

Temperature at 20 Meters in Icelandic Waters  
in May - June 1950 - 1959

By  
UNNSTEINN STEFÁNSSON

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## I. INTRODUCTION

For about a decade hydro-biological surveys have been carried out in late May and in June in the waters surrounding Iceland and between Iceland, Greenland and Jan Mayen. During the last eight years the Icelandic investigations have been made in cooperation with Danish and Norwegian expeditions working in the Norwegian Sea, east of the area surveyed by the Icelanders. During the last three years the Soviet Union has taken part in this program. These joint investigations were initiated largely for the purpose of following the migrational routes of the herring, studying the distribution of plankton and physical and chemical conditions.

The present paper is based on the results of the Icelandic investigations and deals with the temperature conditions in the surface layers during the years 1950—1959. The 20 meter level was considered most suitable for this study. This level was chosen with the following considerations in mind:

a) At 20 meters the hydrographic conditions will be less affected by sudden meteorological changes than at the sea surface. Hence, the errors involved, when treating the material, as if it were synoptic, will be less for the 20 meters level than for the sea surface.

b) After the thermocline has been established, it will in most instances be located below the 20 meters level, therefore this level represents conditions in the surface layer.

c) The concentrations of herring during May—June have been located by means of echosurveys. Experience has shown that during this period the shoals preferably inhabit the layers around and above the thermocline. Therefore, the temperature distribution at the 20 meter level roughly indicates the temperature at which the shoals are found. However, there are many exceptions to this.

During the years 1950—53 observations were made at 25 meters instead of 20 and 30 meters which have been standard depths since 1954. The temperature values at 20 meters in the years prior to 1954 were determined by interpolation between the values at 10 meters and 25 meters. It is unlikely that the temperature distribution derived in this manner, will deviate appreciably from the true temperature distribution.

## 2. TEMPERATURE AND ICE CONDITIONS IN DIFFERENT YEARS

Although the seasonal temperature fluctuation at 20 meters will be more gradual than at the sea surface, it is still considerable, especially during May and June. This will be evident from figure 1 which shows the seasonal variations in temperature, salinity and density at 20 meters for two stations north

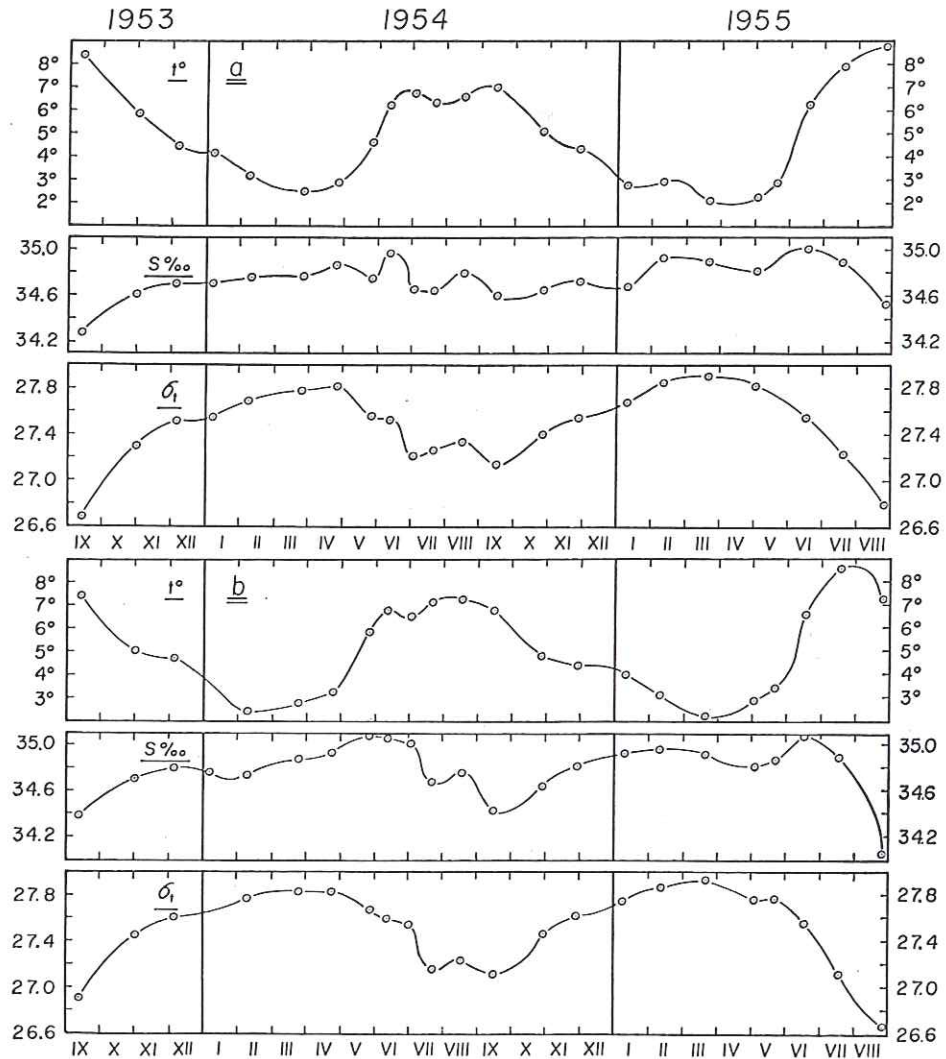


FIG. 1. Variations in temperature, salinity and density in 20 meters at two stations north of Siglunes, North Iceland, September 1953 to September 1955. a) is located at  $66^\circ 16' N$ ,  $18^\circ 50' W$  and b) at  $66^\circ 45' N$ ,  $18^\circ 50' W$ .

of Siglunes, North Iceland, during the period September 1953 to September 1955. In the spring of 1954 the main temperature rise of about  $3^{\circ}\text{C}$  occurred in May, whereas in 1955 a similar rise (of about  $3.5^{\circ}\text{C}$ ) was observed almost one month later. Thus marked seasonal as well as year to year variations exist in the sea temperature north of Iceland. When comparing the temperature conditions in different years, the effect of varying the dates of survey must therefore be kept in mind.

