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CAPELIN AND HYDROGRAPHY OFF THE NORTHWEST PENINSULA OF ICELAND DURING THE WINTER 1977

by

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1. INTRODUCTION

It is well known that most of the Icelandic capelin arrive at the south and west coast from the east sometime in late January and early February to spawn in those regions in March and early April. Subsidiary spawning is also known to take place elsewhere, particularly off North Iceland. These spawning runs are, however, much smaller and have never been the basis of a large fishery as has the south and south-west coast capelin since 1965 (Vilhjálmsson 1973).

About 4-5 years ago the Marine Research Institute began to get occasional but persisting reports on the occurrence of mature capelin off the northwest peninsula of Iceland (Vestfirðir) from trawlers and other fishing vessels operating in that region in January, February and March.

In 1974 the main spawning migration arrived at the southeast coast already 22 January. Consequently the spawning process itself took place at an unusually early date that year. By the second week of March all major capelin concentrations, that had arrived on the spawning grounds from the east in the usual manner, either had completed spawning already or were just at the point of doing so. In the 3rd week of March a new spawning migration was located on the grounds just off the central west coast at the tip of the Snæfellsnes peninsula. This migration was of a fairly large size and its discovery resulted in a lively fishery that lasted for the following 10 days with a total of nearly 50 000 tons (Vilhjálmsson 1974).

It seemed almost inconcievable that a migration of this size could have gone undetected, by both research vessels and the large fishing fleet, along the entire south coast and across the bay of Faxaflói. A more reasonable explanation of its presence in the Snæfellsnes area would, however, have been that it had arrived there from the west or northwest. If that was the case, this probably was the very same capelin that various fishing vessels had on occasion been observing on the grounds off the Vestfirðir peninsula earlier that year and in the years before.

The Marine Research Institute did not get the opportunity to look closely into this new problem for the next two years. During that period it was, nevertheless, established that considerable quantities of capelin did indeed aggregate on or just off the outer banks of the Vestfirðir peninsula in January, February and March. In 1975 and 1976 at least part of this capelin started migrating southwards in early March. In both years a similar phenomenon to that already described for the year 1974 was observed, namely the invasion of spawning concentrations in the area 10-20 nautical miles to the west of the Snæfellsnes peninsula. While such factors as age and size distribution were not much different from those of the capelin known to have arrived on the spawning grounds from the east, maturity was less advanced than what one would have expected in case of such capelin. This, together with a somewhat different behaviour and migratory pattern, quite clearly pointed to a different geographical origin. Both in 1975 and 1976 the migration resulted in a sizeable fishery (Anon 1976).

In view of the facts that now have been described, a research programme was developed in order to try to establish the origin and magnitude of the spawning runs in question as well as the composition and size of that part of the capelin stock, which apparently occurs off northwest Iceland in winter, and as far as possible to relate its movements to the conditions and changes in the environment.

This programme was carried out during the period January to April 1977 and the purpose of this paper is to report the data thus obtained as well as to explain the information as far as possible.

2. CRUISES AND SAMPLING

In the period 6 January to 5 April 6 cruises were made in the area to the northwest of Iceland on the R/V Bjarni Sæmundsson and R/V Árni Friðriksson. Opportunities for research were much restricted by unfavourable ice-conditions and bad weather, particularly in January and the first half of both February and March. Intermittently, some work also had to be done on other species so the time spent on capelin and environmental research was in fact much less

During January and February several standard hydrographic section were worked whenever possible. These were timed as follows:

Siglunes	9-10	January	Figure 6
Kögur	8	"	" 7
"	18	"	" 8
"	7	February	" 9
"	9-12	"	" 10
Látrabjarg	6-7	January	" 11
"	16-17	"	" 12
"	14-15	February	" 13
"	22	"	" 14
Snæfellsnes	1-3	"	" 15
"	20-21	"	" 16
Reykjanes	31	January - 1 February	" 17

On these sections temperature and salinity measurements were made at standard stations and depths and the position of the ice-edge and the movements of the ice were recorded.

Horizontal distribution of temperature and salinity at 50 m depth is shown during six time periods, the temperature distribution being not only based on hydrographic sections but also on expandable BT (XBT) observations. These time periods were:

6-10 January from Látrabjarg to Siglunes (Fig. 1)
15-18 January from Látrabjarg to Kögur (Fig. 2)

31 January - 3 February from Reykjanes to Snæfellsnes (Fig. 3)
7-9 February from Látrabjarg to Kögur (Fig. 3)
9-12 February from Djúpáll to Húnaflói (Fig. 4)
20-22 February from Snæfellsnes to Djúpáll (Fig. 5)

The sections off Látrabjarg and Kögur usually extended from the coast to the ice-limit.

Sonar and echo sounders were operated throughout the cruises but the success of operation of the acoustic gear and the interpretation of such data proved exceptionally difficult. This was both because of the often persistent bad weather and high seas as well as due to a thin layer of cold water of low salinity that often covered large areas of relatively warm water of Atlantic origin. Nevertheless, the distribution of capelin was chartered and its behaviour and migrations were studied as far as possible. Samples were collected with pelagic trawl and so distributed as to give the best possible idea of the composition of the stock with respect to yearclasses, size and stage of maturity and to keep track of the relative migrations of the stock units.

3. RESULTS

3.1. Hydrography

3.1.1. Horizontal distribution of temperature and salinity (Figs. 1-5)

The horizontal temperature and salinity distribution at 50 m depth was more or less different during the six observation periods. This is naturally best demonstrated as regards the warm and saline Atlantic water northwest of Iceland.

On 6-10 January the Atlantic influx indicated by temperatures of 4-6°C and salinities of 34.7-34.9 $^0/00$ reached at least to Siglunes. In the waters northwest of Iceland it covered most of the shelf area, whereas the polar water with temperature below ÷ 1°C was found above the deepest parts of the Denmark Strait.

On 15-18 January the Atlantic influence in the waters northwest of Iceland seemed to be similar or to decline slightly from 6-10 January, but the polar water was further out this time.

On 31 January to 3 February the temperature off Reykjanes and Snæfellsnes was 4-6°C at 50 m depth and the salinity was from about $34.8^{0}/00$ to slightly above $35.0^{0}/00$. The salinity in the area south and west of Iceland has been relatively low since 1975 (Malmberg, in press), or around $35.0^{0}/00$ against 35.15-$35.20^{0}/00$ prior to 1975.

On 7-9 February the Atlantic influence had declined considerably since January in the waters northwest of Iceland, and no Atlantic water was observed off Kögur, where the temperature was 2°C on 7 February and the salinity about $34.6^{0}/00$ at 50 m depth.

On 9-12 February a slight increase of "inflow" was observed north of Kögur with a temperature of 3-4°C and a salinity above $34.8^{0}/00$. This "inflow" had not reached the area off Húnaflói.

On 20-22 February the temperature and salinity in the Atlantic water northwest of Iceland had increased again to 4-6°C and above $35.0^{0}/00$ respectively, or to conditions comparable with those found earlier in January. On the other hand polar water had also moved into the study area in the central Denmark Strait, forming there a cold intrusion into or even a pool in the Atlantic water.

3.1.2. Vertical distribution of temperature and salinity (Figs. 6-17)

The vertical sections reveal the variability of temperature and salinity described in the horizontal charts. These sections are certainly more detailed and basically more accurate than the horizontal charts. The main results are briefly outlined by considering one section after another.

Siglunes, 9-10 January (Fig. 6)

On this section temperatures of 4-5°C and salinities above $34.8^{0}/00$ were observed. These values are relatively high or "favourable" as regards the Atlantic inflow for this time of the year.
On the other hand cold, polar water of low salinity covered the surface layers to a rather unusual extent. The frontal zone between the North Icelandic water masses and the polar current further north was at least 100 n.m. offshore, and so was the ice-limit. The polar water at the surface in the shelf area was probably connected to rather unfavourable drift-ice conditions from time to time in North Icelandic waters during last winter.

Kögur, 8 January (Fig. 7)

The temperature was above 5°C and the salinity above 34.8^{0}/00 in the Atlantic inflow. These values are relatively high, but on the other hand the polar front was only 25 n.m. offshore. There a 50 m thick layer of polar water was observed as also shown in Figure 1. This flow of polar water seems to be intermittent and possibly related to the bottom topography and other local conditions, and later on to its own physical parameters.

Kögur, 18 January (Fig. 8)

Temperature and salinity in the Atlantic inflow were still relatively high or above 5°C and 34.8^{0}/00 respectively. The polar front had moved since 8 January to 50 n.m. offshore, the cold polar surface water being replaced by Atlantic water.

Kögur, 7 February (Fig. 9)

No inflow of Atlantic water was observed off Kögur at this time. The temperature was only 2-3°C and the salinity about 34.6^{0}/00. The polar front was about 60 n.m. offshore.

Kögur, 9-12 February (Fig. 10)

No inflow of Atlantic water was observed off Kögur, but the temperature and salinity were slightly higher than a few days earlier, or 3-4°C and 34.7-34.8^{0}/00 respectively. The polar front was 50 n.m. offshore.

Látrabjarg, 6-7 January (Fig. 11)

The temperature was above 6°C and the salinity was 34.9-35.0^{0}/00 in the shelf area. The polar water was about 60 n.m. offshore. Noteworthy is the trend of the isolines near the bottom over the Icelandic shelf edge, with slightly decreasing temperature and salinity to below 6°C and 35.0^{0}/oo respectively.

Látrabjarg, 16-17 January (Fig. 12)

The warm saline water with temperatures above 6°C and salinities of about 35.0^{0}/00 had this time a greater extension seawards and downwards in the Denmark Strait than a week before. The polar front was thus 75 n.m. offshore and the cool intrusion above the bottom at the Icelandic shelf edge was not observed.

Látrabjarg, 14-15 February (Fig. 13)

The temperature and salinity was 5-6°C and 34.9-35.0^{0}/00 respectively above the Icelandic shelf and shelf edge. This is a slight decrease from the observations made a month earlier. Also a depths below 400-500 m in the Denmark Strait, water with temperature of about 2-4°C and salinity of less than 34.9 had replaced the Atlantic water found in January. The polar front was again found about 75 n.m. offshore.

Látrabjarg, 22 February (Fig. 14)

The temperature and salinity in the Icelandic shelf area had decreased from a week earlier and were even lower than those found 6-7 January. The polar front was possibly 65 n.m. offshore, or at least a tongue or pool of polar water was observed there with a depth of 100-200 m. This cold "pool" is shown in the horizontal distribution at 50 m depth in Figure 5. Noteworthy is also the trend of the isolines above the bottom over the Icelandic shelf edge like that found on 6-7 January.

Snæfellsnes, 1-3 and 20-21 February (Figs. 15-16)
Reykjanes, 31 January to 1 February (Fig. 17)

All three sections include Atlantic water of the Irminger Current west of Iceland with temperature of 5-6°C and salinity of about 35^{0}/00. These conditions may be described as "moderate". As noted above the salinity in the area south and west of Iceland has been relatively low since 1975, but prior to that time it was 35.15-35.20^{0}/00 (Malmberg, in press).

3.1.3. Concluding remarks on the hydrographic conditions

The following can be concluded about the hydrographic conditions in the waters north, northwest and west of Iceland in January-February 1977:

On 8-10 January the hydrographic conditions in North Icelandic waters were "favourable" with relatively high temperature and salinity values in the Atlantic inflow at intermediate depths. Light polar water covering the surface was unusually extensive, but the polar front itself was far offshore.

In the area off Northwest Iceland, from Kögur to Látrabjarg, different conditions were found from time to time, both as regards the Atlantic influence and the distance of the polar front from the coast. Off Kögur an Atlantic influx was observed in January but not in February. The polar front was nearest to the coast in the first week of January. Off Látrabjarg temperature and salinity in the Atlantic water were lower, and the polar front was nearer to the coast in the first week of January and the last week of February than in mid January and mid February.

In the area west of Iceland, off Snæfellsnes and Reykjanes, the Atlantic water dominated as usual. The salinity in the area was, however, lower than prior to 1975.

4. THE CAPELIN

4.1. Distribution and behaviour

On account of the inhospitable weather and ice conditions there is little to report on the capelin in January. On 7 January some very scattered recordings were located near the warm-cold water boundary about 75 nautical miles to the WNW of Látrabjarg. Further search in that area was prevented by foul weather and ice but a sample taken around noon from a depth of 250-300 m showed that these capelin were exclusively juveniles. On 18 January another sample was obtained at the ice edge 75-80 nautical miles to the N of Kögur. This sample consisted mostly of mature capelin. Although they were scattered, the abundance in the area was much higher than observed earlier in the month about 120 nautical miles further to the SW. As before the capelin stayed at depths between 250 and 300 m during the daylight hours but due to drift-ice no night observations were made.

During the second week of February good working conditions prevailed, the area being mostly free of ice and the weather good. Scouting and sampling operations revealed the presence of considerable quantities of capelin in deep waters off the shelf, from 80-90 nautical miles WNW of Látrabjarg north to 55-70 nautical miles N of Kögur as shown in Figure 20A. Although there undoubtedly was a lot of capelin in the above area they remained scattered and only occasional shoals were encountered (Fig. 21). As before the capelin stayed at depths between 200-350 metres during the day and only on rare occasions came closer to the surface than 100-150 m at night. Sampling showed the percentage of immatures to be from 50-80, the highest proportion of juveniles being caught in the SW as before.

No research was carried out on the capelin grounds in the 3rd week of February but on 22 February work was resumed and continued under favourable conditions until 1 March. During the intervening period the southeastern border of the capelin area had shifted 5-15 nautical miles towards, and in places quite close to, the edge of the shelf off the Vestfirðir peninsula (Fig. 20B). At the same time the percentage of immatures had decreased to 25-32, the juveniles being in the process of leaving for the deep waters of the Denmark Strait. Although the capelin recordings still had to be classified as scattered rather than dense, shoaling was more pronounced and large shoals were even encountered on occasions (Figs. 22-23). As before the capelin kept to depths in excess of 200 m during most of the daylight hours. They rose to a depth of 50-100 m at night and sometimes even to 5-15 m when night were unusually dark and the weather calm (Figs. 22-23).

