Danmark (until 1961), Iceland, and USSR (from 1957). In the years 1961-1964 the Norwegian part of the joint work has been confined to the area from the Faroes along the east and north-east coasts of Iceland to Jan Mayen. The observations made on herring, temperature and zooplankton during these years provide material for this study which demonstrate the invasion of Norwegian herring to the north-east coast of Iceland in relation to these environmental factors.

A summary of the work has been given annual in the joint reports to the Herring Committee (Jakobsson & Østvedt 1961, Anon 1962, 1963 and 1964).

During the cruises of 1962, 1963 and 1964 the work was carried out on a fixed number of sections with stations 20 or 40 miles apart and at approximately the same time period (in 1962: 26 May - 8 June, 1963: 22 May - 5 June and 1964: 27 May - 10 June). Additional observations were continued each year until about 20 June when the joint meeting was held. In 1961 the first survey on the east and north-east coasts of Iceland was undertaken during the period 7 - 17 June.

Measurements on temperature and salinity have been taken from each station at standard depths to 500 meters. Zooplankton has been collected by vertical hauls from 50-0 m. In 1961 and 1962 a Juday net (diameter 80 cm, silk no. 0) was used while in 1963 and 1964 a standard Hensen net (diameter 73 cm, silk no. 3) was used instead. The volume of each zooplankton sample was measured by the displacement method and the development stages composition of C. finmarchicus was determined by counting 100 individuals of the species. The percentage occurrence of copepodites stages I-III are shown as 25%, 50%, and 75% isolines. According to a short cut method (Halgrimsson 1958), the percentage frequencis of other species or groups of species in the samples were also counted, but these are not considered in detail in the present paper. For 1961 and 1962 (by Lie) only preliminary data on zooplankton are available.

During these investigations herring shoals have been located with sonar and echo-sounders and drift net was frequently used for sampling these shoals.

Results

1961

The distribution of herring and temperature at 20 m depth in the period 7 - 17 June is shown in Figure 1. Herring shoals were recorded 60-70 n. miles north-east of Langanes on the 9th of June. During the following week the herring apparantly moved further north west-ward and dense concentrations were recorded north of Melrakka in the second half of June. It was shown in the joint report (Jakobsson and Østvedt 1961) that the temperature at 20 m depth on the north-east coast was somewhat above average. In the area where the herring occurred the temperature at 20 m varied from 2° - 4°C (Fig. 1). The zooplankton density off the north coast of Iceland was also higher than in previous years, but off the east coast it was about normal. Comparing the herring distribution with the percentage distribution of C. finmarchicus copepodite stages I-III (Fig. 2), it appears that during June the herring shoals were generally encountered in the areas with low zooplankton densities (c.f. Joint report) and with less than 25% of C. finmarchicus in stages I-III, i.e. in areas where the older stages of C. finmarchicus presumably the overwintering stock, predominated.

According to Jakobsson (1962), 24,8% of the Icelandic catch in 1961 came from the area north of Melrakka during three weeks in June-July. Later in summer the herring immigrated to the traditional grounds on the east coast of Iceland where young stages (I-III) of C. finmarchicus predominated in the beginning of June. These stages - eventually metamorphosed - forming more suitable food for the herring in July.

1962

In 1962 the investigation started in the last week of May and dense concentration of herring were observed on May 30th between 40 to 110 nautical miles north-east of Langanes (Fig. 3). The shoals were mainly found in waters of temperature below 3°C, extending into watermasses of temperature below 2°C (Anon 1964 (1)). The herring then moved quickly in a north westerly direction and on 5 June dense concentrations were already recorded north-east of Kolbeinsøya. Samples secured from drift net catches showed that mainly Norwegian spring spawners were present, but the Icelandic spring spawners had also already immigrated the north coast. As stated in joint report (Anon 1964 (1)), the herring concentrations were found much further west during the first half of June in 1962 than in 1961.

The density of zooplankton off the north coast is shown in Figure 4. In the cold waters with low densities the overwintering stock of C. finmarchicus was predominant while in waters with maximum densities the zooplankton consisted of Calanus in stages I-IV. In accordance with the observation of 1961 it was found again that in

1962 the Norwegian herring invaded the north coast, mainly keeping to the cold water areas east and north-east of Langanes where zooplankton densities were relatively low, but with a high proportion of older stages of C. finmarchicus.

1963

The distribution of temperature and herring from 21 May to 5 June east and north-east of Iceland is illustrated in Fig. 5. Herring were registrated in two regions. In the most southern region (situated between latitudes 64°N and 65°N and about longitude 6°W) only smaller shoals were found. Here the herring seems, however, to be present nearly all the year round mostly scattered over a wide area. Further north, dense concentrations were found about 150 n. miles north-east of Langanes in watermasses with temperature below 2°C. The vertical distributions in relation to the temperature are illustrated in Figures 7 and 8. The sections show that the shoals were found in depths ranging from surface to 300 m, where the temperature varied from > 5° to < 0°C.

The temperature conditions in the 0-200 m layers in the area was lower than the average for the last ten years and the 3° isotherm was situated 120 n. miles more south-east than in 1962 (Anon 1963).