The warming up of the surface layers of north Icelandic waters will not only depend upon the air temperature and/or the nearness of the drift ice, but also on the influx of Atlantic water to this region. Thus in 1954 and 1955 the most rapid temperature rise nearly coincided with the time of maximum salinity.

The density is seen to follow the salinity rather closely, whereas there is an inverse relation between the density and the temperature. Generally, the salinity affects the density more than does the temperature. The lowest density is found in late summer, and the highest in late winter or early spring, February to April.

During the climatic amelioration of recent decades, drift ice has only rarely been observed in Icelandic coastal waters. However, the ice conditions on the Iceland—Greenland Ridge and north of Húnaflói are quite variable, especially in late spring and early summer. In some years the ice limit can in May—June be located midway between northwest Iceland and Greenland, whereas in other years it may be only few miles off the coast.

This will be apparent from figures 2—13 which illustrate the ice conditions and the temperature at 20 meters in May—June in the years 1950 and 1952—1959. Of these, the years 1952, 1954 and 1955 were the most favourable ice years, the distance from the northwest coast to the ice limit being 80 miles or more. In late May 1950 scattered ice floes were observed some 40 nautical miles northeast of Cape Kögur on the northwest coast, and in June 1953 and May—June 1956 it was only 20—30 miles north of Kögur. The years 1957, 1958 and 1959 were moderate ice years, the drift ice being observed at a distance of 30—60 miles off the northwest coast. Low surface temperature, especially in the western part of the area, is usually associated with the proximity of the ice limit.

The temperature distribution at 20 meters during the years 1954—58 has been included in the author's reports on the hydrographic conditions in Icelandic waters, published in *Annales Biologiques*, (STEFÁNSSON, 1956—1959). Figures 5, 6, 7, 9, and 10 are reproduced from these reports, whereas figures 2, 3, 4, 8, 11, 12 and 13 have not been published elsewhere.

In the text of figures 2—13 a characterization of each year has been attempted. These indicate that considerable variations exist in the temperature distribution at 20 meters. As was pointed out before, these may be due to some extent to the different dates of the surveys, but largely they are year to year

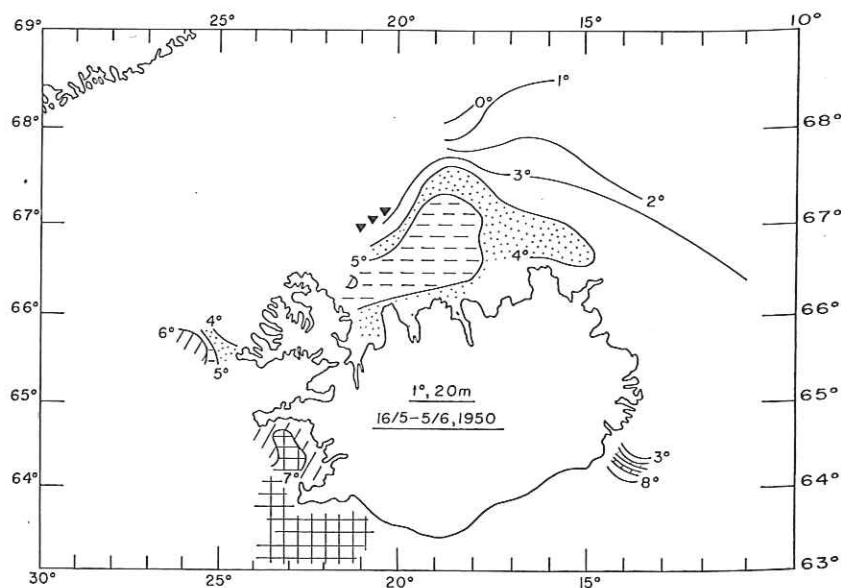


FIG. 2. Temperature distribution at 20 meters, 16/5—5/6 1950.  
 CHARACTERIZATION: Drift ice observed 40 miles NE of Horn. Probably closer to the northwest coast than normal. Temperature conditions: Off the west coast moderate to cold. North Icelandic grounds, western part, above normal. North Icelandic grounds, eastern part, moderate to warm.

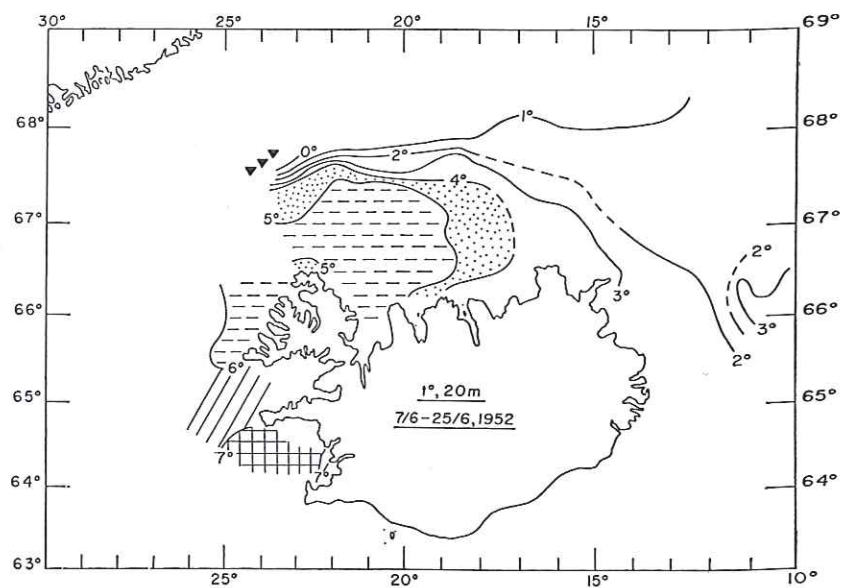


FIG. 3. Temperature distribution at 20 meters, 7/6—25/6 1952.  
 CHARACTERIZATION: Drift ice limit north of Kögur farther off than normal. Temperature conditions: Off the west coast about 1° below normal. North Icelandic grounds, western part, about 0.5°—1° below normal. North Icelandic grounds, eastern part, about 1° below normal. The tongue of cold water, abnormally cold, 1°—2° below normal.

