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the Exploration of the Sea

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ATLANTO-SCANDIAN HERRING AND CAPELIN WORKING GROUP REPORT

Part II

Copenhagen, 28 - 30 October 1981

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ATLANTO-SCANDIAN HERRING AND CAPELIN WORKING GROUP REPORT - PART II

1. INTRODUCTION AND PARTICIPATION

1.1 Terms of Reference

At the 68th Statutory Meeting of ICES in 1980 it was decided that the Atlanto-Scandian Herring and Capelin Working Group should assume responsibility for capelin assessment in the ICES area. As a result of this, it was decided that the Working Group would meet twice in 1981, i.e. in May to assess the state of the Atlanto-Scandian herring and from 28-30 October to assess the state of capelin stocks in Sub-areas I, II, V and XIV, and advise on any necessary management measures for these stocks.

1.2 Participants

J Carscadden	Canada
A Dommasnes	Norway
J Hamre	Norway
J Jakobsson (Chairman)	Iceland
H í Jakupsstovu	Faroe Islands
S Tjelmeland	Norway
H Vilhjálmsson	Iceland.

The reports of the Norwegian/USSR Acoustic Survey of the Barents Sea Capelin Stock in September/October 1981 and of the Icelandic-Norwegian Acoustic Survey of the Icelandic Capelin Stock in October 1981 were presented to the Working Group. Since the results of these surveys are the basis for the present assessment of the capelin stocks, the reports are appended to this Working Group report. In addition, the Working Group made use of an assessment report of a USSR/Norwegian Working Group on the Barents Sea Capelin.

2. BARENTS SEA CAPELIN

2.1 General Biology

The Barents Sea capelin spawn when they are 3-6 years old and normally 4 year old fish dominate the spawning stock. Most of the capelin may spawn only once. The most important spawning months are March and April, but spawning may occur to a lesser extent during the period February and May to July. Spawning takes place on gravel and sand bottoms within depths from 10 - 100 m. The main spawning areas are found along the Norwegian and USSR coast from Vesterålen in the west to the entrance to the White Sea in the east. Incubation time varies from 1 to 2 months, depending on the temperature. After hatching the larvae drift with the current towards the north and east, and 0-group capelin may in some years be found as far north as 77°N.

The distribution of older capelin is north of the 0-group, and they are found north to the ice border at approximately 80°N during the autumn. During summer, capelin mostly occur as scattering layers, although schools suitable for purse seining are also frequently found. In autumn, capelin migrate southwards in front of the advancing ice border. The immature capelin do not enter the warm water along the coast, but remain in far offshore waters throughout the winter. The maturing capelin tend to aggregate in certain areas before they continue their migration towards the coast to spawn. In the aggregation areas, and during the migration from these to the coast, capelin are often found in dense schools suitable for purse seining. The main area of capelin distribution is shown in Figure 1 (p.25).

The growth period extends from June to October and the growth rate per month is high. It is, therefore, essential to reduce fishing during the summer months in order to maximize the sustainable yield. The growth rate varies considerably and is, to some extent, correlated to the density of the stock.

2.2 The Fishery

Barents Sea capelin are exploited almost exclusively by Norway and the USSR. The total catch since 1965 is given in Table 2.1. Monthly catches in number by age for 1980-81 are given in Table 2.2. From the mid-1960s the Norwegian fishery developed rapidly, the catch increasing from 20 000 tonnes in 1964 to 1.5 million tonnes in 1972. Up to 1974 Norway took more than 95% of the total catch, but subsequently the USSR fishery increased its proportion. Since 1978 the fishery has been regulated by catch quotas, allocating 60% of the TAC to Norway and 40% to USSR.

Traditionally the fishery was based upon the adult stock approaching the coast during winter and early spring for spawning. Since 1968, however, the fishery has been extended into the open sea during the summer/autumn. This fishery exploits also the immature stock above 2 years, and the fishery lasts from August to December.

2.3 Fishery Management

The Barents Sea capelin fishery has been subjected to various forms of regulation. Opening dates have been set for both the winter and the summer fisheries, and areas have been closed to avoid exploitation of small capelin. During the spawning period the most important spawning grounds have been closed to fishing. Prior to 1979, these regulations were applied to the Norwegian capelin fishery only. In the winter 1974, and in 1978, Norway also regulated its capelin fishery by setting maximum catch quotas. In the winter 1978 the catch quota was, however, not filled.

In 1979 and later years the Barents Sea capelin fishery has been regulated by a bilateral fishery management agreement between USSR and Norway. According to this, the exploitation of capelin is controlled by a seasonal maximum catch quota regulation, allocating TAC for the winter fishery and for the summer/autumn fishery separately. Since 1979 a minimum landing size of 11.0 cm has been enforced, and the capelin fishery has been closed during the period 1 May to 15 August. In 1981 a minimum mesh size of 16 mm was introduced.

2.4 Stock Size Estimate

The acoustic stock measurement technique has been applied by Norwegian scientists in the investigations of the Barents Sea capelin stock since the early 1970s. The acoustic instruments and theories used and the biological sampling programme applied to identify recordings and stock composition are described in and discussed by Nakken and Dommasnes (1975 and 1977). The results of the surveys have been made available through current reports published in "Fiskets Gang", "Fisken og Havet" and in reports to the USSR/Norwegian Fisheries Commission. Since 1978 the capelin surveys have been carried out jointly by USSR and Norway.

In the early 1970s, attempts were made to survey the capelin stock 3 times a year. One survey was conducted in the winter after the maturing component had left the juvenile stock and was migrating to the coast for spawning. The second survey was made in June, when the stock is found in a relatively small area south of the ice border in the central part of the Barents Sea. The third survey was made in September, when the stock is distributed over a wide area between 73°N and 78°N in the whole Barents Sea. The experience gained in those years indicated that the conditions for making acoustic stock surveys on capelin were most favourable in the autumn. The assessment of the capelin stock has, therefore, been based on the survey made in September - October as a compromise between favourable weather conditions and favourable distribution and behaviour of the fish.

There are several sources of error in the estimate which tends to underestimate stock abundance. The most serious ones are probably surface schooling and fish distribution within the bottom shadow of the beam. The first one underestimates the smallest capelin mainly (0- and 1-group fish), the second one the older fish. Capelin schools just within the transducer range may also be underestimated due to avoidance reaction of the fish. The acoustic stock estimate may, therefore, be considered as an index of abundance rather than an abundance estimate in absolute terms.

The acoustic stock estimate for age groups 2 years and older obtained in September 1974 to 1981 is given in Table 2.3. This is the stock available to the fishery in the autumn.

2.5 Estimation of the Spawning Stock

Since most of the capelin die after spawning, information on the stock/recruitment relationship is the most important in a management context aiming at MSY.

The method of estimating the parent stock is based on the hypothesis that the maturing of the capelin is determined by fish length, i.e., that the age of the fish is of secondary importance in this respect. Thus, we assume that there exists a length, such that the longer fish constitute the mature stock, and the shorter fish constitute the juvenile stock. Table 2.4 shows typical length distributions obtained from an acoustic survey. If the position of the line shown is changed, this will affect both the age distribution of the calculated mature stock below the line and the age distribution of the calculated juvenile stock above the line. Now the maturing length is the length that produces a mature stock that has an age distribution similar to the age distribution of the spawning stock and a juvenile stock that has an age distribution similar to next autumn's total stock. Mathematically, this is done by minimizing the least squares function given below:

$$L = \sum_{i=3}^{5}\left(\frac{s_i(\ell)}{s_3+s_4+s_5} - \frac{c_i}{c_3+c_4+c_5}\right)^2 + \sum_{i=3}^{5}\left(\frac{n_i(\ell)}{n_3+n_4+n_5} - \frac{m_i}{m_3+m_4+m_5}\right)^2$$

where:

L Function to be minimized by varying the maturing length ℓ.

s_i Spawning stock in numbers by age i calculated from the previous autumn stock and ℓ.

c_i Spawning stock in numbers by age i (March catches).

n_i Total stock in numbers by age i in the autumn calculated from the previous autumn.

m_i Total stock in numbers by age i in the autumn measured at the acoustic survey.

The catches have been taken into account in the calculation of n_i and s_i and an M value of 0.05 has been used. The text table below shows the resulting maturing lengths for the years 1973-80.

Years	1973	1974	1975	1976	1977	1978	1979	1980x)
Maturing length	14.50	14.94	13.96	14.37	14.04	13.79	14.57	15.03

x) Autumn 1981 catches not used.

A change in the M value will not affect the resulting maturing length to any considerable degree, but will alter the spawning stock and the next year's simulated stock.

2.6 Natural Mortality Estimate

Based on the acoustic estimates obtained and the maturing lengths estimated, the following M values per month for 2-3 year old fish have been calculated:

Years	M values
1973-74	0.056
1974-75	0.047
1975-76	0.051
1976-77	0.048
1977-78	0.047
1978-79	0.085
1979-80	0.053
1980-81	0.12

In the calculation of the M value for 1980-81 the autumn catches are not used, since they are not reported on age yet. This does not affect the calculated M value very much.

The M value from 2- to 3-years depends only little on the estimated maturing lengths, because most of the 2 year old fish are below the estimated maturing lengths. These M values therefore give a good indication of the consistence in the data set, as far as the overall acoustic performance is concerned. From 1973-74 to 1977-78 the M values are remarkably constant. In 1978-79 there is a considerable increase. The M value for 1979-80 is comparable to the period 1973-78, but in 1980-81 there is an increase. The abrupt increase in the M value for the period 1978-79 can have several explanations:

- a true variation in natural mortality
- a random error in the abundance estimate
- a loss of acoustic performance.

2.7 TAC Assessment

The regulatory period is the autumn one year and the winter-spring the following year. After the completion of an acoustic autumn survey, a TAC recommendation for the following calendar year was given by the USSR/Norwegian Working Group meetings 1979-81. The TAC for the winter-spring period was a revision of a preliminary TAC given the previous year. In addition, a TAC recommendation for the following autumn and a preliminary TAC for the winter-spring period thereafter were given.

Due to the lack of adequate knowledge it has not been possible to devise an optimal harvesting strategy. The USSR/Norwegian Working Group meetings have, however, recommended that the spawning stock index should not be reduced below 500 000 tonnes. Thus, the TAC recommendation has been given as the maximum catch allowing a spawning stock index of capelin of 500 000 tonnes two successive years ahead in time.

The input data have been:

- the acoustic survey data
- a selected maturing length
- a typical fishing pattern defined by F values by age and month for the winter-spring fishery and autumn fishery, respectively
- an estimated M value of 0.05 per month.

The maturing length must be selected on the basis of the previous year's maturing length, calculated as shown earlier in this report.

2.8 The Present State of the Stock

Based on the method described in Appendix I, the joint USSR/Norwegian acoustic survey in September-October 1981 gave the following abundance estimate:

Year class	No. x 10^{-11}	Mean weight (g)	Biomass tonnes x 10^{-6}
1980	3.85	2.2	0.85
1979	1.95	9.4	1.82
1978	0.48	17.0	0.81
1977	0.14	23.3	0.33

Compared to the abundance estimate in September-October 1980, the number of 1 year old capelin was higher, and the number of 2 year old capelin about the same. But the numbers of 3 and 4 year old capelin were only around one-third of the numbers of the previous year. Also, the mean weight of 3 and 4 year old capelin was somewhat lower than in the previous year, so that the total biomass for the 3 and 4 year old capelin was reduced from 3.6 million tonnes in 1980 to 1.1 million tonnes in 1981.

As shown in the text table (para. 2.6) on page 4, the calculated M value for the period 1980-81 is almost twice as high as that obtained during the years 1973-74 to 1977-78. Based on previous years' experience it was unexpected that the estimate of natural mortality should be as high as this, and a more likely explanation is that the high M value is partly due to an underestimate of the stock size. Keeping this in mind, the present state of the stock can be summarized as follows:

The 1980 year class seems to be abundant. However, the coverage of the main distribution area of 1 year old capelin (south-eastern part of the Barents Sea) was better this year than the previous year. This may be the reason for the high estimate of this year class compared with earlier estimates of the 1 group capelin.

The 1979 year class is approximately of the same strength as that of the 1978 year class in 1980.

The 1978 year class is considerably reduced since the autumn 1980. In addition, the mean weight of 3 year old fish is reduced from 18.2 g in 1980 to 17.0 g in 1981. The reduction in biomass of 3 year old fish is therefore considerable, from 2.79 x 10^{-6} tonnes to 0.81 x 10^{-6} tonnes.

The 1977 year class is also reduced, and the number of 4 year old fish this year is smaller than the number of 4 year old fish in 1980. The mean weight is reduced from 24.7 in 1980 to 23.3 g in 1981, and the total biomass of 4 year old fish is reduced from 0.81 x 10^{-6} tonnes to 0.33 x 10^{-6} tonnes.