The zooplankton densities between 22 May and 5 June are shown in Fig. 6. As pointed out in the Joint report, the density of zooplankton off the north-east coast of Iceland was generally below the mean value in comparison with previous years and considerably lower than in 1962. The areas with high densities (above 1.5 $^{ml}/_{m^3}$) were also situated much further off the coast than in 1962. In both years C. finmarchicus constituted the bulk of the population along the coast where the densities were low. In the cold waters, beside C. finmarchicus, C. hyperboreus, Pseudocalanus minutus, Themisto spp. and Sagitta spp. were also numerous.

Comparing the herring distribution with the percentage distribution of copepodites of C. finmarchicus (Fig. 9) it appars that the herring, as in previous year, was found in watermasses predominated by the older stages.

The herring shoals, observed north-east of Langanes at the end of May, seemed to move west-ward passing through the East Icelandic current. When the observations were repeated, in the period 11 - 21 June, dense concentrations were found 19 June in the area north and north-east of Langanes between 67°N and 68°N at 16°W (Fig. 10).

The percentage distribution of C. finmarchicus, stages I-III, illustrated on the same figure, reveals that the invasion of herring to the north-east coast followed the transition area between the cold water with a stock of adult C. finmarchicus and the mixed coastal watermasses with young Calanus (stages I-III). The westward migration of the Norwegian herring in 1963 was delayed at least two weeks in comparison to 1962 (Anon 1963).

1964

The investigation started 5 days later than in 1963. When the area east of Langanes was surveyed on the 4-5th of June dense concentrations of herring were recorded 60 n. miles off Langanes (Fig. 11). The herring were mainly found in waters of 2° - 3°C on the western side of the East Icelandic Arctic current. The herring migrated quickly further west and on 8 June dense concentrations were found off Langanes from 67°30'N, 68°30'N and between 12°W. Drift net samples consisted exclusively of old Norwegian spring spawners with a mean length of 37,5 cm.

In the Joint report for 1964 (Anon 1964 (2)) it is shown that the temperature off the north coast of Iceland in the uppermost 200 m was generally 1°C above normal and 2°C higher than in 1963.

The zooplankton densities in the same area were much lower than in 1963, plankton volumes above 1,5 $^{ml}/_{m^3}$ were only recorded in a few stations (Fig. 12). In all areas with high densities. C. fin-

marchicus was the numerous species.

The percentage distribution of C. finmarchicus stages I-III shown in Figure 13 reveals that the stock consisted of less than 25% young copepodites only north of latitude 66°30'N. The spawning of C. finmarchicus had apparently occurred somewhat earlier this year than in 1963 when the older stages dominated over a much wider area. This may be ascribed to the higher temperature in 1964 and an early formation of a thermocline in the upper water layers off the east and north-east coast of Iceland. This was followed by an unusual early spring bloom of phytoplankton which thus initiated the spawning of C. finmarchicus (Anon 1964 (2)).

Repeated observations from 11 June - 20 June showed that the temperature quickly increased along the northeast coast followed by an extension of the spawning area of C. finmarchicus (Fig. 14). The herring observed north og Langanes on 8 June either moved further north or dispersed (Anon 1964). But during the first half of June purse seine fishery both by Icelandic and Norwegian vessels, were going on further off the north coast of Iceland than in any previous years. However, dense concentration of herring were found on the 10th of June close to the east coast of Iceland. Samples from this area showed that also younger herring were present, constituting from 5 - 35% of the samples.

As concluded in the Joint report the migration pattern of the first invasion was similar to that in 1963, but such dense concentrations of herring detected also close to the east coast in the first half of June have usually not been observed before the beginning of July.

Discussion

Comparing the distribution of herring in May-June 1961-1964 it appears that in each year the herring was first recorded east or north-east of Langanes at the end of May and early June. During the first or second week of June the herring shoals have migrated further westwards, and became mainly confined to the areas between 67°N and 68°N and as far as about 18°W.

It should be pointed out that in 1961 and 1962 an early influx of Iceland spring spawners from the west was observed on the north coast. In June 1963 and 1964, however, there have only been insignificant or no immigration of Icelandic spring spawners to the north coast.

Although the migration pattern of the first invasion of herring from east to the north-east coast of Iceland in the last four years have been rather similar, yet there seems to be variation in time from year to year. Dense concentrations of herring were recorded at 18°W already on 5 June 1962, but the main invasion was still west of 14°W. In 1964, herring were observed at 16°W on 8 June. In 1963, no herring shoals were found west of 16°W until 17 June and the invasion was delayed nearly two weeks as compared with 1962 and 1964.

When comparing these data with the temperature conditions in June for the respective years, there is an apparent close relationship. In the annual joint reports the following tentative conclusions regarding the temperature conditions off the north and east coasts of Iceland in early June were given: In 1961 the temperature in the surface layers (at 20 m) on the north coast was a little above normal on the north coast, and normal off the east coast; in 1962 the temperature was near to the mean values for the period 1950-60, while in 1963 below the mean values and in 1964 about 1°C above normal and nearly 2°C higher than in 1963. It appears therefore that the herring immigrated during the "normal temperature" years of 1961 and 1962 to the north coast in the 1st or 2nd week of June. This invasion was delayed in the cold year of 1963 and was early, especially on the east coast, in the warm year 1964.