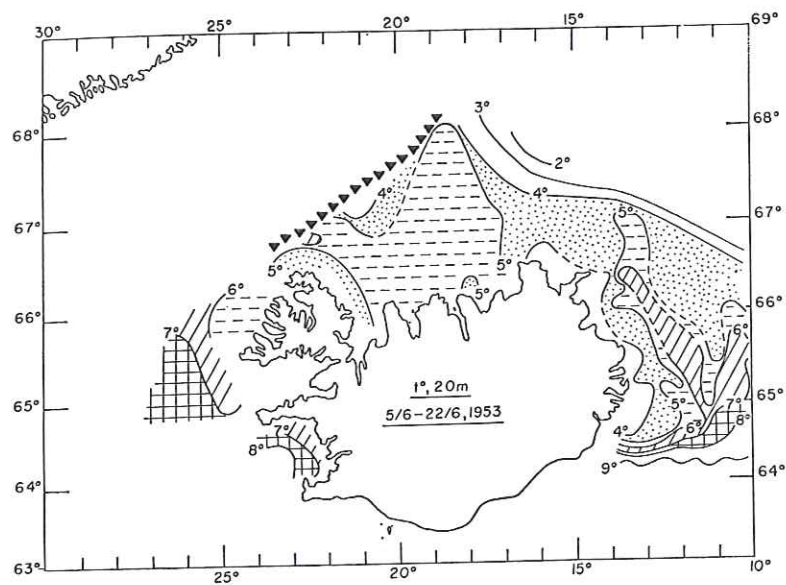


FIG. 4. Temperature distribution at 20 meters, 5/6—22/6 1953.

CHARACTERIZATION: Drift ice limit closer to the northwest coast than normal. Temperature conditions: Off the west coast about normal. North Icelandic grounds, western part, about normal or slightly below. North Icelandic grounds, eastern part, normal or slightly above normal. The tongue of cold water about normal.

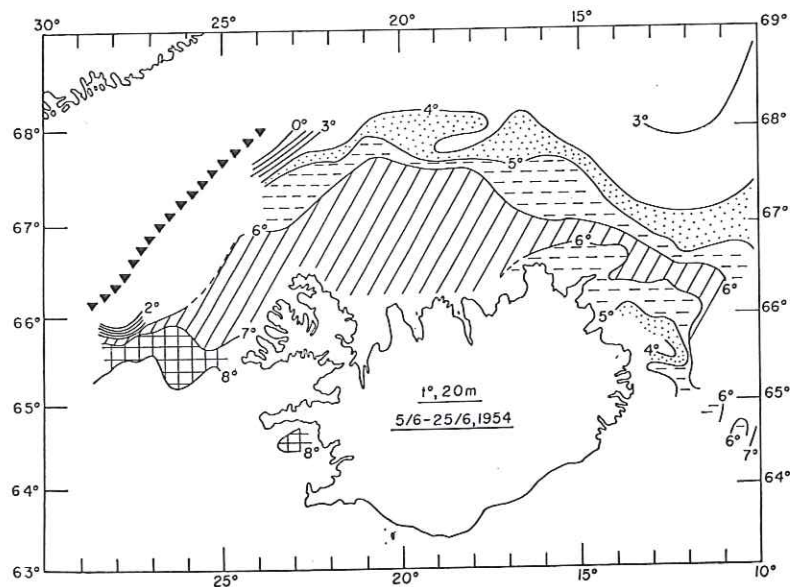


FIG. 5. Temperature distribution at 20 meters, 5/6—25/6 1954.

CHARACTERIZATION: Drift ice limit unusually far off the northwest coast. Temperature conditions: Off the west coast, about 1° above normal. North Icelandic grounds, western part, 0.5°—1° above normal. North Icelandic grounds, eastern part, 1°—2° above normal. The tongue of cold water, abnormally warm, 1°—2° above normal.

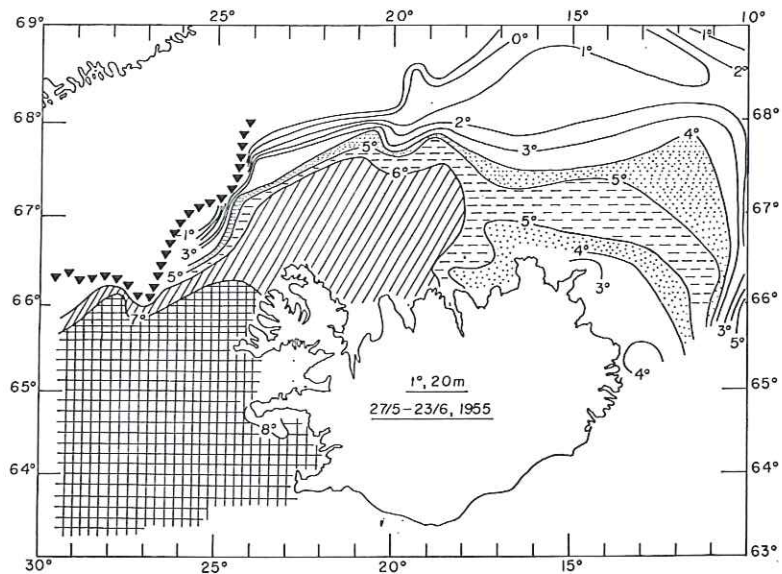


FIG. 6. Temperature distribution at 20 meters, 27/5—23/6 1955.

CHARACTERIZATION: Drift ice limit farther off the northwest coast than normal. Temperature conditions: Off the west coast, about normal or slightly above, North Icelandic grounds, western part, 0.5°—1° above normal. North Icelandic grounds, eastern part, 0.5°—1° above normal. The tongue of cold water, north-east of Langanes located farther off than normal. East of Langanes, however, it showed up very sharply at its normal position.