2.9 TAC for the Winter Fishery in 1982

A preliminary TAC of 600 000 - 800 000 tonnes was recommended for the winter fishery in 1982 by the USSR/Norwegian Working Group meeting in October 1980. The spawning stock in 1982 will mainly consist of the year classes 1978 and 1979, and the estimated size of this stock component (Table 2.5) will, to a large extent, depend on the length at which the capelin is expected to mature.

The maturing length for 1980 has been estimated to be be 15.0 cm, using the 1981 March catches in determining the age composition of the spawning stock. This results in a considerable over-estimation of the stock in the autumn 1981, compared to what has been measured during the 1981 acoustic survey. It is noted that the maturing lengths calculated for the previous years results in a fairly good agreement between predicted and measured autumn stock. It is, therefore, suggested that the spawning length for 1980 had been smaller than 15.0 cm, but that the increased number of mature fish spawned at a later time than usual and had no influence on the calculated maturing length based on the March catches. A maturing length that gives a reasonable fit between predicted and measured numbers of capelin in autumn 1981 using an M value of 0.05 would be about 14.0 cm.

The stock in number by age at 1 January 1982 was calculated from the acoustic estimate in Table 2.5 reduced by the expected catch after 1 October 1981 and with a monthly natural mortality of 0.05. The surviving stock in numbers above 14.0 cm is considered as the mature stock component at 1 January 1981. This stock in number by age was then used as input data in calculating the effects of the winter catches on the spawning stock. In this calculation the same monthly natural mortality of 0.05 was used. The effects of various winter catches on the expected parent stock in 1982 are given in Table 2.6. The calculation shows that a TAC of 600 000 tonnes will reduce the spawning biomass to a level of 580 000 tonnes, whereas a TAC of 800 000 tonnes will reduce it to 400 000 tonnes. This is under the condition that all fish above 14.0 cm will mature and spawn. It should, however, be noted that the spawning biomass is highly dependent on the maturing length as shown in Table 2.6.

A TAC of 800 000 tonnes will (Table 2.6) reduce the spawning biomass below the minimum level of stock size (500 000 tonnes) agreed as guideline for the TAC assessment. It was, however, felt that the apparently high mortality rate estimated in 1980-81 for the immature part of the stock could partly be due to an underestimate of the present stock in the 1981 survey. On this basis, the Working Group therefore agreed that the TAC for the period 1 January to 1 May 1982 should be set at the range of 600 000 - 800 000 tonnes.

2.10 TAC for the Autumn Fishery in 1982

TAC for the autumn fishery in 1982 is expected to consist of the year class 1979 as the dominating one, but should receive contribution from the 1980 year class. For a spawning length of 14.0 cm it is expected that the 1978 year class is depleted as 4 year old fish. Parent stock indices for the winter 1983 are calculated by using the immature stock (smaller than 14.0 cm) measured in 1981 as input data, 0.05 as monthly natural mortality rate, for various catch quotas equally divided on the autumn fishery in 1982 and the winter fishery in 1983 as shown in Table 2.6. From this table it can be seen that a total catch of 1.6 - 1.8 million tonnes divided equally on the two seasons may reduce the parent stock to the same level as in 1982. Based on this study, the Working Group agreed to recommend a TAC for the autumn fishery (15 August - 31 December) in 1982 of 800 000 tonnes.

3. THE ICELANDIC CAPELIN

3.1 General Biology

Most of the Icelandic capelin spawn as 3 year olds. A varying proportion of each year class does, however, not mature until one year later. Thus, the spawning stock consists of 2 age groups, 3 and 4 year olds, the ratio of which varies depending on the relative year class strength as well as on the external factors such as feeding conditions. Spawning mortality is for all practical purposes considered total.

Spawning occurs mainly in March and the first half of April, although further spawning also takes place later in April, May and June. The first spawners arrive at the southeast coast of Iceland in late January or the first 3 weeks of February and migrate west along the south coast. Spawning begins, usually off the western south coast or southwest Iceland, 2-3 weeks later. Subsequent runs of capelin may spawn elsewhere off the south and southeast coasts. During March of some years a western component of the spawning stock arrives on the spawning grounds at southwest Iceland directly from the northwest. When this happens it is usually in March.

The main spawning area extends from southeast Iceland along the south coast to the Snæfellsnes peninsula or Látrabjarg in the west. The south and west coast spawning lasts for 3-6 weeks and is usually finished by mid-April. Spawning also takes place off the eastern north coast as well as on occasion off the western north coast and the northwestern peninsula. These are later spawnings which may last throughout May into early June. In addition, some local spawning occurs at East Greenland. It is, however, not known whether these local populations contribute at all to the Icelandic capelin stock.

The larvae and post-larvae drift with the current to the west, north and east of Iceland. In some years at least, a considerable proportion also drifts towards East Greenland north of the Irminger Sea basin. The feeding area of the capelin during its first summer and autumn is therefore wide and in some cases even oceanic.

In early winter, 0-group capelin migrate coastwards again and tend to concentrate off east, north, and northwest Iceland as well as on the western side of the Denmark Strait, mainly in the Dohrn Bank area.

The main feeding area of the Icelandic capelin stock is in the Arctic and sub-Arctic waters between Iceland, Greenland and Jan Mayen. During the summer, part of the stock may even migrate considerable distances north of Jan Mayen before returning to more southerly latitudes in autumn.

Mature and immature 2- and 3-group capelin are usually mixed on the feeding grounds in the area between northwest Iceland and East Greenland. Further east, the admixture of juveniles diminishes and in the northerly Jan Mayen - Greenland area only 2- and 3-group adults have been encountered. The 1-group feeds mainly off north and northwest Iceland over, or a short way off, the continental shelf as well as on or near the East Greenland plateau south of Scoresby Sund.

In September the capelin begin their return migration from the feeding grounds. By the end of October most of the stock has assembled off north or northwest Iceland at, or not far off, the edge of the continental shelf from where the main spawning migrations begin, usually some time in December. During this period, adults and juveniles are often mixed, especially near the southern border of the distribution area.

In January pre-spawners followed by juveniles are usually found near the edge of the continental shelf off northeast Iceland. From there the migration continues southwards, and mature and immature fish segregate. Until the following spring the juveniles remain in the cold waters off east and northeast Iceland, while the spawners continue to the warm waters at southeast Iceland where they usually arrive in February.

In some years part of the spawning stock is left behind off northwest Iceland among the juveniles which overwinter there. This stock component remains in that area until February, when it usually migrates south to arrive on the west coast spawning grounds in March or somewhat later than its eastern counterpart.

3.2 The Fishery

Prior to 1964 the catch from the Icelandic capelin stock was only for bait and amounted to a few hundred tonnes annually at the most. In 1964 Iceland started a purse-seine capelin fishery for reduction to meal and oil. During 1964-72 this fishery was limited to coastal waters during the spawning season but in 1973 it was extended to include more offshore waters off east and northeast Iceland. Since then, the winter season has begun already in the first days of January. This development resulted in a sharp increase in the winter catch which then stabilised around 450 000 tonnes. Apart from a small catch taken by the Faroes in 1977-79, the winter capelin fishery has been conducted by Iceland alone.

In 1976 Iceland started a summer and autumn fishery for capelin on the feeding grounds in deep water areas of northwest and north Iceland. This fishery proved highly successful, the catch increasing from about 115 000 tonnes in 1976 to nearly 500 000 tonnes during the 1978 season. In that year Norway joined in the summer fishery taking 154 000 tonnes in the area west and northwest of Jan Mayen. The latest development is a capelin fishery by the Faroes as well as EEC countries in the area between East Greenland and Jan Mayen. This fishery has yielded some 30 000 - 40 000 tonnes during the last two summer and autumn seasons.

During the last three seasons Iceland and Norway have bilaterally agreed to limit their catches in order to preserve the spawning stock.

The gear used almost exclusively is the purse seine during both the winter and summer fisheries. The annual and seasonal catch is shown in Tables 3.1 and 3.2. Monthly catches in number by age for 1978-81 are given in Table 3.3.

3.3 Estimates of Stock Size

Because of the capelin's short life-span and high spawning mortality researchers have to depend on direct observations of stock size.

Comparative measurements of the abundance of 0-group capelin have been obtained in August annually since 1972 (Table 3.4). During the period 1972-75 the 0-group index indicates a high level of recruitment which is followed by a downward trend and a distinctly lower level during the last 5 years. This development coincides with the large increase in fishing effort as well as the change in fishing pattern brought about by the new multinational summer and autumn fishery.

An acoustic estimate of the size of the 1979 pre-spawning stock of the Icelandic capelin was obtained in October 1978. Since then, comparable estimates of that stock component (Vilhjálmsson et al., 1980) have been obtained jointly by Iceland and Norway in the autumn and by Iceland in January-February (Tables 3.5 - 3.15). It should be noted that Tables 3.6 and 3.7 combined give the stock estimate in early February 1979, while Tables 3.8 and 3.9 combined give the stock estimate in the latter half of that month. In order to make these estimates (within season) comparable, they have been back-calculated to 1 August each year, taking account of the fishery as well as M values of 0.04/month in August-December and 0.08/month in January-March. As shown in Table 3.16 the within-season estimates have been remarkably consistent with the exception of the July-August survey 1979, when the behaviour of the capelin caused a serious underestimate.

As yet it has proved difficult to assess the relative or absolute strength of the 1-2 group juvenile stock component because of its frequent distribution in or near areas that are impassable due to drift ice for long periods of time.

3.4 Management

Initially, regulatory measures were mainly precautionary in nature. In Iceland there has been a closed season in spring and early summer since 1973 and lasting for 2-4 months. Juvenile over-wintering areas have since 1970 been closed to Icelandic fishing vessels and in 1981 the main feeding area of the juvenile 1-2 group capelin, i.e. west of 21°W and also south of 68°N remained closed to them until 15 September.

In 1975 a minimum landing size of 12 cm was introduced with a minimum mesh size of 19.6 mm. In order to facilitate the release of the small juvenile capelin, Iceland increased the minimum mesh size to 21 mm in 1981.

During the 1979 winter fishery the spawning stock divided into two components of about equal size (Tables 3.6 and 3.7). The one at which the fishery was then directed entered the spawning grounds from the east to spawn at the south coast. The other approached from northwest to spawn at southwest Iceland, about 2 weeks later. Fishing of the eastern component was stopped soon after the capelin entered the spawning area but was allowed to continue on its western counterpart until spawning was about to commence. In 1980 and 1981 similar limitations were enforced.

Since most of the capelin spawn only once and die thereafter, the main management objective is to prevent the spawning stock from being reduced to the level of reduced recruitment, not to mention recruitment failure.

In 1979, when fishing was stopped in the 3rd week of March, about 600 000 tonnes were left to spawn according to acoustic estimates of stock size, when account had been taken of the fishery and the natural mortality rate.

In 1980 it was decided that while gaining further experience it would be inadvisable to reduce the spawning stock to more than 2/3 of the 1979 level or 400 000 tonnes. This has been the management advice in the last two years, 1980 and 1981. As shown in Table 3.17, the 1980 and 1981 spawning stocks were in fact reduced to about 300 000 tonnes and 160 000 tonnes respectively. Thus, there has been a drastic reduction in the spawning stock during the last 3 years. These estimates are based on the winter acoustic surveys (Tables 3.8, 3.9, 3.13 and 3.15).

Table 3.18 gives the number of 1-ringers calculated from acoustic surveys for the year classes from 1976-79 as well as 0-group indices for the same year classes. It should be pointed out that the estimates of 1-ringers for the first three year classes are averages of back-calculations from October and January-February surveys. The last estimate, on the other hand, depends on one survey only, which was carried out in October 1981 under unusually difficult ice conditions.

In the case of the Icelandic capelin stock, the available series of data on stock/recruitment relationship is too short to pinpoint the minimum amount that must be allowed to spawn in order not to reduce recruitment for that reason. The data nevertheless strongly indicate overfishing, and should be borne in mind when assessing TACs in the future.

3.5 The Present State of the Stock

Through previous surveying by Iceland and Norway, it has been established that the best acoustic estimates of the size of the

Icelandic stock of capelin are obtained at the end of the feeding period in late autumn - early winter and during the first stages of the spawning migration in January-February before the fish enter the shallow coastal waters at south and southwest Iceland.