Only sporadic scouting was carried out in March. It is, however, clear that no spawning migration from the NW region towards the Snæfellsnes area took place in 1977. Following reports of heavy concentrations of mature capelin from trawlers working on the outer banks off the Vestfirðir peninsula during the last days of March, research and fishing trials were carried out there for a short time in the very beginning of April. It was then established that spawning was taking place in the area between Víkuráll and Djúpáll, 25-45 nautical miles offshore (Fig. 20B). Consequently the capelin kept close to the bottom most of the time and was, therefore, generally not available to the fishermen.

In the last days of March unusually heavy concentrations of prespawning capelin were also located just off the central northcoast of Iceland. This spawning runs resulted in a small fishery and could have originated from the Vestfirðir area. It will be further examined in a later section.

4.2. Biological

In all 16 samples counting 1543 capelin were collected off NW-Iceland in January-April in order to establish the structure of this part of the stock, the relative movements of its units and by comparison to reveal eventual differences from the composition of the main spawning stock of capelin which, in December-March, migrates clockwise almost round the country to the S- and SW coasts of Iceland. Although in many ways inconclusive, the above sampling and other observations are comprehensive enough to provide ideas on, if not answers to, many of the questions and problems the present investigation was intended to answer and solve.

4.2.1. Age and sex distribution

The overall age distribution by 2 week periods is shown for both stock units in Table 1.

The January data from NW-Iceland represent only two samples, one taken from the extreme southwestern part of the area and the other at its northern limit. With regard to age and maturity the above samples are very dissimilar and they can hardly be taken as representative for this area as a whole.

The February sampling of the northwestern area was, however, much more comprehensive and should give a reasonably correct picture of the age distribution. In February the age composition of the northwestern stock unit thus differs from the remainder in the lower proportion of 4 year olds and a much larger admixture of 2 and 3 year old juveniles (Tables 1 and 2). It should be noted, however, that sampling off N- and E-Iceland is biased in favour of the adults. The majority of the samples comes from the commercial catch which is mostly taken at the apex of the spawning migration where the proportion of immatures usually is negligible compared to what it becomes off N- and E-Iceland as the season advances.

In March little scouting or sampling could be carried out off NW-Iceland. Juveniles, which in February had begun to leave the area for the deeper waters of the Denmark Strait, continued to do so. By the end of March they had left the more coastal part of the northwestern area altogether.

About 2/3 of the 144 capelin examined in the latter half of March were collected from 3 bottom trawl hauls in the Dohrnbank region at 65°40'N, between 28°20' and 29°32'W. Sex and age distribution was almost the same as that of the remainder, which was taken at the edge of the shelf to the WNW of the northern Vestfirðir peninsula (Table 3).

The age distribution of males, females and immatures is shown for both areas in Table 3. The NW-Iceland males and females are considerably younger than their counterparts elsewhere and the proportion of 2 year olds is higher among the NW-Iceland immatures than off N- and E-Iceland. In addition it might be pointed out that among the N- and E-coast capelin 3 year old females always have been much more numerous than their male counterparts and vice versa for the 4 year old (unpublished data). This also holds true for the 1977 N-, E-and S-coast capelin and for the 3 year olds of the NW-area. Among the latter, however, 4 year old females also appear in higher numbers than 4 year old males (Table 3). Consequently the male/female ratio was very uneven off the Vestfirðir peninsula or 32/68 while the N-, E- and S-coast capelin yielded the more normal figure of 46/54.

The mean age of the NW-Iceland spawners was 3.2 years but 3.5 years among the main spawning migration south and southwest of Iceland.

4.2.2. Length and weight

The length at age is compared in Table 4. The sexual difference is similar in both areas being in the order of 1.2-1.6 cm for age groups numerous enough to allow such comparison. With the exception of the 2 year olds it is, however, clear that the capelin undertaking the lengthy migration along the edge of the continental shelf off N- and E-Iceland to the southern spawning grounds are consistently larger than their stationary NW-Iceland counterparts.

The weight at age, which is shown in Table 5, shows a similar tendency as the length. Thus 3 and 4 year old spawners and all immatures that migrate to E-Iceland and onwards are on average always heavier than corresponding NW-Iceland capelin of the same age.

4.2.3. Maturity and spawning

In Figure 24 the rate of advanced of sexual maturity of the females (i.e. changes in the ratio: weight of ovary/total body weight with time) of NW-Iceland capelin in compared to that of the capelin from the main S- and SW-coast spawning migration.

In the beginning the stages of maturity is not much different in the two populations. After mid February, however, maturity advances much more quickly in the migrating population than in the stationary one off the Vestfirðir peninsula.

As illustrated in Figure 24 spawning thus commenced around or just before mid March off S- and SW-Iceland but not until approximately 3 weeks later in the Vestfirðir region. In 1977 the S- and SW-coast spawning was practically finished by the end of March as is verified by the catch record for the season. The above difference in the rate of advance of sexual maturity between the two populations reflects the difference in temperature to the polar water off the Vestfirðir shelf and coastal waters off the S- and SW-coast of Iceland.

Figure 20B illustrates the known 1977 spawning areas of the northwestern component of the Icelandic capelin. As mentioned in a previous section it is absolutely certain that none of the northwestern stock component migrated south to spawn in the Snæfellsnes region together with the remnants of the capelin from the main migration that had arrived there from the east. On the other hand unusually heavy spawning of capelin took place close to the shore at the central N-coast of Iceland (Siglunes area), particularly during the first half of April. The route of arrival of this capelin could not be traced except that it was due S and SSE for the last 20-30 miles. The exact origin of the N-coast spawners is, therefore, not clear. It will, nevertheless, pe pointed out again that the age composition (Table 1B, April 1-5 and 16-30) is very like that of the northwestern spawners (Table 1A, March 16-31 and April 1-15) while dissimilar from the unusually large percentage of 4 year olds characteristic for the S- and SW-coast spawners in 1977 (Table 1B, 1 January to 15 March).

4.2.4. Vertebral counts

Due to the long hours involved in preparing and in counting the vertebrae of the capelin the data collected are insufficient in volume for a valid comparison of vertebral frequencies of the two components to be made. The results are shown in Table 6, sections A and B and, with the possible exception of the 1973 yearclass, do not indicate different origin of the two stock units in question.

Table 6, section C, further shows the vertebral frequencies and average number of vertebrae among the capelin from the main spawning migration in 1976. In this case the 1973 yearclass average is 69.42 which is only different by 0.07 from the 1977 data from the northwestern area.

5. DISCUSSION

The hydrographic descriptions in this paper are meant to outline those climatic factors (Eyþórsson and Sigtryggsson 1971) in the seas around Iceland which are most likely to influence the general distribution of capelin in the Icelandic area, and more specifically in the waters northwest of Iceland as well as in the Denmark Strait.

Charts of mean surface temperature of the oceanic areas around Iceland have been prepared by Krauss (1958, Fig. 18) and for South Icelandic waters by Malmberg (1962, 1969). These charts reflect the current system in Icelandic waters, i.e. the warm Irminger Current, the cold East Greenland Current, the East Icelandic Current and the coastal current (Fig. 19, Stefánsson 1961, 1962). This current system again pinpoints the location of Iceland near or at the oceanic polar front.

The main feeding and nursing grounds of the Icelandic capelin are situated in the cold waters off N- and NW-Iceland. In wintertime (December-March) most of this capelin migrates for spawning to the area east of Iceland and hence westwards along the south coast into the warmer coastal waters with relatively low salinity. The route of migration is now familiar and has been investigated since 1969. It is clearly correlated to hydrographic conditions, following the western boundary of the East Icelandic Current and the coastal current at the south coast. In both cases the route is in the direction of the current. A migration from the Denmark Strait area directly to spawning grounds in the Breiðafjörður or Faxaflói regions would, however, be of a somewhat different nature. In that case the capelin would have to migrate cross-current or even counter-current in the warm and saline Atlantic waters of the Irminger Current to reach its destination in the coastal waters (Fig. 20).

Because of the small dimensions of the Denmark Strait - 275 km wide with a sill depth of about 620 m - the exchange between the powerful watermasses involved must result in complicated and variable hydrographic conditions (Dietrich 1957, Malmberg 1972, Stein 1974). This interesting area has also been the object of intensive study particularly during the international "Overflow '73" investigations carried out under the auspices of ICES in 1973 (Dietrich 1971, Anon. 1976). Only some of the results of these investigations will be pointed out here, i.e. variability of ocean currents in the area with periods of 2-3 days and 2-3 weeks, in addition to tidal variability. These variations are related to atmospheric and oceanographic conditions in a more or less complicated way (Smith 1975, Meincke 1976, Ross 1976, Malmberg, unpublished data).

Hydrographic observations in the Denmark Strait such as those reported in this paper have shown that the boundaries between the waters of the surface current are very sharp and often shift suddenly forming curved flows or eddies. These outbreaks of cold or warm water may become detached and form isolated eddies or pools (Figs. 5, 14). The undulating flow in the surface layers seems to be initiated by the bottom topography and other local conditions as they are found very much at the same locations from one time to another (Gade et al 1965, Nagurny and Semenov 1976). The phenomenon may develop further on its own or due to atmospheric conditions. Some observations on extreme drift-ice conditions in the waters northwest of Iceland in April 1969 (Malmberg 1970) are of interest in this connection as they may show the main course of inflow of cold or cool pools of water through the warm Atlantic water into the shelf area west of Iceland (Figs. 5, 14).

A close relationship has also been shown between extreme drift-ice conditions in East and South Icelandic waters as in 1695 and 1968 and the general current system in these waters (Vilmundarson 1972, Malmberg 1972) which again is the main course of migration of capelin in these waters during late winter (Vilhjálmsson 1972 and 1973). Extreme drift-ice conditions which can be observed visually, may indicate the course of ocean currents and at the same time describe the migration route of pelagic fishes such as capelin during more "normal" conditions.

It should perhaps not come as a surprise to find capelin aggregating off NW-Iceland in winter. As has been described this is a border area between polar water, Atlantic water and Icelandic coastal water and suitable spawning grounds a relatively short way off. All through January, February and most of March the mature capelin remained on the outer and colder side of the borderline between these water masses, being more or less stationary apart from small local migrations probably induced by variations in the southeastern limit of the cold water from the north. This situation did not change until the last days of March and in early April when the capelin moved on to the Vestfirðir banks to spawn in relatively warm water there. Exceptions are the juveniles which gradually left for the cold channel area between Iceland and Greenland as well as the migration of part of the capelin to spawn off the central north coast of Iceland as some of the evidence suggests.

On the basis of differences in behaviour, age, size composition, maturity and spawning time the capelin observed off the Vestfirðir peninsula in the winter of 1977 can not be considered to belong to a different stock from the rest of the Icelandic capelin. The above differences are much more likely to be induced by a different environment and the meristic data, although inconclusive, certainly do not suggest two different origins of the stock units in question. Somehow this capelin is left behind when the main spawning migration begins in December to stay in the cold water off the NW-peninsula until maturity is reached. Spawning follows, either in the vicinity or at some not too distant locations farther south, north or east as the case may be.

It is known (Sæmundsson 1926, Jakobsson 1969 and 1976, Vilhjálmsson 1972 and 1976) that the bulk of the maturing capelin feed in the polar waters off N- and NW-Iceland while feeding capelin have also been recorded further to the west on the Greenland side of the Iceland-Greenland channel. Possibly it is capelin from these western feeding grounds that arrive off NW-Iceland too late to undertake the long journey more or less around the Icelandic continental shelf to spawn off the S- and SW-coasts. It seems, however, clear that, in the last few years at least, these northern spawners have only represented a relatively minor proportion of the spawning stock of the Icelandic capelin. It is also possible that the presence of pre-spawning capelin off the Vestfirðir peninsula in winter is a relatively recent phenomenon and connected with the apparent shift of the main feeding grounds to the west or south-west in the last few years.

During capelin research off East-Iceland in the winter of 1969 it was discovered that immature 2-3 year olds migrated with or followed the spawners to those waters to be left behind off East Iceland to return to the N- and NW-coast feeding grounds in spring and early summer (Vilhjálmsson 1972 and 1973). For a time it was thought that these immatures accounted for most if not practically all prospective spawners of the following year. This would have been excellent indeed since these capelin are more or less accessible for monitoring changes in abundance in March and April. In addition to last winters findings of high numbers of immature 2-3 ringers off the Vestfirðir peninsula, summer research in June-July 1976 had established the presence of large concentrations of 2 and 3 ringers to the N and NW of the peninsula which were slowly migrating northeastwards. At that time the E-coast immatures were found 100-120 nautical miles off the central N-coast (Vilhjálmsson 1976).

Although a much closer study of the overwintering grounds is needed, it is clear that during the last few years at least a large proportion if not the majority of the Icelandic immature capelin overwinters off NW-Iceland. At the same time large amounts have of course migrated to East-Icelandic waters as well. On account of the often severe ice conditions in the Iceland-Greenland region in spring and early summer it will, therefore, not be possible in future to evaluate the amount and composition of next year's spawning stock until much later in the year than we had hoped.

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Table 1 Percentage Age Distribution by 2 Week Periods
January-April 1977 (M+F+Immatures)
NW-Iceland.

A

Age	January 1-15	January 16-31	February 1-14	February 15-28	March 1-15	March 16-31	April 1-15	April 16-30
1	3							
2	92	4	33	15	5	10	4	
3	5	62	57	69	82	62	74	
4		32	10	15	12	27	21	
5		2		1	1	1	1	
Number	99	101	399	498	100	144	200	

B E- and Southern-Iceland

Age	January 1-15	January 16-31	February 1-14	February 15-28	March 1-15	March 16-31	April 1-15	April 16-30
1								
2	1	+	+	5	1	2	3	1
3	59	49	54	52	48	56	67	64
4	40	51	46	42	50	42	29	35
5		1		1	1		1	
Number	801	699	1000	1147	732	500	100	100

Table 2 Age and Percentage of Immatures in Capelin, January-April 1977. NW-Iceland.

A

Age	January 1-15	January 16-31	February 1-14	February 15-28	March 1-15	March 16-31	April 1-15	April 16-30
1	3							
2	92	3	30	11	4	2		
3	5	7	21	28	17	3	1	
4			1	1	1	1		
Total %	100	10	52	30	22	6	1	

B N-, E- and Southern Iceland

Age	January 1-15	January 16-31	February 1-14	February 15-28	March 1-15	March 16-31	April 1-15	April 16-30
1								
2	+	+		4				
3	6	2	3	2	1	+		
4	+	1	1	1	+	+		
Total %	6	3	4	7	1	+	0	0

Table 3 Percentage Age Distribution of Males, Females and Immatures, Winter 1977 NW = NW-Iceland; NES = N-, E- and Southern Iceland.