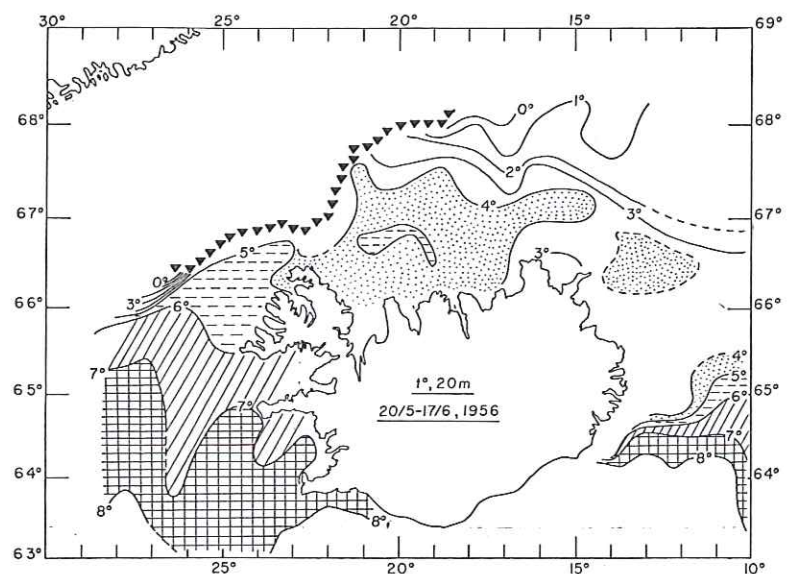


FIG. 7. Temperature distribution at 20 meters, 20/5—17/6 1956.

CHARACTERIZATION: Drift ice closer to the northwest coast than normal. Temperature conditions: Off the west coast, about normal. North Icelandic grounds, western part, about normal. North Icelandic grounds, eastern part, about normal or slightly below. Tongue of cold water, about normal or slightly below.

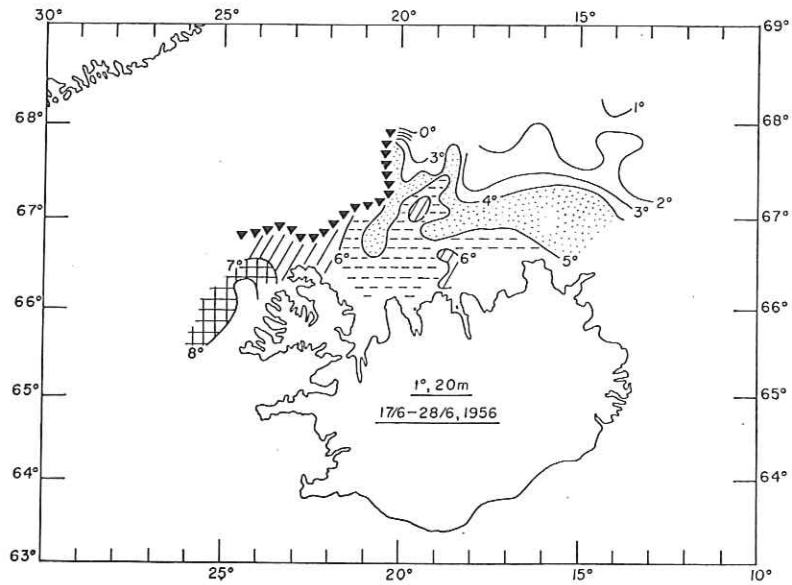


FIG. 8. *Temperature distribution at 20 meters, 17/6—28/6 1956.*  
 CHARACTERIZATION: *Ice conditions: Drift ice unusually close to the northwest coast. Temperature conditions: North Icelandic grounds, western part, about normal or slightly below. North Icelandic grounds, eastern part, about normal. Tongue of cold water, probably below normal.*

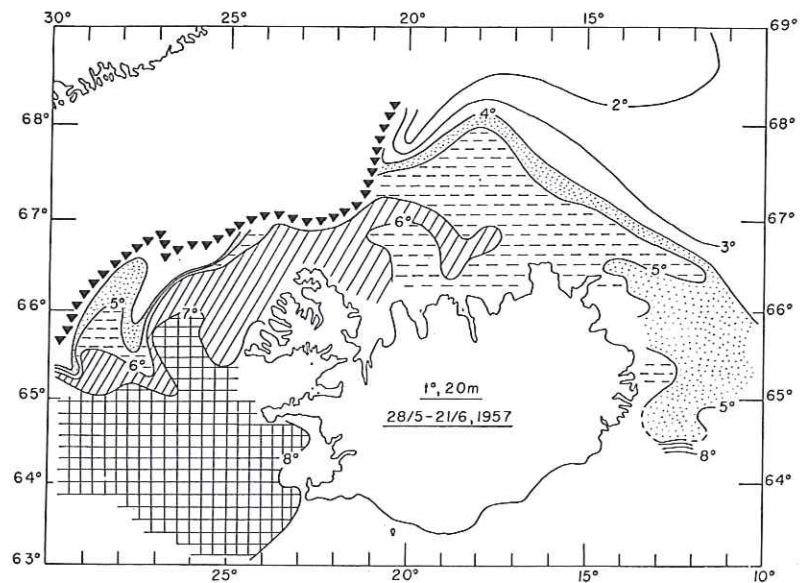


FIG. 9. *Temperature distribution at 20 meters, 28/5—21/6 1957.*  
 CHARACTERIZATION: *Ice conditions about normal. Temperature conditions: Off the west coast, about normal. North Icelandic grounds, western part, 0.5°—1° above normal. North Icelandic grounds, eastern part, about 1° above normal. Tongue of cold water about normal.*



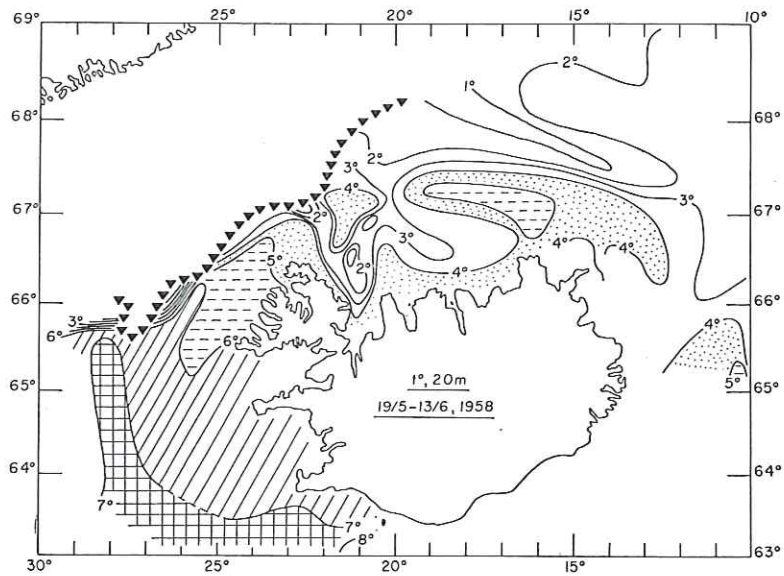


FIG. 10. Temperature distribution at 20 meters, 19/5—13/6 1958.