As in the previous year, the joint survey 1981 was, therefore, carried out during 14-23 October. Two vessels participated: R/V "Bjarni Sæmundsson", Marine Research Institute, Reykjavik, and R/V "G. O. Sars", Institute of Marine Research, Bergen. The report of this joint survey is given as Appendix III (p.51) and it contains the most up-to-date stock estimate. The survey tracks are shown in Appendix III, Figure 1, and the distribution and the relative density of the echo abundance of the capelin are shown in Appendix III, Figures 2 and and 3.

Geographically, the capelin were distributed much further to the north and east than at the same time last year, but, as then, kept to the zero and sub-zero temperatures of the East Greenland current and adjacent waters.

It should be noted that the area between 66°15'N and 67°30'N west of 21°40'W, where the bulk of the stock was located last year, was covered by drift ice during the 1981 survey and could not be investigated.

Based on the method described in Appendix I (p.26), the total abundance estimate in weight of 1-3 year old capelin amounted to 144 000 tonnes. Details of the total stock estimates are given in Appendix III, Table 1. An abstract is given in the text table below, together with corresponding values for 1979 and 1980.

Age	1981		1980		1979	
	Number x 10^{-9}	Tonnes x 10^{-3}	Number x 10^{-9}	Tonnes x 10^{-3}	Number x 10^{-9}	Tonnes x 10^{-3}
1	0.9	5	23.6	171	22.3	141
2	7.0	135	19.6	378	42.4	639
3	0.2	4	4.8	128	7.9	167
Total	8.1	144	48.0	677	72.6	947

The acoustic abundance estimate in 1981 is much lower than those obtained in corresponding surveys in 1980 and 1979, being only 1/6 of the estimated biomass in 1979.

It is, however, clear that the extension of the drift ice prevented surveying in areas, where dense concentrations of capelin were located in 1980. It is, therefore, possible that the estimate given for 1981 is a serious underestimate.

3.6 Management Advice

A preliminary TAC of 700 000 tonnes has been agreed between Iceland and Norway. At the time of the survey, approximately 360 000 tonnes had been taken by various nations fishing on the stock.

Although the estimate may be an underestimate, as pointed out in the previous section, there is a real danger that if the remainder of the allocated TAC of about 340 000 tonnes is taken, the spawning stock will be fished out before the spawning season begins.

In previous years it has been established that an acoustic estimate can be obtained in January (Vilhjálmsson *et al.*, 1980) at the beginning of the spawning migration, when the capelin have migrated away from the ice border. In view of this and the fact that the remainder of the preliminary TAC can be taken during the winter season 1982, it is recommended that the fishery on the Icelandic capelin stock should be stopped until a new acoustic abundance estimate has been obtained.

In the light of the results of that estimate, a final TAC should be set.

References

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Vilhjálmsson, H, Reynisson, P, Hamre, J and Røttingen, I. 1980. Acoustic abundance estimates of the Icelandic stock of capelin, October 1978 - January 1980. ICES, Doc. C.M.1980/H:63 (mimeo.).

Table 2.1. International catch of Barents Sea capelin ('000 tonnes) in the years 1965-80.

Year	Norway	USSR	Other	Total
1965	217	7		224
1966	380	9		389
1967	403	6		409
1968	522	15		537
1969	679	1		680
1970	1 301	13		1 314
1971	1 371	21		1 392
1972	1 556	37		1 593
1973	1 291	45		1 336
1974	987	162		1 149
1975	943	431	43	1 417
1976	1 949	596		2 545
1977	2 116	822	2	2 940
1978	1 122	747	25	1 894
1979	1 109	669	5	1 783
1980	999	641	9	1 649

Table 2.2 Capelin catches in the Barents Sea in 1980 numbers.

Numbers x 10^{-9}									
Age	January Total	February Total	March Total	April Total	August Total	September Total	October Total	November Total	December Total
1					0.06	0.33	0.44	0.06	0.01
2				0.10	1.23	3.76	1.53	0.15	0.17
3	0.15	1.35	0.59	2.65	4.10	11.36	3.56	0.57	1.50
4	2.80	21.75	12.76	2.49	0.50	2.09	0.56	0.14	0.43
5	0.27	1.98	1.20	0.09	0.002	0.03		0.01	0.03
6+		0.02	0.05						
Sum	3.22	25.10	14.60	5.33	5.89	17.57	6.09	0.93	2.14

Capelin catches in the Barents Sea in 1981 numbers.

Numbers x 10^{-9}				
Age	January Total	February Total	March Total	April Total
1				
2		0.21	0.26	0.12
3	0.61	2.08	0.60	0.11
4	8.81	18.48	6.20	1.04
5	3.27	6.99	2.78	0.46
6+	0.08	0.35	0.21	0.05
Sum	12.77	28.11	.05	1.78

Table 2.3. Acoustic stock estimates ('000 tonnes) made in September of Barents Sea capelin above 2 years old for the years 1974-81.

	1974	1975	1976	1977	1978	1979	1980	1981
Stock in September	4 457	6 810	5 355	3 920	4 012	4 080	5 462	2 960

Table 2.4. Acoustic estimate of the Barents Sea capelin stock in September 1979. Numbers x 10^{-7} distributed on length and age. The horizontal line separates juvenile and mature fish.

Total Length (mm)	Age 1	2	3	4	5+	Total numbers x 10^{-7}
40 - 45						6
45 - 50						326
50 - 55						724
55 - 60						583
60 - 65	77					77
65 - 70	77					77
70 - 75						0
75 - 80						0
80 - 85	13					13
85 - 90	6					6
90 - 95	38					38
95 - 100	134	79				209
100 - 105	325	464				789
105 - 110	373	1 623				1 682
110 - 115	215	2 935				3 145
115 - 120	183	6 697	140			7 023
120 - 125	31	8 438	114			8 583
125 - 130		6 522	1 048			7 570
130 - 135		3 944	2 293			6 230
135 - 140		1 897	1 683	39		3 620
140 - 145		576	1 695	12		2 271
145 - 150		111	1 441	48		1 598
150 - 155		56	1 228	89		1 376
155 - 160		52	629	33		706
160 - 165		9	580	82		672
165 - 170			165	49	2	219
170 - 175			170	76		245
175 - 180			55	44		99
180 - 185			8	6		14
Number x 10^{-7}	1 472	33 403	11 249	478	2	47 901

Table 2.5 Acoustic estimate of the Barents Sea capelin stock in September-October 1981. Numbers x 10^{-7} distributed onlength and age. The horizontal line separates juvenile and mature fish.

Total length (cm)	Age					Total number x 10^{-7}	Biomass tonnes x 10^{-3}	Biomass (cumulative)
	1	2	3	4	5			
6.5 - 6.9	1 805					1 805	16.2	
7.0 - 7.4	3 180					3 180	31.8	
7.5 - 7.9	5 814					5 814	75.7	
8.0 - 8.4	6 387					6 387	115.2	
8.5 - 8.9	5 723	8				5 731	120.6	
9.0 - 9.4	5 188	34				5 222	135.0	
9.5 - 9.9	4 142	132				4 274	129.3	
10.0 - 10.4	2 643	256				2 899	108.2	
10.5 - 10.9	2 162	470				2 632	113.6	
11.0 - 11.4	786	896				1 682	88.5	
11.5 - 11.9	299	1 743	5			2 047	127.4	
12.0 - 12.4	162	3 069	19			3 250	233.7	
12.5 - 12.9	125	4 195	59			4 379	363.5	
13.0 - 13.4	50	3 276	229	4		3 559	342.4	
13.5 - 13.9	20	2 347	466	1		2 834	315.1	
14.0 - 14.4	7	1 532	641	2		2 182	276.5	1 549.7
14.5 - 14.9		676	701	20		1 397	201.4	1 273.2
15.0 - 15.4		355	705	140	4	1 204	197.4	1 071.8
15.5 - 15.9		164	697	199		1 060	189.8	874.4
16.0 - 16.4		94	468	197	2	761	155.4	684.6
16.5 - 16.9		79	344	259		682	155.6	529.2
17.0 - 17.4		67	157	172	4	400	106.7	373.6
17.5 - 17.9		52	162	182	6	402	120.0	266.9
18.0 - 18.4		38	66	129		233	77.7	146.9
18.5 - 18.9		17	51	49	10	127	46.3	69.2
19.0 - 19.4			15	2		17	7.8	22.9
19.5 - 19.9			5	19		24	11.5	15.1
20.0 - 20.4			1	3		4	2.3	3.6
20.5 - 20.9			2			2	1.3	1.3
Number x 10^{-7}	38 493	19 500	4 793	1 378	26	64 190		
Number >14.0 cm	7	3 074	4 015	1 373	26	8 495		
Biomass (tonnes x 10^{-3})							3 865.6	
Biomass fish >14.0 cm							1 549.7	

Table 2.6. TAC estimates (in '000 tonnes) and corresponding spawning biomass. l_s = maturing length.

TAC winter 1982	1982 Spawners		TAC autumn 1982	TAC winter 1983	1983 Spawners	
	l_s = 14.0	l_s = 14.5			l_s = 14.0	l_s = 14.5
600	5 84	3 81	500	500	9 48	8 15
700	4 93	2 91	600	600	8 10	6 79
800	4 01	2 01	700	700	6 71	5 44
900	3 12	1 13	800	800	5 33	4 11
1 000	2 23	0 32	900	900	3 97	2 79
			1 000	1 000	2 62	1 50

Table 3.1. The total annual catch from the Icelandic capelin stock 1964-1981 (tonnes x 10^{-3}).

Year	Winter season		Summer and autumn season			Total
	Iceland	Faroes	Iceland	Norway	Faroes and EEC	
1964	8.6					8.6
1965	49.7					49.7
1966	124.5					124.5
1967	97.2					97.2
1968	78.1					78.1
1969	170.6					170.6
1970	190.8					190.8
1971	182.9					182.9
1972	276.5					276.5
1973	440.9					440.9
1974	461.9					461.9
1975	457.6		3.1			460.7
1976	338.7		114.4			453.1
1977	549.2	25.0	259.7			833.9
1978	468.4	38.4	497.5	154.1		1 158.4
1979	521.7	17.5	441.9	126.0	2.5	1 109.6
1980	392.0		367.2	118.6	38.7	916.5
1981	156.0			91.4		

Table 3.2. The seasonal catch (1 August - 30 April) from the Icelandic capelin stock 1964-1981 (tonnes x 10^{-3}).

Season Summer - Winter	Iceland	Norway	Faroes and EEC	Total
1964	8.6			8.6
1965	49.7			49.7
1966	124.5			124.5
1967	97.2			97.2
1968	78.1			78.1
1969	170.6			170.6
1970	190.8			190.8
1971	182.9			182.9
1972	276.5			276.5
1973	440.9			440.9
1974	461.9			461.9
1975	457.6			457.6
1975 - 1976	341.8			341.8
1976 - 1977	663.6		25.0	688.6
1977 - 1978	728.1		38.4	766.5
1978 - 1979	1 019.2	154.1	17.5	1 190.8
1979 - 1980	833.9	126.0	2.5	962.4
1980 - 1981	523.2	118.6	38.7	680.5

Table 3.3. The total catch in numbers (x 10^{-9}) from the Icelandic stock of capelin 1978-1981.

Age	1978						Age	1979						
	Jul	Aug	Sep	Oct	Nov	Dec		Jan	Feb	Mar	Aug	Sep	Oct	Nov
1	-	-	-	-	0.1	-	1	-	-	-	0.1	0.2	0.3	-
2	0.9	6.3	5.5	4.5	3.2	1.0	2	0.2	0.5	0.3	8.5	7.4	9.4	2.9
3	0.8	2.2	5.6	2.5	0.4	0.7	3	4.9	10.1	5.8	2.3	1.7	-	-
4	-	-	0.1	0.1	-	-	4	1.1	2.0	1.7	-	-	-	-
5	-	-	-	-	-	-	5	+	0.1	+	-	-	-	-

Age	1980								Age	1981					
	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec		Jan	Feb	Mar	Aug	Sep	Oct
1	-	-	-	0.4	0.1	2.2	2.1	0.1	1	-	-	-	+	0.1	0.1
2	1.0	0.1	0.2	4.6	2.2	5.5	3.1	1.8	2	0.9	0.2	0.6	5.7	4.8	4.7
3	7.4	6.3	3.9	0.9	0.8	2.0	1.1	0.6	3	1.4	1.4	2.2	0.9	3.5	0.1
4	1.2	1.5	0.8	-	-	-	-	-	4	0.5	0.2	0.5	0.8	0.5	0.1
5	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-

Table 3.4. O-group indices 1972-81.

Year	O-group index
1972	89
1973	116
1974	134
1975	89
1976	60
1977	43
1978	31
1979	49
1980	41
1981	29

Table 3.5. Acoustic estimate of the Icelandic capelin stock ($N \times 10^{-9}$, $W \times 10^{-3}$ tonnes), 16-29 October 1978.

