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**A Preliminary Review of the Joint Investigations on the Distribution
of Herring in the Norwegian and Iceland Seas 1950-1970.**

by

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Abstract

The paper reviews the joint international investigation of the distribution of the Atlanto-Scandian herring in relation to temperature during the period prior to the collapse of the stock in the late 1960s. The results of the international surveys clearly show that the ocean climate was relatively mild during 1950-1964. On the other hand the years 1965-1969 were very cold and the nature of the East Icelandic Current changed dramatically. During the mild period the herring were able to cross the cold tongue while during the cold period the migration pattern of the herring as well as the feeding area shifted from north of Iceland to the Bear Island area. The mapping of the migration route of the Atlanto-Scandian herring was of great practical value for the herring industry during the 1950s and in the 1960s.

Keywords: Atlanto-Scandian herring, feeding migration, effect of climate change.

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Introduction

It is well known that the Atlanto-Scandian herring (the Norwegian spring spawners) collapsed during the late 1960s. Prior to the collapse, the herring migrations from the spawning grounds at western Norway across the Norwegian Sea to the feeding grounds off Iceland where intensively studied. However, after the collapse this migration pattern ceased and the remainder of the stock stayed in Norwegian coastal waters for almost 25 years. It is only in the most recent years that the herring have shown some indication of more extensive feeding migrations into the Norwegian Sea. The purpose of this paper is to give a preliminary review of the results of the joint investigations that were carried out prior to the collapse of the Atlanto-Scandian herring.

The interest for these joint surveys probably arose from two different sources. The first one was the fact that the internal tagging of herring, initiated by Dr. Á. Friðriksson and Mr. O. Aasen (1950), had proved that the Atlanto-Scandian herring migrated between the spawning grounds off western Norway and the feeding grounds at Iceland. These tagging experiments began in 1948 and gave immediate results. The migration routes between these two areas were, however, not known at the time but the fact that it had been proved that the herring migrated between Norway and Iceland presented a challenge to monitor these migrations. In addition, Danish scientists working on board the research vessel Dana had located large concentrations of herring northeast of the Faroes at the southeast border of the East Icelandic Current and samples from this area showed that these herring were similar to those found at Norway and Iceland. These investigations were also carried out in 1948.

As a result of this development, it was recommended at the Statutory Meeting of ICES in the autumn of 1948 that "owing to the important changes to be going on in the Atlanto-Scandian stock of herring the countries interested in the northwest-area herring fisheries or fisheries investigations should conform to a common plan of investigations to be coordinated by the chairman of the northwest-area committee. The investigation would cover the Norwegian Sea and would extend as a minimum from June to September. The work would include hydrographical sections, drift bottles release, plankton sampling, echo soundings for herring and if possible the fishing of herring". In conformity with this recommendation Denmark, Iceland, Norway, Scotland and Sweden carried out research in the area in 1949.

The recommendation from 1948 can be considered as the first initiative for the

joint international herring surveys. At the ICES meeting in Amsterdam in 1951, Denmark, Iceland and Norway agreed to cooperate in an extended herring research programme to cover the whole area of the Norwegian and Iceland Seas. As from 1957 the USSR participated in the programme.

These joint surveys had hardly begun when information on the migration routes and summer distribution of the Atlanto-Scandian herring started to pour in as already mentioned. Tåning (1951) located herring north and northeast of the Faroes at the southeast border of the East Icelandic Current in July-August 1948 and in subsequent years. Similarly, Devold (1950) located herring south of Jan Mayen and in the border areas of the East Icelandic Current in 1949 and especially in 1950, when he carried out a herring survey with the new G.O. Sars, using sonar for the first time to locate herring in the Norwegian and Iceland Seas.

As shown in Figure 1 herring concentrations were located in oceanic areas north of the Faroes, east of Iceland and in particular between NE-Iceland and Jan Mayen as well as east of Jan Mayen. These findings were of great practical value because the herring fishery at N-Iceland had failed in 1950 as in the previous five years. Several Norwegian herring vessels were able to take advantage of the information obtained by G.O. Sars and start an oceanic fishery. It is also of interest to note that large concentrations of 0-group herring (1950 year class) were registered in the eastern Norwegian Sea off N-Norway. The 1951 Norwegian survey followed a similar plan (Fig. 2) as that developed in 1950.

In subsequent years the joint meetings of scientists participating in the surveys were held at the end of June each year. During these meetings it became the practice to chart herring observations along with the distribution of temperature at the depth of 20 meters. The herring observations were usually presented in four categories, i.e. very scattered, scattered, dense and very dense. The charts from the period 1950-1960 had been kept in the archives of the Marine Research Institute, Reykjavík. The 1961 chart comes from an ICES contribution by the present authors. Thereafter the charts were reproduced from those printed in *Annales Biologiques*.

The distribution charts of herring and temperature at 20 m depth

1952

The distribution temperature at 20 m as well as that of herring during the first joint

Scandinavian (Denmark - Iceland - Norway) survey is shown in Figure 3.

Compared to the subsequent warm years in 1954-1957 it is clear that the 3°C isotherm reaches much farther south in 1952 than was the case later on. Accordingly, the main herring concentrations were located in the mixed waters relatively close to the Faroes.

1953

The distribution of the temperature at 20 m as well as that of the herring during the joint investigations in 1953 is shown in Figure 4. The extension of the 3° isotherm is much more restricted than in 1952 and herring concentrations were observed over wide areas right accros the Norwegian Sea, extending into the mixed waters of the East Icelandic Current where the temperature was 3-7°C.

1954

The chart from 1954 is shown in Figure 5. Compared to later periods the temperature reflecting the East Icelandic Current was exceedingly mild. Thus, the lowest temperature at 20 meters was 2°C northeast of Iceland and the herring distribution, as shown by asdic (sonar) contacts was mainly along the eastern and southern border of the East Icelandic current. It is worth noting that herring were also registered right across the cold tongue at temperatures between about 2 and 3 degrees. Another feature of interest is the wide distribution of the herring near the southern limit of the East Icelandic Current in the area north of the Faroes. Some herring were also located far offshore to the north of Iceland at a temperature of about 4°C,

1955

The distribution of herring in 1955 is shown in Figure 6. Here we note that the herring were distributed over a wide area, some of them at a temperature of 8°C in the eastern part of the Norwegian Sea. As in 1954, considerable concentrations were located northeast and north of the Faroes. Scattered registrations of herring were observed in a wide area between Iceland and Jan Mayen and also in offshore waters north of Iceland at temperatures varying from about 2-5°C. It is also worth noting that the 3° isotherm extends much farther east and south than in 1954. This could possibly be associated with variation in the warming of the surface layers due to solar radiation.

1956

The distribution of temperature at 20 meters depth and herring in 1956 is shown in Figure 7. Once again the water masses of low temperature had a limited distribution between Iceland and Jan Mayen and the herring were, as in 1955, observed over exceedingly wide areas. Thus, either dense or scattered echoes were located in the eastern part of the Norwegian Sea and very dense concentrations were located north and northeast of the Faroes over a wide area in the southern parts of the East Icelandic Current. In addition, scattered and dense concentrations of herring stretched right across the East Icelandic Current northeast of Iceland in temperatures between 2 and 3°C. Very dense concentrations at even lower temperatures of 1-2° C were located in the offshore waters off the eastern part of North Iceland between 67°30'N and 68°N from 12°W to 15°W. It is also worth noting that in 1956 as well as in 1955 dense concentrations of herring were located northwest of Iceland at the eastern border of the East-Greenland Current.

1957

The distribution of temperature at 20 meters depth and that of herring in May-June 1957 is shown in Figure 8 (Anon 1957). Once again the main hydrographic feature of this temperature distribution is the relatively mild character of the East Icelandic Current with 2°C as the lowest temperature in the area between Iceland and Jan Mayen. Like in 1956, dense concentrations of herring were located north of the Faroes but also in the northeastern part of the Norwegian Sea. Very dense concentrations were located in the southeast border of the East Icelandic Current east of Iceland as well as dense concentrations extending right across the cold tongue midway between Iceland and Jan Mayen at temperature between 2° and 3°C. It should also be noted that dense concentrations of herring were located off the northwestern peninsula of Iceland and off the western north coast.

1958

The distribution of temperature at 20 m depth and that of herring in May-June is shown in Figure 9. It is clear that 1958 must be classified as a cold year compared to several preceding years.

The situation off the N-coast of Iceland was characterized by a cold tongue which reached the coast and prevented any influx of Atlantic water to the area north of Iceland.

Similarly, the 3°C isotherm in the East Icelandic Current extended farther to southeast than in the preceding years.

The herring were mainly located in the mixed waters between the Faroes and E-Iceland. Dense concentrations were also located in the core of the East Icelandic Current northeast of Langanes where the temperature was about 2°C.

1959

The distribution of temperature at 20 meters and the distribution of herring in May-June 1959 is shown in Figure 10 (Anon 1961). In the report on the joint surveys it is stated that the waters of the East Icelandic Current and of the Jan Mayen branch of East-Greenland Current were considerably colder than usual. It is also stated that the eastward extension of the East-Icelandic current, as given by the 5° isotherm at 20 meters depth, was wider than in any year since 1954 except in 1955, when another tongue of cold water stretched farther eastwards in a restricted area as a local phenomenon. On the herring distribution the report states:

"Concentrations of herring were smaller than in previous years especially in the northern part of the Norwegian Sea. Only small concentrations were found in the area north of Iceland."

It appears that the main concentrations of herring during June 1959 were located along the southern and western border of the East Icelandic Current. Thus the distribution of herring was much reduced in 1959 as compared to the period 1950-1957. This is probably a reflection of the decreasing stock abundance of Atlanto-Scandian herring during a period of poor recruitment.

1960

The report from the joint 1960 surveys was presented at the Council meeting in 1960 (Anon 1960). This report was, however, not published in *Annales Biologiques* and in the copy available to the authors no chart was presented. However, a copy of the original chart was located in the archives of the MRI. In addition Jakobsson (1978) presented redrawn versions of all the joint survey charts for the period 1960-1968.

In the report presented at the ICES statutory meeting 1960 it is stated that in the southern part of the Norwegian Sea north of the Faroes as well as north of Iceland, the influx of relatively warm Atlantic water had pushed the borderline against the cold East Icelandic Current (the cold tongue) further to the north than usual. The 5°C isotherm at

20 meters was pushed farther to the west and north than was the case during the previous six years. This is clearly shown in Figure 11.

The distribution of herring was said to be characterized by three main features: "The good concentration of herring off the north coast of Iceland, the absence of herring in the eastern and the northern parts of the Norwegian Sea and, finally, by good concentrations of herring found in the region northeast of the Faroe Islands, as registered by the Soviet drifters." It should be noted that these commercially located herring concentrations are shown as scattered in the distribution chart as they were recorded by the research vessels although they gave good driftnet catches. It is clear that the distribution of herring is similar to that of 1959 with no concentrations in the eastern part of the Norwegian Sea. The difference is, however, that in 1960 the research vessels registered good concentrations of herring off North Iceland near the border of the East-Greenland Current.

1961

The result of the joint surveys in 1961 were presented to the ICES statutory meeting that year in a paper by Jakobson and Ostvedt (1961). Only Icelandic and Norwegian research vessels participated in the joint investigations this year. The temperature at 20 meters (Fig. 12) was somewhat above the average off the western north coast of Iceland but off the east coast it was about normal as compared with the average of the previous 10 years. The border areas of the warm Atlantic and the cold waters of the East Icelandic Current, although about normal, lie considerably closer to the north coast than in the exceptionally warm year of 1960.

On the distribution of herring it is stated in the report that the herring concentrations were recorded in three areas:

- a) at the edge of the shelf off the northwest coast of Iceland a considerably quantity was recorded,
- b) off the eastern part of the north coast from 11°W to 17° W between 67° and 68° N where considerable number of both small and large shoals were found, nearly all of them above 50 meters depth and
- c) scattered shoals were recorded north of the Faroes between 64°N and 65°N from 7°W to 9°W.

Compared with the previous year, 1960 it is clear that the north coast herring concentrations had a more easterly distribution than in 1961. A marked change in

shoaling behaviour of the herring concentrations was observed in these cold water areas since large shoals were frequently met with at temperatures below 3°C, where they were rarely encountered in 1960.

In the paper it is also stated that "during the previous years the investigations have shown that the summer herring fishery of the north coast of Iceland is based on feeding migration of both Icelandic herring, mainly entering the fishing grounds from the west, and the Norwegian herring approaching from the east. This migration pattern is shown more clearly now than in any previous year of the joint investigations".

1962

The distribution of temperature and herring as registered by the Icelandic and the Norwegian research vessels during the period 26 May to 8 June 1962 is shown in Figure 13. In the report of the joint meeting (Anon 1964) it is stated that: On the whole the temperatures at 20 and 100 meters during the period 26 May-6 June 1962 were approximately the same as those given by Stefánsson (1962) for the period 1950-1960.

It is further stated that from 14 to 16 June the work was hampered by strong northeasterly winds during which there was an inflow of cold water to the northeastern part of the area. Thus it was impossible to present a chart of the temperature distribution covering the whole period of investigation.

On the herring distribution the reports states that: in the area north of the Faroes and off the east coast of Iceland very scattered concentrations were recorded over large areas. Off the northeast coast dense concentrations were found. Generally these were encountered in waters below 3°C extending in to waters below 2°C. Although the major part of these concentrations most probably were westward moving Norwegian spring spawners, the good concentrations recorded northwest of Kolbeinsey in positions 67° 40'-68° N (between 20°-21° W) indicate that an influx of Icelandic herring had already taken place during the first week of June.

It is further indicated in the report that very little if any herring were recorded in the eastern and northeastern part of the Norwegian Sea and in conclusion it is stated that the joint investigations show that during the first half of June the main herring concentrations were located in the area off the eastern north coast of Iceland and within the limits of the southern half of the Norwegian Sea south of 66°N.

1963

In the 1963 report (Anon 1965) the herring distribution is shown on one chart without any temperature information (Fig. 14). In fact there is no other picture in the published report. Therefore, the redrawn chart shown by Jakobsson (1978) with the temperature distribution off North Iceland and in the East Icelandic Current is shown here as well (Fig. 15). In the published report it is stated that the most characteristic feature of the temperature conditions of the waters of the East Icelandic Current was a sharp decrease in temperature as compared with that of 1962 (which was a normal year). The current has increased in strength and as a result the 3°C isotherm was found 120 nautical miles farther to the southeast than in 1962. The strong influx of Polar water resulted in unusually close position of the ice border to the northwest coast of Iceland.

On the herring distribution the report states:

During the period 22 May to 5 June in the waters between Faroes, Jan Mayen and east and northeast of Iceland, herring concentrations were mainly observed in two areas, i.e. from 64°N to 65°N at 8°W and from 66°30'N to 68°N between 8°W and 10°W. The densest concentrations were found at temperatures between 0° and 2° approximately 150 nautical miles ENE of Langanes. It is further stated that in general the herring concentrations found during this year's (1963) investigations northwest, north and northeast of Iceland were not as extensive as in 1962.

Samples of the herring in the area north and northeast of Iceland showed that they consisted mainly of old Norwegian herring whereas the Soviet investigations had shown that the younger year classes were located in the central and eastern part of the Norwegian Sea. At the time of investigation these concentrations were migrating towards north and northeast. This was a considerable change because herring concentrations had not been observed in the eastern part of the Norwegian Sea since 1957. This is an indication of the fact that the strong 1959 year class had migrated out of the Barent Sea and in to the Norwegian Sea.