	Males		Females		M + F		Immatures	
Age	NW (n)	NES (n)	NW (n)	NES (n)	NW (n)	NES (n)	NW (n)	NES (n)
1							1 (3)	
2	1 (5)	1 (11)	6 (44)	1 (25)	5 (49)	1 (36)	51 (364)	26 (50)
3	68 (214)	42 (971)	73 (494)	62 (1612)	71 (708)	53 (2583)	47 (257)	60 (114)
4	30 (96)	56 (1277)	20 (135)	37 (975)	23 (231)	46 (2252)	1 (7)	13 (24)
5	1 (4)	1 (11)	1 (5)	+ (7)	1 (9)	+ (18)		1 (1)
Number	319	2270	678	2619	997	4889	546	189

Table 4 Length at Age (in gms) of Males, Females and Immatures, Winter 1977 NW = NW-Iceland ; NES = N-, E and Southern Iceland.

	Males		Females		M + F		Immatures	
Age	NW	NES	NW	NES	NW	NES	NW	NES
1							6.8	
2	14.7	14.6	13.3	13.3	13.4	13.7	10.5	10.2
3	15.8	16.3	14.6	15.0	15.0	15.5	14.2	14.8
4	16.7	17.5	15.4	15.9	15.9	16.8	15.1	16.0
5	18.0	17.8	14.6	16.4	16.1	17.3		17.0
Average	16.1	17.0	14.7	15.3	15.1	16.1	12.3	13.8

Table 5 Weight at Age (in gms) of Males, Females and Immatures, Winter 1977 NW = NW-Iceland ; NES = N-, E- and Southern Iceland.

	Males		Females		M + F		Immatures	
Age	NW	NES	NW	NES	NW	NES	NW	NES
1							0.6	
2	16.6	16.6	11.9	11.7	12.4	13.2	4.2	5.1
3	21.6	22.8	15.8	16.1	17.6	18.6	12.7	14.4
4	27.0	29.7	19.5	21.0	22.6	25.9	16.2	18.9
5	29.1	31.7	18.0	19.8	22.9	27.0		23.5
Average	23.2	26.2	16.3	17.9	18.6	21.4	8.3	12.7

Table 6

A Vertebral frequencies NW-Iceland 1977

Age	Yrd	66	67	68	69	70	71	72	73	Total	Average
2	75			2	4		1	1		8	69.38
3	74	1	2	23	52	58	10	3		149	69.38
4	73		1	7	12	14	6	1		41	69.49
5	72				1		1			2	70.00
Total		1	3	32	69	72	18	5		200	69.41

B Vertebral frequencies N-, E- and SW-Iceland 1977

Age	Yrd	66	67	68	69	70	71	72	73	Total	Average
2	75			2	1	1	1			5	69.20
3	74		1	16	44	22	7	3		93	69.29
4	73		2	24	49	20	6			101	69.03
5	72				1					1	69.0
Total			3	42	95	43	14	3		200	69.16

C Vertebral frequencies N-, E-, S- and SW-Iceland 1976

Age	Yrd	66	67	68	69	70	71	72	73	Total	Average
2	74				2	1				3	69.33
3	73		7	35	138	106	35	3		324	69.42
4	72	1	2	38	157	133	37	3		371	69.46
5	71					2				2	70.0
Total		1	9	73	297	242	72	6		700	69.44