Year class	Survey 1		Survey 2		Average	
	N	W	N	W	N	W
1977	0.4	3.5	0.4	3.5	0.4	3.5
1976	50.5	944.4	55.4	1 036.1	52.9	989.6
1975	20.5	548.5	22.6	603.4	21.6	576.5
1974	0.4	13.6	0.5	17.0	0.5	15.4
Total	71.9	1 510.0	79.0	1 660.0	75.5	1 585.0

Table 3.6. Acoustic estimate of capelin by number and weight at age ($N \times 10^{-9}$, $W \times 10^{-3}$ tonnes), E-Iceland, 1-7 February 1979.

Year class	Survey 1		Survey 2		Survey 3		Average	
	N	W	N	W	N	W	N	W
1977	5.0	31.5	5.2	32.8	5.6	35.2	5.3	33.4
1976	23.2	457.0	24.0	472.8	25.7	506.2	24.3	478.7
1975	3.1	77.8	3.2	80.3	3.4	85.3	3.2	80.3
1974	4.0	1.7	0.1	3.1	0.1	2.3	0.1	2.6
Total	31.4	568.0	32.5	589.0	34.8	629.0	32.9	595.0

Table 3.7. Acoustic estimate of capelin by number and weight at age NW-Iceland, 8-9 February 1979.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1977	3.6	41.0
1976	28.3	512.0
1975	4.6	107.0
Total	36.5	660.0

Table 3.8. Acoustic estimate by number and weight NW-Iceland, 17-18 February 1979.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1977	2.4	26.9
1976	23.5	283.0
1975	6.0	132.0
1974	0.1	3.1
Total	32.1	545.0

Table 3.9. Acoustic estimate of capelin by number and weight at age, SE-Iceland, 27 February - 1 March 1979.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1977	0.7	7.7
1976	13.5	249.5
1975	3.7	92.8
Total	17.9	350.0

Table 3.10. Acoustic estimate by number and weight at age, Iceland - E.Greenland - Jan Mayen, 27 July - 12 August 1979.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1978	3.0	14.3
1977	33.0	390.2
1976	5.0	85.8
1975	+	0.8
Total	41.0	490.9

Table 3.11. Acoustic estimates of the Icelandic capelin stock, 29 September - 5 October 1979.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1978	22.0	140.6
1977	42.0	638.8
1976	8.0	166.5
1975	+	3.6
Total	72.0	949.5

Table 3.12. Acoustic estimate of capelin by number and weight at age, N- and NW-Iceland/Greenland, 14-26 October 1979.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1978	10.0	62.0
1977	49.7	780.3
1976	9.1	209.3
1975	0.4	8.3
Total	69.2	1 059.9

Table 3.13. Acoustic estimate of capelin by number and weight at age, N- and NW-Iceland, 25-28 January 1980.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1978	13.5	84.2
1977	41.7	663.7
1976	3.8	92.1
Total	59.0	840.0

Table 3.14. Acoustic estimates of the Icelandic capelin stock 11-22 October 1980.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1979	23.6	171
1978	19.6	378
1977	4.8	128
Total	48.0	677

Table 3.15. Acoustic estimates of the Icelandic stock of capelin, 5-30 January 1981.

Year class	N (x 10^{-9})	W (x 10^{-3} tonnes)
1979	3.3	28.1
1978	11.4	234.7
1977	3.2	87.3
Total	17.9	350.1

Table 3.16. Back-calculations of Echo stock.
M = 0.04/month August - December
M = 0.08/month January - March

I Ref. to 1 August 1978

Surveys	Year class				Total
	1977	1976	1975	1974	1976-74
16.10 - 29.10.78	0.5	77.7	36.1	0.8	114.6
01.02 - 09.02.79	12.1	98.0	24.0	0.4	122.4
14.02 - 01.03.79	5.5	94.6	30.5	0.4	125.5

II Ref. to 1 August 1979

Surveys	Year class				Total
	1978	1977	1976	1975	1977-75
26.07 - 12.08.79	3.0	33.0	5.0	+	38.0
25.09 - 05.10.79	24.1	62.0	12.9	+	74.9
14.10 - 26.10.79	11.9	82.9	17.7	0.5	101.1
25.01 - 28.01.80	19.8	94.8	14.6	+	109.4

III Ref. to 1 August 1980

Surveys	Year class			Total
	1979	1978	1977	1977-78
11-22.10.80	27.6	31.7	8.1	39.8
5-30.01.81	10.0	33.8	10.1	43.9

Table 3.17. Spawning stock size 1979-81 (tonnes x 10^{-3}) and 0-group indices from corresponding years.

Year	Spawning stock	0-group index
1979	600	49
1980	300	41
1981	160	29

Table 3.18. 0-group indices and acoustic estimates of 1-ringers (x 10^{-9}).

Year class	No. of 1-ringers	0-group index
1976	145.6	60
1977	129.1	43
1978	54.0	31
1979	45.7	49

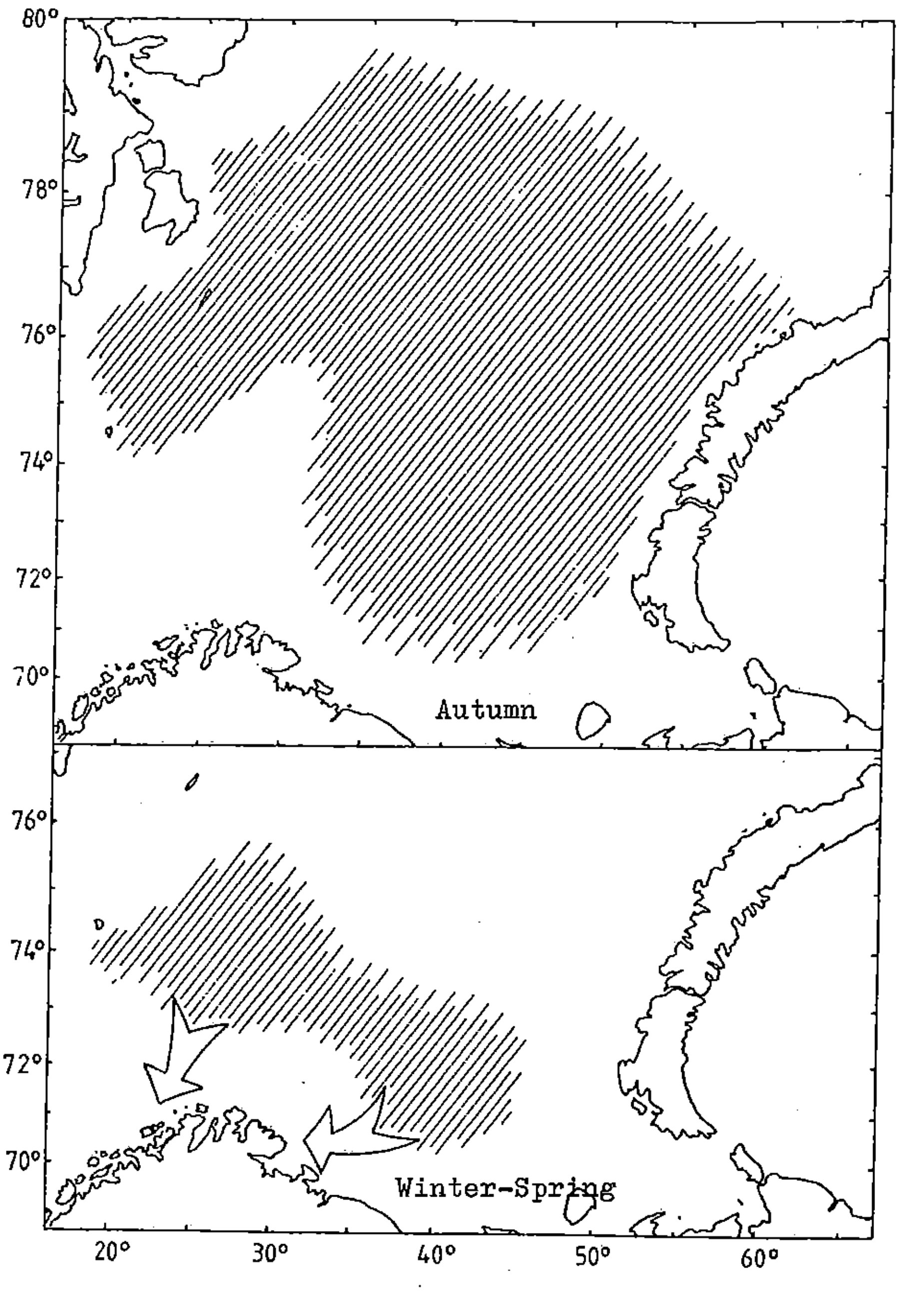


Figure 1. Main areas of Barents Sea capelin distribution in autumn (top) and winter-spring (bottom). The main spawning migration routes are indicated by arrows.

APPENDIX I

THE METHOD USED IN THE ACOUSTIC SURVEYS OF THE BARENTS SEA AND ICELANDIC CAPELIN STOCKS

The method has been described by Nakken and Dommasnes (1975 and 1977, see References, p. 12).

Cruise tracks are planned so that a good representation of the fish densities in the area can be obtained. In the Barents Sea the distance between tracks is 30 nautical miles or less, in the Iceland - Jan Mayen area 15 nautical miles or less. Integrated fish densities are recorded as mm per nautical mile and plotted on charts after they have been compared with the paper recordings and subjectively corrected where any disturbance has occurred. The vessels participating in the survey are always intercalibrated, and integrator values from the other vessels are recalculated to "G. O. Sars-level". To make the integrated densities more manageable, the investigated area is divided into "squares" of approximately 30 x 30 nautical miles, and a mean integrated echo density calculated for each "square".

Biological samples are taken with trawl. The most important criteria for trawling are distance from last haul and change in the recordings. From each trawl catch a random sample is taken and the lengths are measured. In addition, the following data are usually recorded for all or part of the sample: weight, sex, maturity, and age (from otoliths).

Before starting calculations, it is decided - on the basis of echo sounder recording patterns - which trawl stations are representative for each of the "squares" into which the area is divided. Each "square" thus has assigned to it a mean integrator value to represent the quantity of capelin and one or more trawl stations to represent the biological parameters of the capelin. The number of fish in each ½ cm group in each "square" is then calculated from the following set of formulas:

$$C_i = 8.1 \times 10^6 \times l_i^{-1.91}$$

$$\rho_i = M \times p_i \times \left(\sum_{i=1}^{i=n} \frac{p_i}{C_i} \right)^{-1}$$

$$N_i = \rho_i \times A$$

$$W_i = N_i \times w_i \times 10^6$$

i denotes the ½ cm length group in question.

C_i is a density coefficient given as number of fish under one square nautical mile of surface per mm integrator deflection per nautical mile sailed.

ρ_i is density of fish given as numbers under one square nautical mile of surface.

M is the mean integrator value for the "square" in question.

p_i is the proportion of the catch which is made up by length group i ($\Sigma p_i = 1$).

N_i is the number of fish in the "square" in question.

A is the area of the "square" in question, given in square nautical miles.

W_i is the biomass in the "square" in question, in metric tonnes.

w_i is the mean weight of individual fish in length group i, given in grammes.

The computations are done by a computer program, which also calculates from the biological samples a "length/age key", which gives the proportion of each age group inside each of the length groups. This "key" is used to transform the numbers and biomass which are now given for each length group to numbers and biomass for each age group.

Numbers and biomass in the total area are calculated by adding up the numbers for the "squares".

APPENDIX II

REPORT ON THE NORWEGIAN/USSR ACOUSTIC SURVEY OF THE BARENTS SEA CAPELIN STOCK IN SEPTEMBER/OCTOBER 1981

Introduction

The survey was carried out during the period September-October 1981. Three research vessels participated:

R/V "Persey III"	Polar Research Institute, Murmansk,	8 Sep. - 4 Oct.
R/V "G. O. Sars"	Institute of Marine Research, Bergen	8 Sep. - 4 Oct.
R/V "Johan Hjort"	Institute of Marine Research, Bergen	7 Sep. - 28 Sep.

Observations were exchanged daily between the three vessels. All data were processed onboard "G. O. Sars", and L Korol from PINRO, who was onboard the vessel between 28 September and 4 October, participated in the work. E Molvær and A Roald, IMR, were onboard "Persey III" during the intercalibrations which took place 27-28 September.

Material and Methods

Courselines and stations are given in Appendix II, Figure 1. The vessels started their work in the eastern part of the Barents Sea and covered the area with transects along every second degree longitude. The transects surveyed by "Persey III" were placed between those of "G. O. Sars" so that the main distribution area of capelin was covered with transects of one degree longitude apart. "Johan Hjort" covered the southern and south-eastern part of the distribution area. The north- and southward extension of the courselines was adjusted according to the distribution of capelin.