When comparing the herring distribution and temperature in May-June it will be seen that herring shoals have been recorded in waters from about 6° to 0°C and even below 0°C (Figures 7 and 8). Allthough dense herring concentrations are mainly found in waters above 1°C there seems to be no clear evidence that the feeding migrations of herring are directed by temperature conditions. In all the years investigated herring have been recorded east or north-east of Langanes migrating through the East Icelandic Arctic Current. Pavshtiks (1956) also found that herring migrates into the cold waters (below 2°C) of the Polar current.

Jakobsson (1963) has shown that the changes in migration pattern of herring in July-August on the north coast fishing grounds is closely related to temperature and feeding conditions. As temperature and plankton are closely connected, it cannot be doubted that the plankton conditions (or rather certain species of the plankton, in particular C. finmarchicus), are important for the migration pattern of feeding herring. Blakter and Holliday (1963) have also emphasized the importance of size and type of plankton when studying plankton herring relationship. Pavshtiks (1956) found that nauplii and young copepodites of C. finmarchicus probably are too small for the adult herring as food.

Although C. finmarchicus usually constitute the bulk of the zooplankton population in the Norwegian Sea, also forms unacceptable as herring food or young copepodites may be particularly abundant. In the latter case a possibly existing positive correlation between eatable zooplankton densities and herring may be confused. The present data on herring plankton relationship show that during May-June herring were mainly found in areas with relatively low zooplankton densities. Lie (1961) also reported that herring were scarse during June 1958 in the areas of the Norwegian Sea richest in zooplankton. Jakobsson (1963) on the other hand demonstrated a positive correlation between herring and the abundance of zooplankton in particular C. finmarchicus off the north coast of Iceland in July-August.

In May and early June stages I-III of C. finmarchicus are usually predominant along the east and north-east coasts of Iceland in areas with high zooplankton densities. The older stages, IV-VI are most abundant in the cold waters further off the coast. In the years 1961-1964 the migration routes of the Norwegian herring have been confined to areas with a high proportion of stages IV-VI of C. finmarchicus. The herring did not invade the more coastal waters north or east of Iceland until the spring generation of C. finmarchicus had further developed, probably to stages III-IV and V. These results confirm the observations by Pavshtiks (1956) and Grusov (1961) that in spring and early summer the older age groups of the Norwegian herring feed on the overwintering stock of C. finmarchicus, the nauplii and young copepodites probably being too small. The immigration of herring to the warmer waters along the east and north coasts of Iceland depend on the further development of the young Calanus population.

In 1963 the temperature off the north east coast of Iceland was about 2°C lower than in 1964. The percentage distribution of C. finmarchicus stages I-III (Figure 9) shows that they were less than 25% over a wide area in the East Icelandic Arctic Current. In the warm year 1964 stages I-III were on the other hand predominant at almost every station south of 66°N. Although the investigations in 1964 were carried out five days later than in 1963. This indicates that the spawning of C. finmarchicus occurred somewhat later in 1963 than in 1964. A further evidence is provided from the continuous transparency recordings. Berge (personal communication) reported that the transparencymeter showed much lower concentration of particles in 1964 than in 1963, indicating a different situation in the phytoplankton. The initiating effect of phytoplankton conditions on the spawning of C. finmarchicus have been shown by several workers particularly by Marshall and Orr (1952) in culture experiments.

Conclusion

The conclusions to be drawn from all these observations is that the time of Norwegian herring invasion to the north-east coast of Iceland as well as the migration routes are closely related to the biological season. The association between the biological season and the hydrographical situation is evident and it explains the apparent correlation between temperature and herring distribution observed several times.

From the above data it may also be permissible to postulate that the first invasion of Norwegian herring generally takes place in the first half of June. The herring migrate through the East Icelandic Arctic Current east off Langanes mainly in waters below 3°C. The shoals usually remain in cold waters feeding on the overwintering stock of C. finmarchicus and approach the coastal waters north and east of Iceland when the spring generation of C. finmarchicus developes into a suitable size.

It should be stressed, however, that the age composition of the stock as well as shift in spawning time and place recently observed on the Norwegian west coast spawning grounds may also have to be taken into account.

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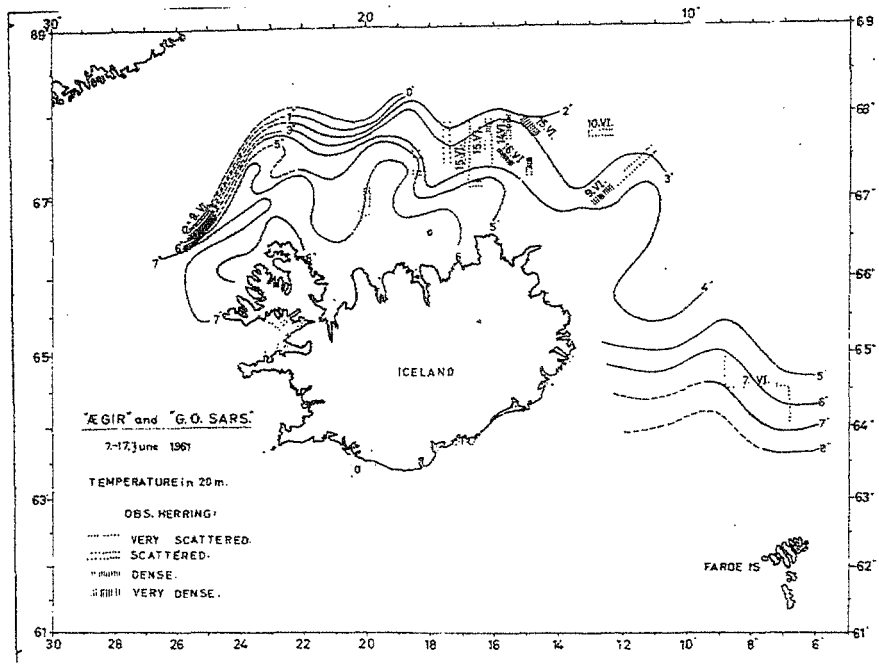

Fig. 1. Herring distribution and temperature at 20 m, 7 - 17 June 1961 (From Jakobsson and Østvedt 1961).