CHARACTERIZATION: Ice conditions about normal. Temperature conditions: Off the west coast, slightly below normal. North Icelandic grounds, western part, abnormally cold, especially in the Húnaflói region. North Icelandic grounds, eastern part, about normal. Tongue of cold water, about normal, or slightly above.

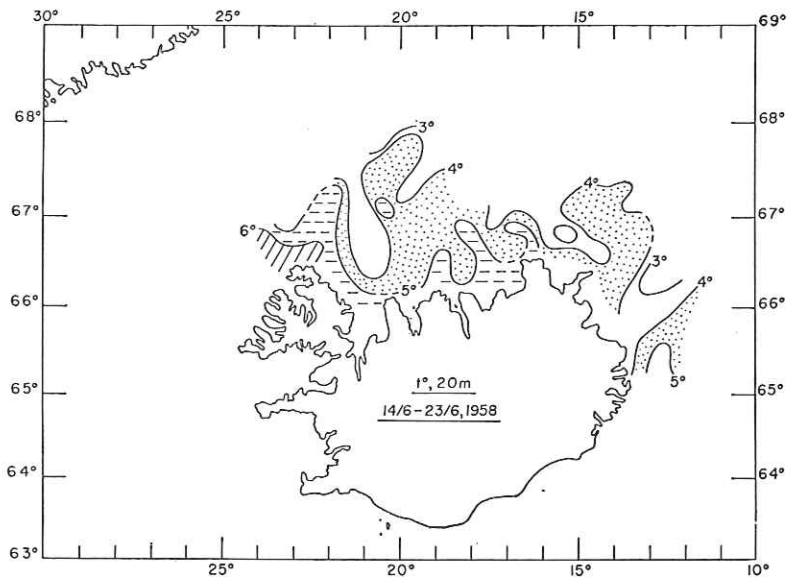


FIG. 11. Temperature distribution at 20 meters, 14/6—23/6 1958.

CHARACTERIZATION: Temperature conditions: North Icelandic grounds, western part, exceptionally cold, especially in the Húnaflói region. North Icelandic grounds, eastern part, below normal.

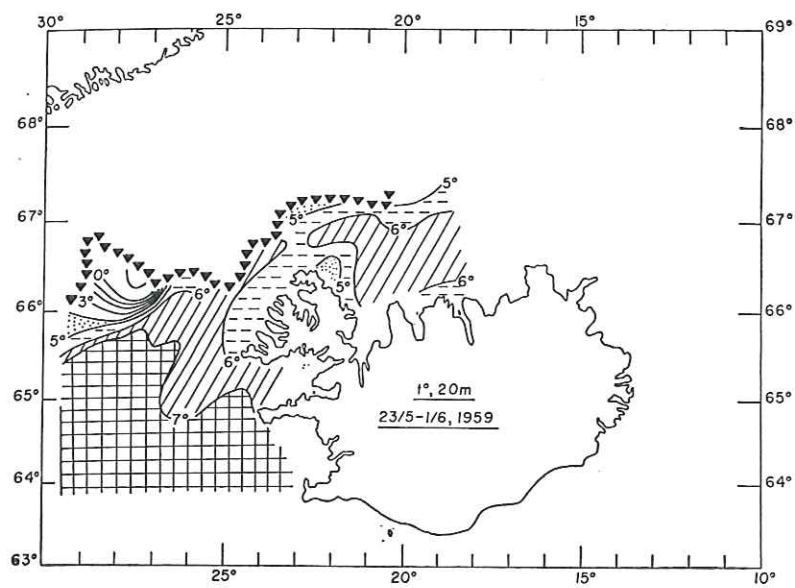


FIG. 12. Temperature distribution at 20 meters, 23/5—1/6 1959.  
 CHARACTERIZATION: Ice conditions: Ice limit closer to the northwest coast than normal. Temperature conditions: Off the west coast, about normal, or slightly above. North Icelandic grounds, western part, 1°—2° above normal.

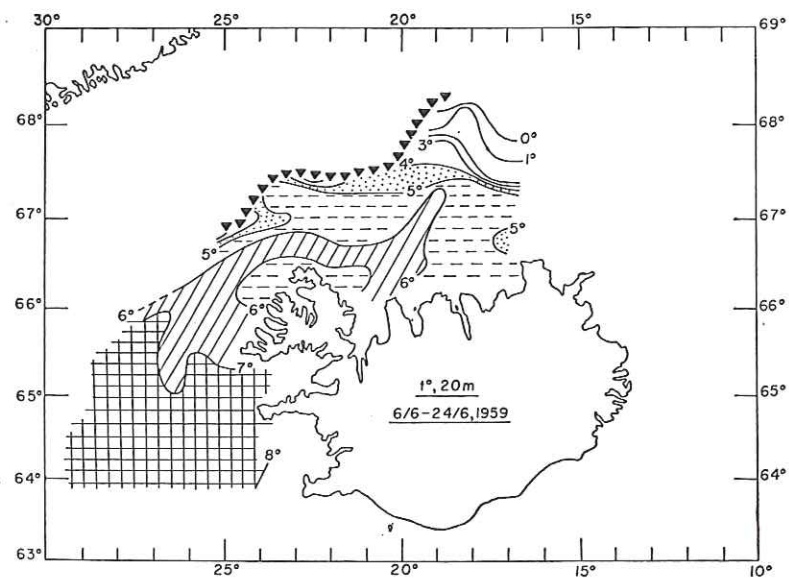


FIG. 13. Temperature distribution at 20 meters, 6/6—24/6 1959.  
 CHARACTERIZATION: Ice conditions about normal. Temperature conditions: Off the west coast about normal. North Icelandic grounds, western part, above normal. North Icelandic grounds, eastern part, above normal. Tongue of cold water, probably below normal.

variations. Of the twelve sets of observations, four were made during the latter half of May and early June (figures 2, 7, 10 and 12), whereas the other eight were largely made during the period June 5th to 25th.