1964

Two charts are published in the report on the joint investigations for 1964 (Anon 1966) one showing the distribution of the herring and the other showing the distribution of temperature at 20 meters (Figs. 16 and 17). It is quite clear from the temperature chart that this year (1964) the Atlantic influence north and northeast of Iceland was extremely strong and similar to that of 1954 and 1960 (which were the warmest years during the

period under discussion).

It is stated in the report that the water of the East Icelandic Current had a relatively high temperature. The statement that the 3°C isotherm at 20 meters was about 230 nautical miles farther to the north than in 1963 is, however, not verified in the published temperature charts which show the 3°C isotherm in similar positions in 1963 and 1964. It is however clear that the 0° and 1°C isotherms are absent in the temperature chart of the East Icelandic Current from 1964 while they are very prominent in the chart from 1963.

As regards the Iceland and the western Norwegian Seas it is clear that the main concentrations of herring were found in the area northeast of Langanes, from 67°30'N to 68°30'N between 12°W and 16°W. In addition, dense concentration were found from 66°20'N to 67°20'N between 10°W and 12°W during mid-June. It is further stated in the report that the distribution of the first invasion of herring to the area northeast of Iceland was similar to that of 1963 and it migrated in a north-westerly direction until about 10 June when it dispersed or moved northeast. It is also noted that dense concentrations of herring assembled in the middle of June off the east coast of Iceland and were expected to remain in this area during the summer.

In addition to these herring concentrations in the western part of the East Icelandic Current, herring concentrations were located in the central and northeastern Norwegian Sea. These concentrations were similar to those observed in 1963 and represented the western migration of the 1959 year class. Thus 1963 and 1964 are similar to the years prior to 1959 when herring concentrations were also located in the central and northeastern part of the Norwegian Sea.

1965

In 1965 the joint investigations started at the end of May and lasted until 20 June (Anon 1967). Prior to this period, Icelandic scientists on board the *Ægir* had made a preliminary survey in the area west, north and east of Iceland during the period 8 to 24 May. It became clear during this preliminary survey that both the nature and the extension of the East Icelandic Current had completely changed with a greatly increased component of pure Polar water with low salinity and very low temperature. Furthermore, the cold water had a much greater extension to the east and south than in any previous years of investigation. This was confirmed by the joint investigations in June and the main conclusion was as follows:

Despite the fact that the Atlantic influx west of Iceland was about normal, no real

Atlantic influx was found north of Iceland in May and June. The temperatures north and east of Iceland found this spring (1965) are the lowest found in any previous investigation during the last 16 years.

The main features of the temperature distribution at 20 meters are shown in Figure 18. The distribution of herring is shown in Figure 19 and in the report the following general conclusions on the herring distribution were reached:

(1) In contrast to previous years the herring concentrations, recorded east of Langanes in May, did not migrate further west but moved north or north-east. The herring shoals kept to cold water (below 3° C) and followed the eastern half of the East Icelandic Current. The north-western migration of herring to the areas north of Langanes and Melrakkaslétta, as observed in 1963 and 1964, were this year in June probably prevented by the most extraordinary conditions off the northeast coast of Iceland.

(2) In the Norwegian Sea north of 69°00'N the distribution of herring concentrations was similar to that of 1964. In the central part of the investigated area between 65°00'N and 69°00'N herring concentration were distributed over a smaller area, chiefly between 8°30'W and 00°00'. South of 65°00'N herring concentrations were distributed in the same way as in 1964. It seems that the herring concentrations with the largest density were generally found farther to the southwest than in 1964.

(3) It is expected that the herring concentrations located in the southwestern part of the Norwegian Sea and along the east coast of Iceland during the coming weeks will show a more westerly distribution and concentrate off the east coast of Iceland. But unless the zooplankton densities off the east coast of Iceland increase considerably, thus providing better feeding conditions, the herring may have a more offshore distribution this year as compared with 1964.

(4) No invasion of Icelandic springspawners has been observed off the west or north coasts of Iceland and it is unlikely that within the coming weeks any herring concentrations of commercial value will be distributed off the middle and the western part of the north coast of Iceland.

1966

In the report of the joint investigations on the Atlanto-Scandian herring distribution in the spring of 1966 (Anon 1968) it was stated that although the sea climate north and north-east of Iceland in 1966 was considerably milder than in 1965 it must be concluded that the temperatures in the first half of June were in general below normal in the

Norwegian and Iceland Seas. The temperatures of the Norwegian Current in the Norwegian Sea and the Irminger current branch north of Iceland were at the lowest and the influence of the cold East-Icelandic Current was considered strong (Fig. 20).

The main conclusion on the herring distribution (Fig. 21) in the report was as follows:

The greatest number of herring shoals was registered in the area between 68°N and 64°15'N from 10°W to 4°W. South of 64°N no herring concentrations were found. The investigations carried out in the area north of Iceland did not reveal any herring concentrations.

It was further concluded that in spite of somewhat milder conditions in June than in May in the area north of Iceland it is thought that appreciable concentrations of herring will probably not migrate to this area and if so not until later in the summer. It was also pointed out that in 1965 the main concentrations were distributed between 12°W and 8°W but this year (1966) they were found from 10°W to 6°W. It is also stated that better feeding conditions caused a more easterly distribution of the herring, since zooplankton biomasses were much lower in the waters along the western edge of the East-Icelandic current than farther east.

1967

In the report of the joint investigations on the Atlanto-Scandian herring in 1967 (Anon 1968) the most outstanding hydrographical features (Fig. 22) in the Iceland Sea and the Norwegian Sea in June 1967 were summarized as follows:

- (1) The extension of drift-ice along the north coast of Iceland in May and early June 1967 was greater than in any other year since 1918, with the exception of 1965 and possibly 1949.
- (2) In early June the temperament in the upper layers west of Iceland was slightly below normal.
- (3) In the shelf area north of Iceland the temperatures in May and early June in the uppermost 300 meters were 2-5° below normal. Thus the spring of 1967 probably rates as the coldest during the last 40 years. The extremely low temperatures found at all levels are the result of a a) abnormally great distribution of ice in the area, b) exceptionally weak influx of Atlantic water from the west and c) low air temperatures and a slow warming up of the surface layers by the sun.
- (4) In the waters of the East Icelandic Current between Iceland and Jan Mayen and east

of Iceland temperature anomalies ranged between -0.7 and -1.7° . In this area the hydrographic conditions resembled those of the previous cold years.

(5) The temperatures of the waters of the eastern branch of the Norwegian Current were $0.5-1.0^{\circ}$ below normal and also lower than in 1966. However, in the intermediate waters (200-500 m) of the western branch of the Norwegian Current positive anomalies ($1.0-1.2^{\circ}$) predominated.

(6) In view of the very low surface temperatures and heat content of the Norwegian Sea as a whole, 1967 may be classified as belonging to the group of recent very cold years.

The distribution of herring concentrations in May-June 1967 is shown in Fig. 23 and in the report the main conclusions on the herring distribution are as follows:

(1) On the whole the herring had a much more easterly distribution than in previous years. During the month of May no significant concentrations were recorded west of $2^{\circ}00'W$ as compared with $08^{\circ}00'W$ in 1966 and $10^{\circ}00'W$ in 1965. The shoals migrated north- and westwards and by mid June they were chiefly located in the area from $68^{\circ}30'N$ to $69^{\circ}45'N$ between $01^{\circ}30'W$ and $06^{\circ}00'W$. Thus, the herring were at all times distributed considerably farther to the east than in previous years.

(2) While it seems unreasonable to attribute a displacement of this magnitude to direct influence of the low water temperatures on the herring, it is likely that deteriorating feeding conditions farther to the west, caused by the strong influence of the East Icelandic Current, discouraged migration in that direction.

(3) Since the situation in 1967 resembles physically and biologically that of the recent cold years it was estimated that during the first half of the summer of 1967 the herring would be distributed mainly over an area south and south-east of Jan Mayen with a considerable part of the stock migrating to feeding grounds west of Bear Island. A more westerly distribution was not expected until late August or September, i.e. not until migrations to the overwintering grounds of Iceland begin.

(4) No migration of Icelandic spring spawners to the area northwest and north of Iceland was observed. In view of the low level of the stock as well as the unfavourable conditions in north Icelandic waters, no herring concentrations of commercial importance were expected to be found there this year.

1968

In the report of the joint Icelandic, Norwegian and Soviet investigations on the Atlanto-Scandian herring in 1968 the main features of the temperature distribution and

oceanic climate in 1968 were summarized in the report as follows:

Remarkable conditions were found in the area between Iceland and Jan Mayen and east of Iceland in the East Icelandic Current (Fig. 24). There the temperatures ranged from -1.8°C to 0°C in a wide area, much wider than in any previous investigation. The mean temperatures in the 0 to 200 m layer were about 1° below normal.

The cold tongue covered about 240 miles of the Langanes-Jan Mayen section and was divided into two branches east of Iceland, one extending SE towards the Faroe Islands, and another one extending along the east coast of Iceland as far south as Hornafjörður (in early June). Between these branches a tongue of warm water was observed with temperatures up to 7°C . The distribution of the 0° isotherm at 50 m depth in June indicates the boundaries of the cold tongue (Fig. 25). Its southern boundary east of Iceland was located at $65^{\circ}00'\text{N}$, compared with the normal position at $68^{\circ}30'\text{N}$, and its eastern boundary was located at about 7°W . Even more noteworthy is the location of the western boundary of the cold tongue, i.e. at the Icelandic coast from Skjálfandi in the north to Reydarfjörður in the southeast.

Thus, the low temperature and salinities observed in this area since 1964 still prevail in 1968 indicating an increasing proportion of Polar water in the Arctic water of the East Icelandic Current.

In the report the following conclusions are drawn on the distribution of herring in 1968:

- (1) On the whole the herring had a much more easterly distribution (Fig. 24) than in previous years. The shoals quickly migrated to the northeast and Norwegian Sea and by 20 June had nearly reached the latitude of Bear Island, whereas at the same time in June 1967 the herring were distributed considerably more to the south and west. In June this year no herring concentrations were observed south of 70°N and to the west of the 0 meridian. At the time of the meeting the great majority of the adult stock of the Atlanto-Scandian herring seemed to be assembled to the west and southwest of Bear Island.
- (2) Hydrographic investigations show that 1968 is an extremely cold year, especially as regards the western half of the Norwegian Sea. This fact, together with deteriorating feeding conditions in that part of the Norwegian Sea is thought to be the main cause of such an easterly distribution.
- (3) Since the situation in 1968 resembles both physically and biologically that of the recent cold years, in particular 1967, it is thought that the herring stock will be distributed over the area west of Bear Island for the coming months and not show a

westerly distribution until after mid-August with the onset of the migration to the overwintering grounds off East Iceland.

1969

The distribution of temperature at 20 m and that of herring in May-June 1969 is shown in Figure 26. Once again there was no sign of any influx of Atlantic water north and east of Iceland. The cold water of the East Icelandic Current was found to be very extensive to the east and in general it was found that the temperature situation off Northeast Iceland was similar to that of 1965, 1967 and 1968 (Anon 1971).

Herring were only located in a small area in the eastern Norwegian Sea and migrated quickly northwards as shown in Figure 27. North of 74°N the herring was often found where capelin also occurred. Identification of the echo traces was therefore often difficult. In the report it was stated that, according to the opinion of the participating scientists the stock size was very small.

This was in fact the last time that contact was made with herring during the joint May-June surveys until the stock recovered in the mid-1990s.

Discussion

Despite the fact that in this preliminary review only the temperature at 20 m depth is presented, it is clear that the charts give a relatively clear picture of the oceanic climate during the almost two decades which the investigations cover. Thus one can divide the period into two parts i.e. warm years during 1950-1964 and cold years from 1965 onwards. Within the warm period one can distinguish especially warm years like 1954, 1960 and 1964, and unusually cold years like 1958 and 1963. During the cold period, 1966 is milder than the other very cold years in that period.

With regard to the distribution of herring, it is clear that the adult herring were mainly concentrated in the western part of the Norwegian Sea and in the Iceland Sea whereas the younger year classes, when they were available, were located in the eastern and northeastern part of the area under investigation. Right at the beginning of the investigations it was observed that the adult herring were often distributed along the frontal areas of the East Icelandic Current, both on the east side (Polar front) and on the

western and southwestern side of the cold water off North and Northeast Iceland. Therefore, it became common to describe the distribution of the herring in the early years of these investigations as depending entirely on the so-called cold tongue northeast of Iceland.

Thus, Devold (1963) gave in his paper "The life history of the Atlanto-Scandian Herring" overview charts showing that absolutely no herring should have occurred within the East Icelandic Current during the time of the joint surveys. On the other hand, if one looks at the actual distribution charts from 1950 onwards, one can see that year after year there are marked dense concentrations of herring along a section right across the East Icelandic Current. This feature of the herring distribution was e.g. observed in 1954-1957 (Figs. 5-8) at temperatures ranging from 1-5°C. This was also crystal clear in 1962 (Fig. 13) when very dense concentrations of herring were observed in the core of the East Icelandic Current.

During very warm years, the temperature at 20 m in this area was usually between 4° and 5°C while in later years like 1962, which was classified as having a temperature near normal, the herring in the East Icelandic Current were located at temperature between 2° and 3°C and even below 2°C. It is also clear from subsequent investigations during the later part of the summer that these herring migrated westward and assembled at the western and southern border of the East Icelandic Current off North Iceland.

It is therefore quite clear from the distribution charts of temperature and herring that during the warm period from 1950-1964 the East Icelandic Current was no real hindrance to the westward feeding migration of the Atlanto-Scandian herring. It is equally clear that on arriving at the Polar Front, the herring assembled there often in large and easily located shoals. They waited for the temperature in the surface layers to increase due to solar radiation in May and June and then migrated across the cold water in the surface layer above the thermocline, feeding intently on their way across the East Icelandic Current. In most years, the herring migrated across the cold tongue in very dense but small shoals while assembling again into larger shoals, more attractive for fishing, on the western side of the East Icelandic Current. But in some years, like 1962, a formation of large shoals in the core of the East Icelandic Current took place.

In 1965, the nature of the East Icelandic Current changed and became characterized by very cold Polar water with low salinity. It was quite natural that the herring found it impossible to penetrate through these very hostile and cold waters which flowed southeastwards between Iceland and Jan Mayen and reached more than half way

to the Faroes.

In addition to demonstrating migrations of Norwegian spring spawning herring to the feeding grounds at N-Iceland, the joint surveys also showed the migrations of Icelandic spring spawners into the feeding area from the west. This was very clear during the period 1957-1962, i.e. while that stock was at a relatively high abundance level.