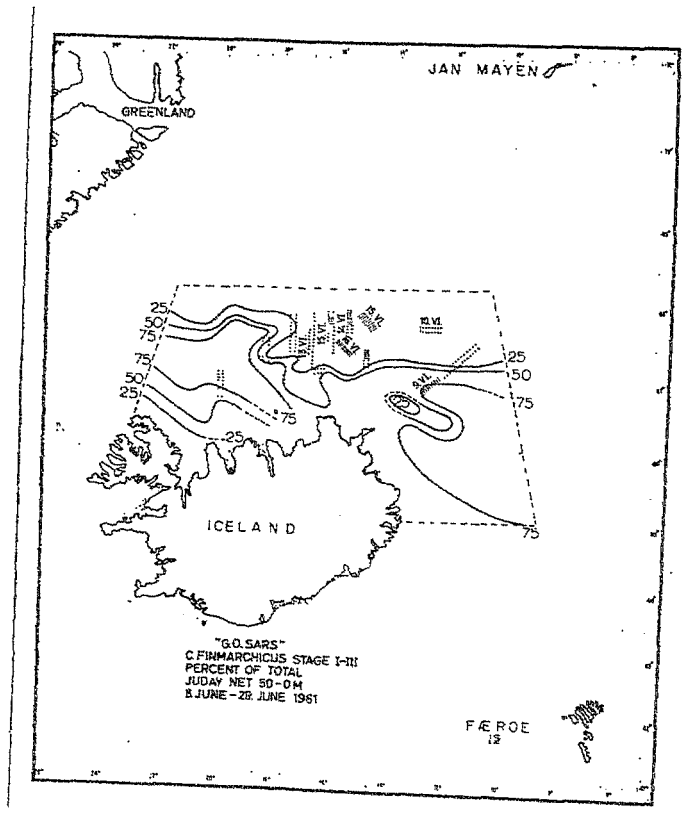

Fig. 2 Herring distribution and percentage distribution of copepodites stages I-III of C. finmarchicus, 8 - 29 June, 1961