Regarding the first group, 1959 was definitely the warmest in the region north of Iceland, 1950 was a moderately warm year, but 1956 and 1958 were cold years, especially 1958. Off the west coast the differences between years were found to be similar but much smaller in magnitude.

Of the eight years considered during the second survey period, 1954, 1955, and 1957 were definitely warm. The year 1959 was a rather warm year, 1953 and 1956 were moderate or rather cold years, and 1952 and 1958 were definitely cold. During the second period also, the variations were found to be relatively large off the north coast of Iceland but small off the west coast.

In the tongue of cold water in the oceanic area northwest of Iceland, the lowest temperatures were observed in 1952 and 1959, and the highest in 1954. In the years 1955 and 1957 the surface layers were also relatively warm in this region.

### 3. MEAN VALUES

Mean values of the sea surface temperature in North Icelandic waters have been calculated for the months June, July and August during the period 1901—1930 (STEFÁNSSON, 1954), and mean charts of the whole North Atlantic based on all available data have been prepared by KRAUSS (1958). However, for other levels in the uppermost 20—30 meters, no such mean charts exist.

Because of the importance of temperature distribution in connection with biological studies, it was considered advantageous to calculate the normals for the period after 1950, for which there exist in most cases simultaneous observations of herring distribution and plankton concentration.

Most of the observations made in west and north Icelandic waters during May and June in recent years, fall within the time interval May 15th—June 25th. Due to reasons discussed on p. 5, it was decided to divide this time interval in two periods, viz. May 15th—June 4th and June 5th—25th, and compute the mean values for each separately. The number of observations from the various years is shown in Table 1.

TABLE 1.  
Number of temperature observations at 20 meters,  
May 15th—June 25th 1950—1959.

<i>Period</i>	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	<i>Total</i>
15/5—4/6 . . . . .	52	—	12	1	11	40	70	20	97	67	370
5/6—25/6 . . . . .	5	16	75	144	161	112	129	144	160	67	1013
15/5—25/6 . . . . .	57	16	87	145	172	152	199	164	257	134	1383

As will be seen from the table, the material is rather scanty during the first period, but fairly extensive during the second.

The temperatures from each individual year were averaged for each  $\frac{1}{2}^{\circ}$  latitude and  $1^{\circ}$  longitude, and the normals for the whole period 1950—59 computed by averaging these mean values for the various years. The results are shown in figures 14 and 15.

The calculated normals for May 15th—June 4th are in many instances based on one or two values only. Observations are especially scarce in the northwestern and the eastern part of the area, whereas in the coastal area along the west coast and the western part of the north coast the data are somewhat more numerous. During the second period, (figure 15) the normals can generally be considered more reliable. On the basis of the inserted values isotherms have been drawn. These follow in the main a similar course during the two periods investigated.

During the period May 15th—June 4th the normal temperature is seen to vary between  $6.5^{\circ}\text{C}$  and  $7.5^{\circ}\text{C}$  in the region west of Iceland between Reykjanes and Látrabjarg. Near  $66^{\circ}\text{N}$ ,  $27^{\circ}$ — $30^{\circ}\text{W}$ , there is a sharp boundary between Atlantic and polar water, and the temperature drops from  $6^{\circ}$  to less than  $2^{\circ}$ . From about  $66^{\circ}\text{N}$ ,  $27^{\circ}\text{W}$  this boundary extends northeastwards, to about  $67^{\circ} 15' \text{N}$ ,  $24^{\circ}\text{W}$ , and then bends towards the east. Off the north coast the boundary is less sharp. Between Húnaflói and Slétta, it will generally be found between  $67^{\circ} 30'$  and  $68^{\circ}\text{N}$ , bending towards the south in the region east of Slétta. In the coastal area along the northwestern peninsula the temperature normally lies between  $5^{\circ}$  and  $6^{\circ}$ , the  $5^{\circ}$  isotherm having a tongue-like shape in the direction of flow of the Atlantic water. Off the north coast the temperature lies between  $4^{\circ}$  and  $5^{\circ}$  between Kögur and Skjálíandi,  $3^{\circ}$ — $4^{\circ}$  between Skjálíandi and Langanes, and less than  $3^{\circ}$  south of Langanes.

During the second period, June 5th—25th, the temperature usually ranges between  $7^{\circ}$  and  $8^{\circ}\text{C}$  in the region west of Iceland between Reykjanes and Látrabjarg. From about  $66^{\circ} 30' \text{N}$ ,  $26^{\circ}\text{W}$  the boundary between the Atlantic and polar water extends to  $68^{\circ}\text{N}$ ,  $22^{\circ}\text{W}$ . From this point it bends towards east, having a similar course as during the period May 15th—June 4th. Off the northeast coast no distinct boundary is indicated on the mean chart. It must be remarked, however, that the mean charts were prepared by averaging conditions which may be quite variable from year to year. The averaging process will therefore tend to make horizontal temperature gradient appear smaller than it actually is at a given time. In the coastal area between Látrabjarg and Kögur the temperature normally lies between  $6^{\circ}$  and  $7^{\circ}$ , the  $6^{\circ}$ -isotherm having a similar course to the  $5^{\circ}$ -isotherm during the former period. In the north Icelandic area, between Kögur and Skjálíandi, the temperature lies between  $5^{\circ}$  and  $6^{\circ}$ , and  $4^{\circ}$ — $5^{\circ}$  in the whole area from Skjálíandi along the northeast and east coast to Papey on the southeast coast.