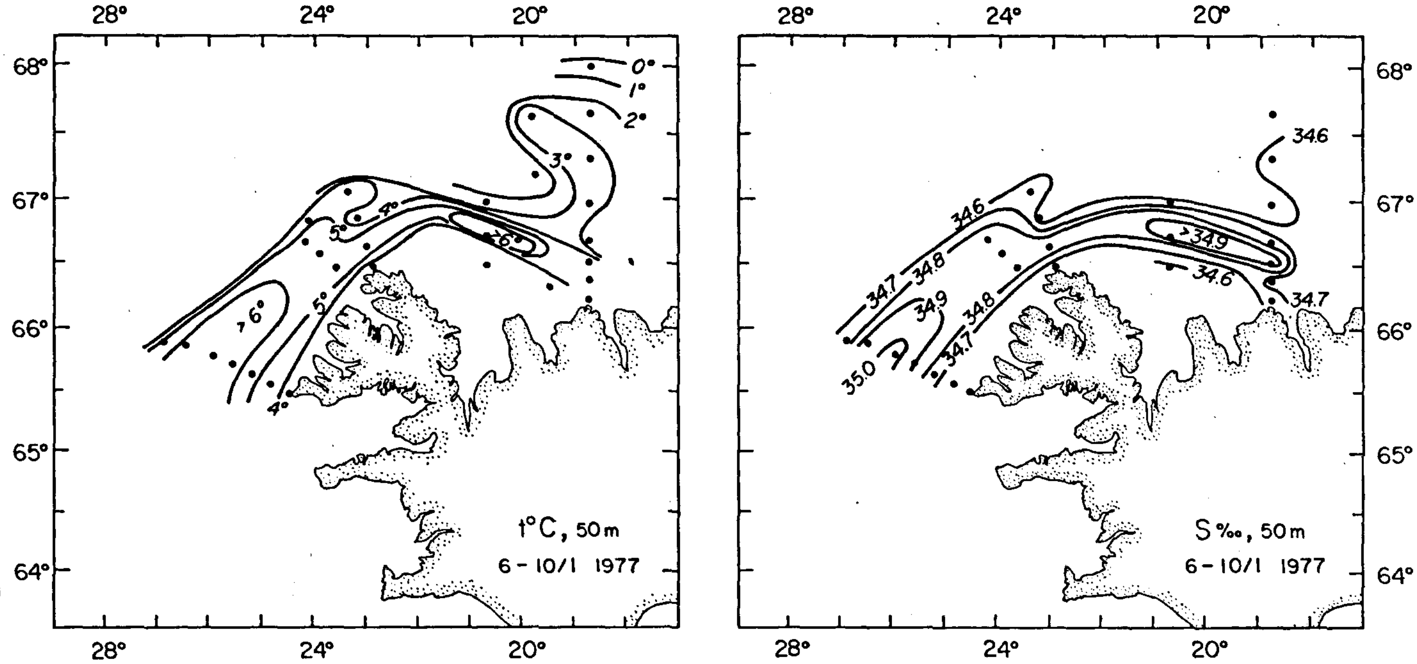


Figure 1 Temperature and salinity, 50 m

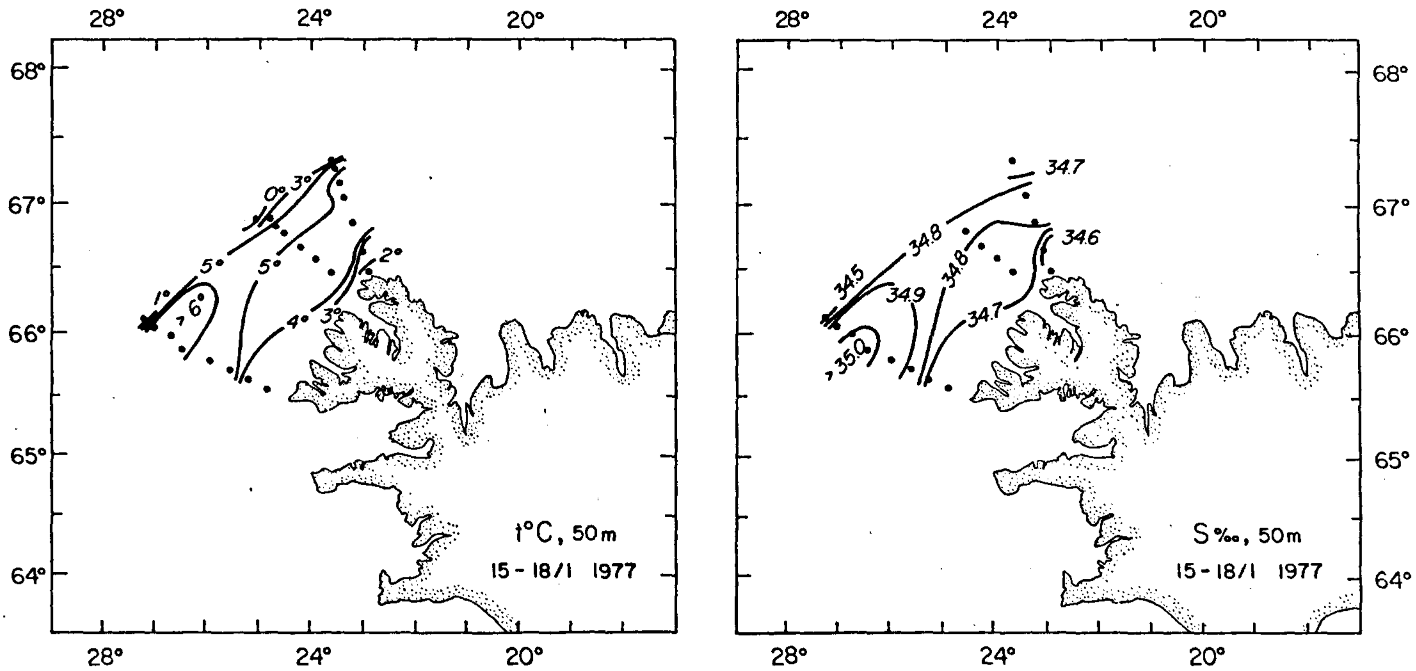


Figure 2 Temperature and salinity, 50 m

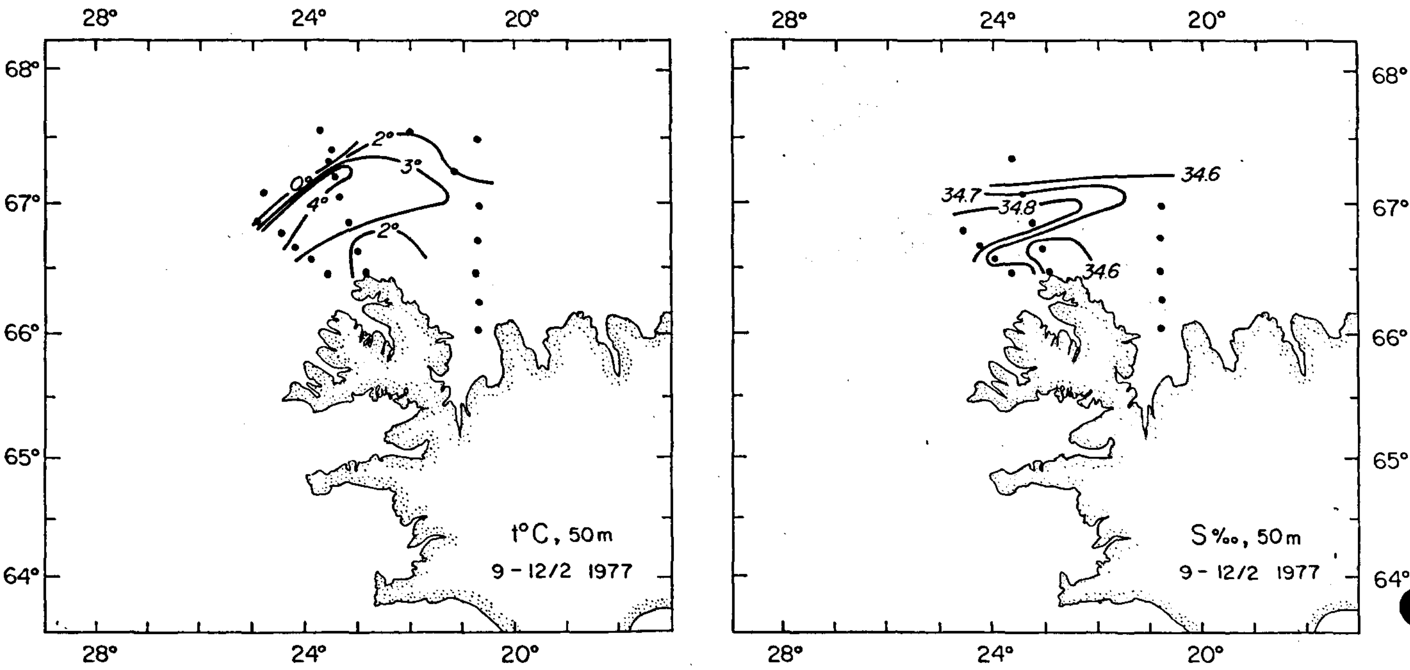


Figure 3 Temperature and salinity, 50 m

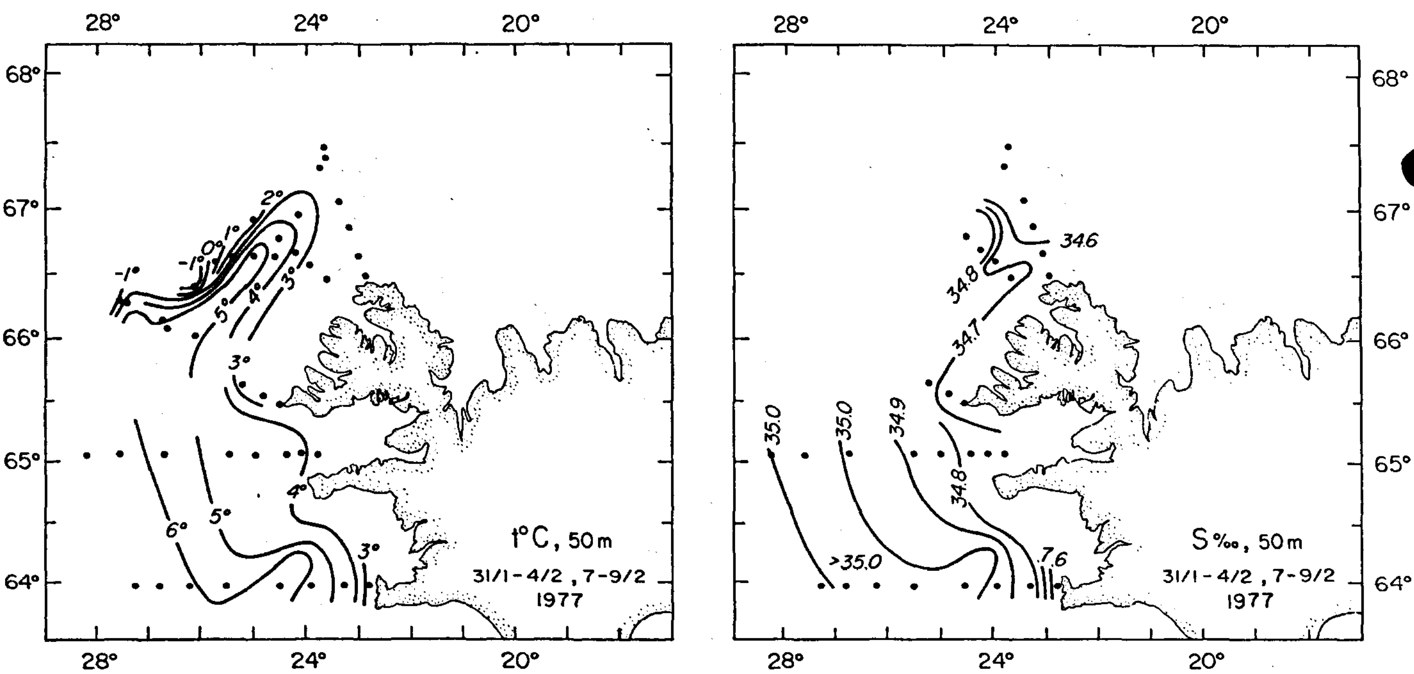


Figure 4 Temperature and salinity, 50 m

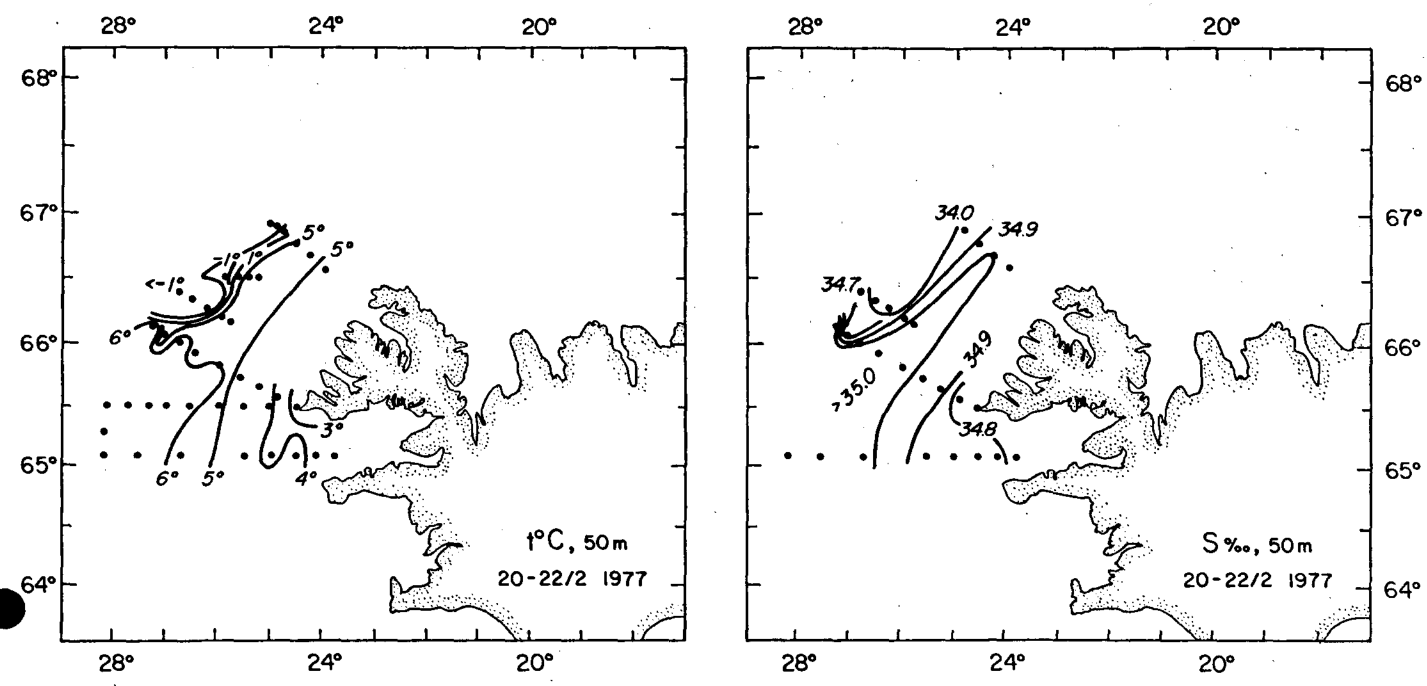


Figure 5   Temperature and salinity, 50 m

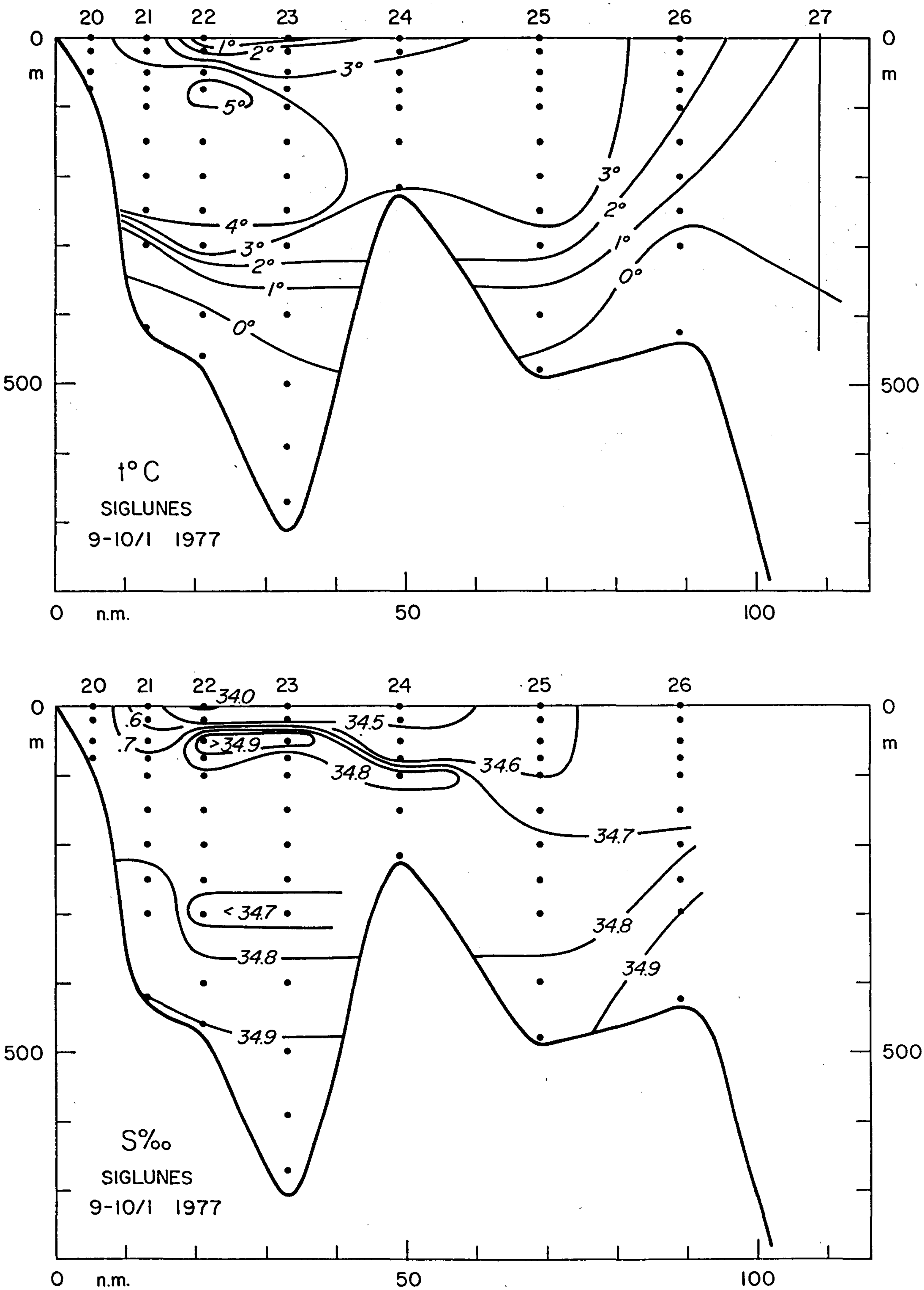


Figure 6 Section north of Siglunes, temperature and salinity