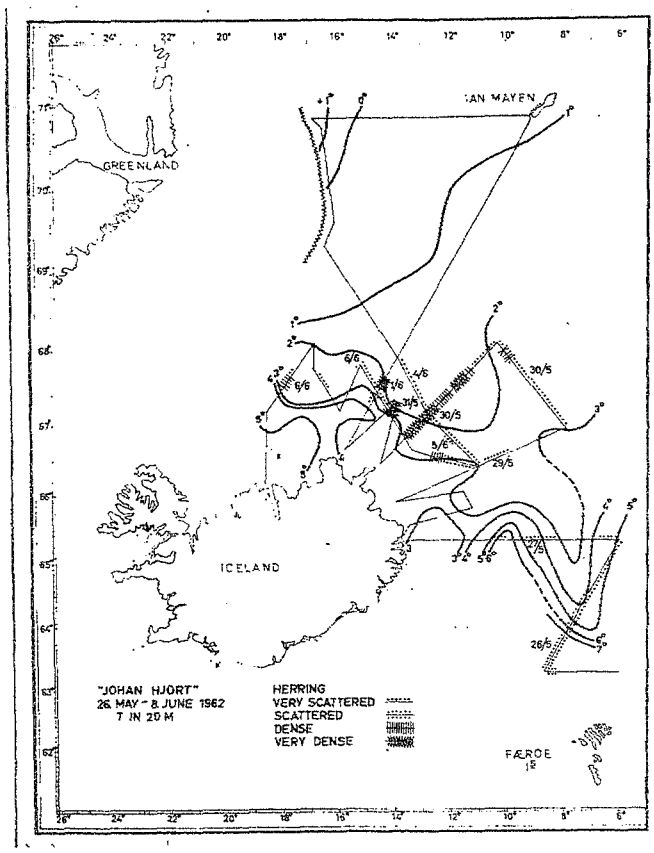

Fig. 3 Herring distribution and temperature at 20 m, 1962

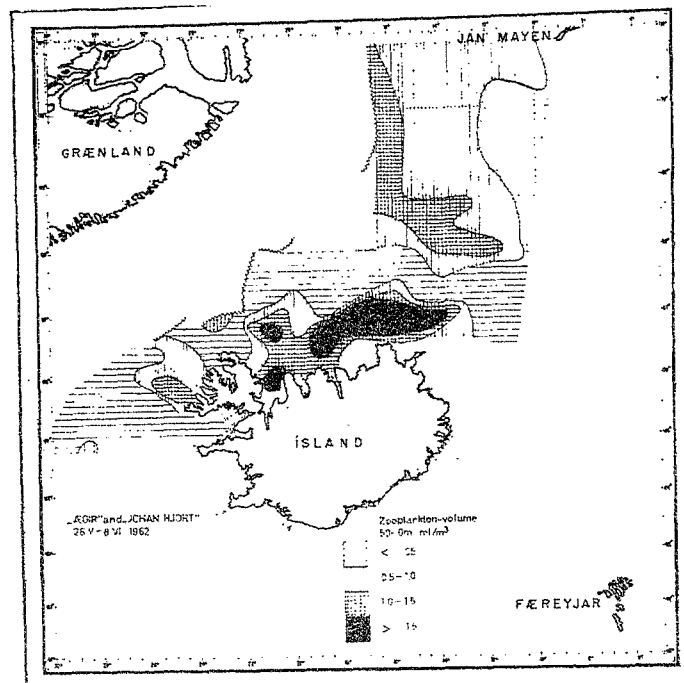

Fig. 4 Zooplankton concentrations 1962 (from Joint report)