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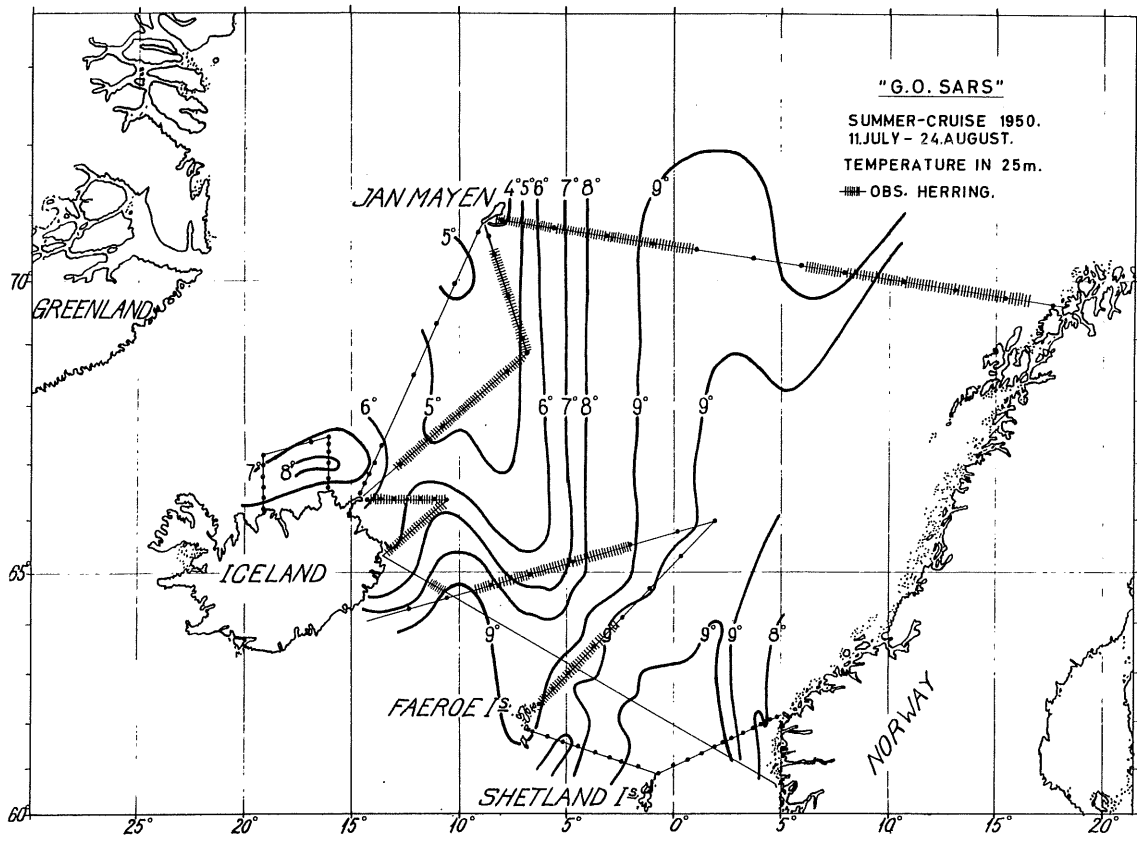


Fig. 1. Herring distribution and temperature at 25 m.

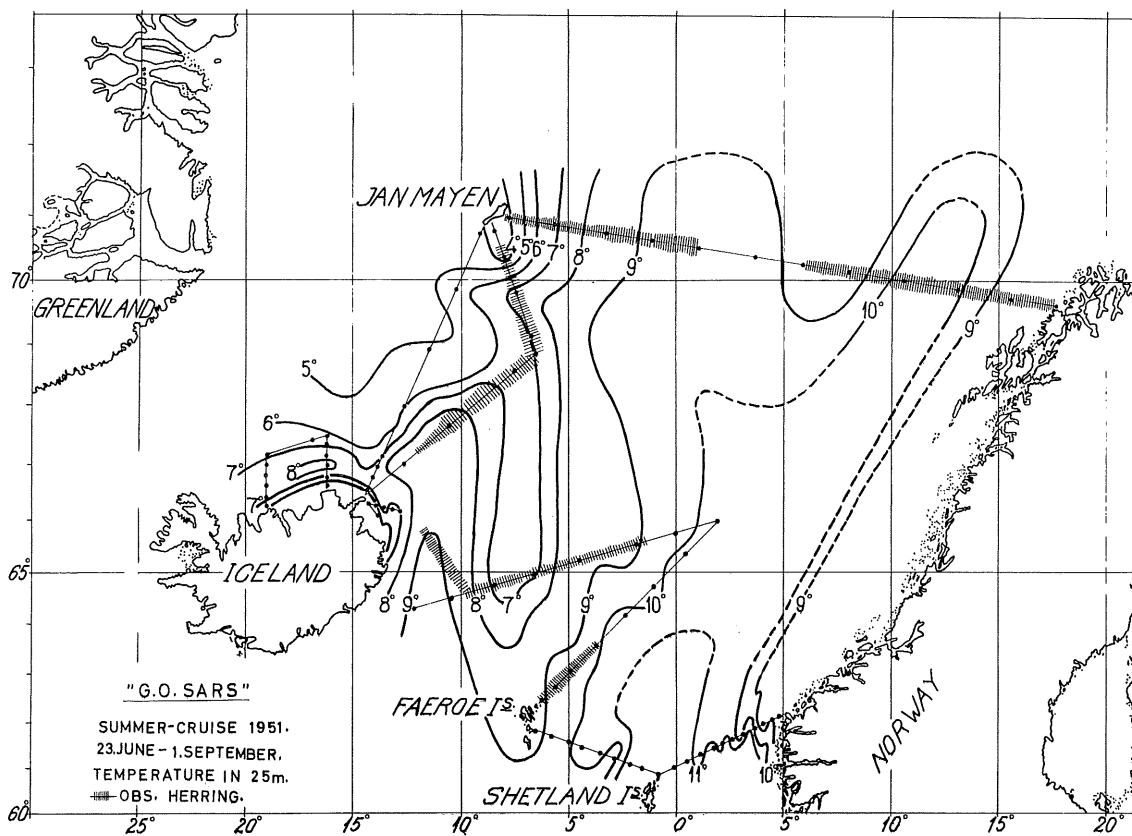


Fig. 2. Herring distribution and temperature at 25 m 1951.

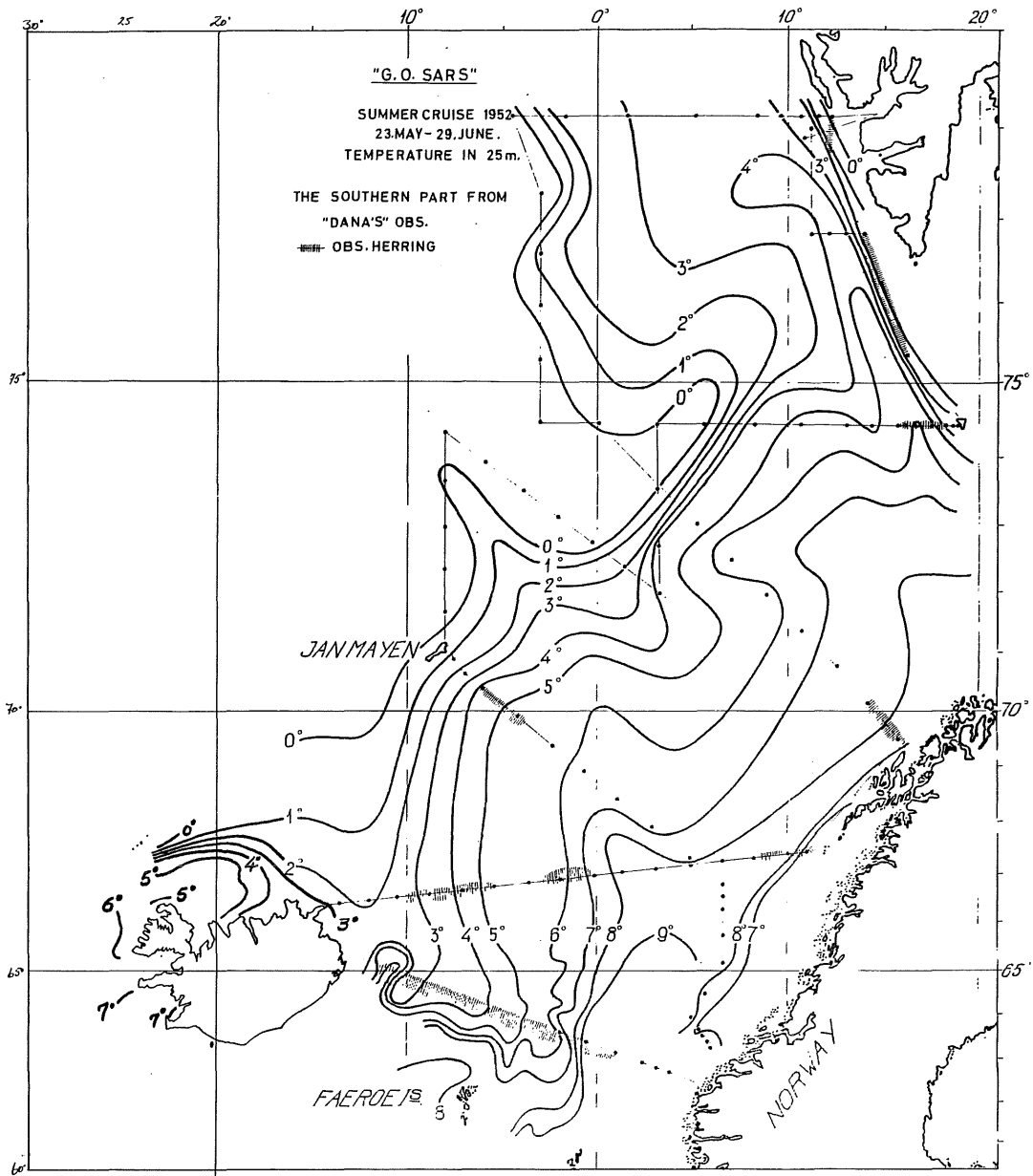


Fig. 3. Herring distribution and temperature at 25 m and 20 m 1952.

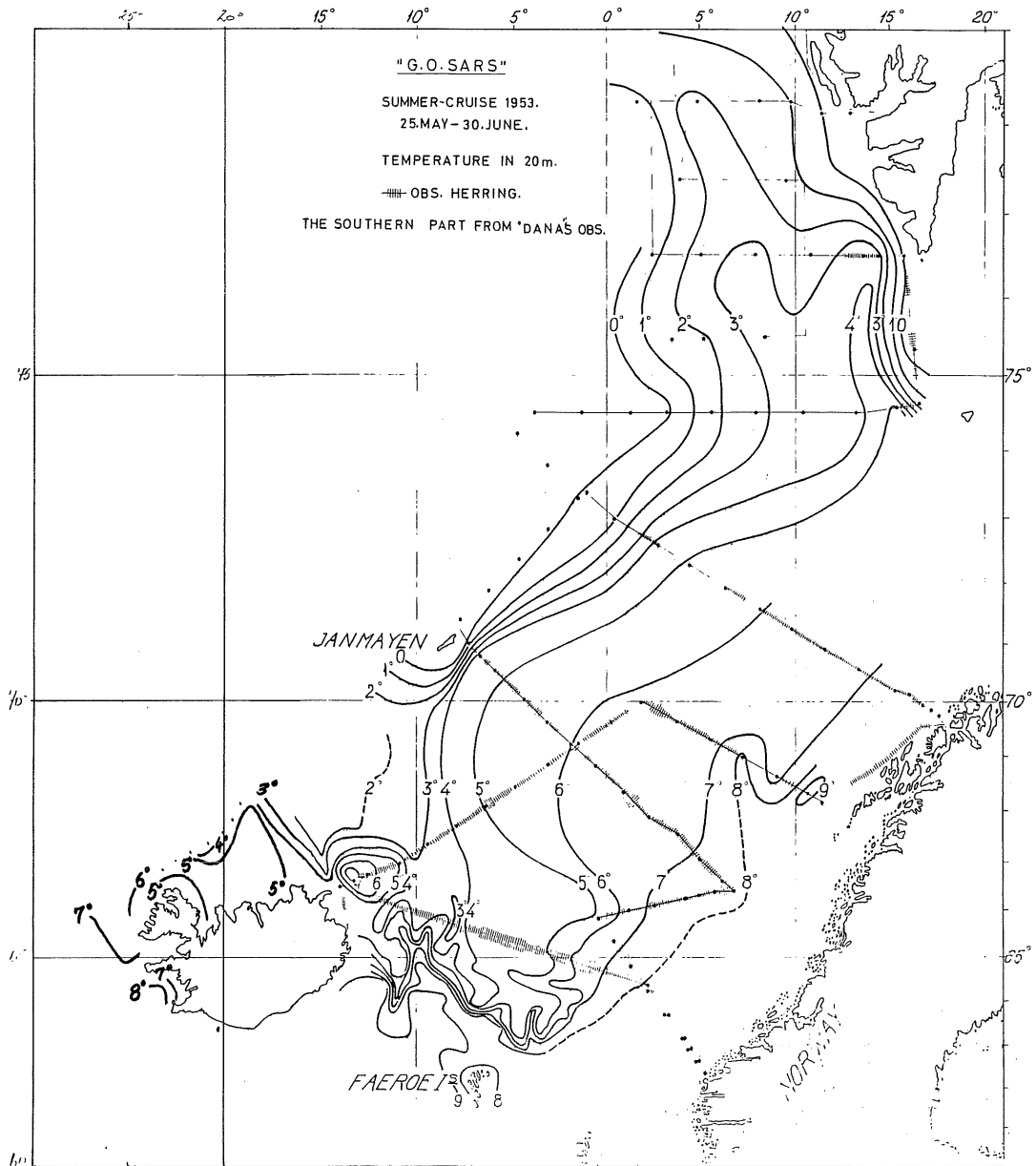


Fig. 4. Herring distribution and temperature at 20 m 1953.

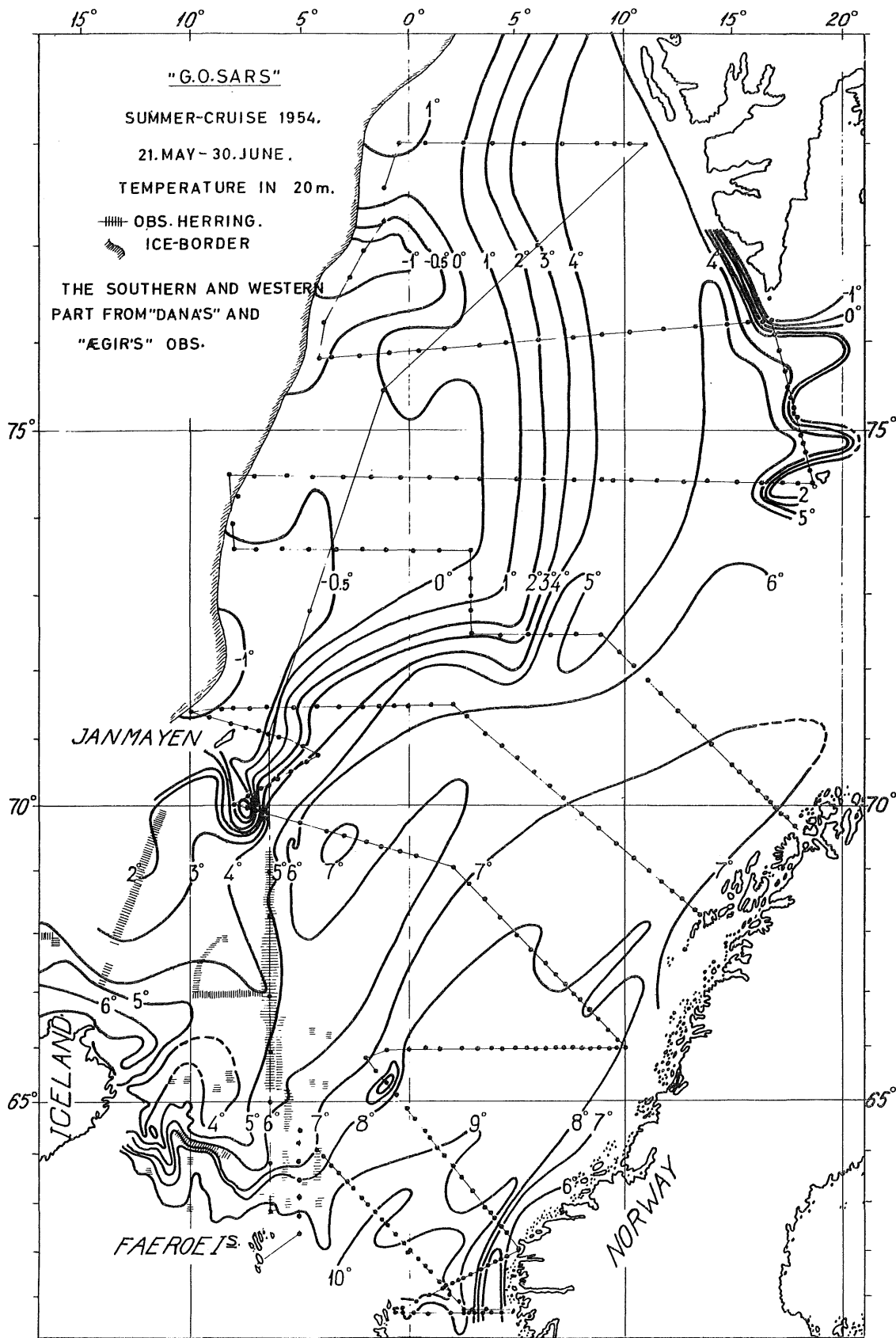


Fig. 5. Herring distribution and temperature at 20 m 1954.