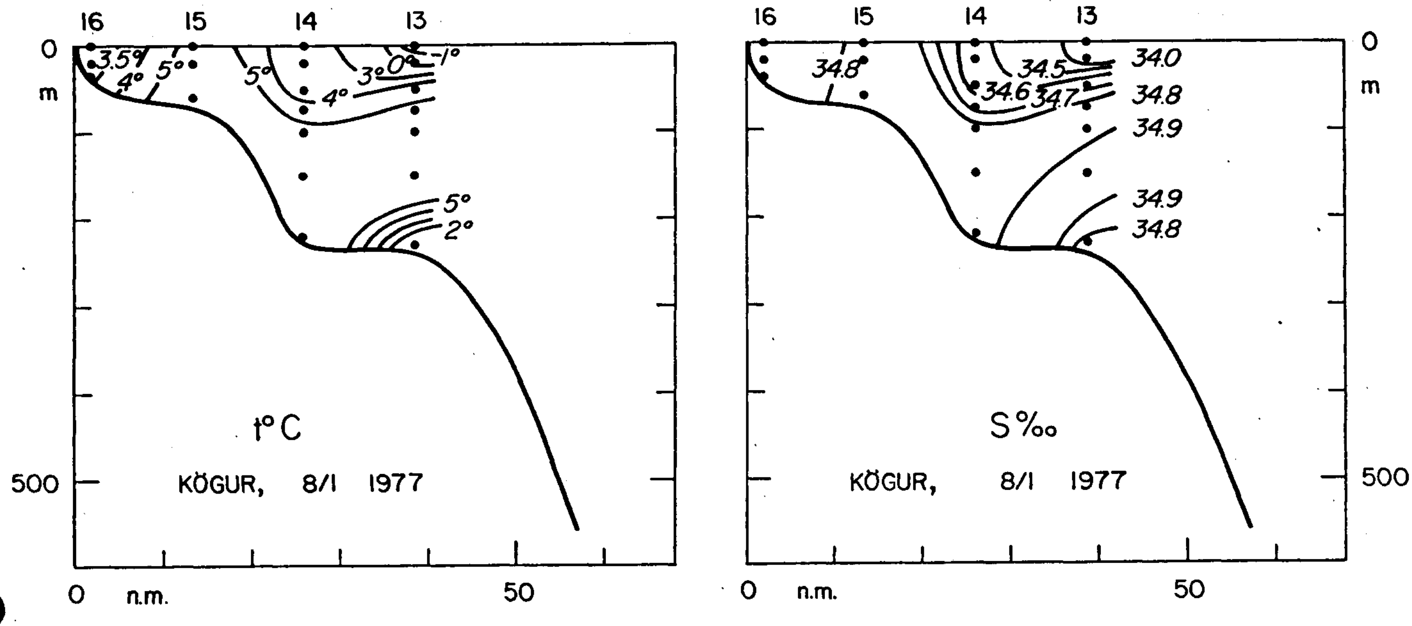


Figure 7 Section north of Kögur, temperature and salinity

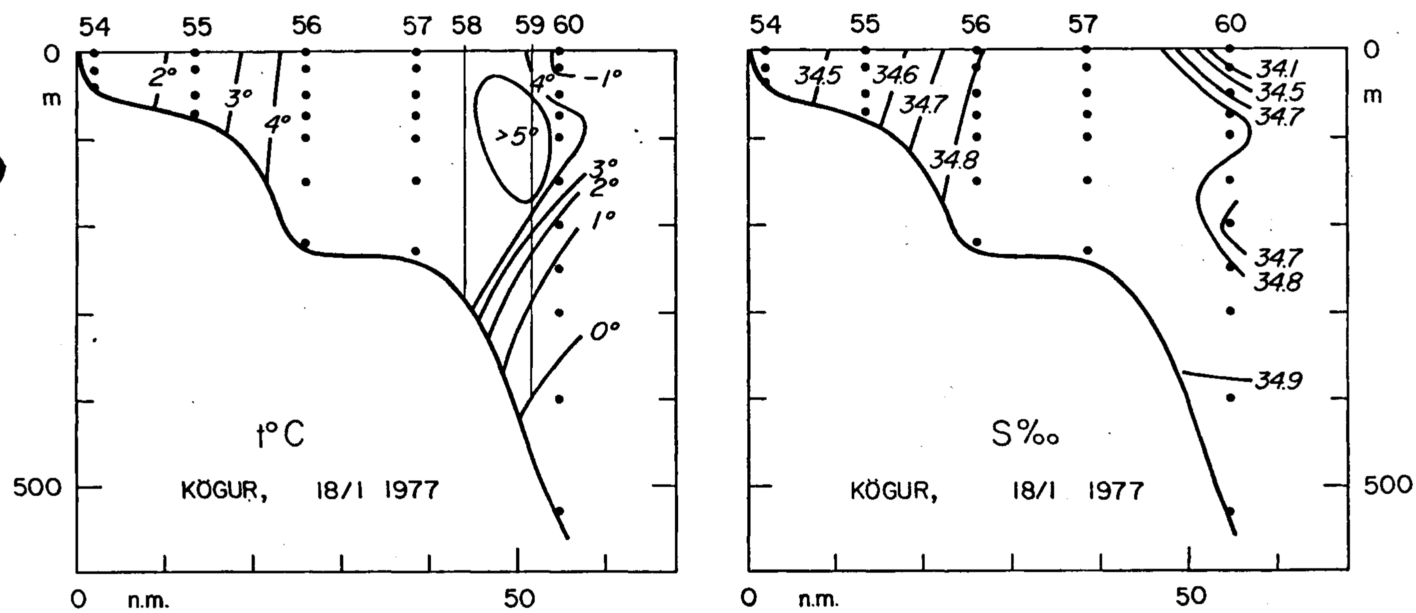


Figure 8 Section north of kögur, temperature and salinity

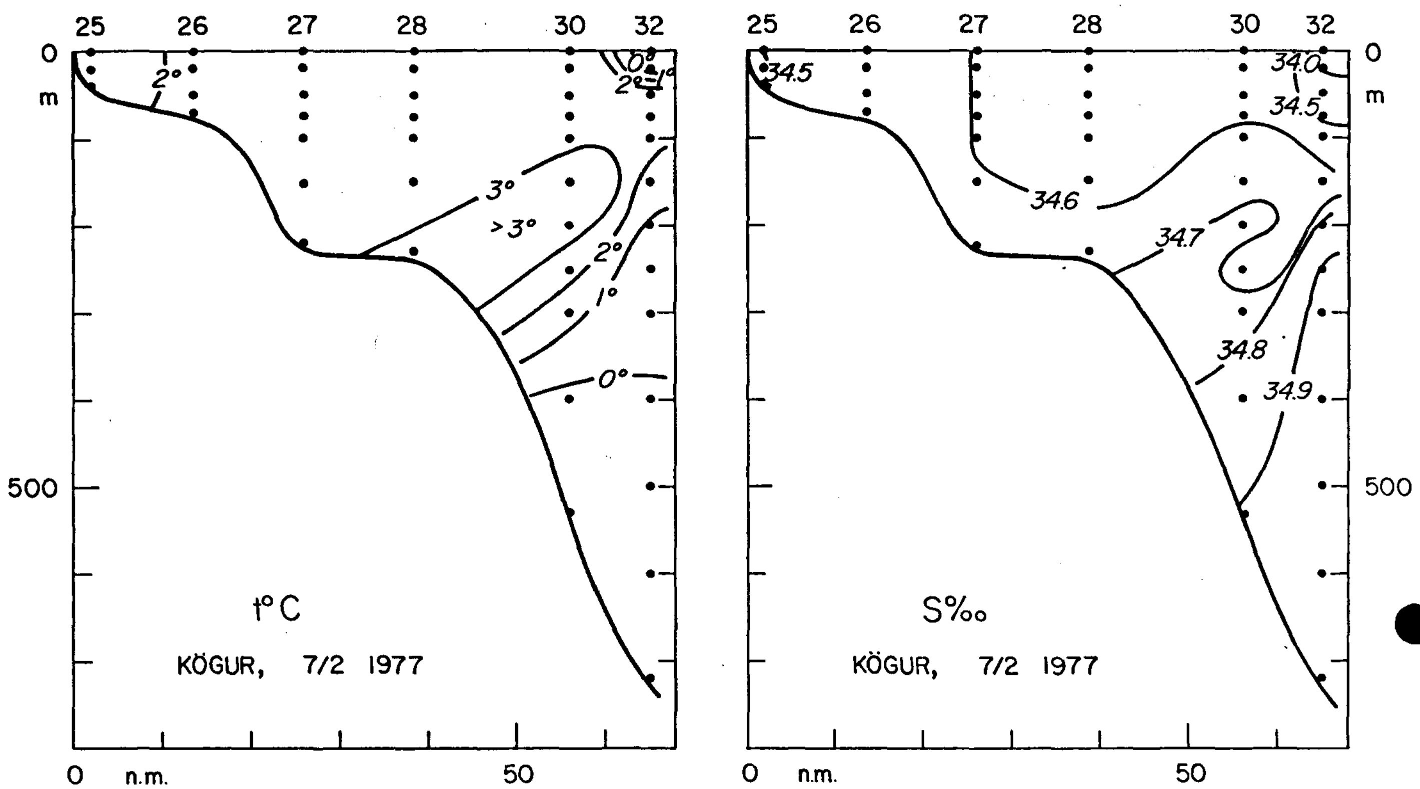


Figure 9 Section north of Kögur, temperature and salinity

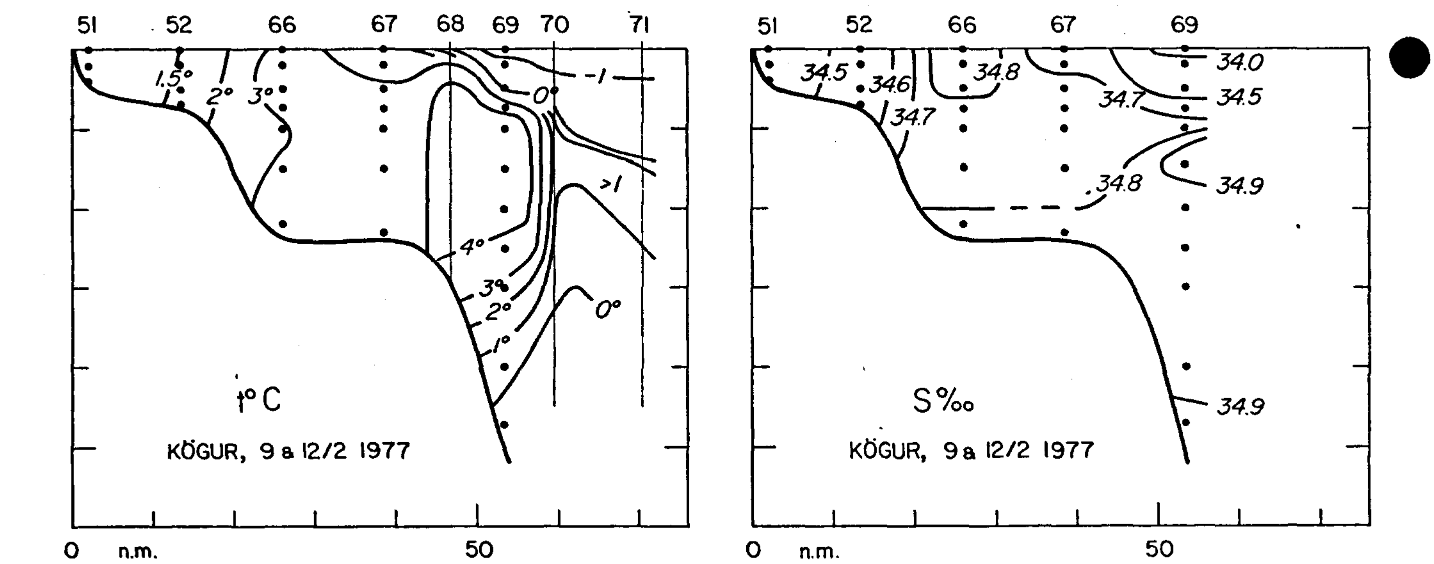


Figure 10 Section north of Kögur, temperature and salinity

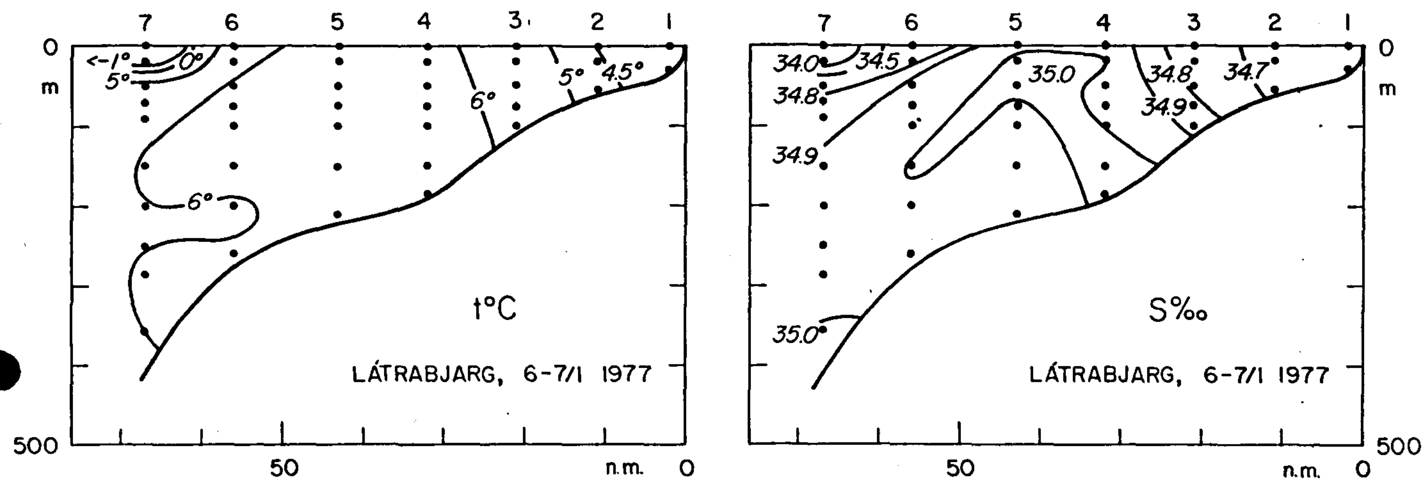