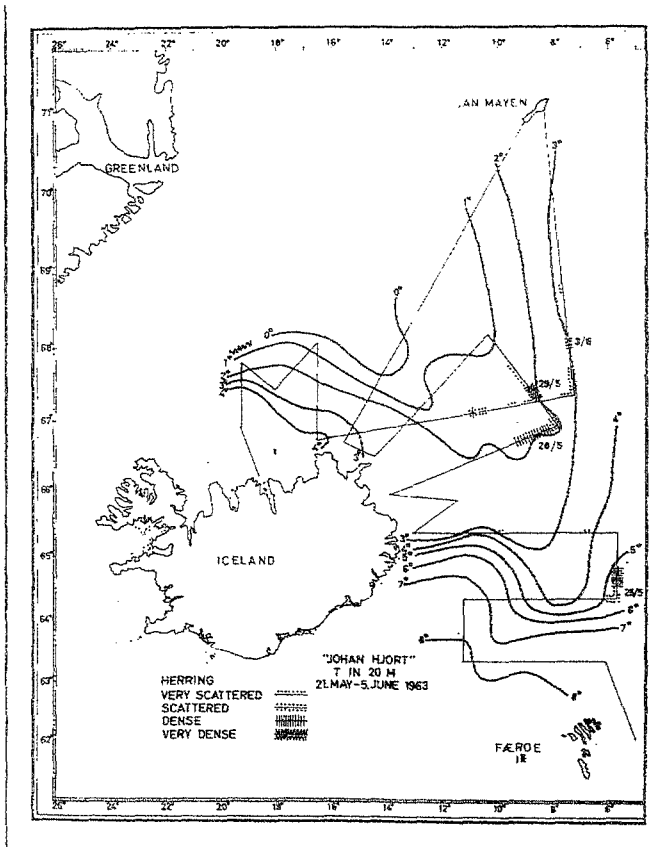

Fig. 5 Herring distribution and temperature at 20 m, 1963

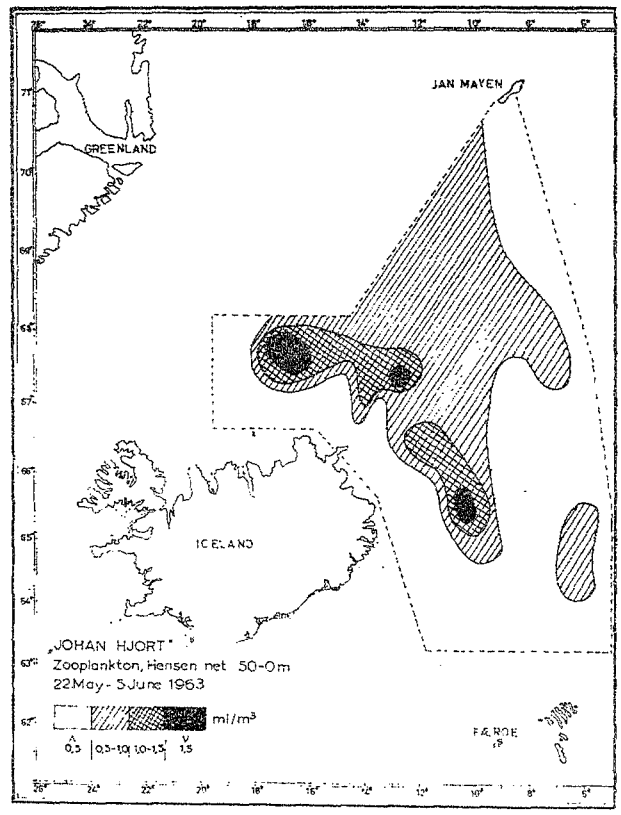

Fig. 6 Zooplankton concentrations 1963

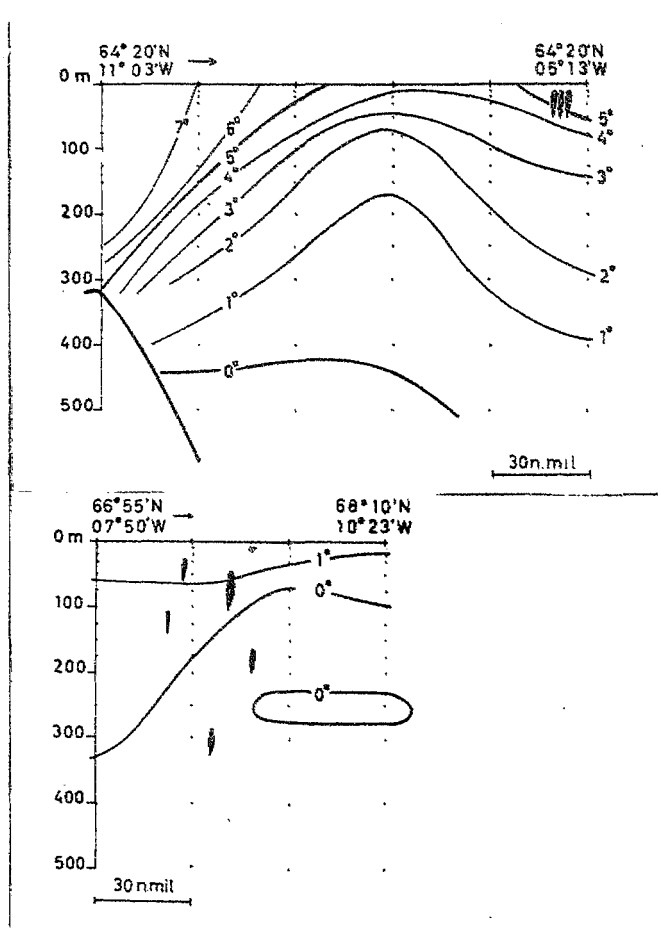

Fig. 7 Temperature sections and herring distribution east of Iceland 25 - 28 May 1963

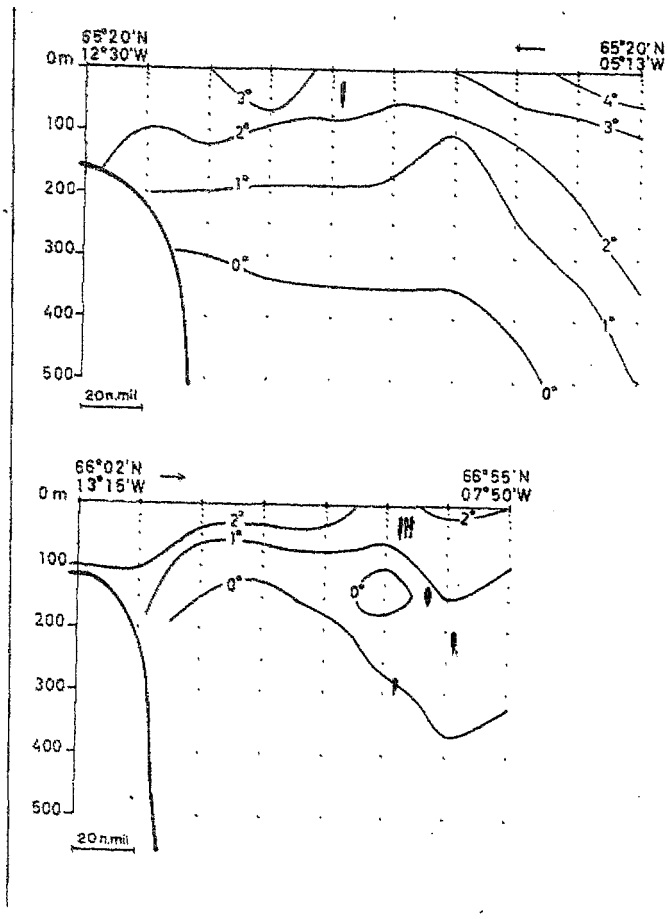

Fig. 8 Temperature sections and herring distribution east of Iceland 24 - 29 May 1963

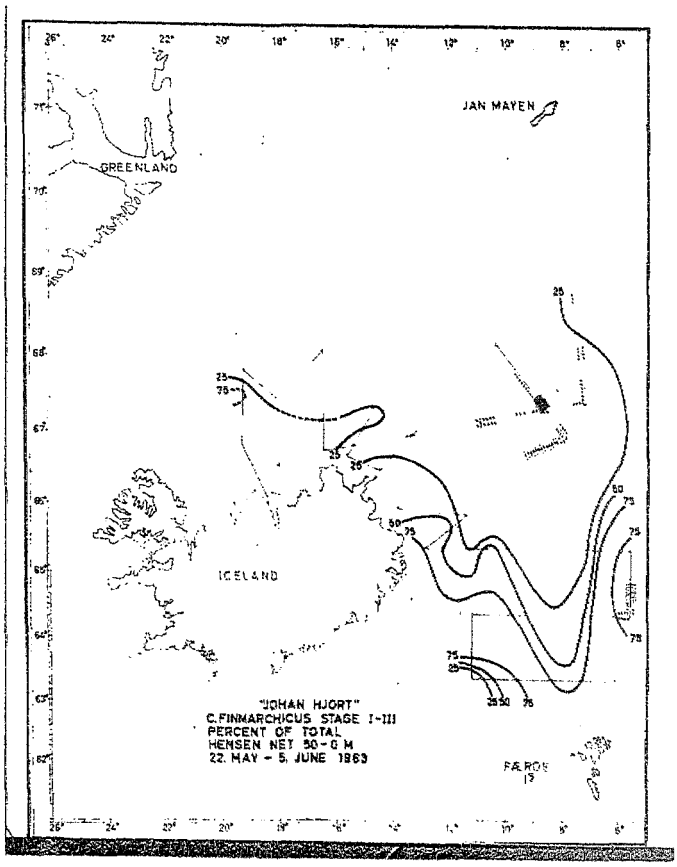

Fig. 9 Herring distribution and percentage distribution of copepodites stages I-III of C. finmarchicus, 22 May - 5 June, 1963