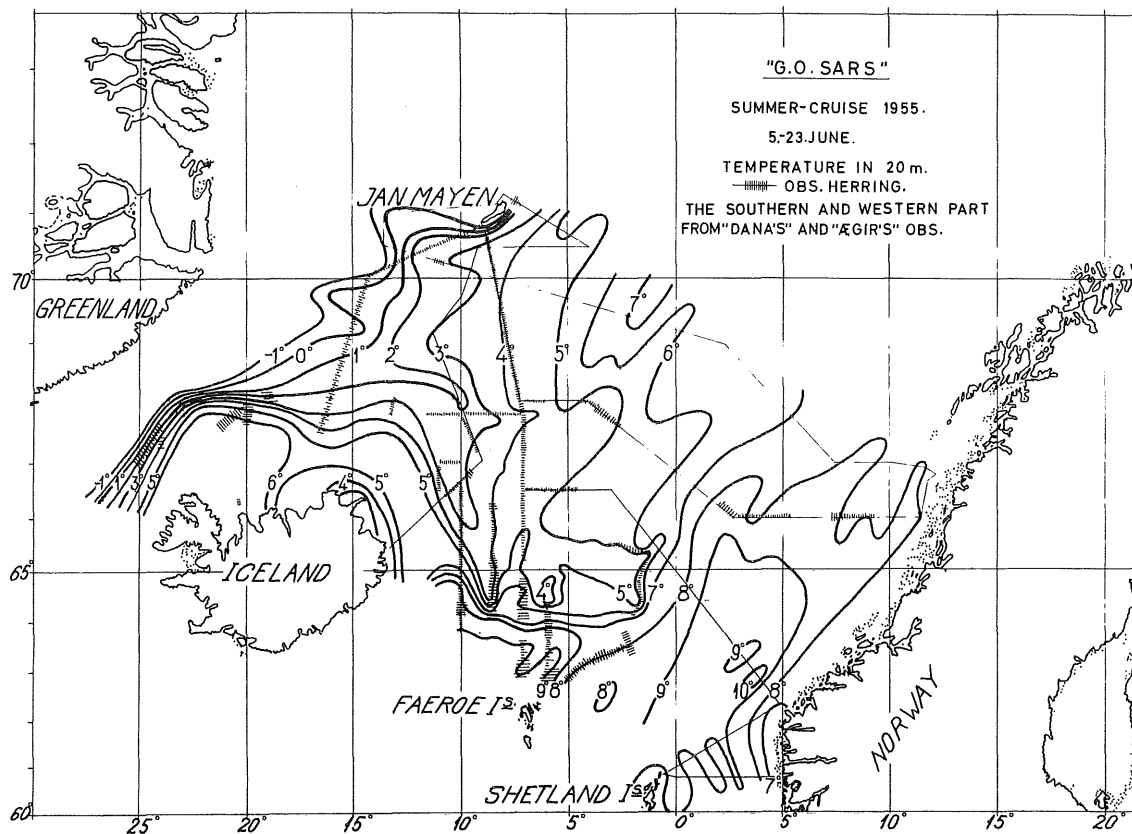


Fig. 6. Herring distribution and temperature at 20 m 1955.

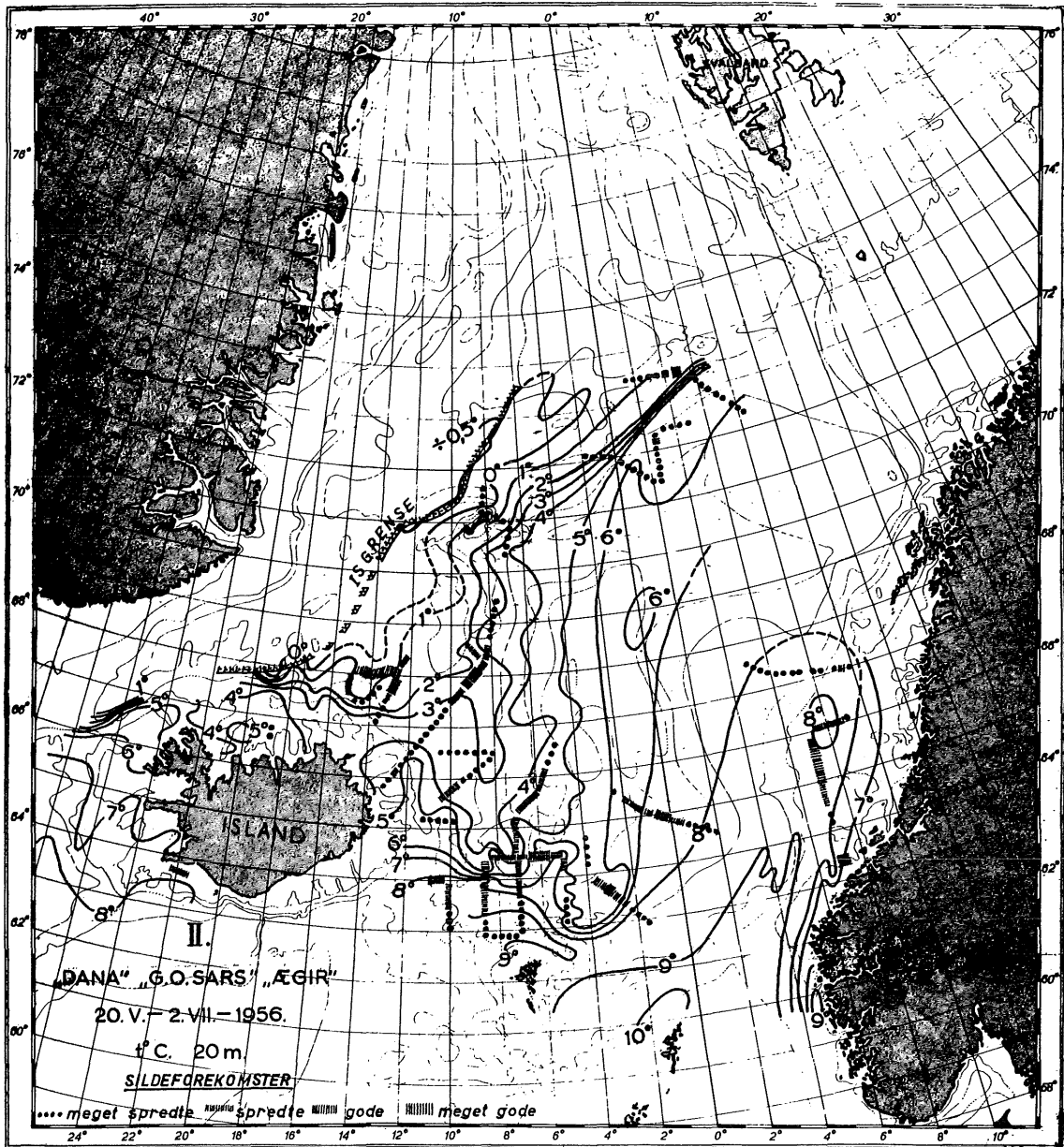


Fig. 7. Herring distribution and temperature at 20 m 1956.

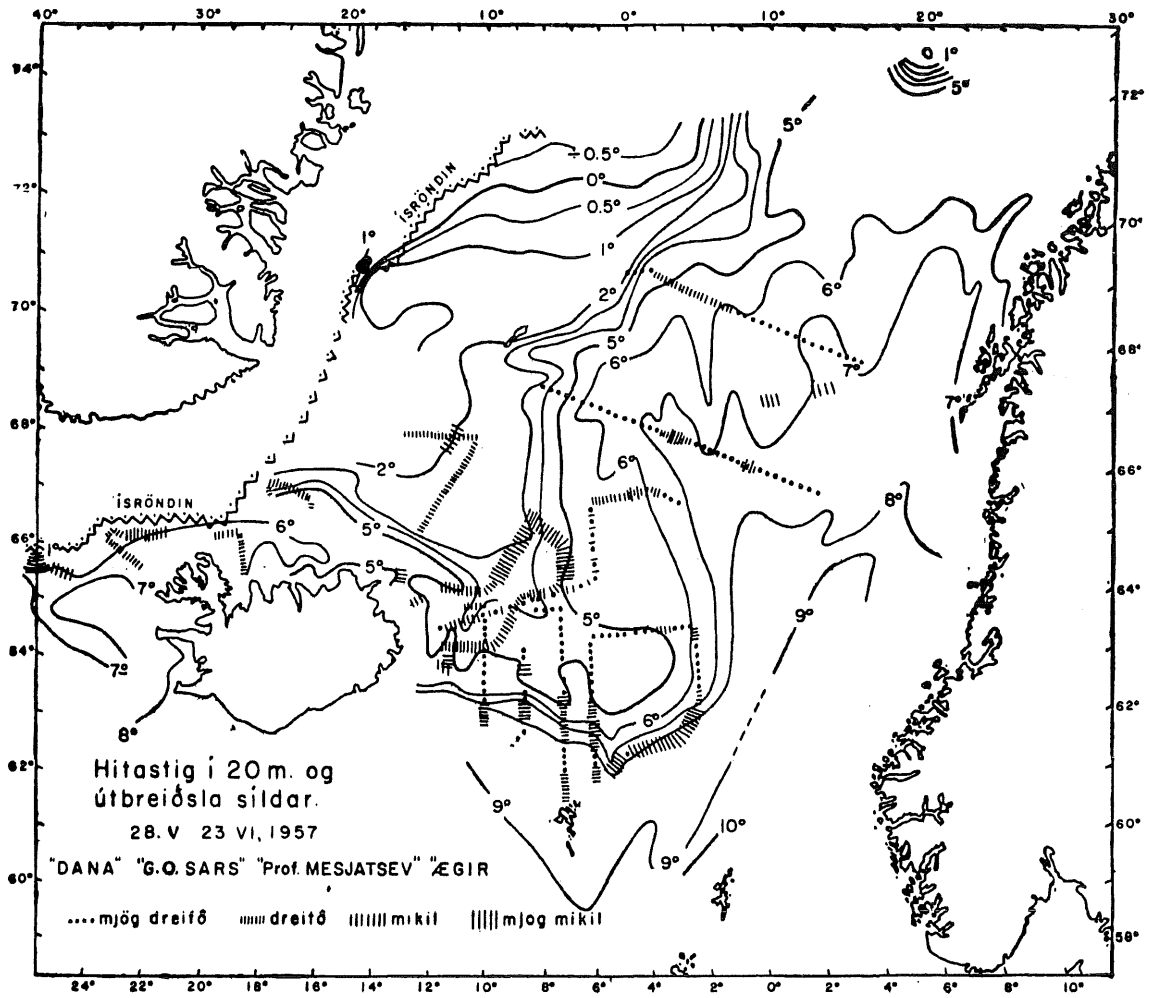


Fig. 8. Herring distribution and temperature at 20 m 1957.