All three vessels were operating digital echointegrators. Echo intensities were integrated continuously, and mean values per nautical mile were recorded for each 5 nautical mile. The echograms, with their corresponding integrator values, were scrutinized every day. Contribution from bottom, false echoes and noise was deleted. The corrected values for integrated echo intensity were distributed to species according to the trace patterns on the echogram and the composition of the trawl catches. Trawling was carried out whenever the recordings of the traces on the echograms changed their characteristics and/or when the need for biological data made necessary. Trawl stations were thus carried out both for identification purposes and in order to obtain observations on length, weight or volume, maturity stage, stomach content, and age of capelin.

Conversion factors for the integrated echo intensities, M, sampled by the different vessels, were obtained by intercalibration between "G. O. Sars" and "Persey III", and "G. O. Sars" and "Johan Hjort". The results of these intercalibrations were:

$$M_{G.O.S.} = 0.21 \quad M_{PIII} - 32 \qquad M_{PIII} > 500$$

$$M_{G.O.S.} = 0.15 \quad M_{PIII} \qquad M_{PIII} < 500$$

$$M_{G.O.S.} = 0.88 \quad M_{JH}$$

The echo intensities recorded by "Persey III" and "Johan Hjort" were converted to "G. O. Sars" values using these relations. A work note on the intercalibration between "G. O. Sars" and "Persey III" is given as an Annex to this survey report (see p. 45).

The computations of number of individuals and biomass in length- and age groups were made onboard "G. O. Sars", using the same computer program as in previous years. The method is described by Nakken and Dommasnes (1975).

Results and Discussion

An estimate based on integrator values from "G. O. Sars" and "Johan Hjort" are given in the text table below:

Year class	Number x 10^{-11}	Mean weight g	Biomass, tonnes x 10^{-6}
1980	3.85	2.2	0.85
1979	1.95	9.4	1.82
1978	0.48	17.0	0.81
1977	0.14	23.3	0.33

Due to intercalibration between "G. O. Sars" and "Persey III", it was possible to convert "Persey III" integrator values into corresponding "G. O. Sars" values. However, in the eastern part of the Barents Sea, there were some days time difference between "G. O. Sars"'s and "Persey III"'s survey of that area. The corresponding integrator values were lower than those of "G. O. Sars". This may be due to a westward migration of the capelin.

The area west of 34°E was surveyed simultaneously by "Persey III", "G. O. Sars" and "Johan Hjort". By using the same trawl stations as basis for biological data as in the estimate above, and the integrator values from all vessels for the area west of 34°E, and the integrator values for "G. O. Sars" and "Johan Hjort" east of 34°E, the following result was obtained:

Year class	Number x 10^{-11}	Mean weight g	Biomass, tonnes x 10^{-6}
1980	3.89	2.2	0.86
1979	1.78	9.3	1.65
1978	0.43	16.9	0.72
1977	0.12	23.1	0.27

The numbers compare fairly well. The discrepancies probably occur from limited capelin concentrations being "hit" by one transect only. In the westernmost part of the distribution area the gradients in density distribution (App.II, Figure 2) are large, and in that area the vessels also encountered some days with bad weather. These factors probably account for most of the differences found in the two estimates.

The main error in the 1981 estimate of the Barents Sea stock of capelin is thought to be mixed echo recording which occurred mainly in the eastern part of the distribution area. In that part of the Barents Sea there were high concentrations of Polar cod, mixed with varying quantities of capelin. Under such circumstances it is very difficult to assess how much of the reflected echo intensity is due to capelin, and this might have caused an unknown variance to the capelin estimate.

App.II, Figure 2 shows the geographical distribution of the capelin stock. The distribution is similar to the distribution observed in 1980, with little capelin in the northeastern part of the Barents Sea. The bulk of the biomass is found west of 34°E. App.II, Figures 3-6 show the geographical distribution of the different year classes.

App.II, Figure 7 shows the age distribution, mean lengths and mean volumes in the three sub-areas used for computations of age/length and age/weight relations. The calculated length frequencies for the different age groups and for the total stock are given in App.II, Figure 8.

Hydrography

App.II, Figures 9-12 show the horizontal distribution of temperature in different depths.

The water temperature distribution in 50 m depth and lower in the western and central areas was comparable to that of 1980, but in the east of the area investigated the water temperature was lower than that of the previous year.

According to the results obtained in the 0-group fish survey, mean water temperatures on sections of the Barents Sea in early September were lower than that of 1980 and long-term mean.

Water temperature anomalies in the western area were:

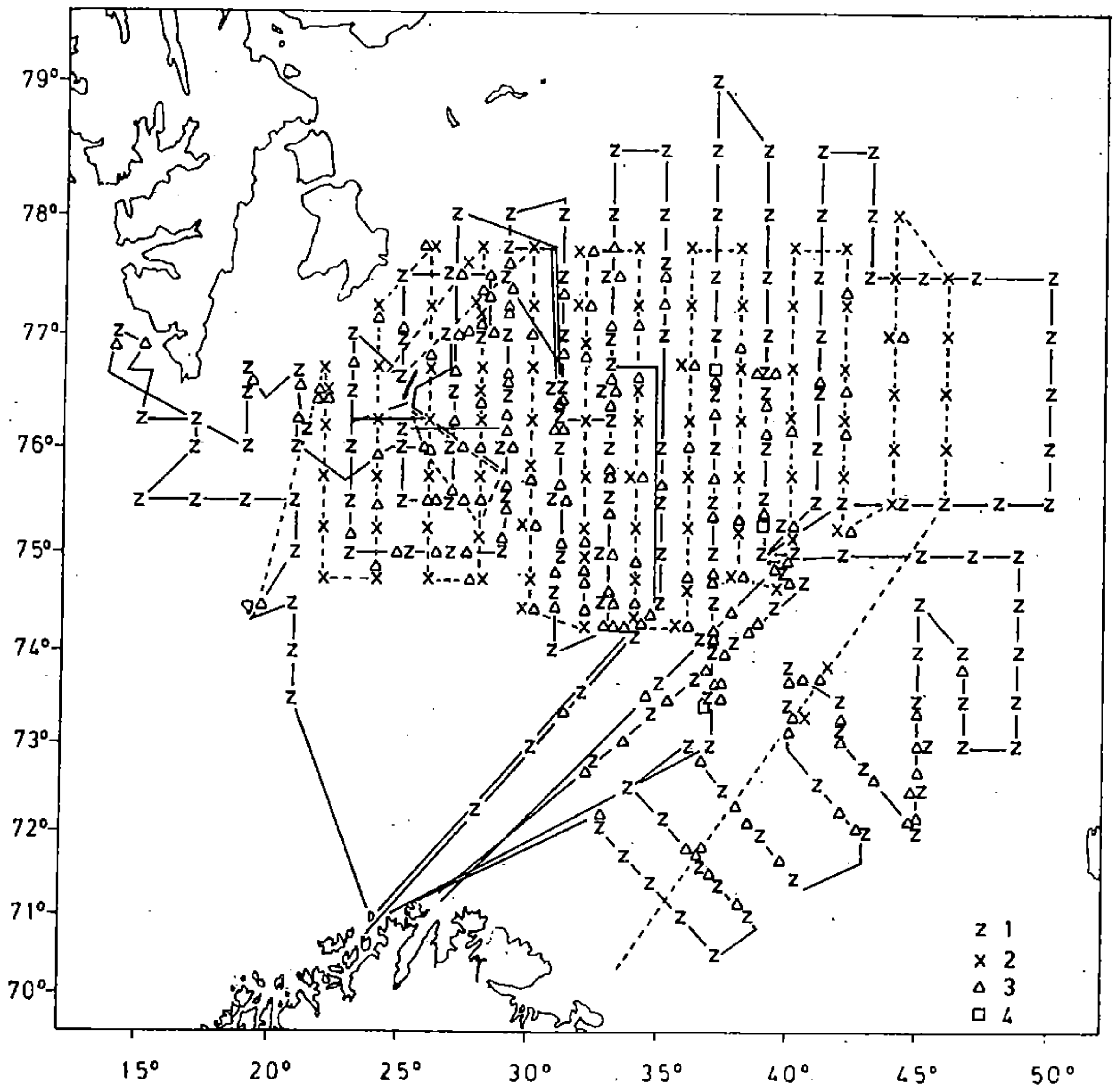
-0.3 (section North Cape-Bear Island), in the central area;

-0.6 to -0.8° (section Kola Meridian) and in the eastern area;

-0.8 to -1.3° (Kanin section).

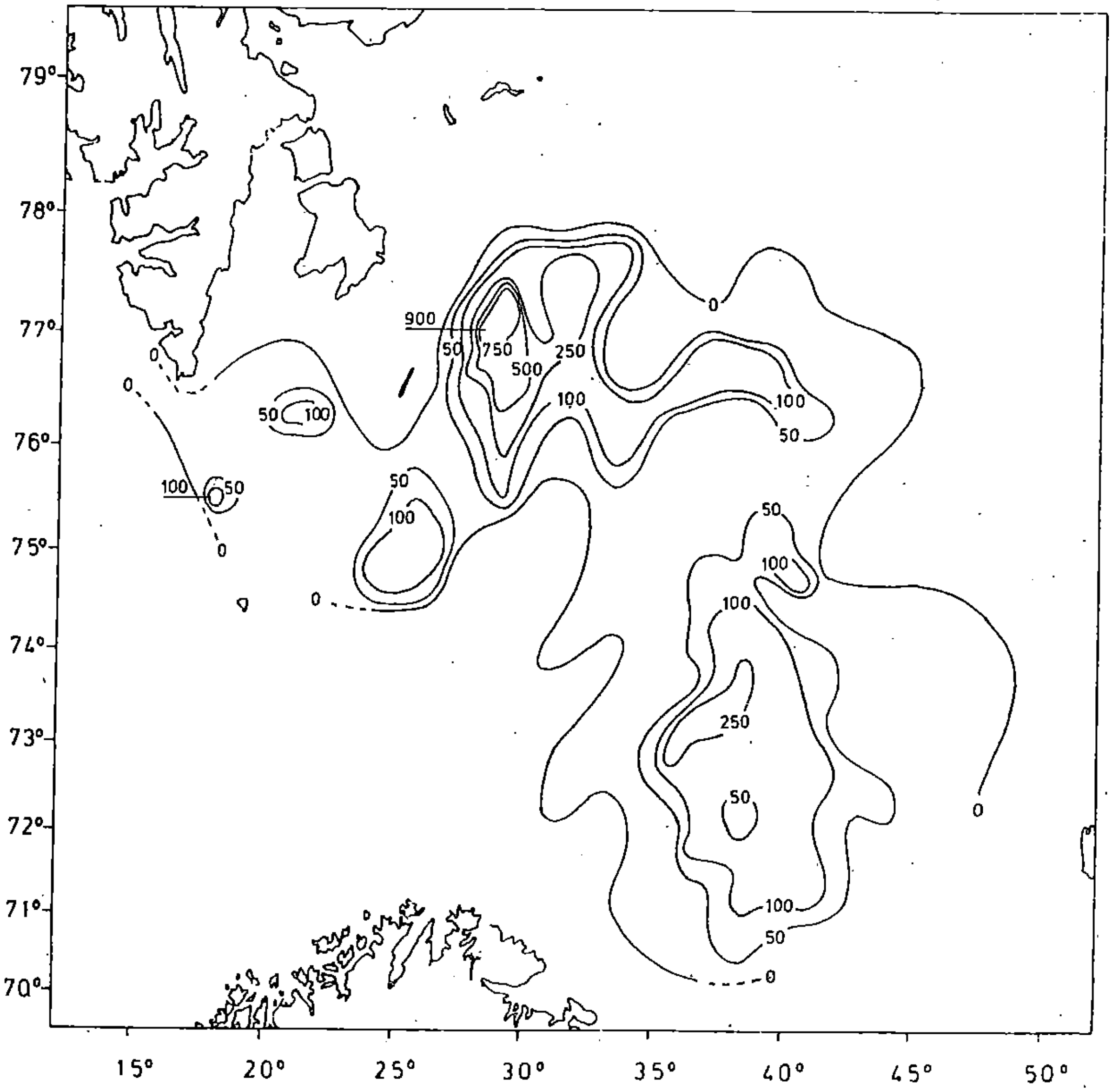
Polar Cod

App.II, Figure 13 shows the geographical distribution of Polar cod observed during the survey. The stock of Polar cod seems to have increased, especially in the southeastern part of the Barents Sea. App.II, Figure 14 shows the length distribution of Polar cod.