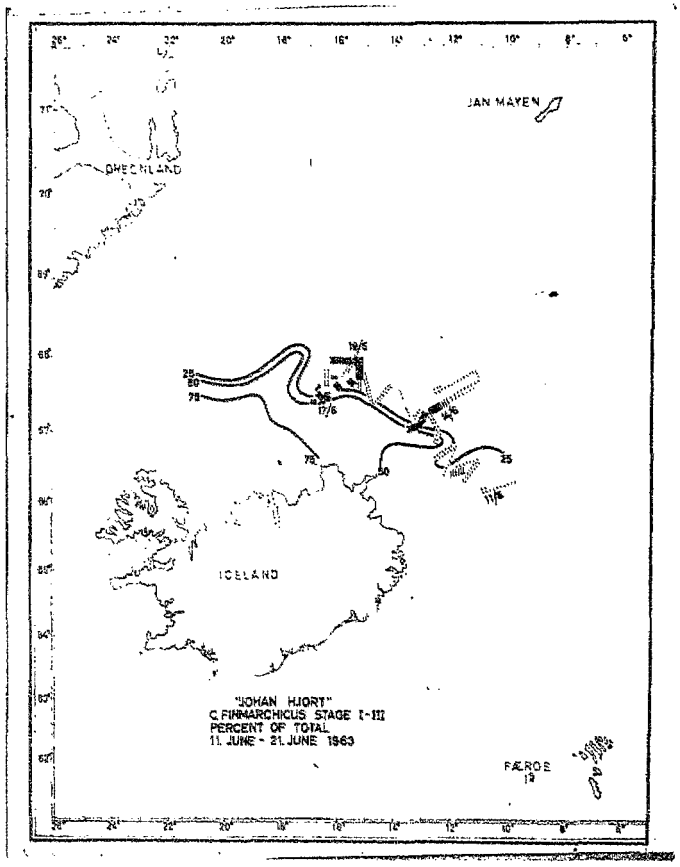

Fig. 10 Herring distribution and percentage distribution of C. finmarchicus, 11 June - 21 June, 1963