Figure 11 Section northwest of Látrabjarg, temperature and salinity

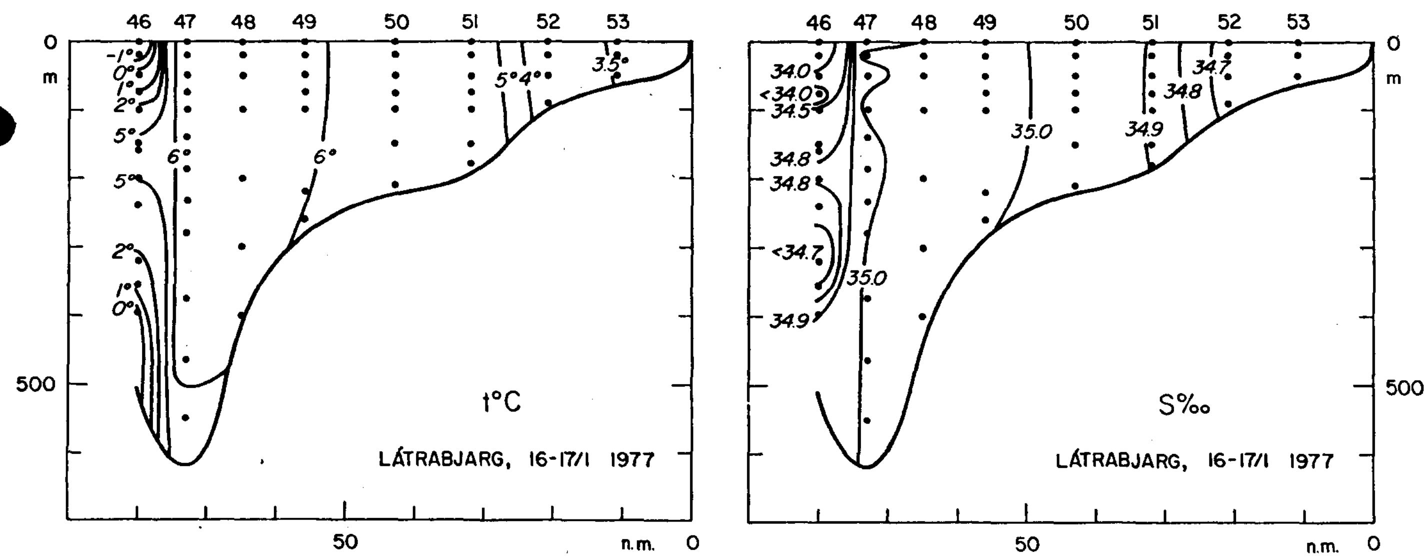


Figure 12 Section northwest of Látrabjarg, temperature and salinity

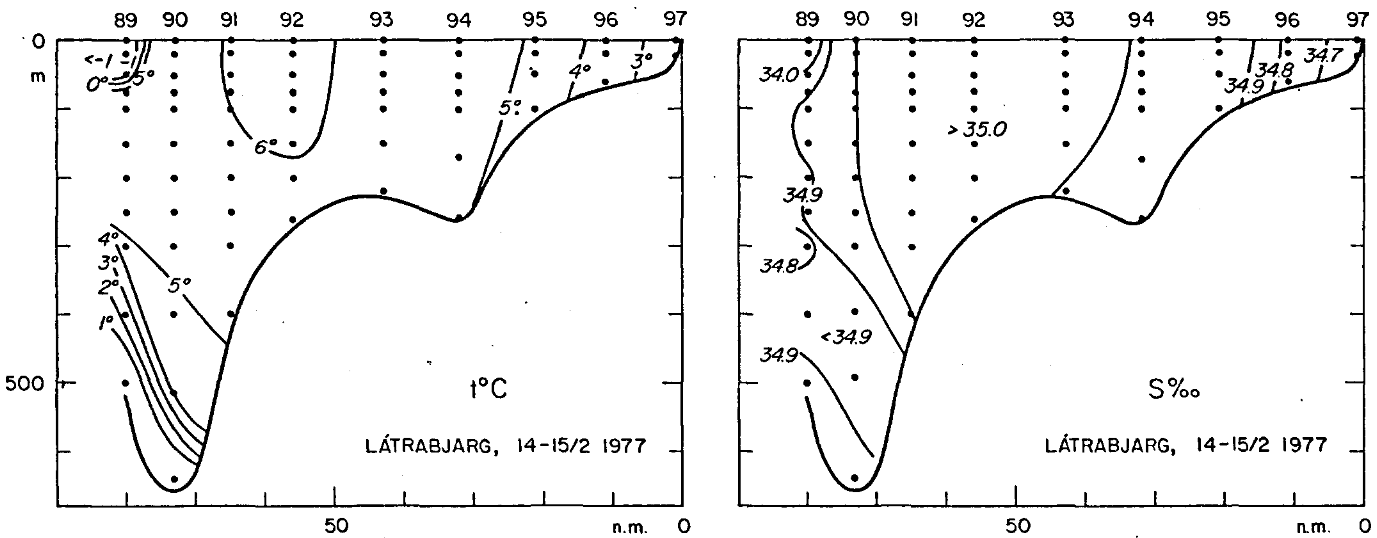


Figure 13 Section northwest of Látrabjarg, temperature and salinity

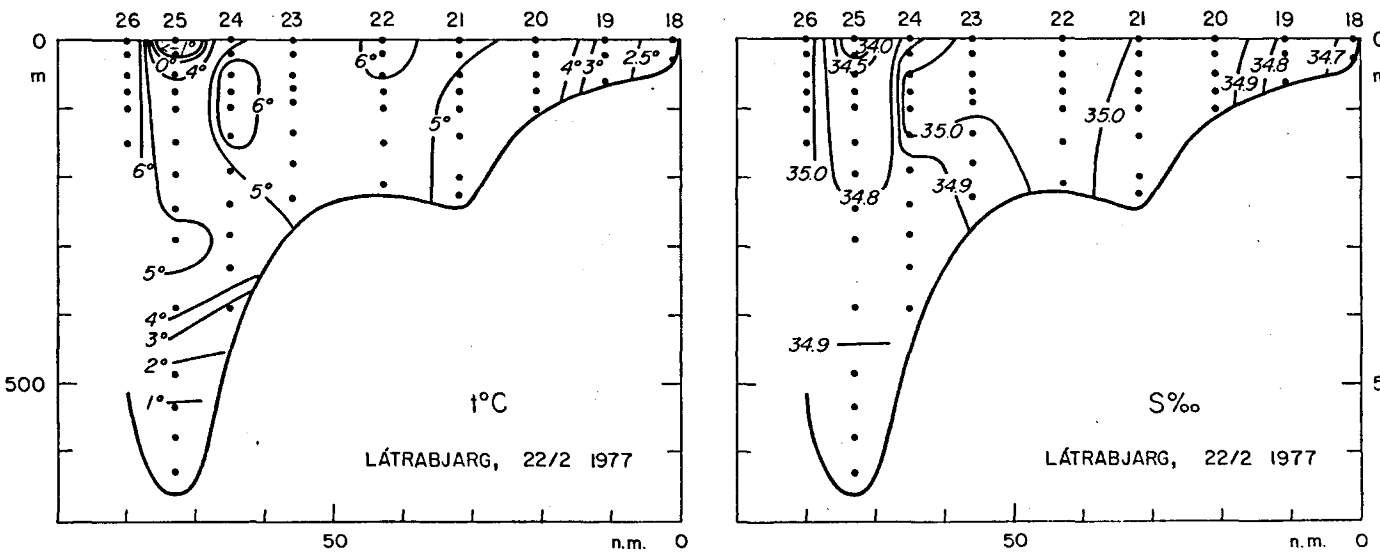


Figure 14 Section northwest of Látrabjarg, temperature and salinity

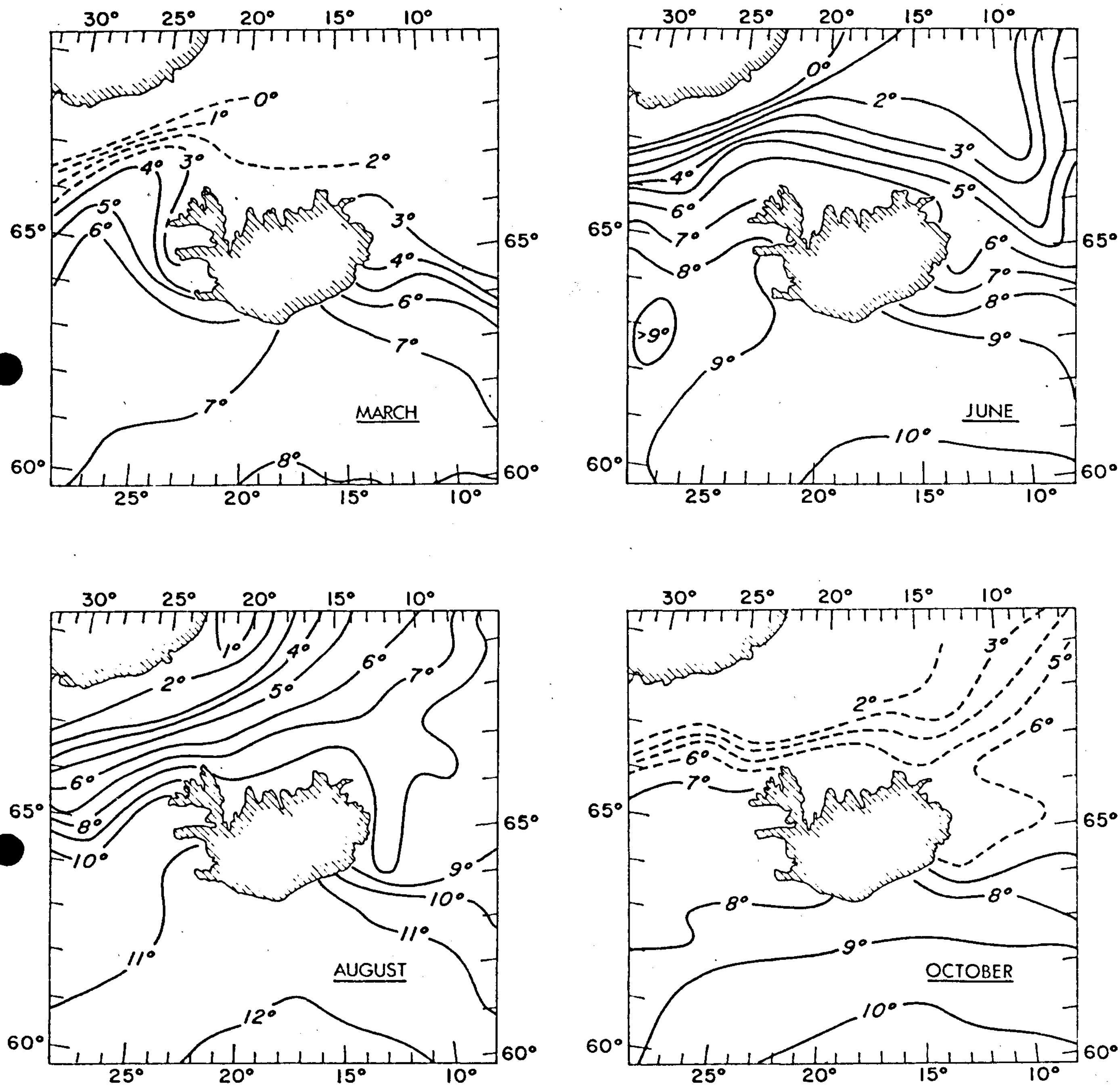


Figure 18 Average sea surface temperature near Iceland (Stefánsson 1961 after Krauss 1958)