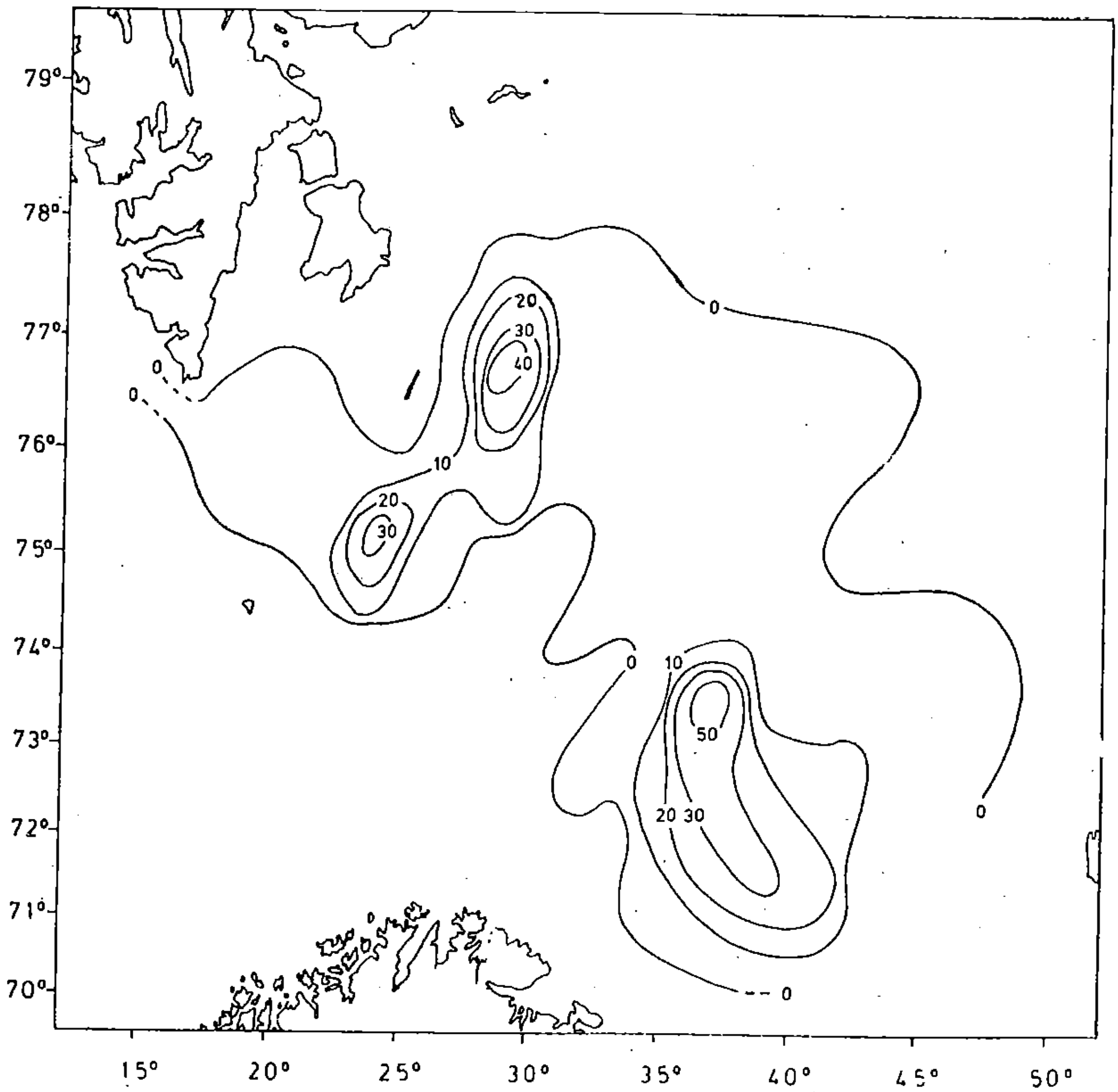


App.II, Figure 1. Survey routes and stations for "G. O. Sars" and "Johan Hjort" (solid line) and "Persey III" (broken line).

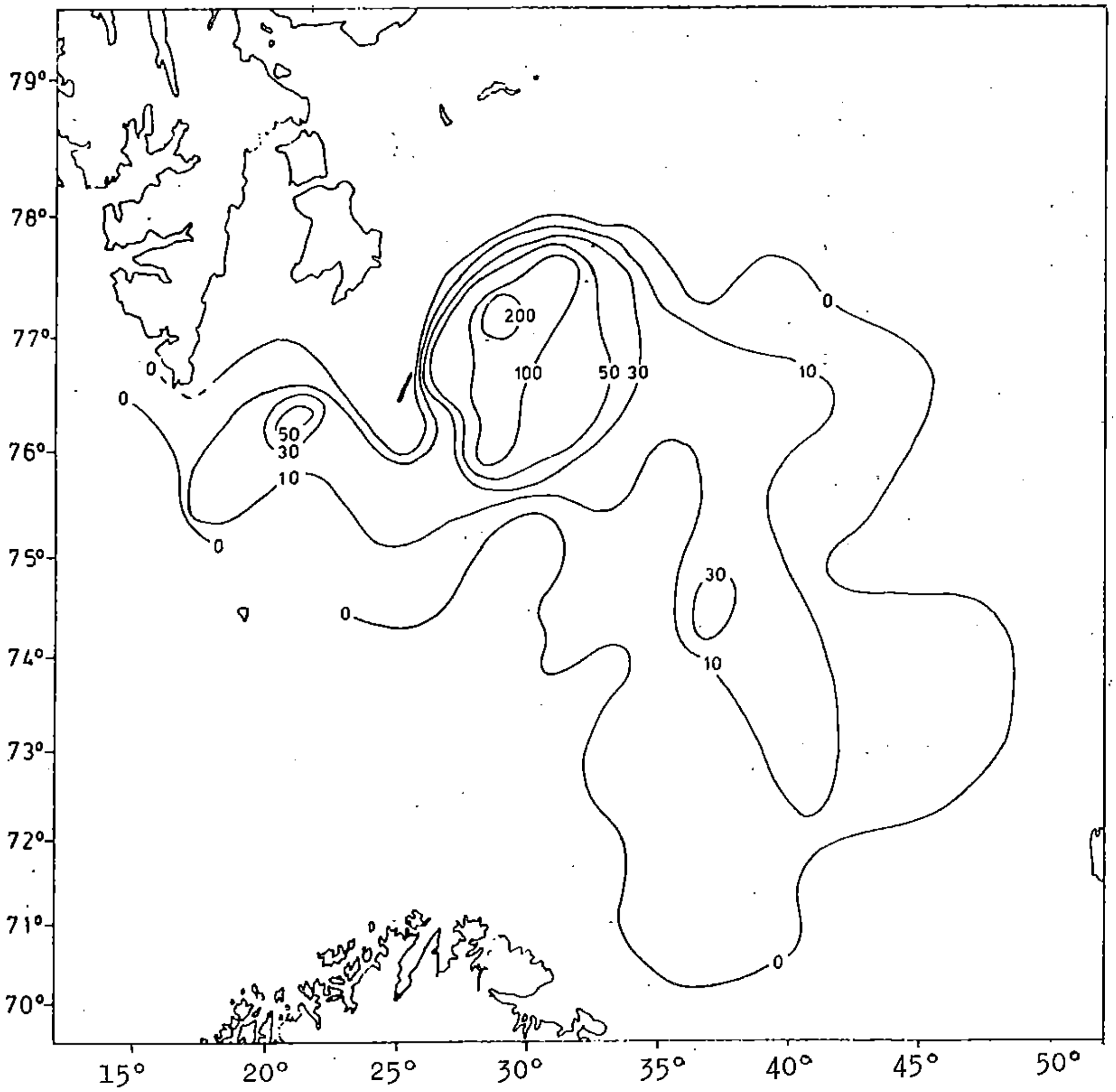
1) hydrographic station with CID-sonde
2) hydrographic station with "Nansen-bottles"
3) bathythermograph
4) pelagic trawl station



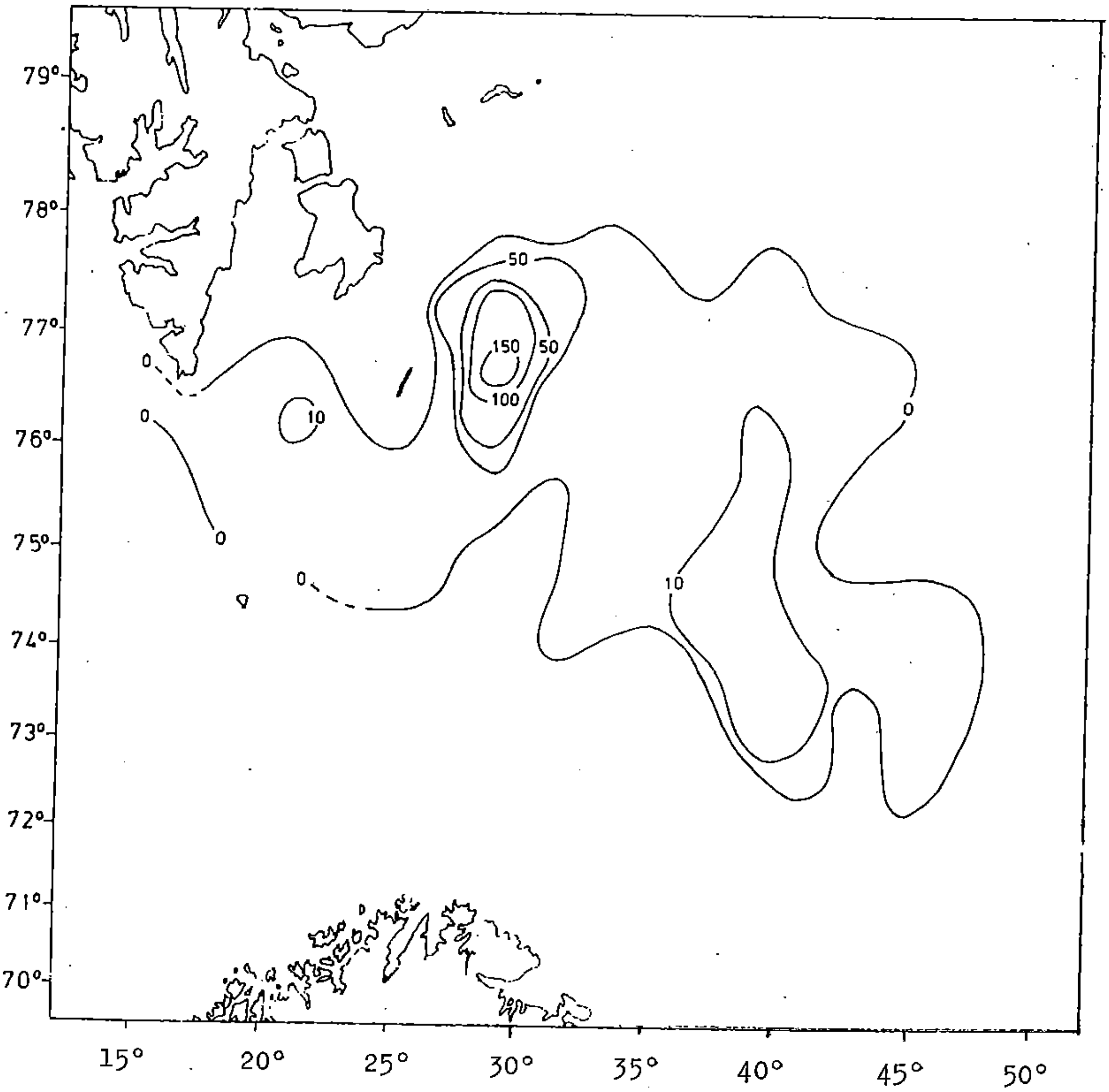
App.II, Figure 2. Geographical distribution of the capelin stock, integrated echo intensity (mm deflection/nautical mile).