South of Papey, there is a well defined boundary between the Atlantic and

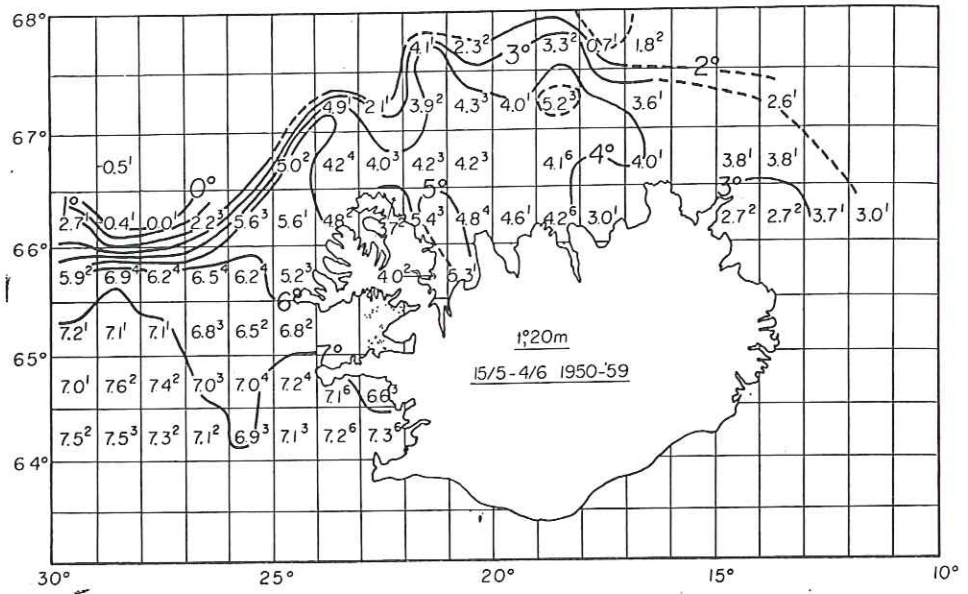


FIG. 14. The mean temperature at 20 meters, 15/5—4/6 1950—1959.

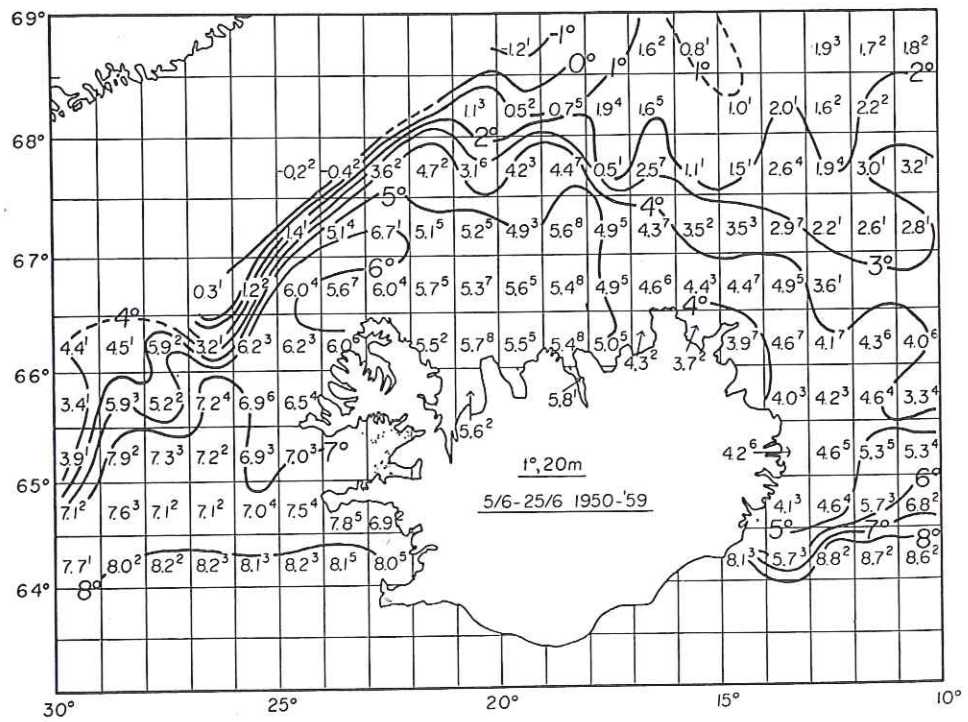


FIG. 15. The mean temperature at 20 meters, 5/6—25/6 1950—1959.

the arctic water. The line of demarcation is normally located a few miles off shore in the region between Eystrahorn and Vestrahorn on Southeast Iceland. From the coastal area, the boundary bends towards the southeast to about  $64^{\circ} 10' N, 13^{\circ} 30' W$ . From this point it is directed eastnortheastwards to about  $64^{\circ} 40' N, 11^{\circ} W$ .

The rise in temperature from the first period to the second, increases progressively from west to east. Thus in the region west of Faxaflói the temperature difference amounts to about  $0.5^{\circ}C$ , about  $1.0^{\circ}$  off the western and the middle part of the north Icelandic area, and about  $1.5^{\circ}$  off the northeast coast.

The mean ice limit for June 1952—59 is shown in figure 16. It is based on the observations made during the Icelandic cruises, 1952—59, supplemented by the ice reports published by EYBÓRSSON, (1953—1958).

The shortest distance from Látrabjarg to the mean ice border (figure 16) is 60—70 nautical miles in direction about  $330^{\circ}$ , and from Kögur about 50 miles in direction  $320^{\circ}$ . The distance due north from Kögur to the mean ice border is about 60 miles and about 120 miles due north from Skagi.

The ice limit shown on figure 16 is very similar to the 50% frequency curve for the period 1919—42 given by the Deutsches Hydrographisches Institut in Hamburg (1950).

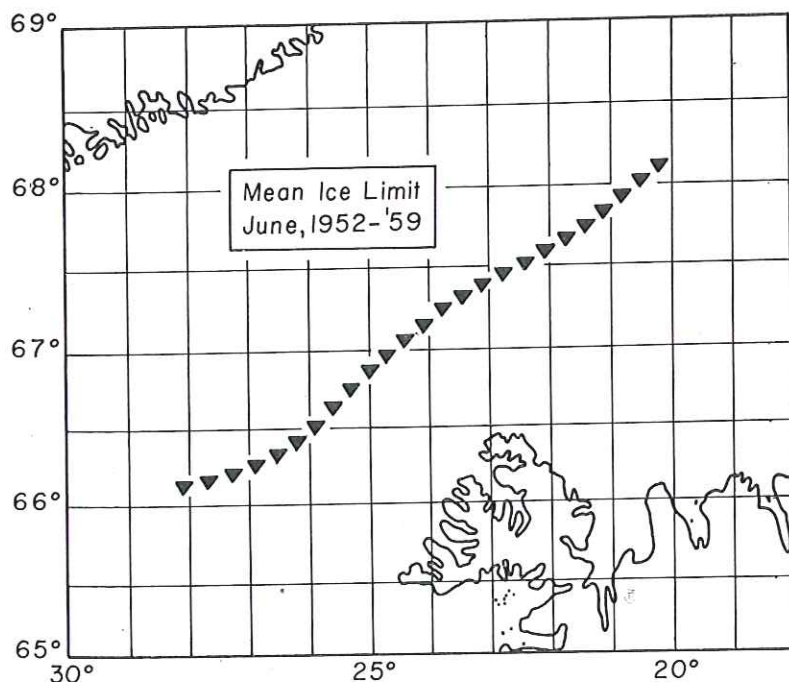


FIG. 16. The mean ice limit in June 1952—1959.