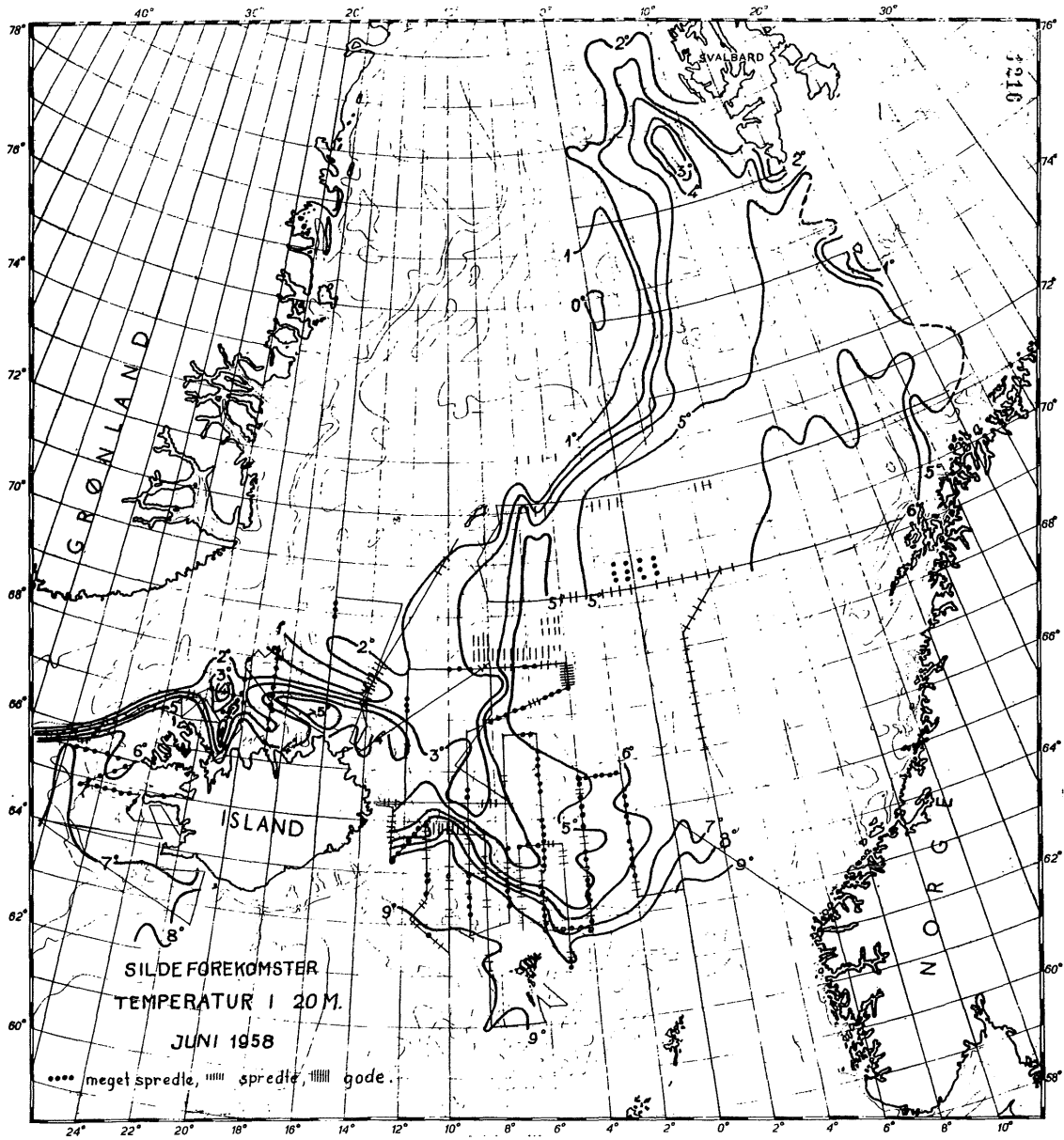


Fig. 9. Herring distribution and temperature at 20 m 1958

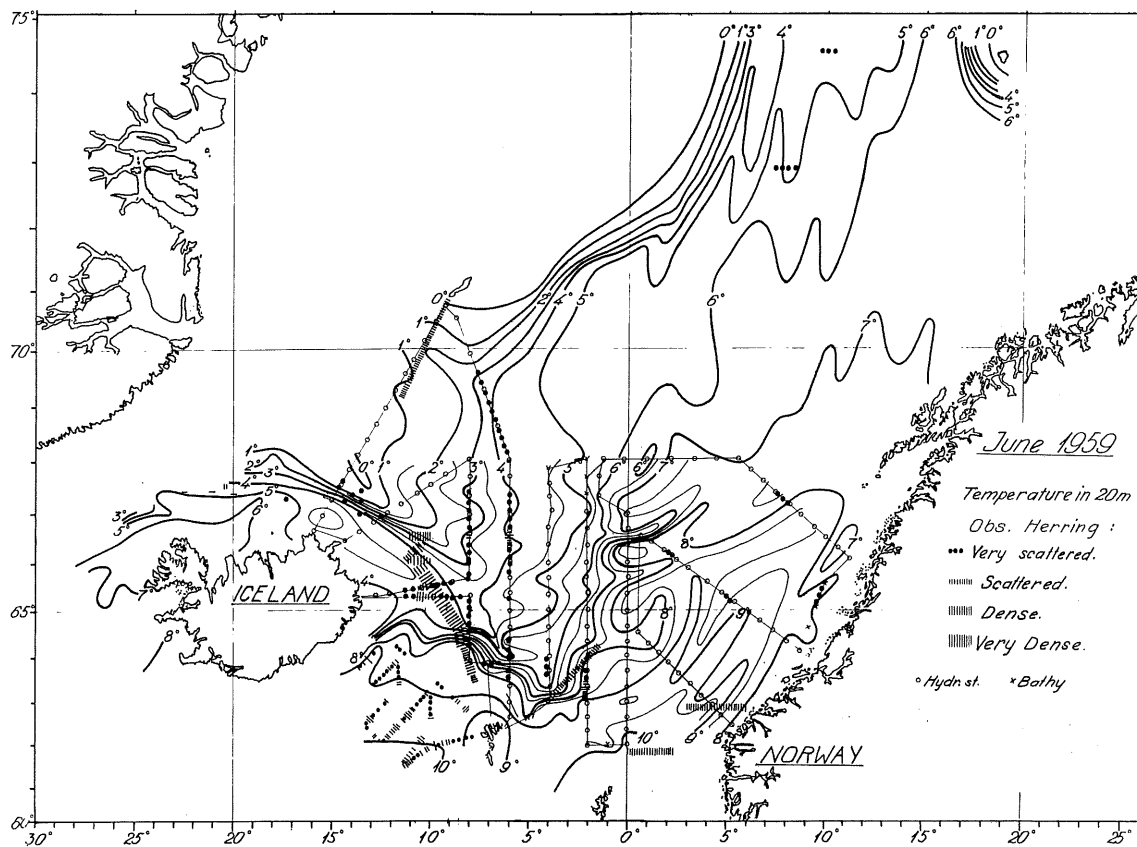


Fig. 10. Herring distribution and temperature at 20 m 1959.

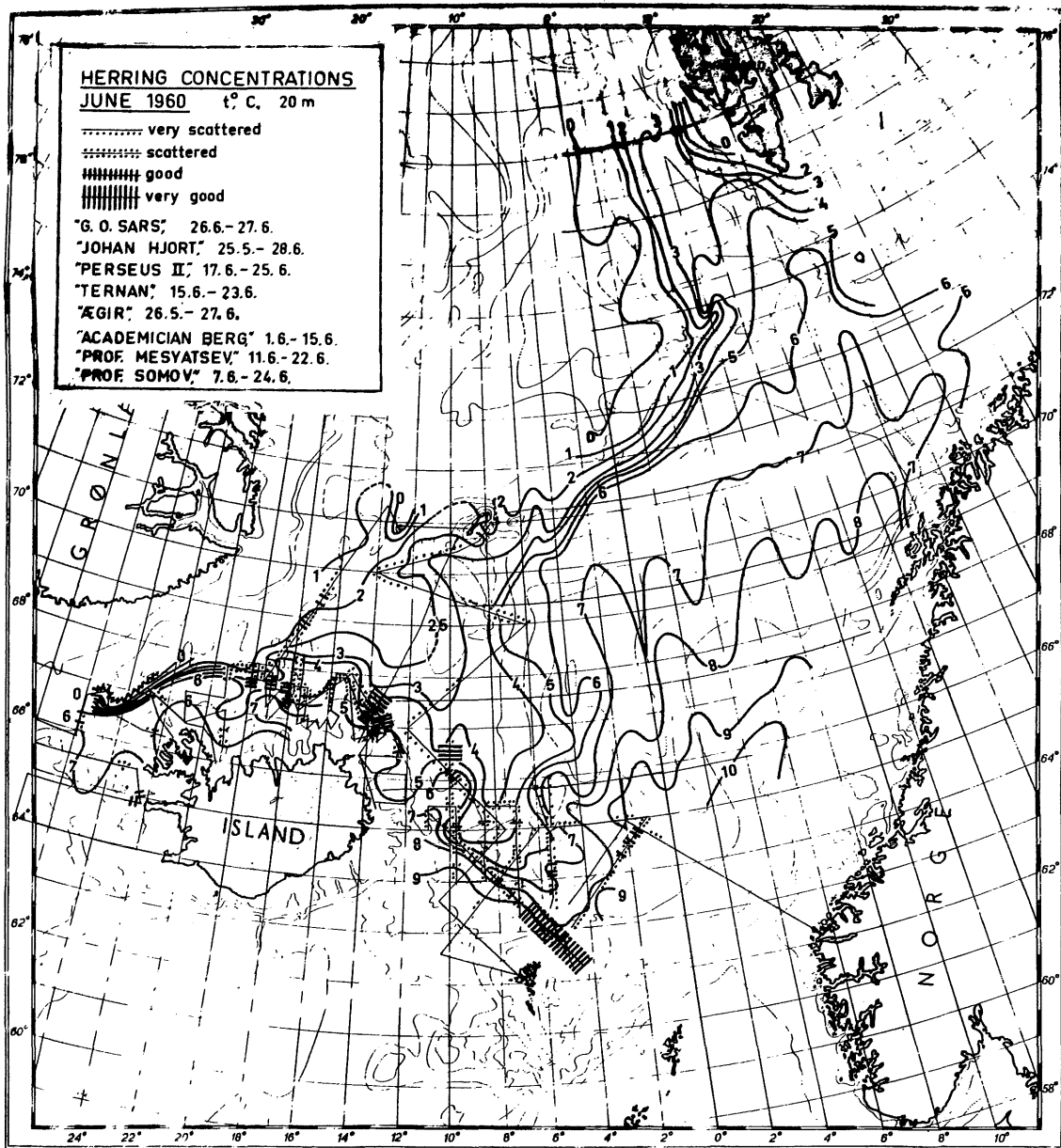


Fig. 11. Herring distribution and temperature at 20 m 1960.

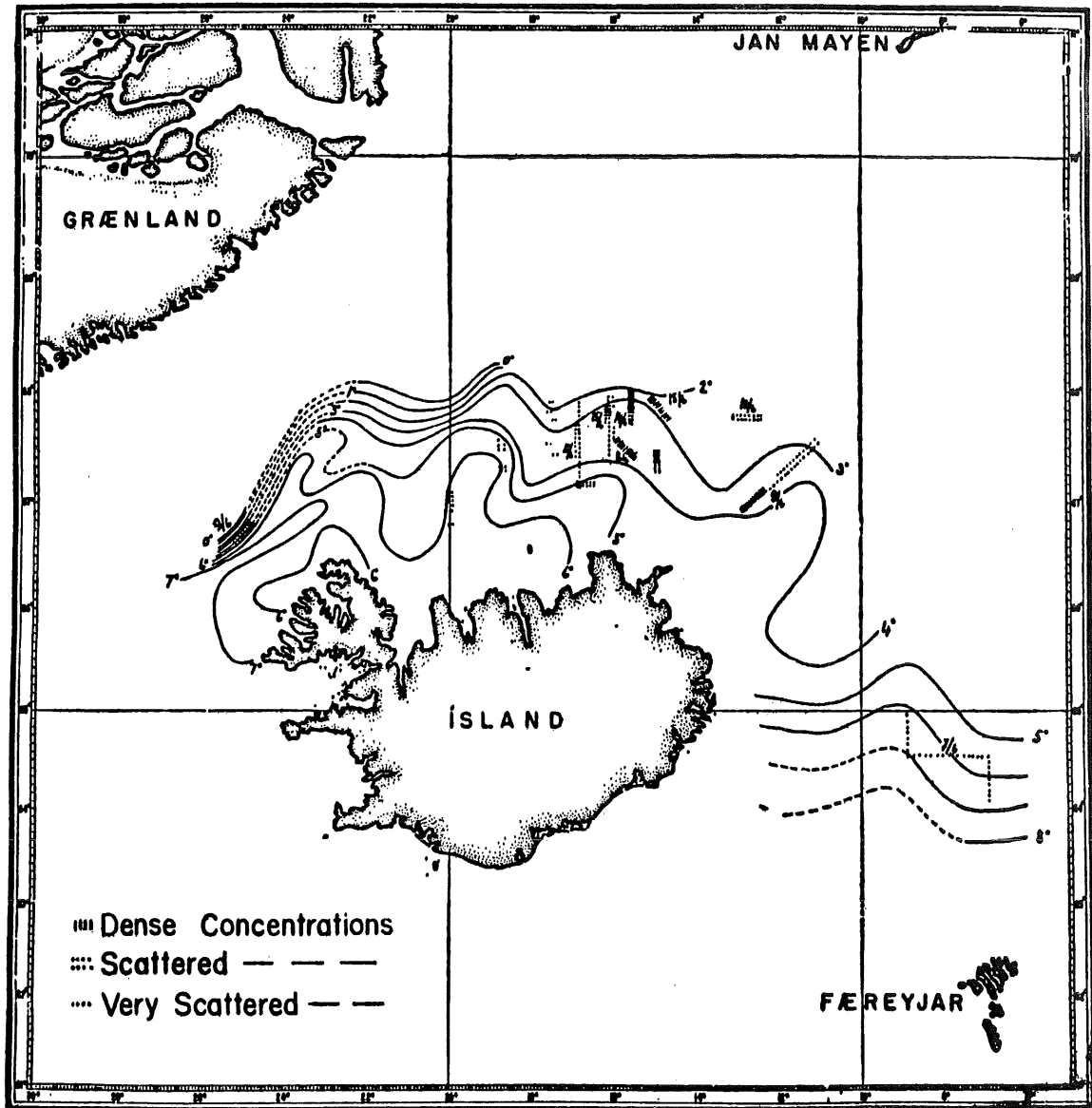


Fig. 12. Herring distribution and temperature at 20 m 1961.

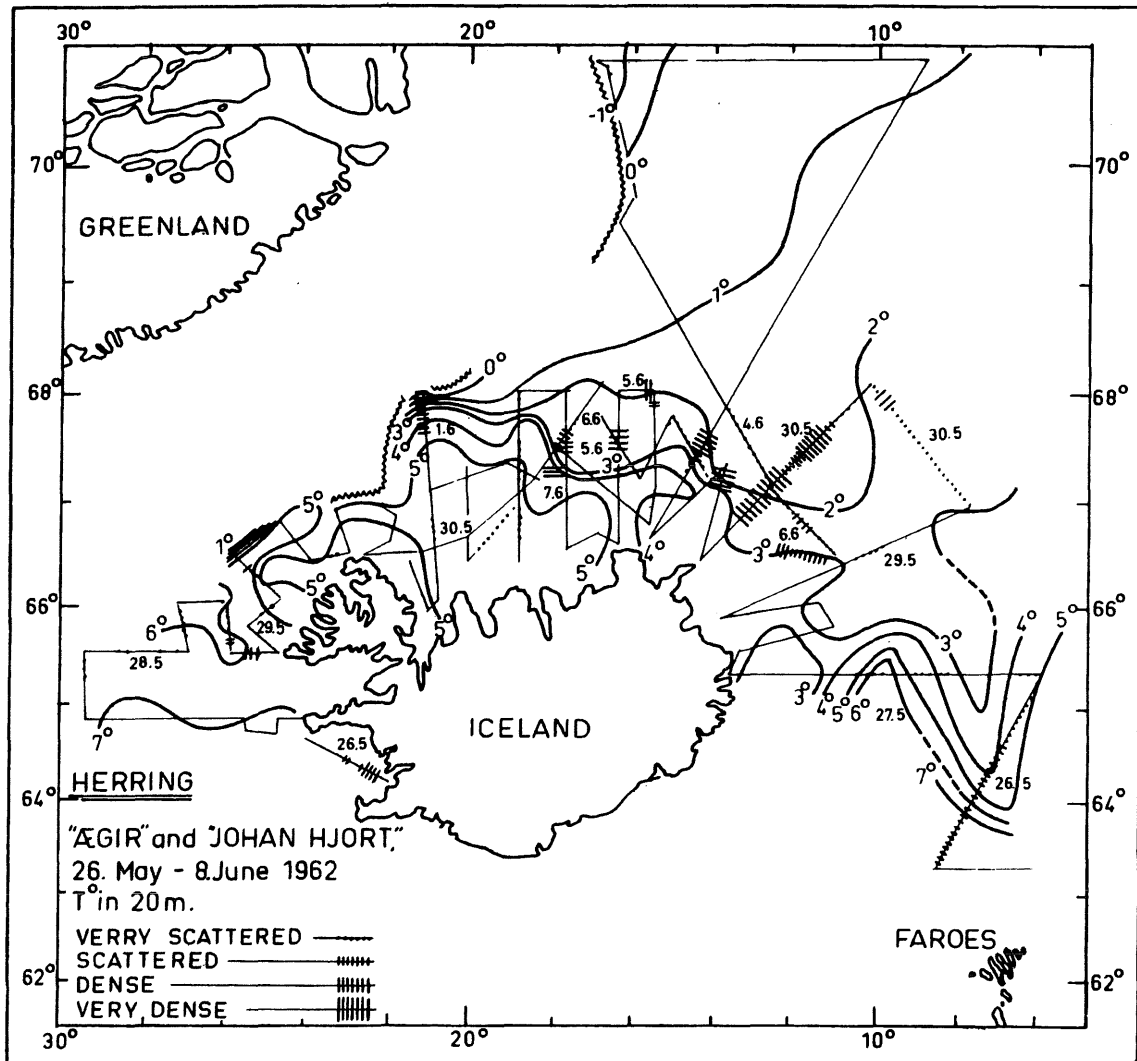


Fig. 13. Herring distribution and temperature at 20 m 1962.