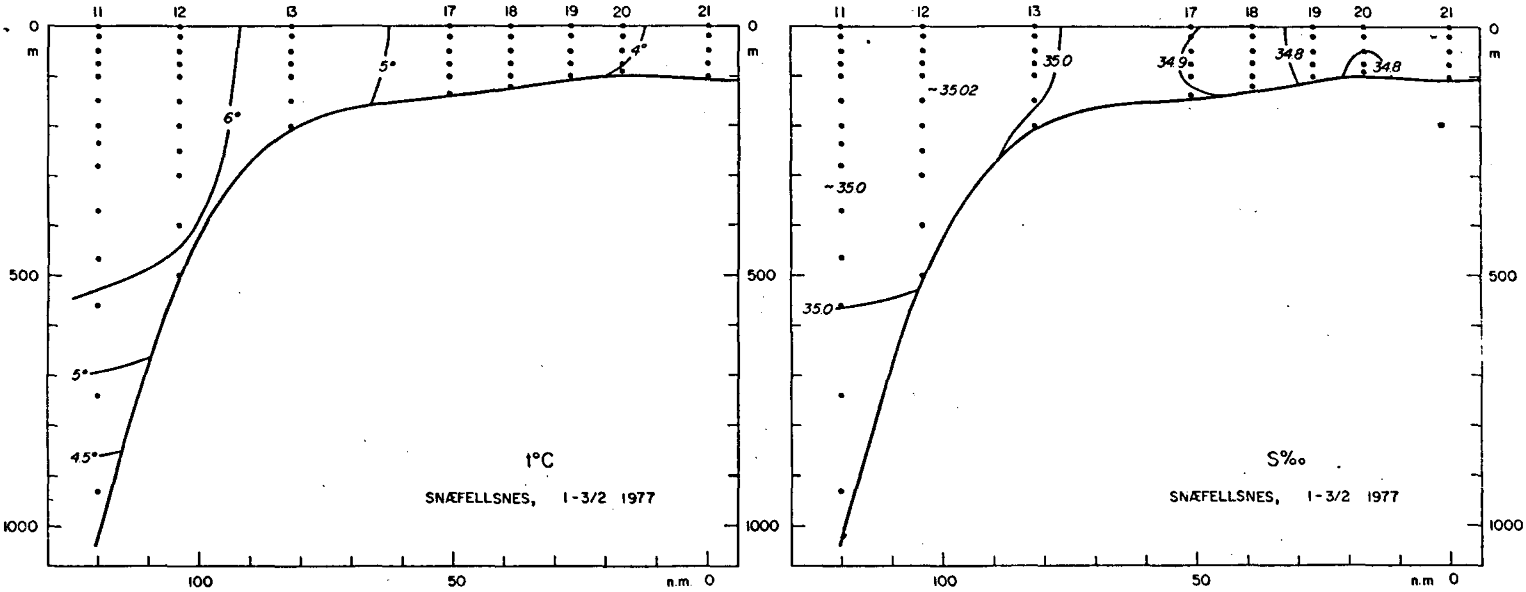


Figure 15 Section west of Snæfellsnes, temperature and salinity

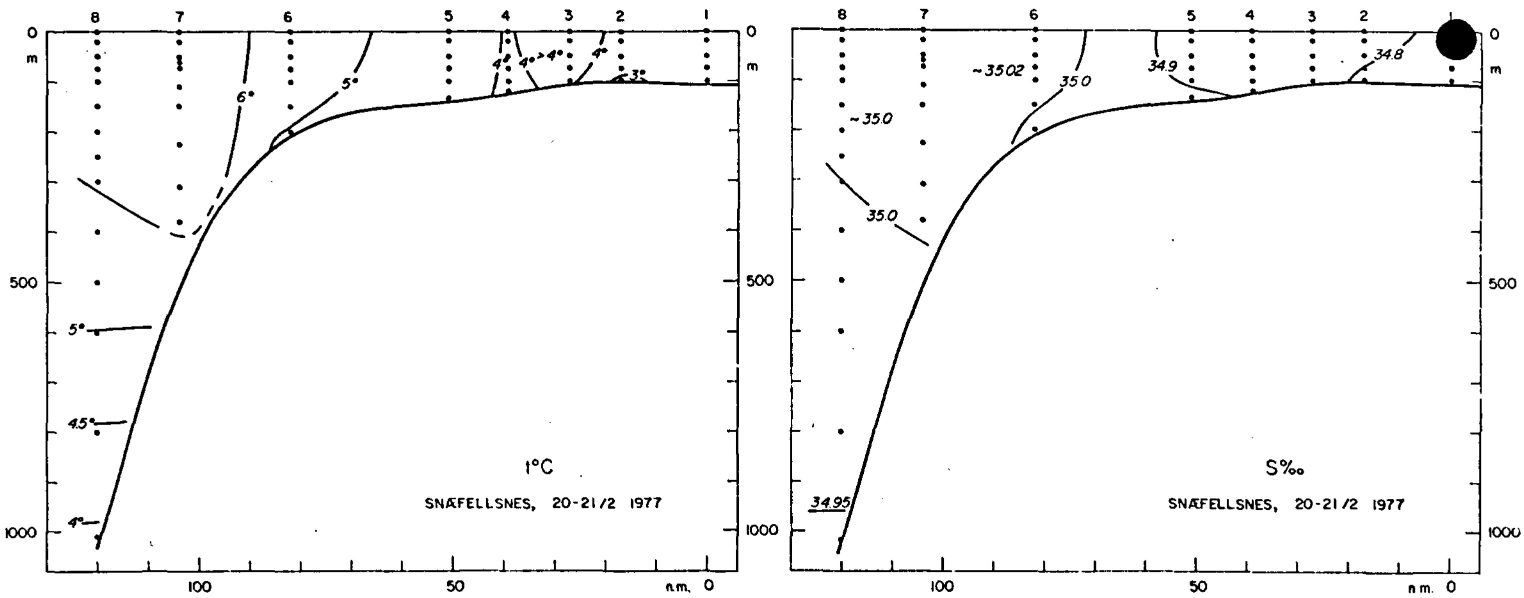


Figure 16 Section west of Snæfellsnes, temperature and salinity

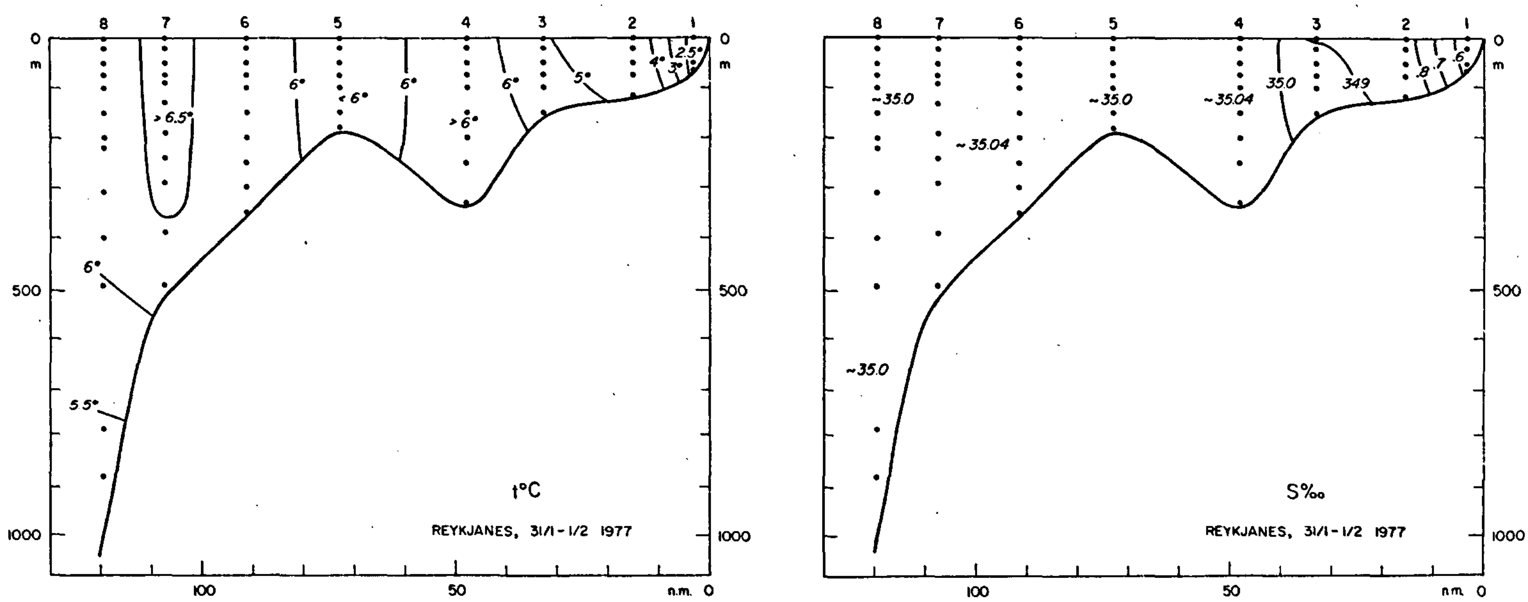


Figure 17 Section west of Reykjanes, temperature and salinity

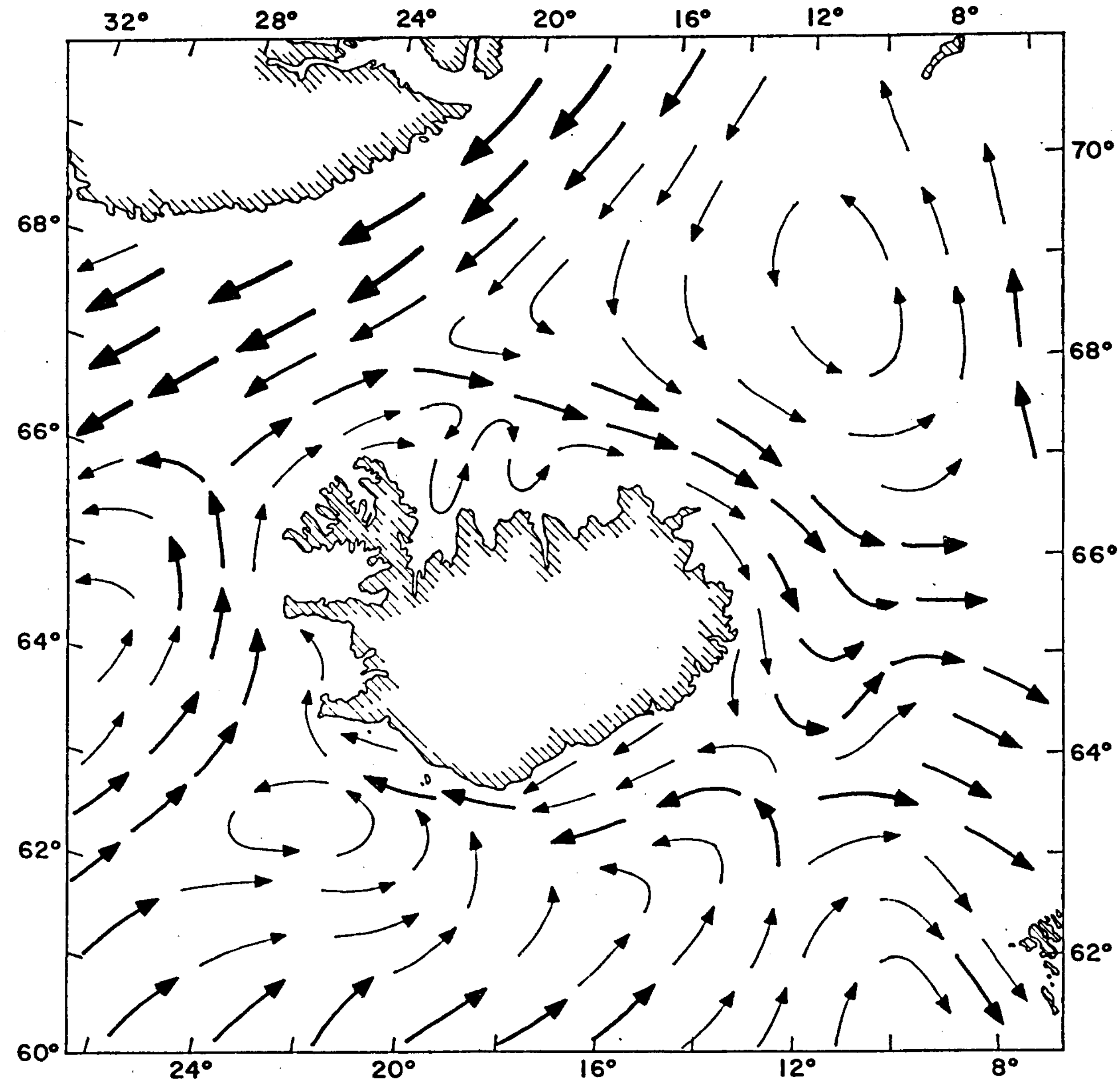
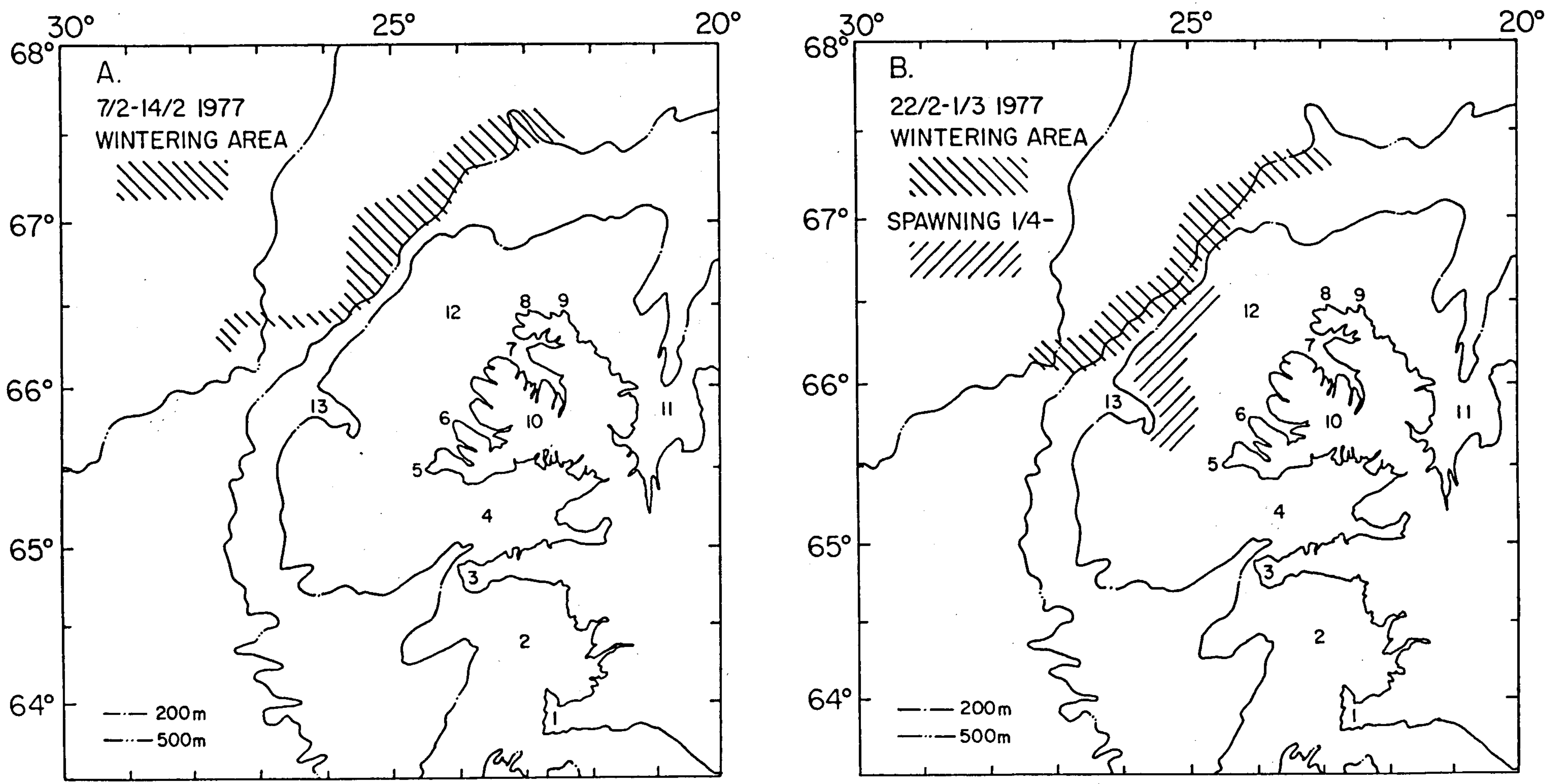


Figure 19 Sea surface currents near Iceland (Stefánsson 1961)



1:REYKJANES, 2:FAXAFLÓI, 3:SNÆFELLSNES, 4:BREIÐAFJÖRÐUR, 5:LÁTRABJARG, 6:KÓPANES, 7:ÍSAFJARÐARDJÚP, 8:KÖGUR, 9:HORN, 10:VESTFIRÐIR-PENINSULA, 11:HÚNAFLÓI, 12:DJÚPÁLL, 13:VÍKURÁLL.

Figure 20 A and B — Distribution of capelin off NW-Iceland, 7-14/2 and 22/2-1/3 1977. Figure 20B further shows the spawning grounds in April. A list of relevant reference positions is included.