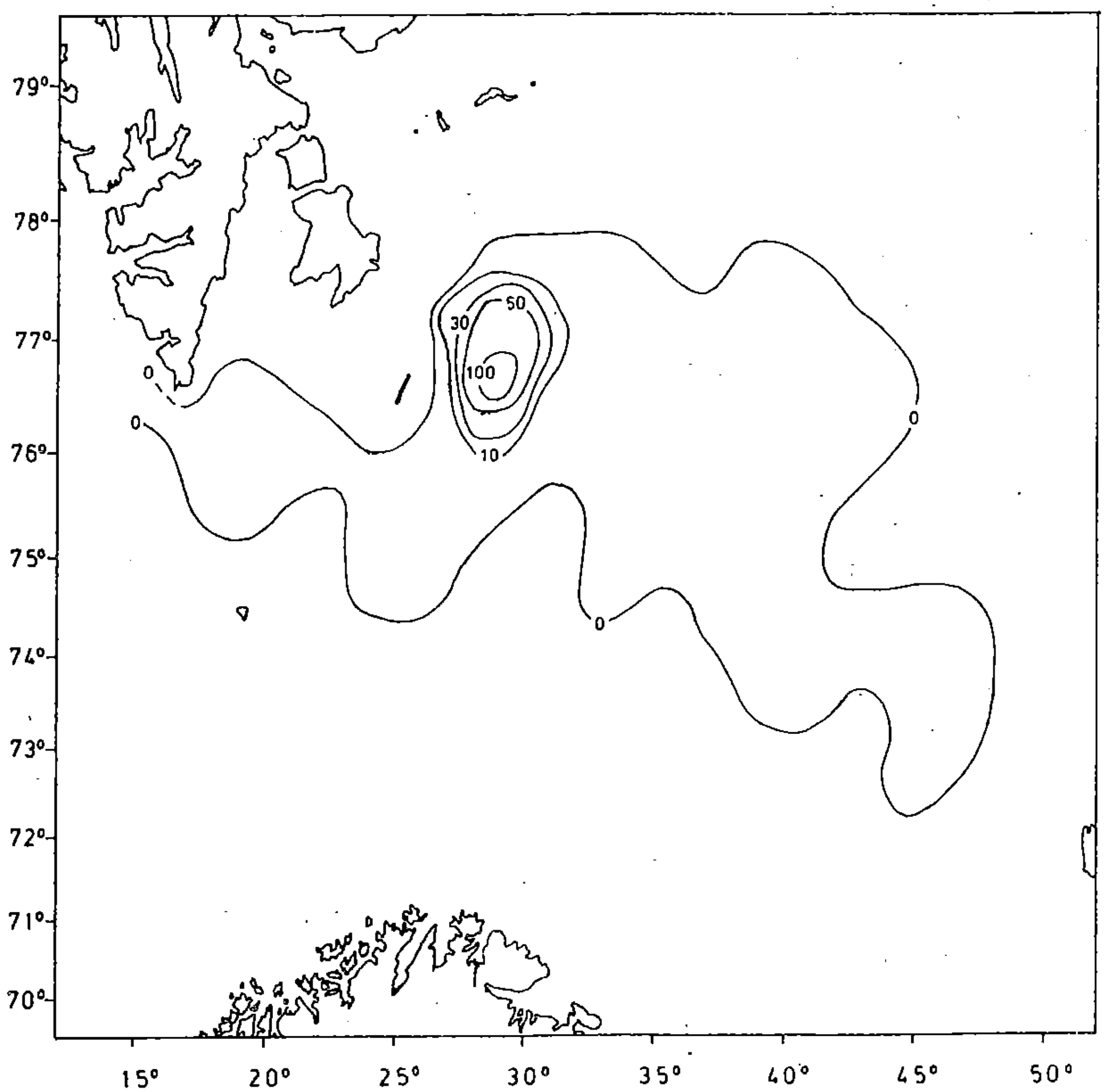
App.II, Figure 3. Estimated density distribution of 1 year old capelin (tonnes/(nautical mile)^2).



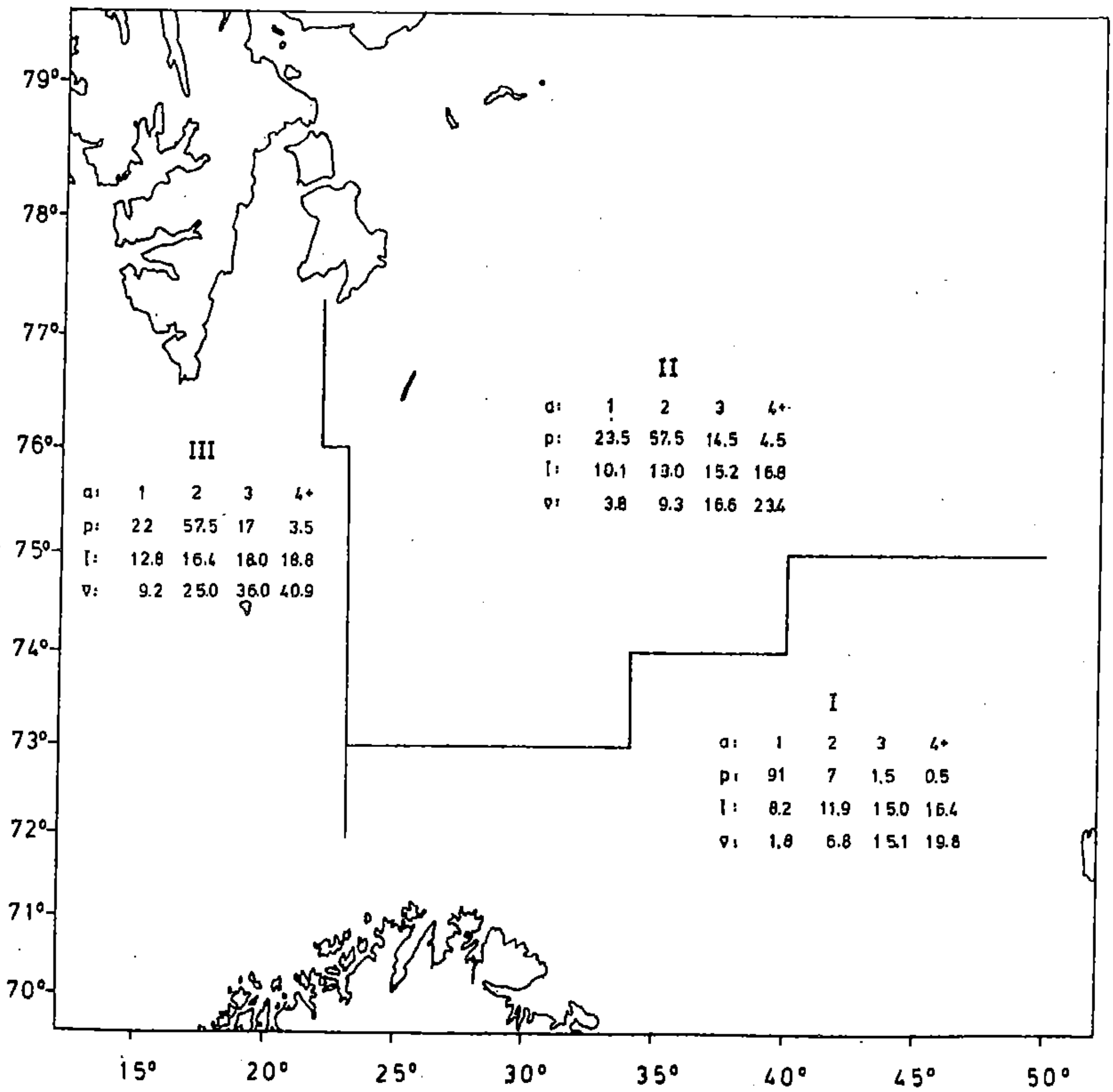
App.II, Figure 4. Estimated density distribution of 2 year old capelin (tonnes/(nautical mile)^2).



App.II, Figure 5. Estimated density distribution of 3 year old capelin (tonnes/(nautical mile)^2).



App.II, Figure 6. Estimated density distribution of 4 year old capelin (tonnes/(nautical mile)^2).



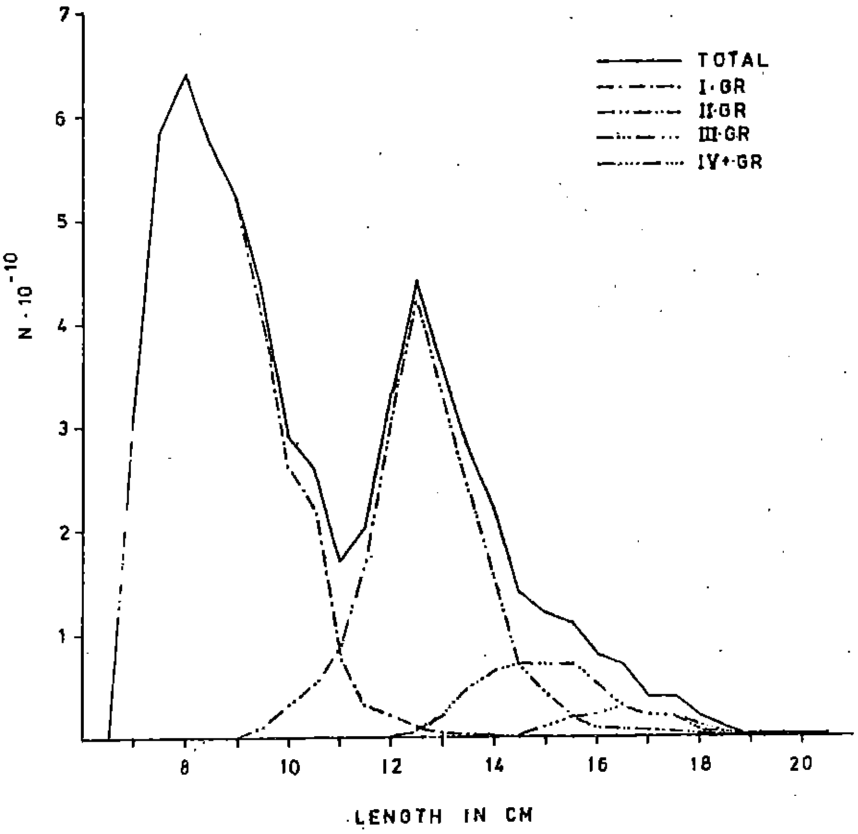
App.II, Figure 7. Biological parameters in the three sub-areas used for the acoustic estimate.

a: age

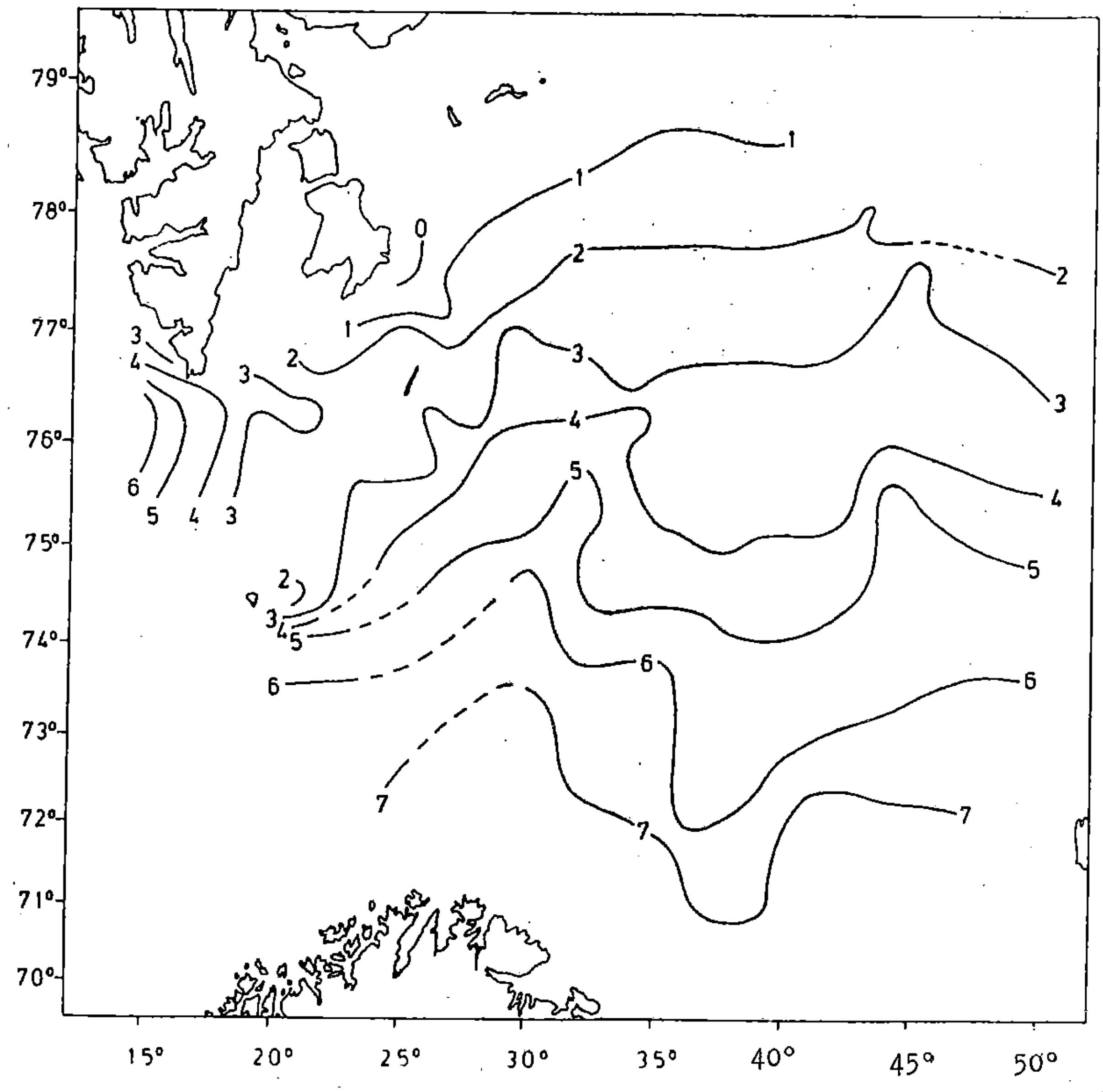
p: percentages

$\bar{l}$: mean lengths (cm total length)