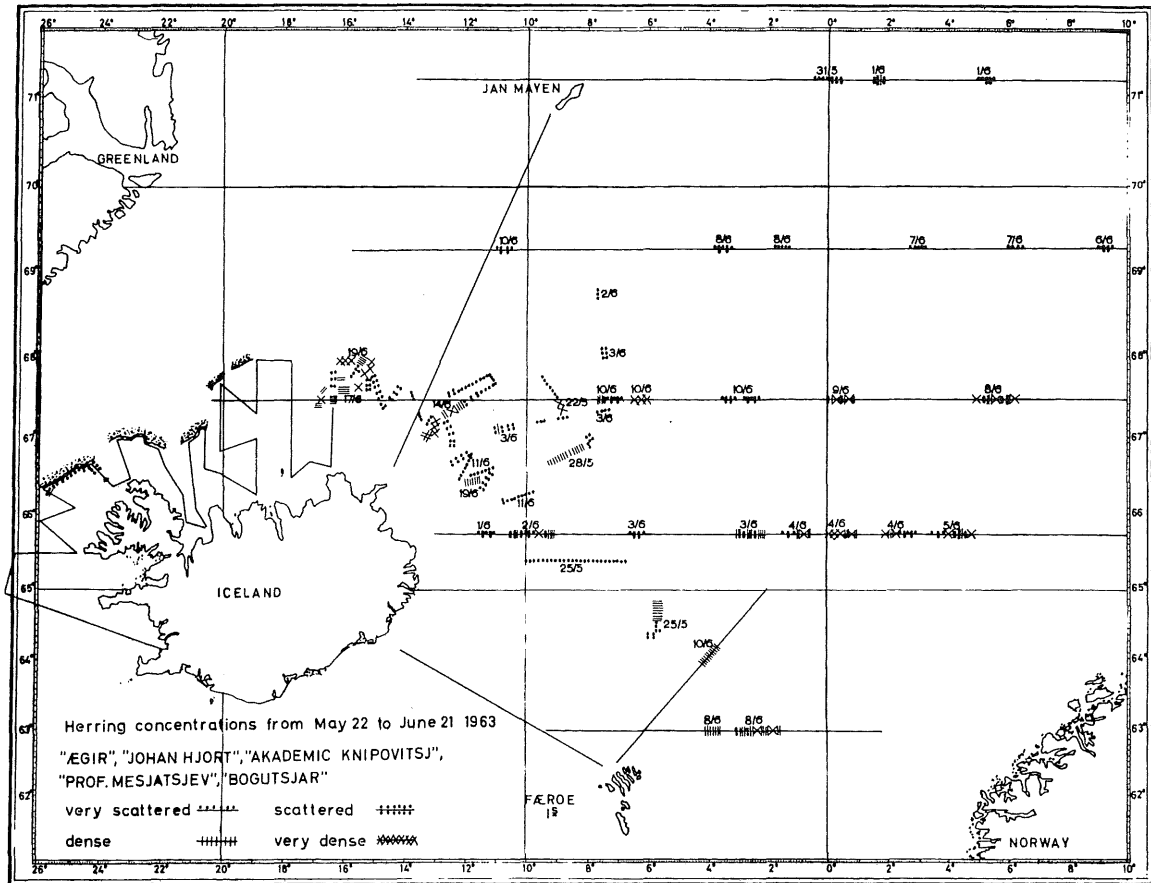


Fig. 14. Herring distribution 1963.

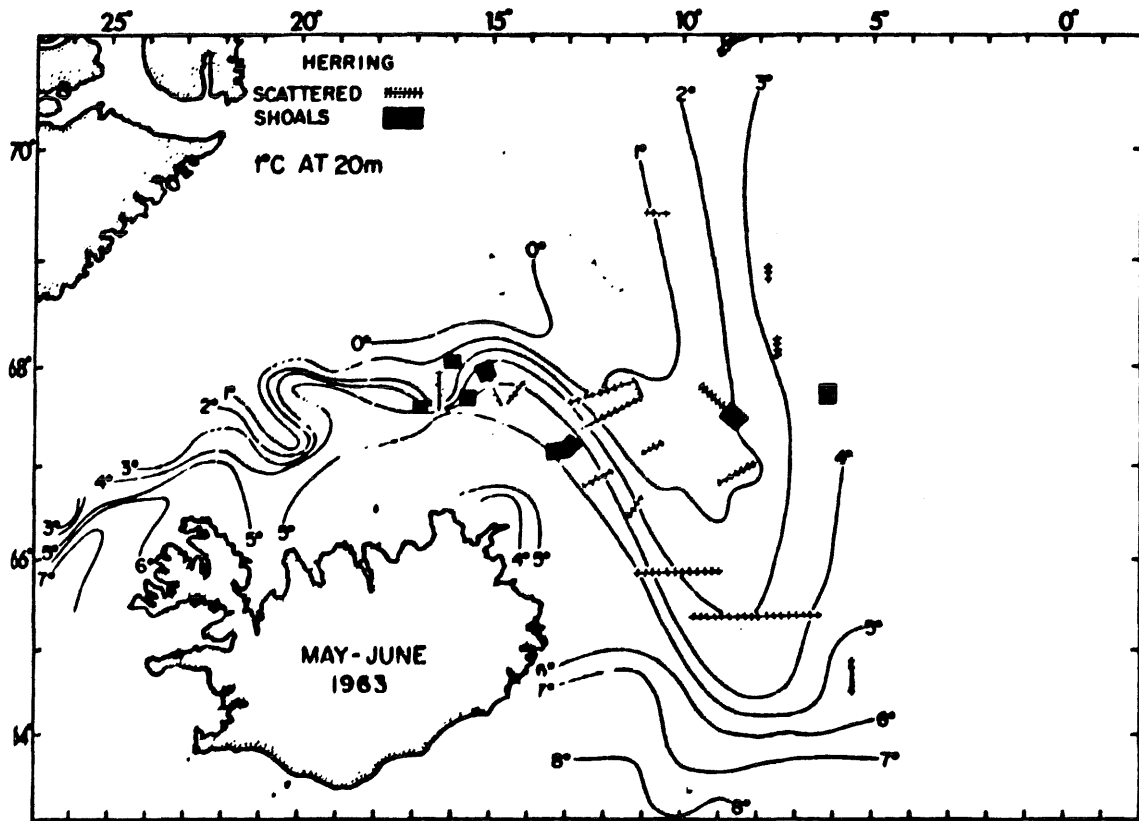


Fig. 15. Herring distribution and temperature at 20 m 1963.

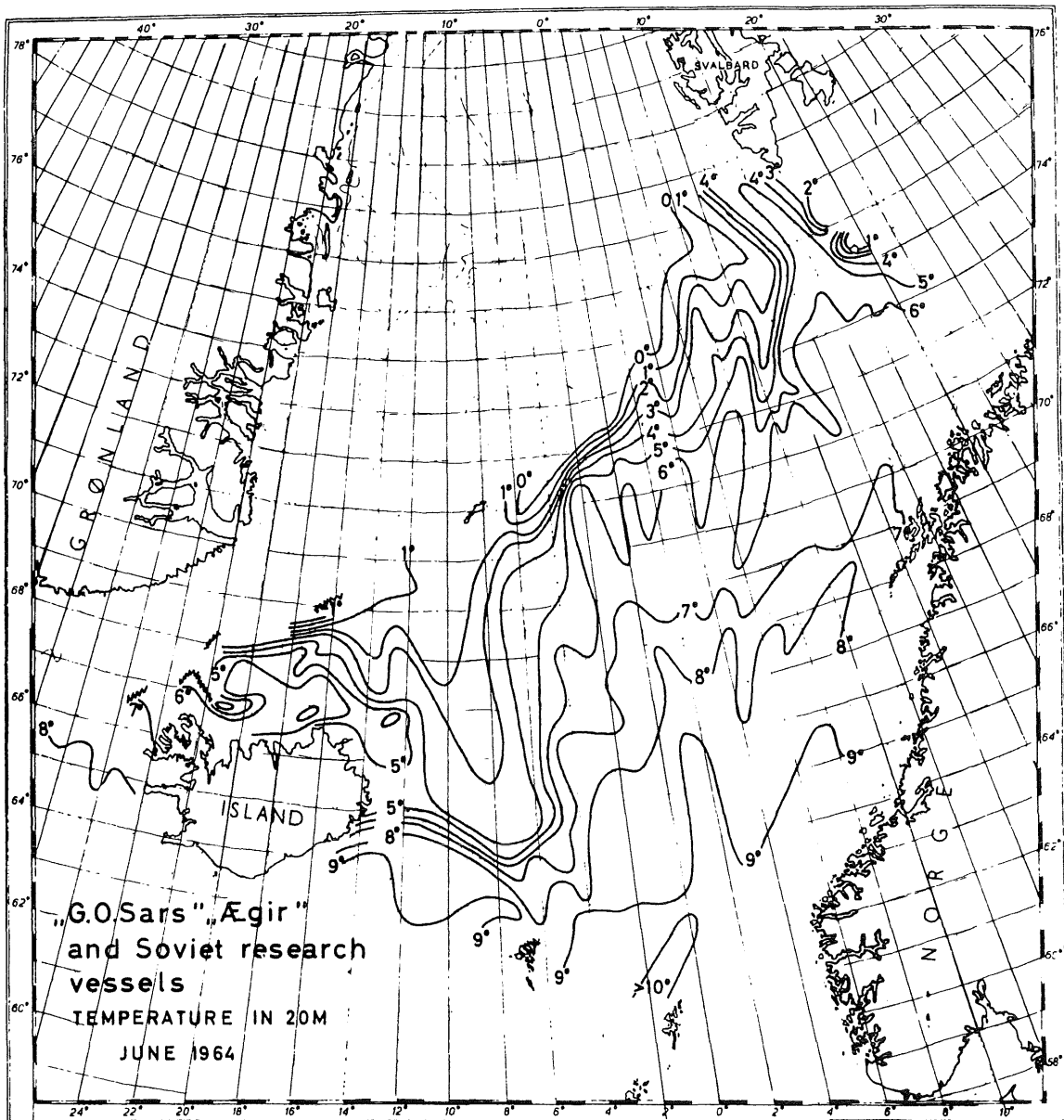


Fig. 16. Temperature at 20 m 1964.

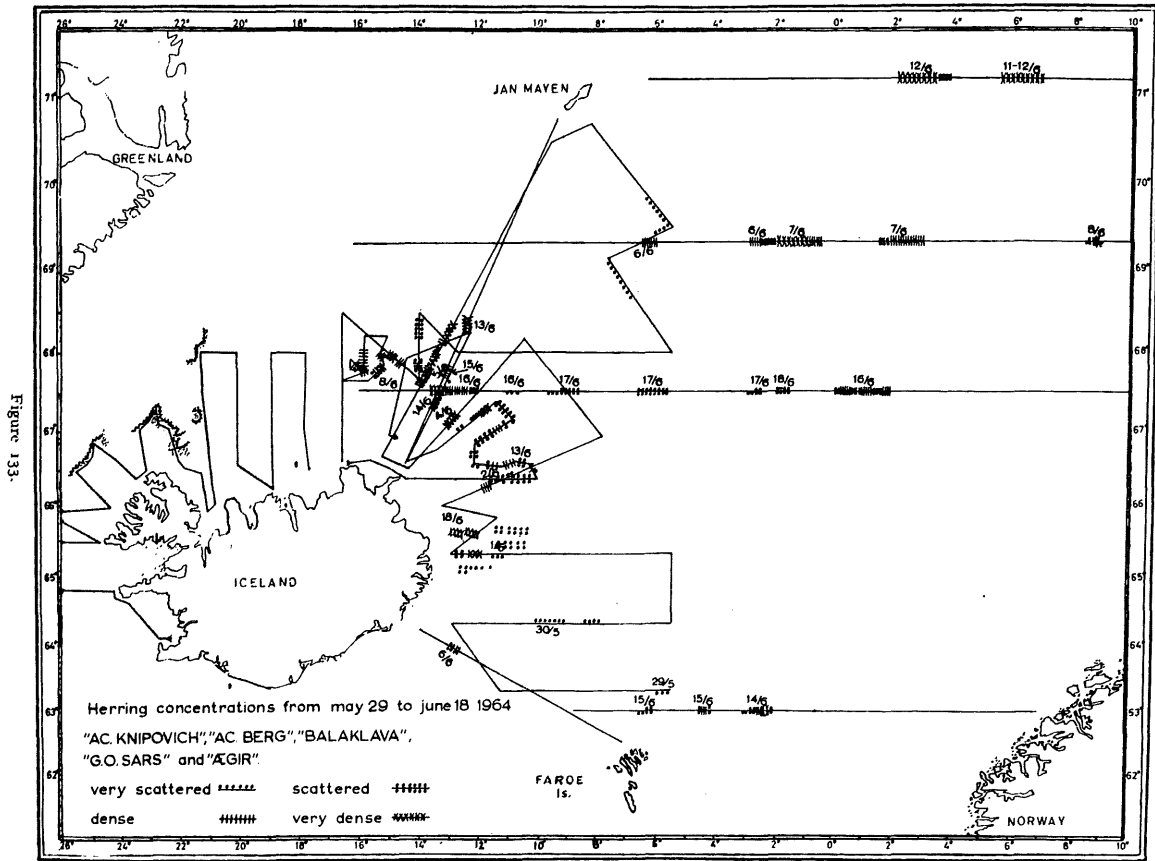


Fig. 17. Herring distribution in 1964.

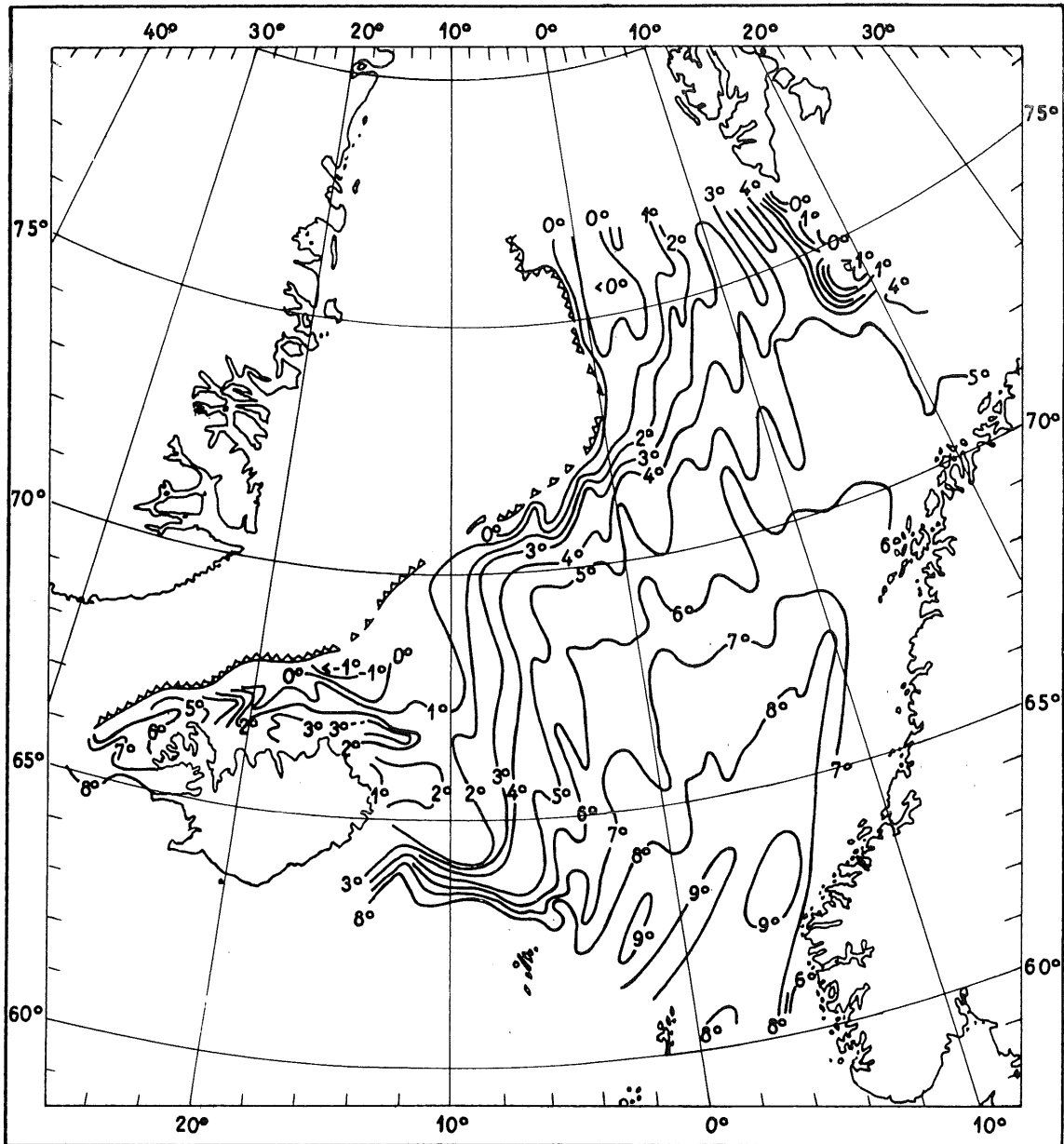


Fig. 18. Temperature at 20 m 1965.