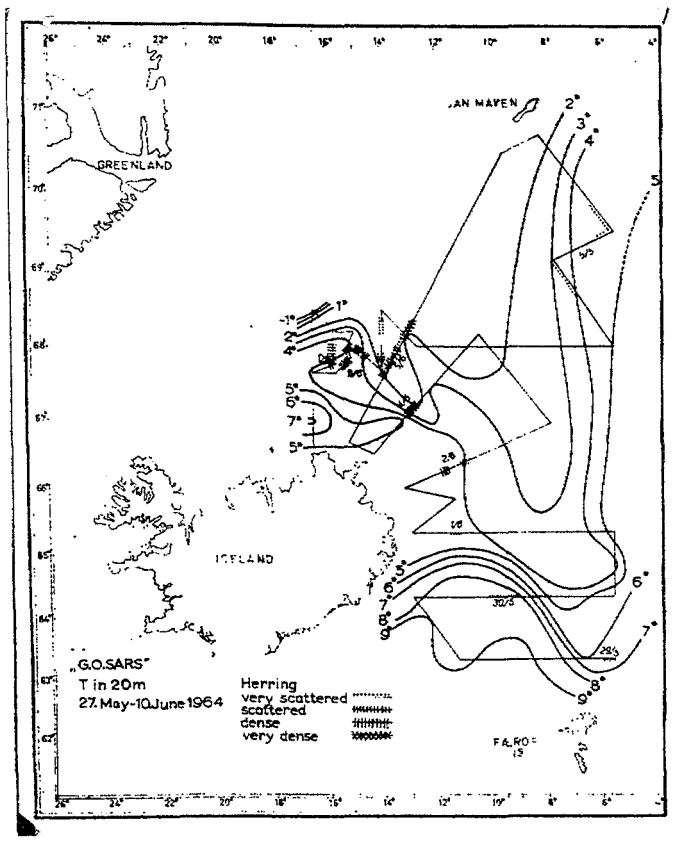

Fig. 11 Herring distribution and temperature at 20 m, 1964

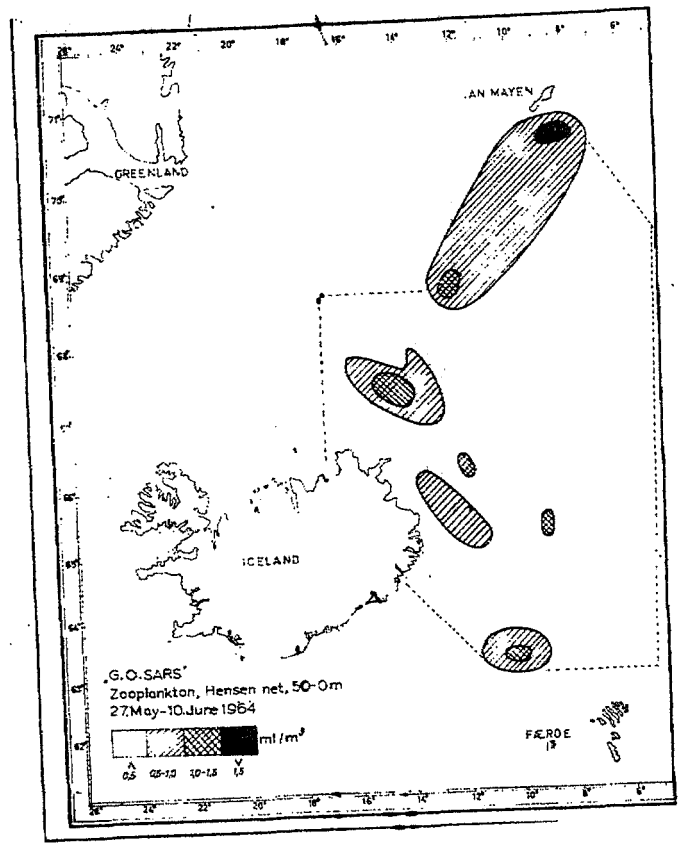

Fig. 12 Zooplankton concentrations, 1964

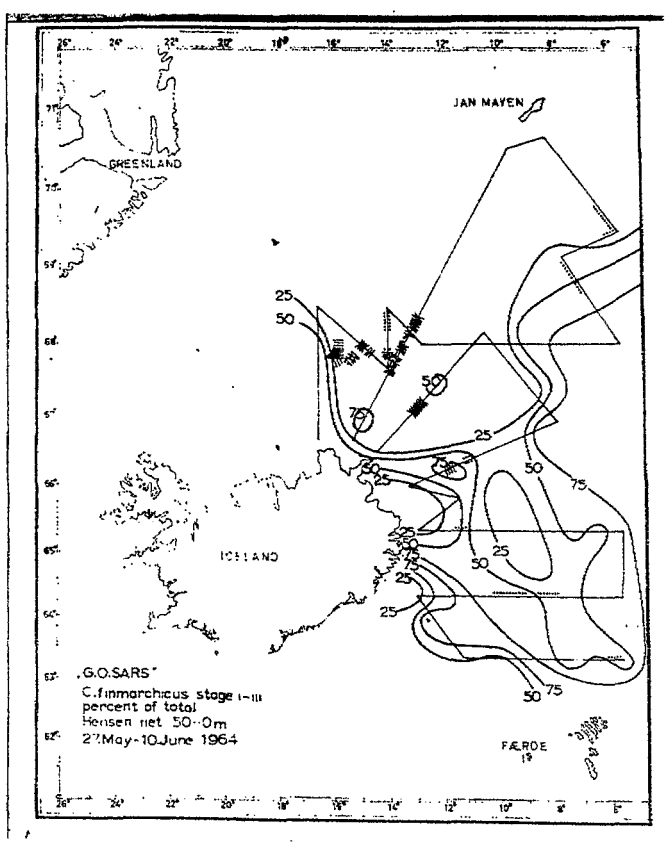

Fig. 13 Herring distribution and percentage distribution of copepodites stages I-III of C. finmarchicus, 27 May - 10 June, 1964

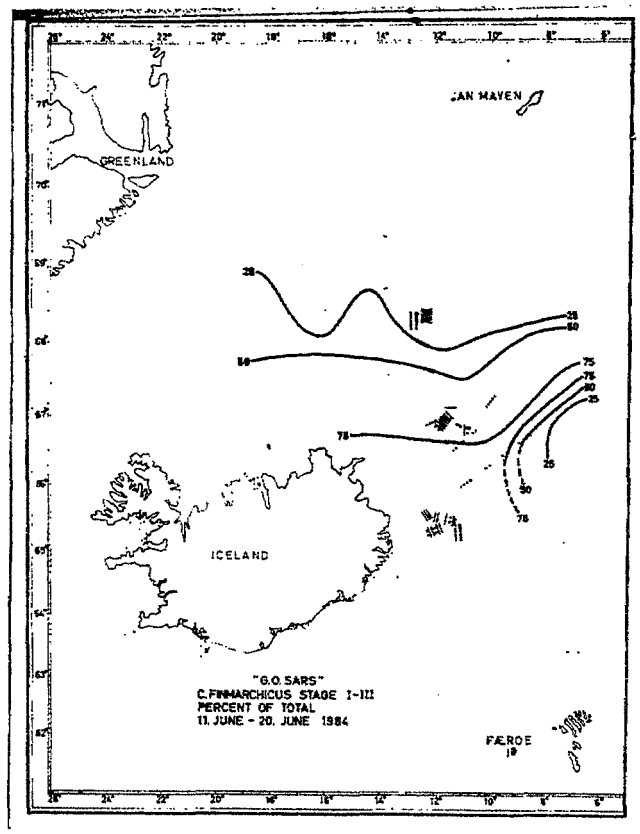

Fig. 14 Herring distribution and percentage distribution of copepodites stages I-III of C. finmarchicus, 11 June - 20 June, 1964