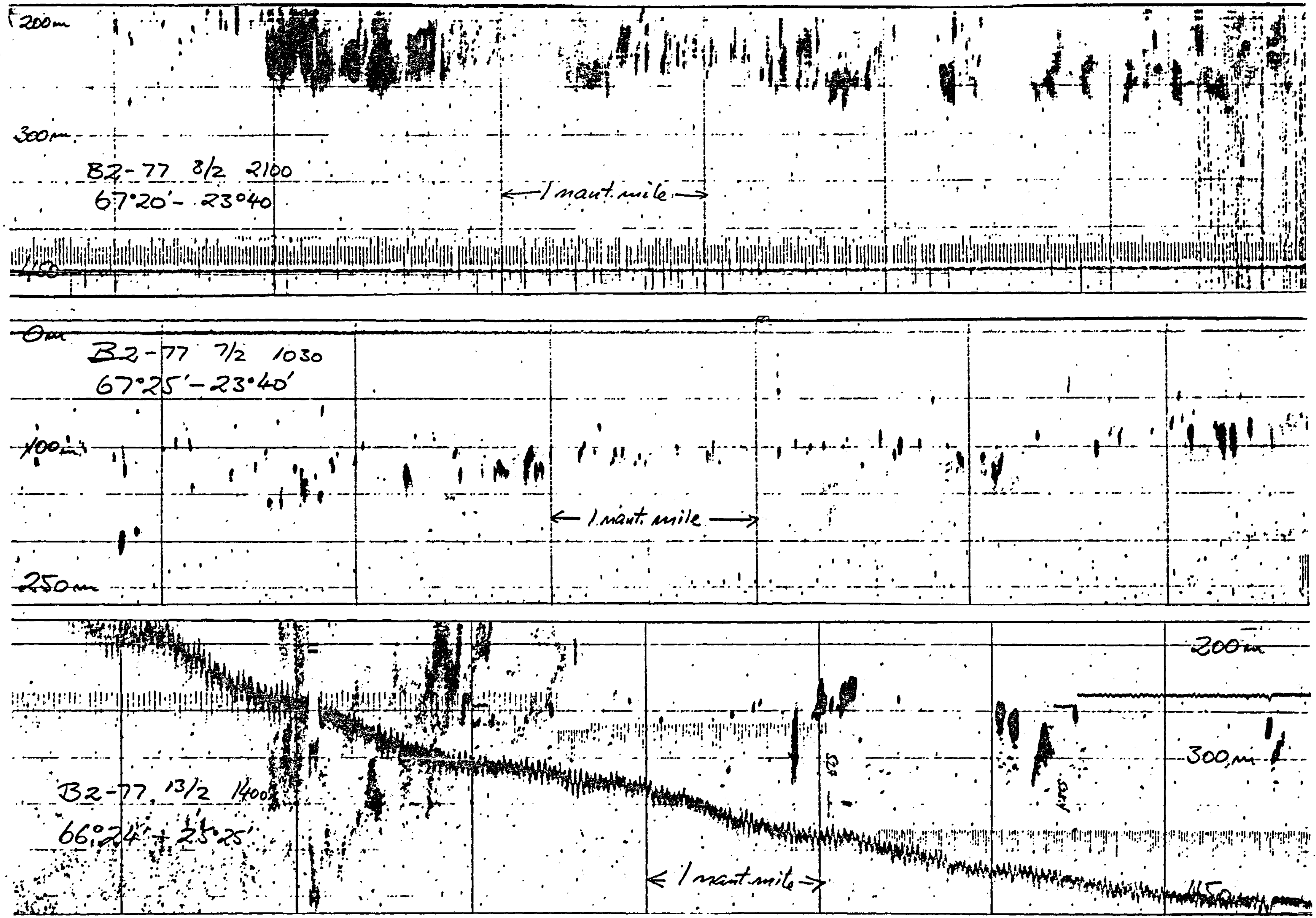


Figure 21   Capelin recordings off NW-Iceland 7-8/2 and 13/2 1977

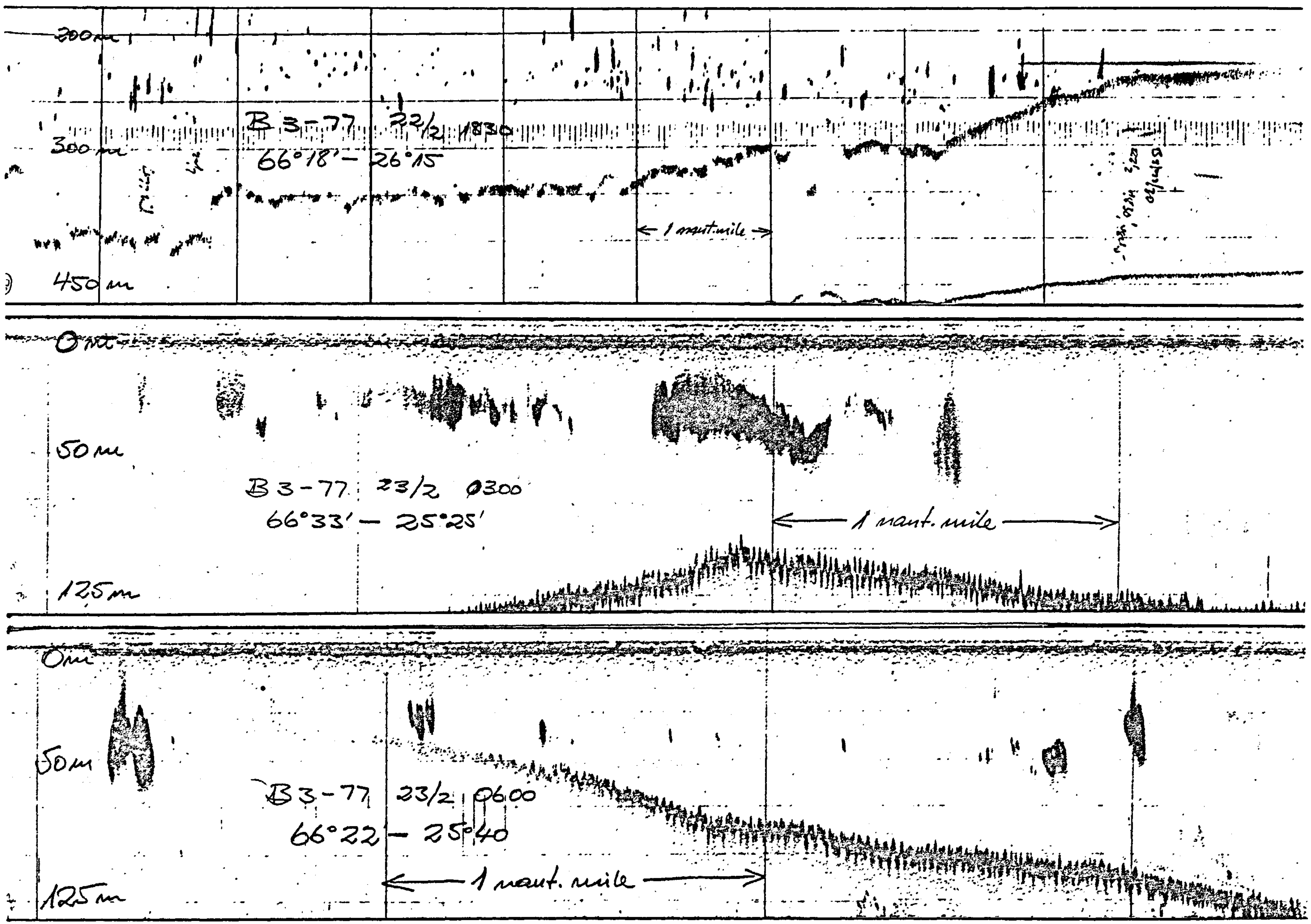


Figure 22 Capelin recordings off NW-Iceland 22-23/2 1977

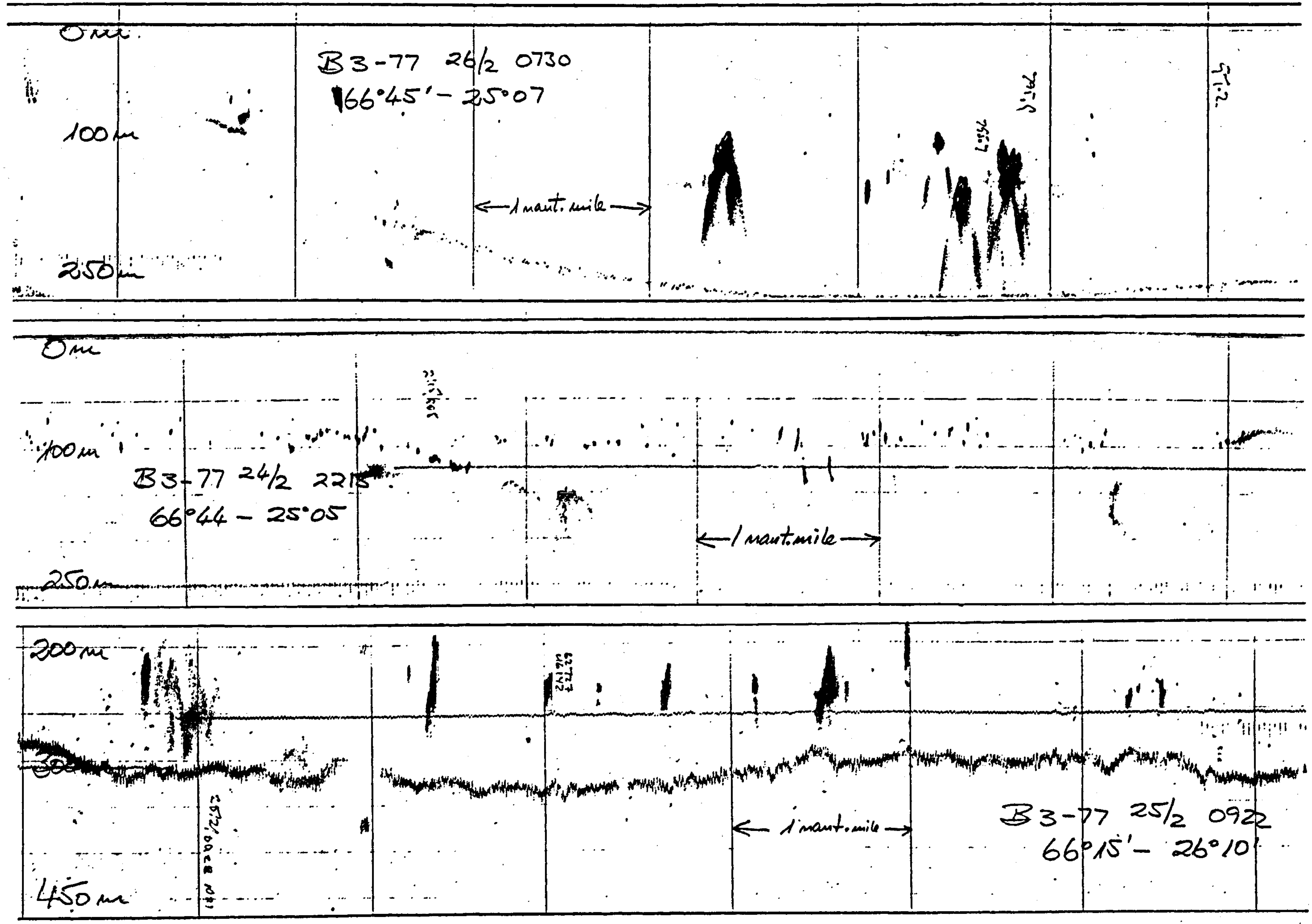


Figure 23 Capelin recordings off NW-Iceland 24-26/2 1977

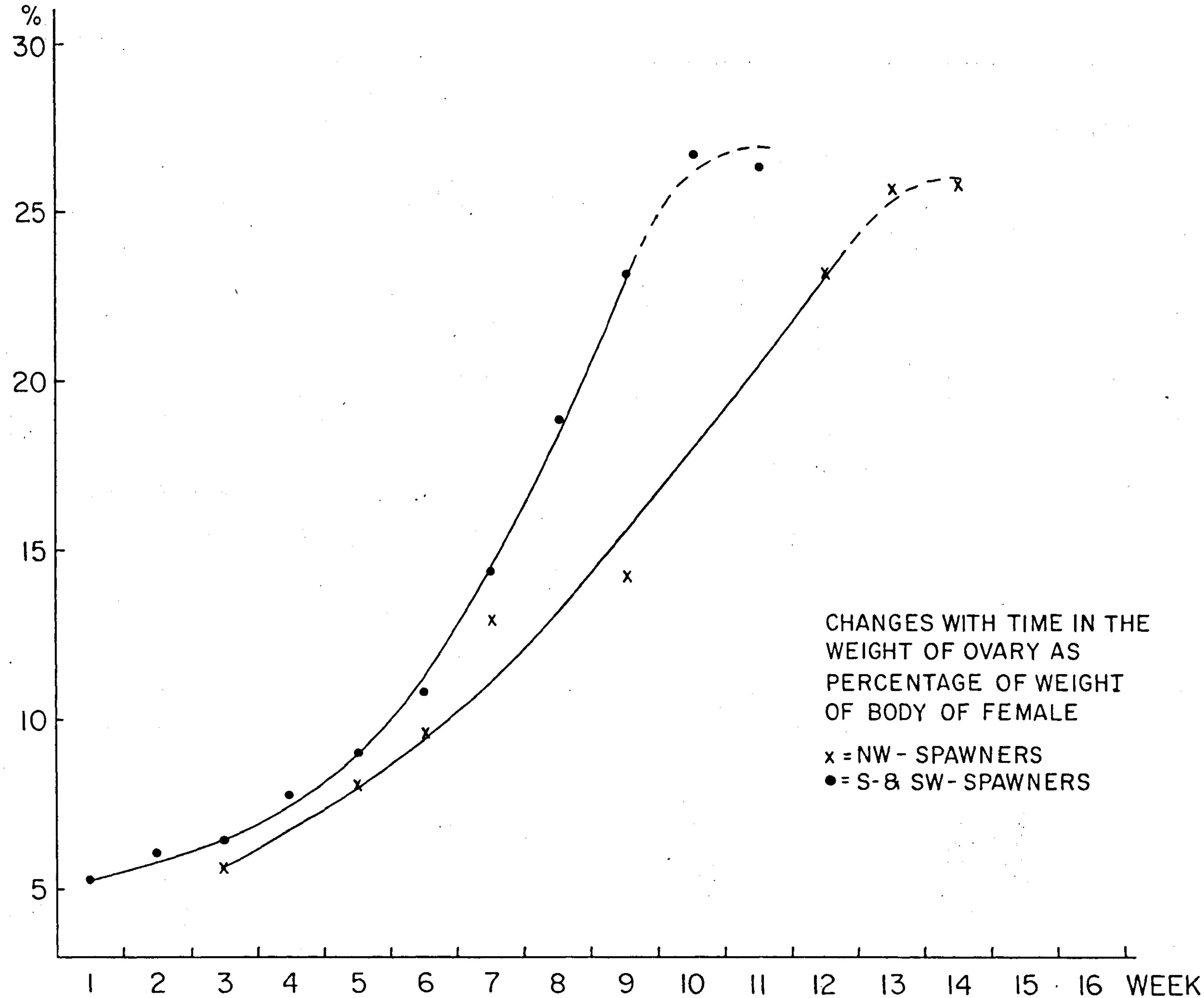


Figure 24 The rate of advance of sexual maturity of the Icelandic capelin, January-April 1977.

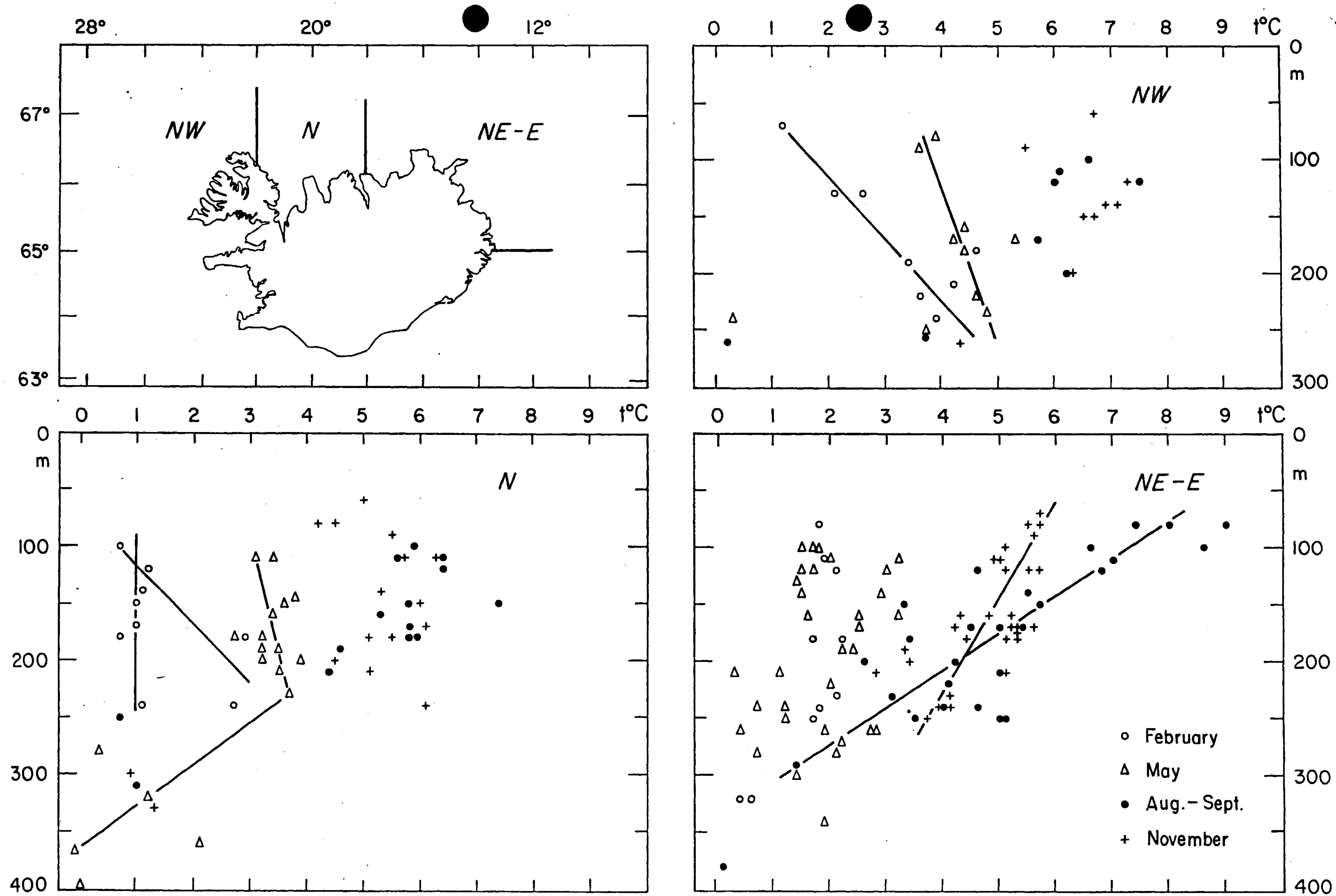


Fig. 28. Near-bottom temperature as a function of station depth for three subareas (N, NW, NE-E) in February, May, Aug.-Sept. and November 1976.