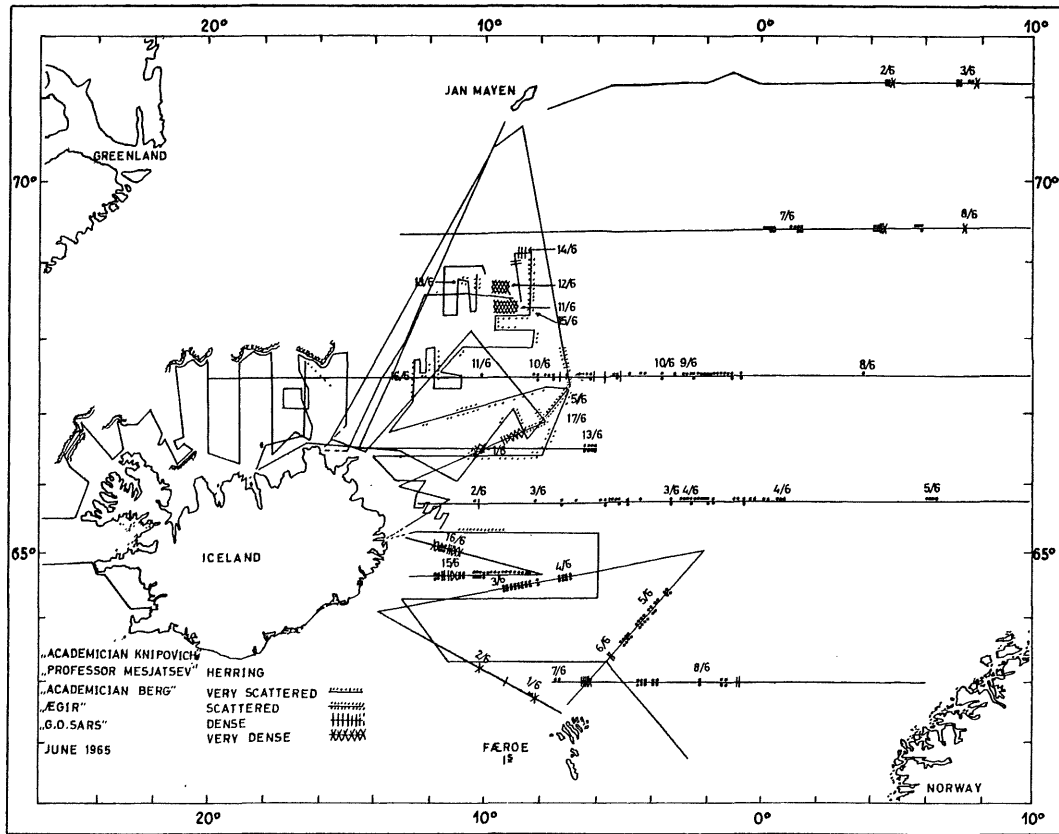


Fig. 19. Herring distribution in 1965.

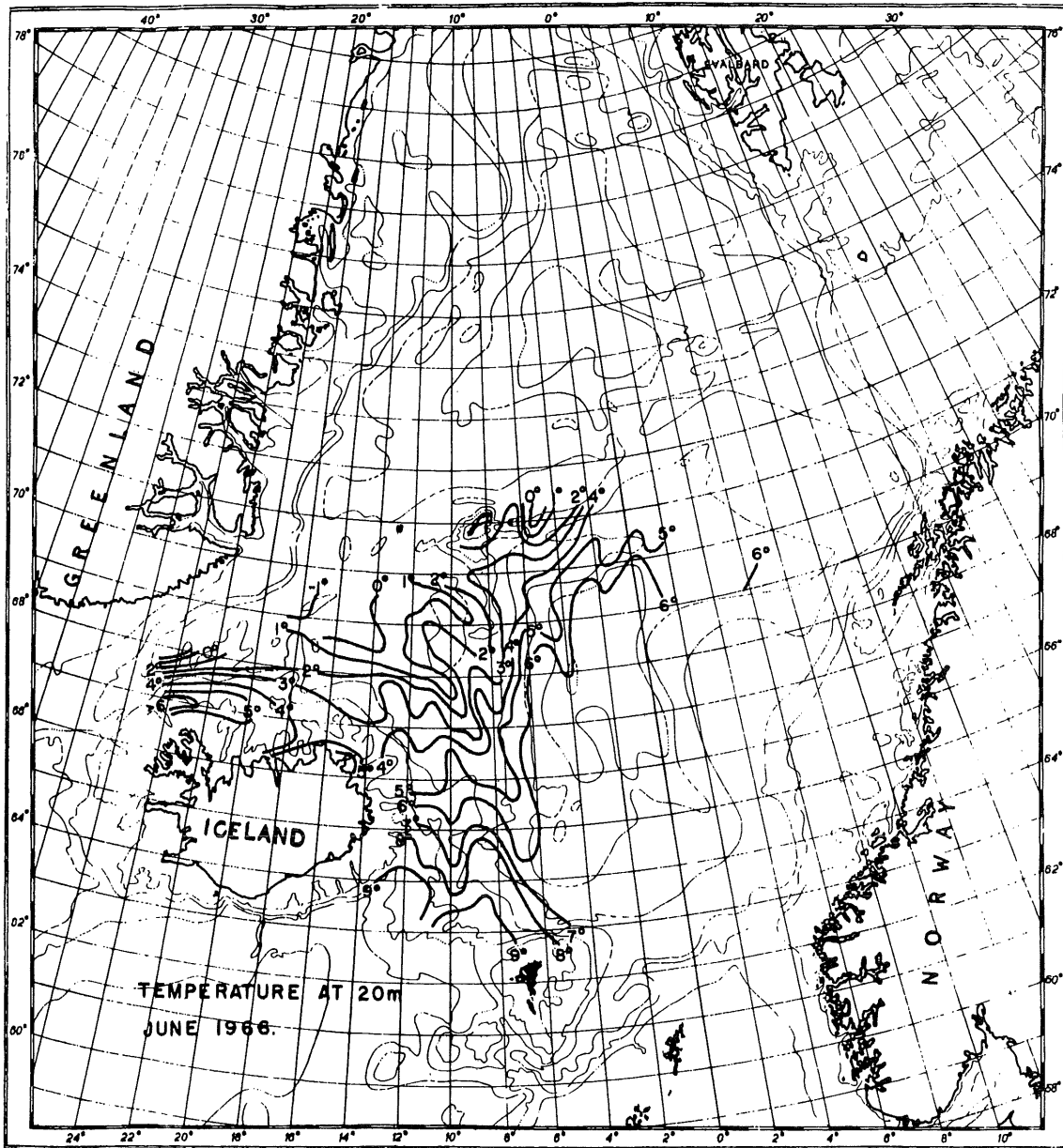


Fig. 20. Temperature at 20 m in June 1966.

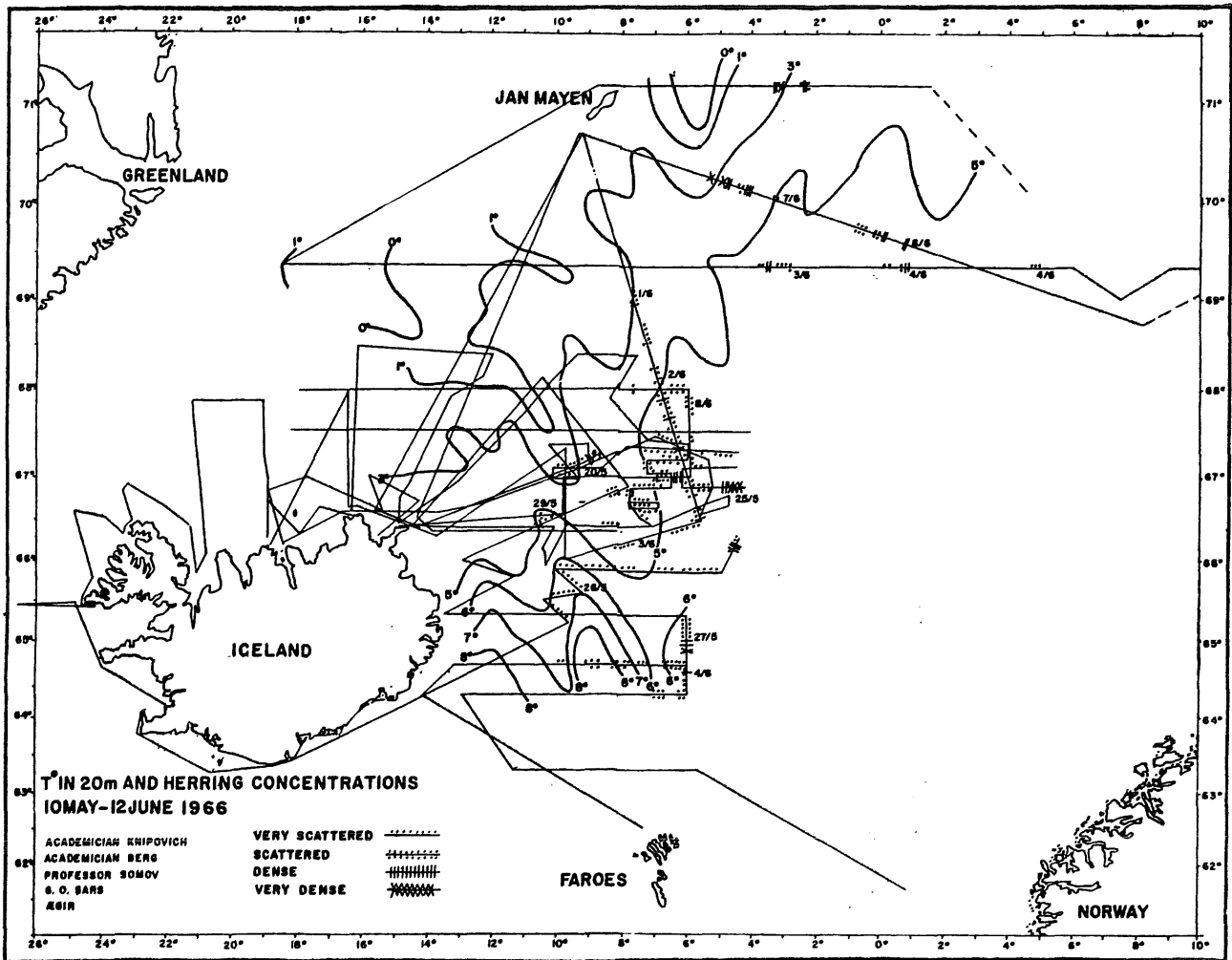


Fig. 21. Herring distribution and temperature at 20 m 10 May - 12 June 1966.

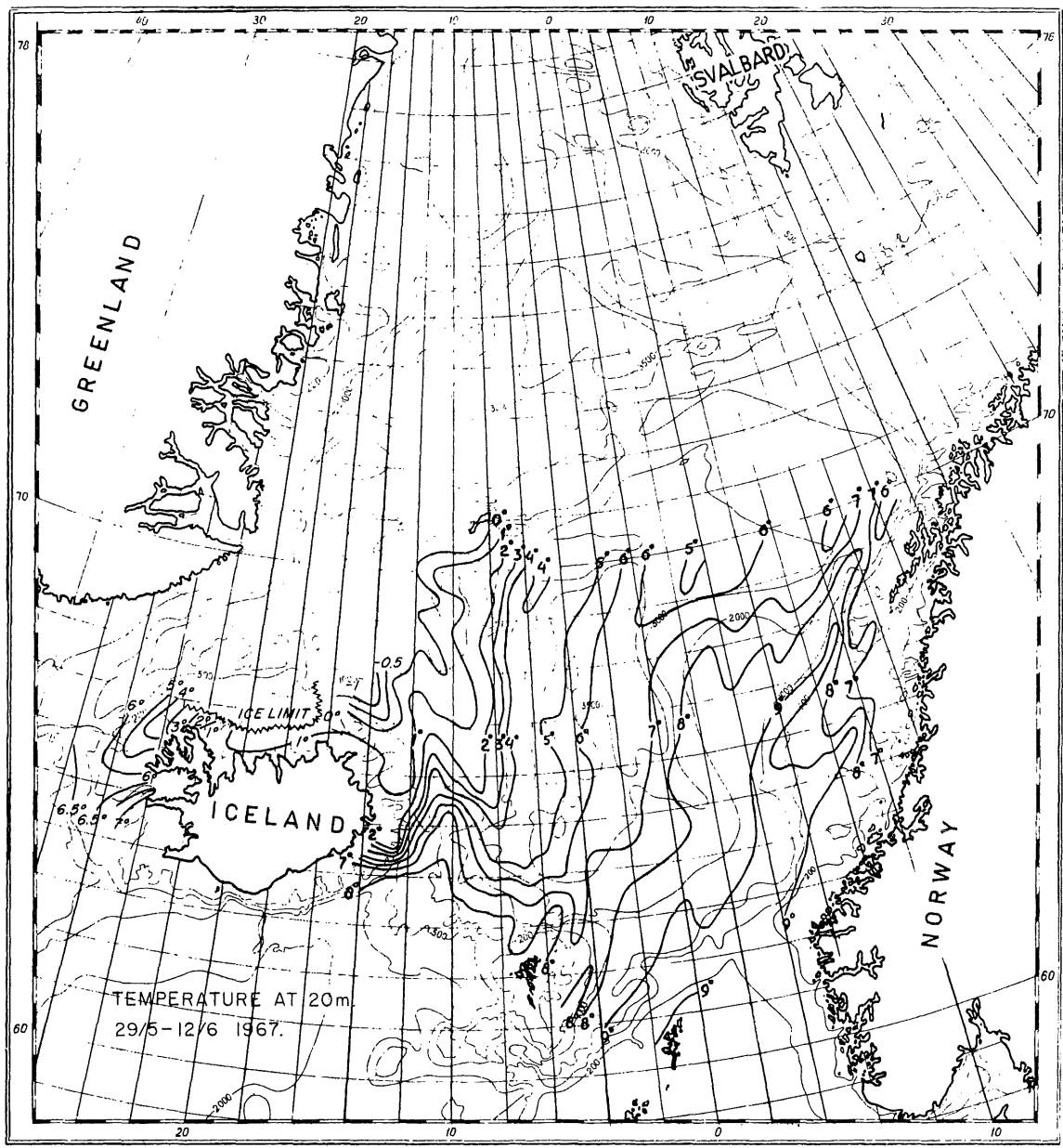


Fig. 22. Temperature at 20 m 1967.