In May the mean ice limit may be presumed to be somewhat closer to the northwest coast of Iceland than in June. The material available, however, was not considered extensive enough to warrant the calculation of a mean ice limit for May.

4. REGIONAL VARIATIONS

It is now desirable to determine what part of the variation of the calculated mean values may be ascribed to strictly local temperature gradients.

Relatively small variations would be expected within subareas (each  $\frac{1}{2}^\circ$  latitude and  $1^\circ$  longitude) as well as from one year to another in the region west of Iceland, where relatively "pure" Atlantic water would be found at all times. Off the north and especially the northeast coast the year to year varia-

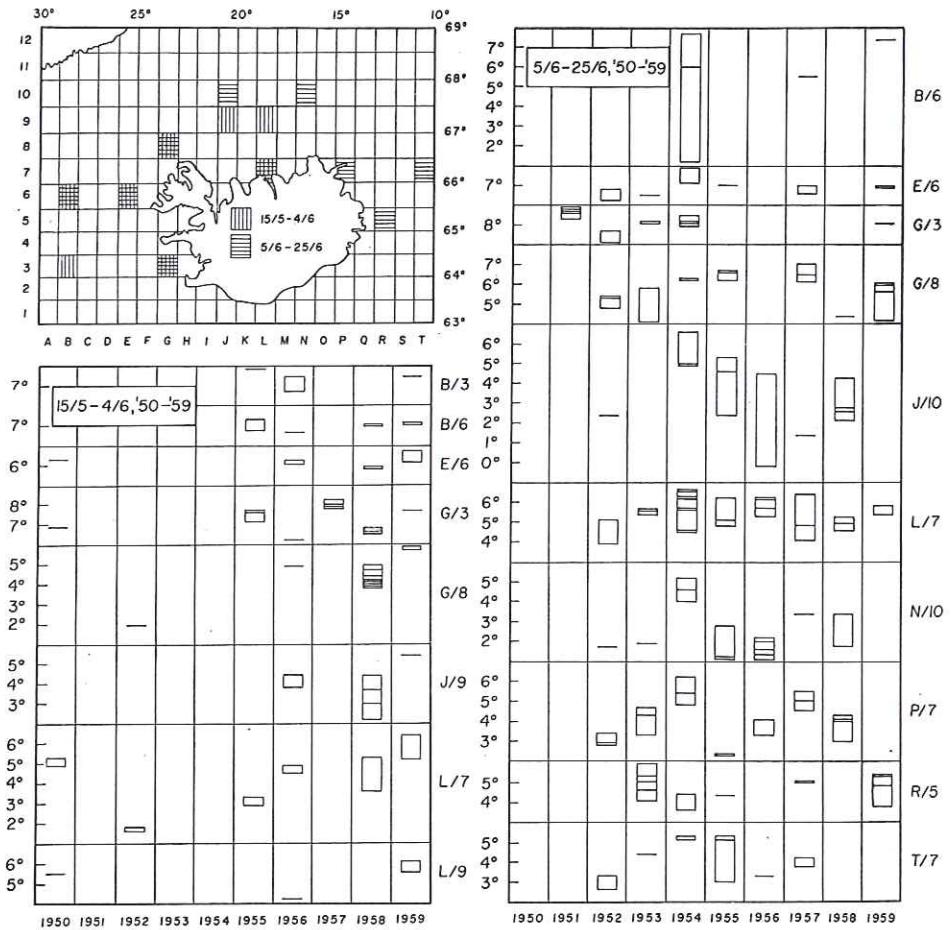


FIG. 17. Temperature fluctuations in subareas from various parts of the region investigated.

tions will be greater, since the sea temperature in these regions is to a large extent dependant upon the influx of Atlantic water which may vary considerably from one year to another. Variations within subareas will, however, be rather small on the north Icelandic grounds.

By far the greatest temperature variations are likely to occur in the boundary regions, where not only great year to year variations will exist, but also variations within subareas, due to shifts of the boundaries between the warm and the cold waters.

These considerations are clearly supported by the existing data. Figure 17 shows the temperature fluctuations in subareas from various parts of the region investigated. In subareas B/3, G/3 and E/6, in the region west of Iceland, only small temperature variations were found in both periods. Along the north coast the variations between years were found to be greater, especially during the period May 15th—June 4th, e.g. at L/7. This variation must be related to the influx of Atlantic water which is intensified in spring. The vernal influx may or may not have reached the middle part of the North Icelandic coastal area in May, but will in most cases have done so in June. Farther east along the coast the Atlantic influence will be delayed. Thus in subarea P/7 the year to year variations are considerable during both periods.

The greatest variations in the subareas here considered were found in B/6 and J/10, located at the boundaries between the Atlantic and polar water, where the variations within the subareas were even greater than the year to year variations. Such boundary areas may thus be quite narrow and fluctuate markedly from year to year.

Experience has repeatedly shown (JÓNSSON and STEFÁNSSON, 1955, p. 17, EINARSSON, 1956, p. 9, unpublished data from the years 1956—1959) that the greatest concentrations of herring in May—June are usually found in mixing areas, near the oceanic fronts, where the horizontal temperature gradients are strongest. For the purpose of finding the herring shoals, the importance of locating the water fronts must therefore be emphasized. In such regions the routine surveys should be made as detailed as possible and repeated at close time intervals.

#### ACKNOWLEDGEMENTS

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