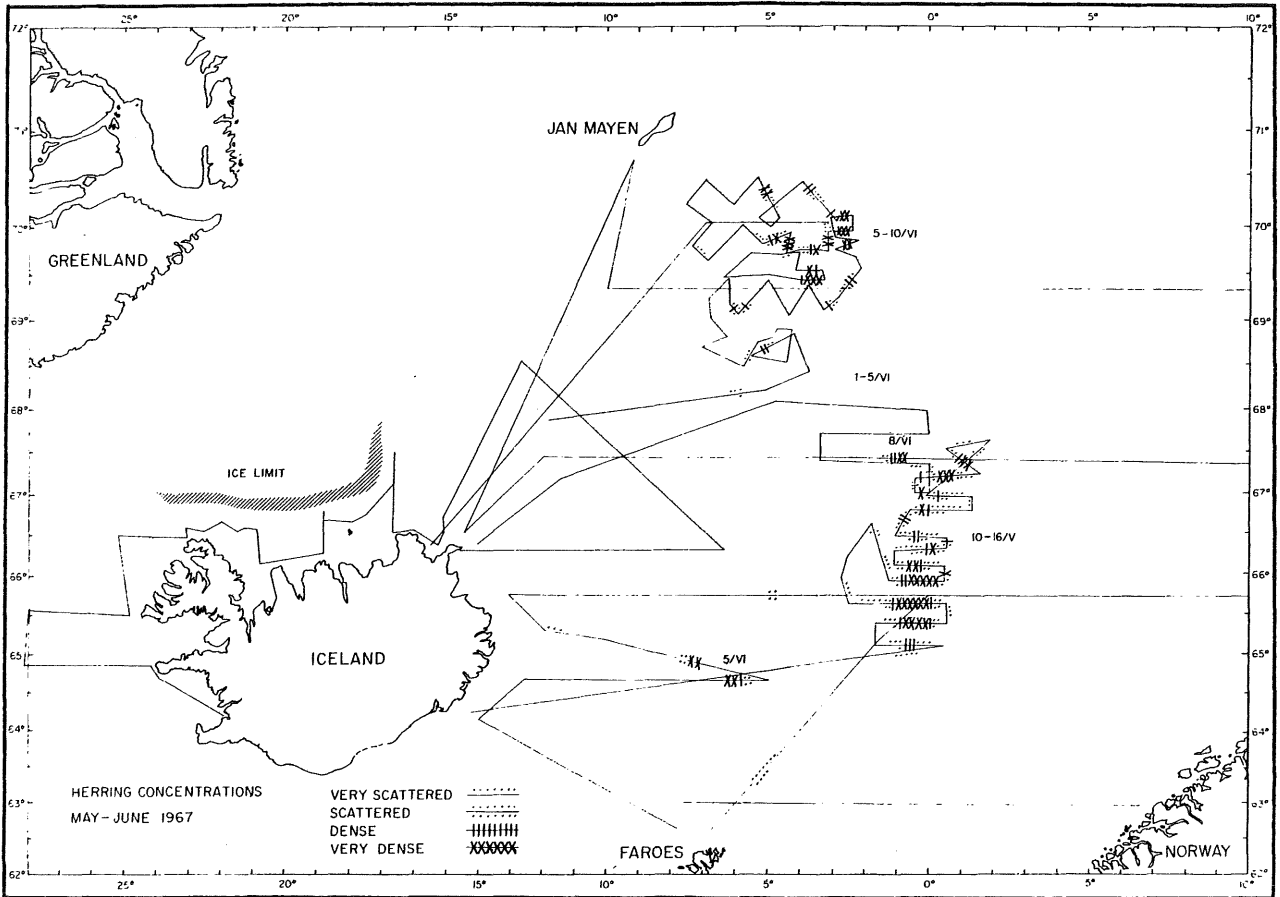


Fig. 23. Herring distribution in 1967.

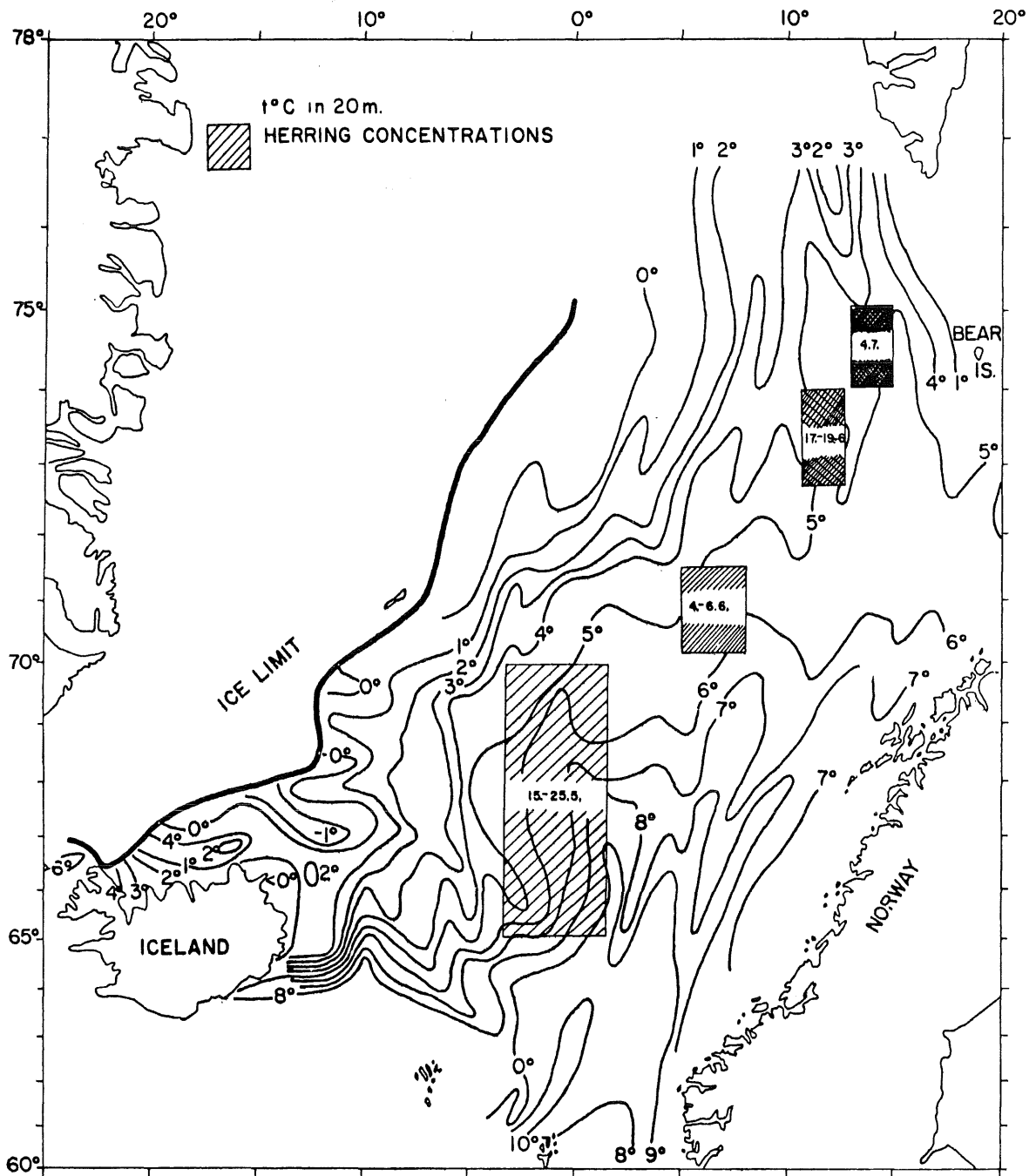


Fig. 24. Herring distribution and temperature at 20 m 1968.

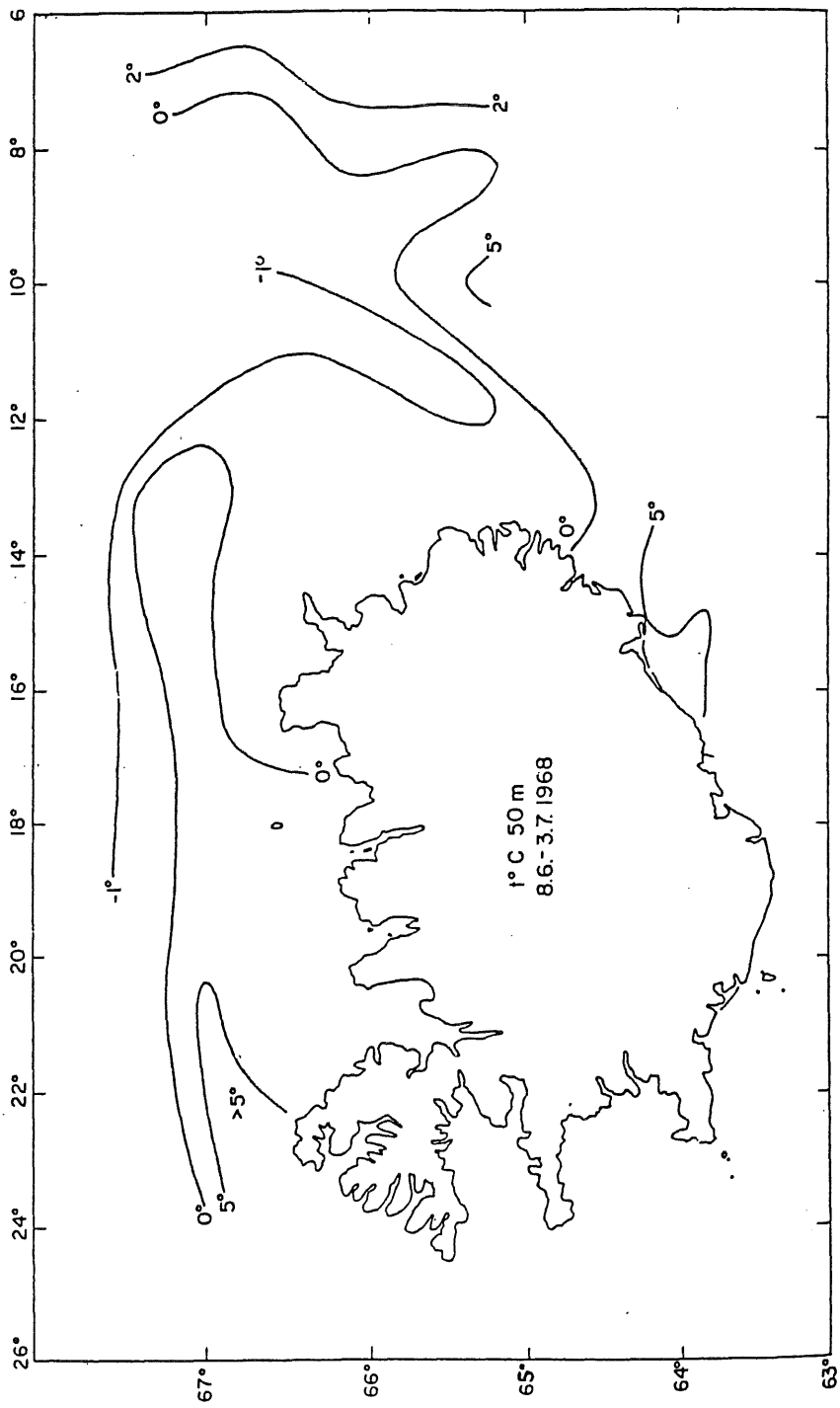


Fig. 25. Temperature at 50 m 1968.

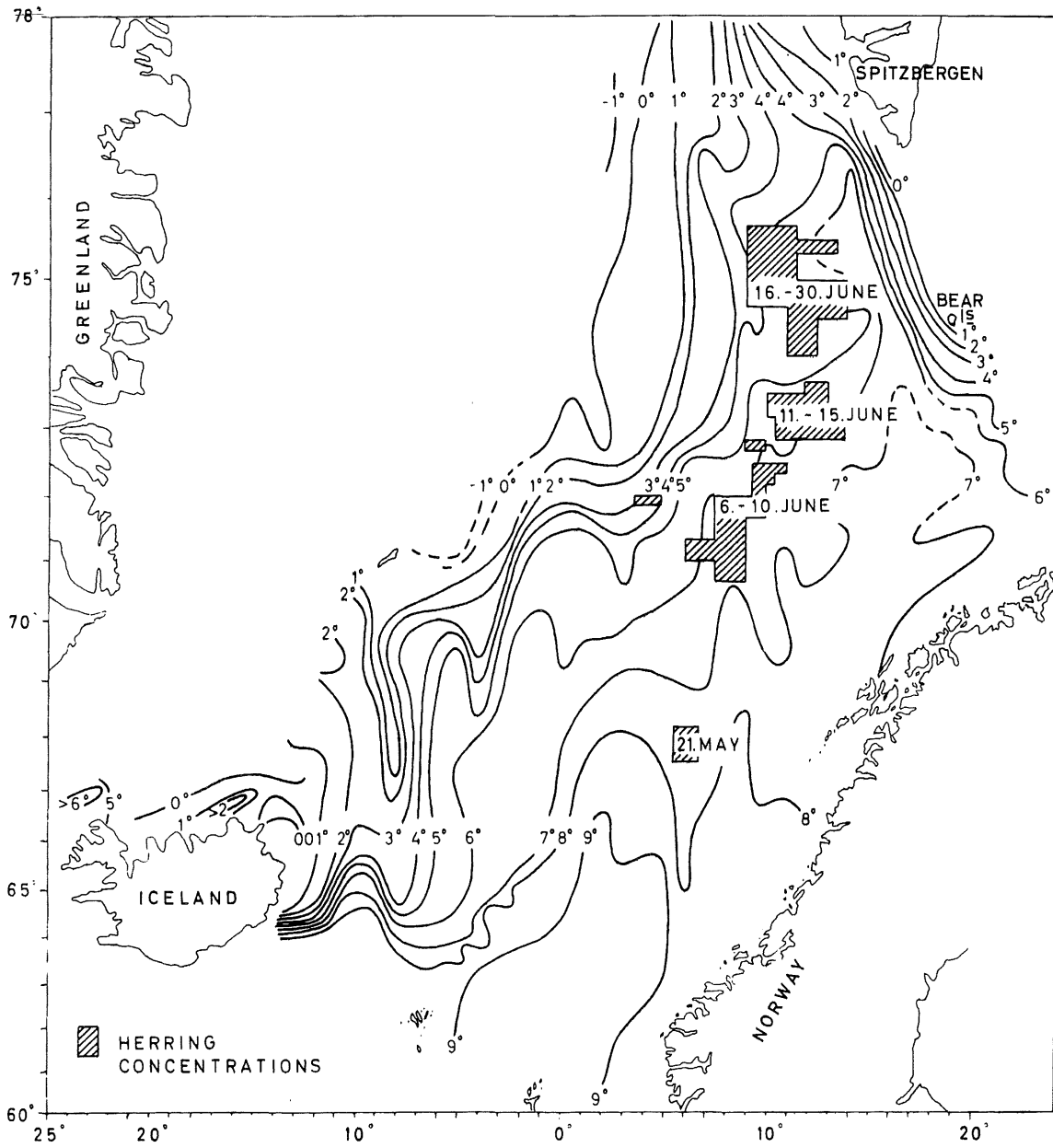


Fig. 26. Herring distribution and temperature at 20 m 1969.

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