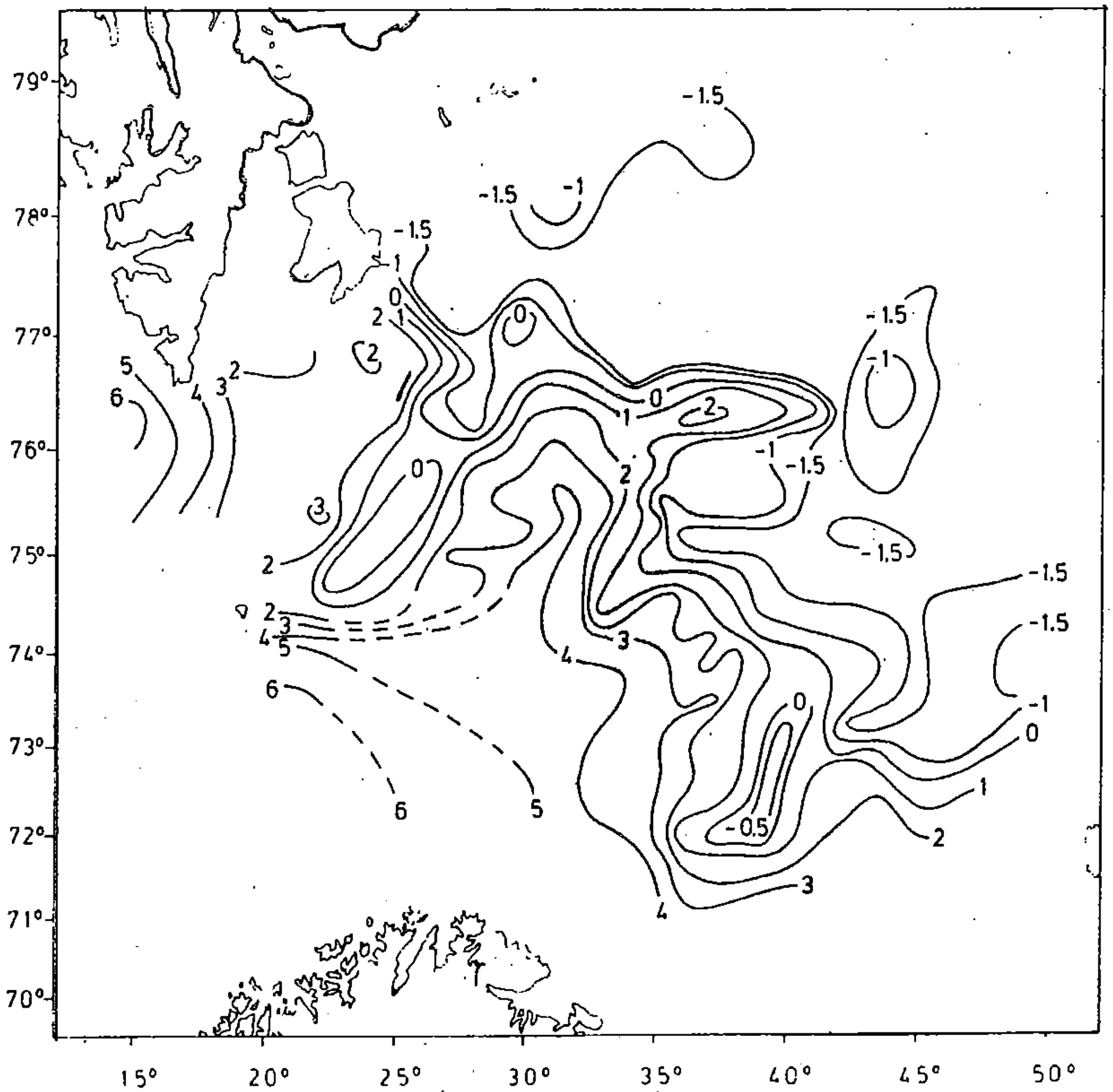
$\bar{v}$: mean volumes (ml).



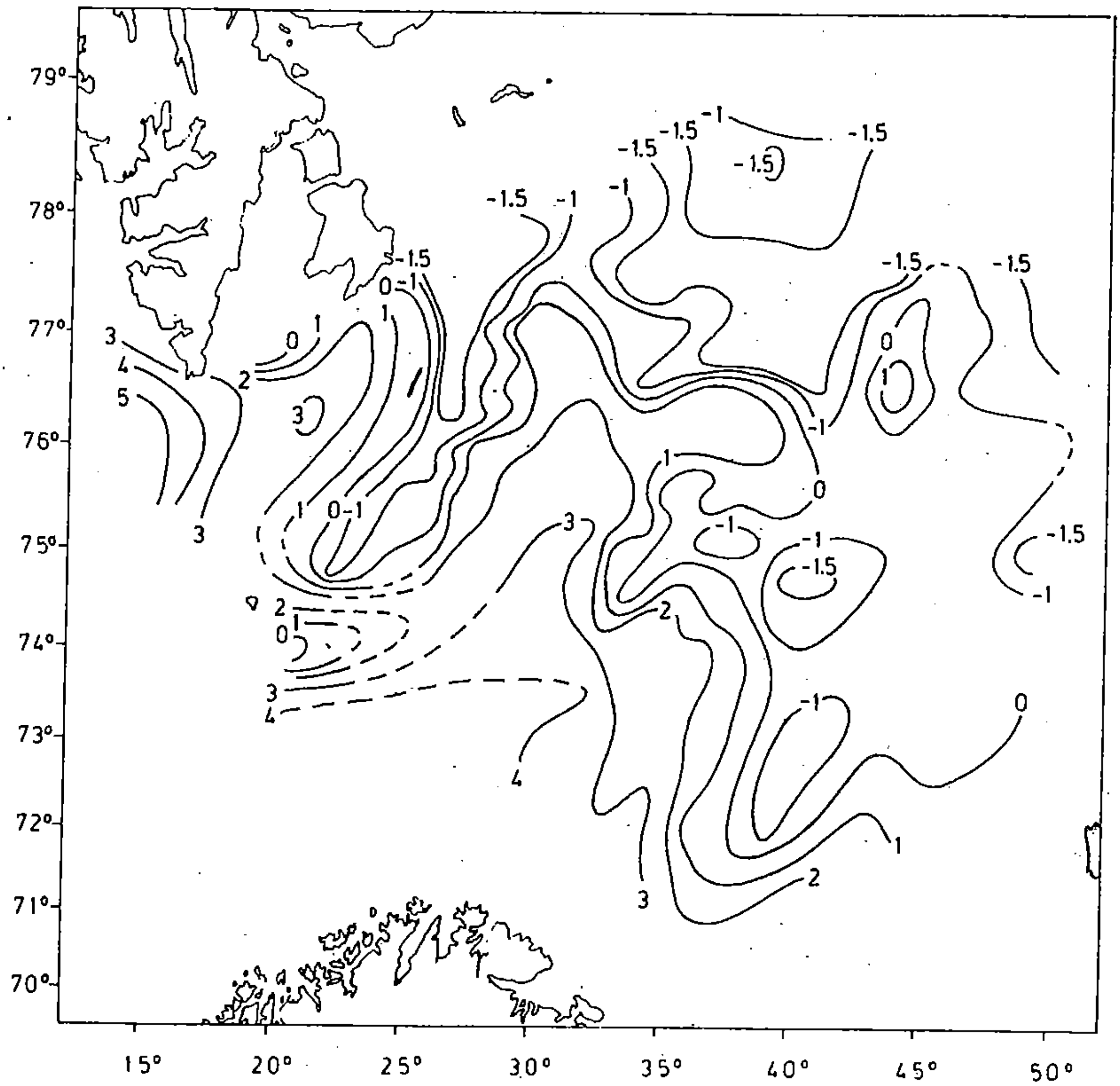
App.II, Figure 8. Length distribution of 1, 2, 3 and 4 year old capelin.



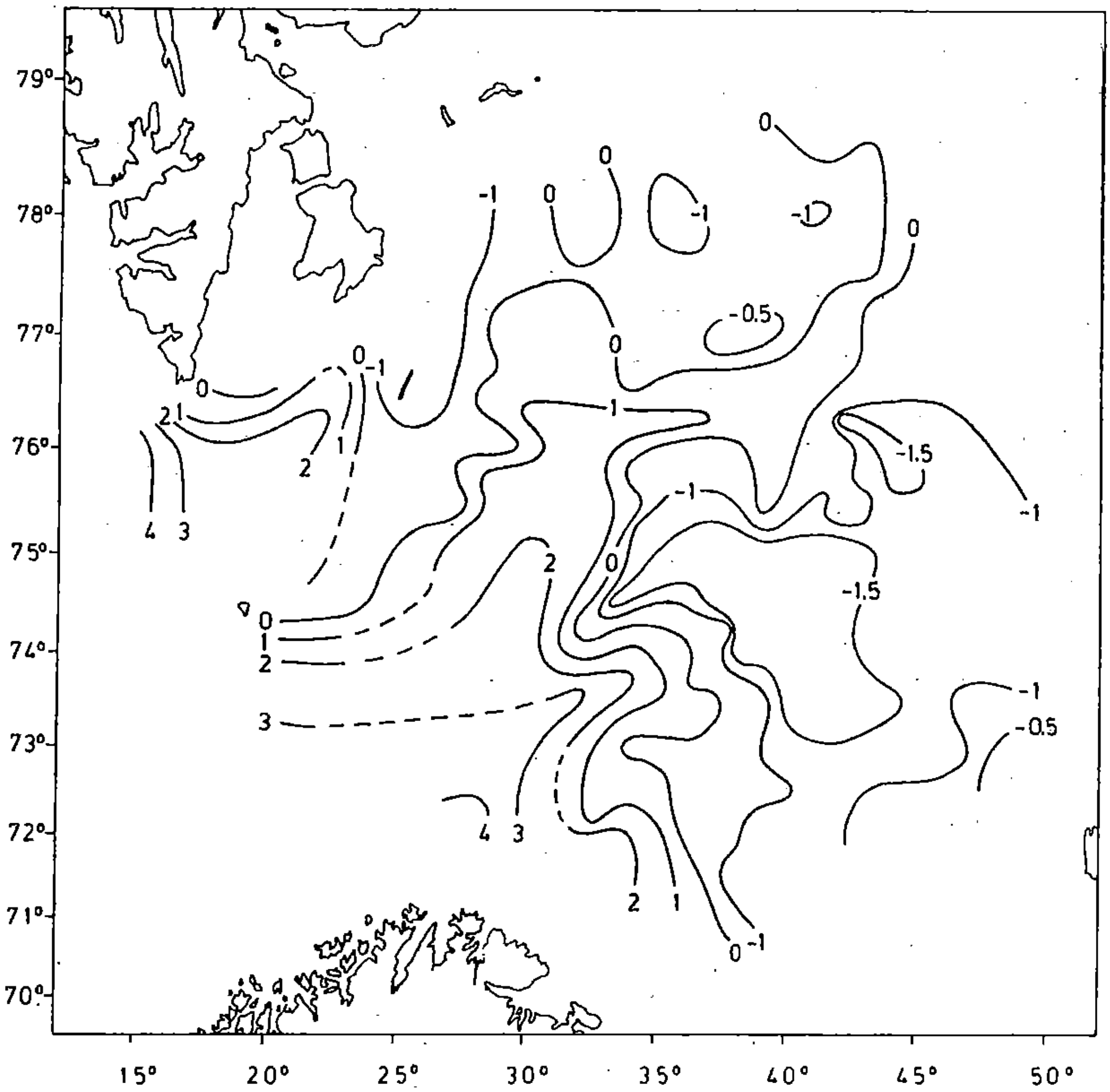
App.II, Figure 9. Distribution of temperature (t°C) at the surface.



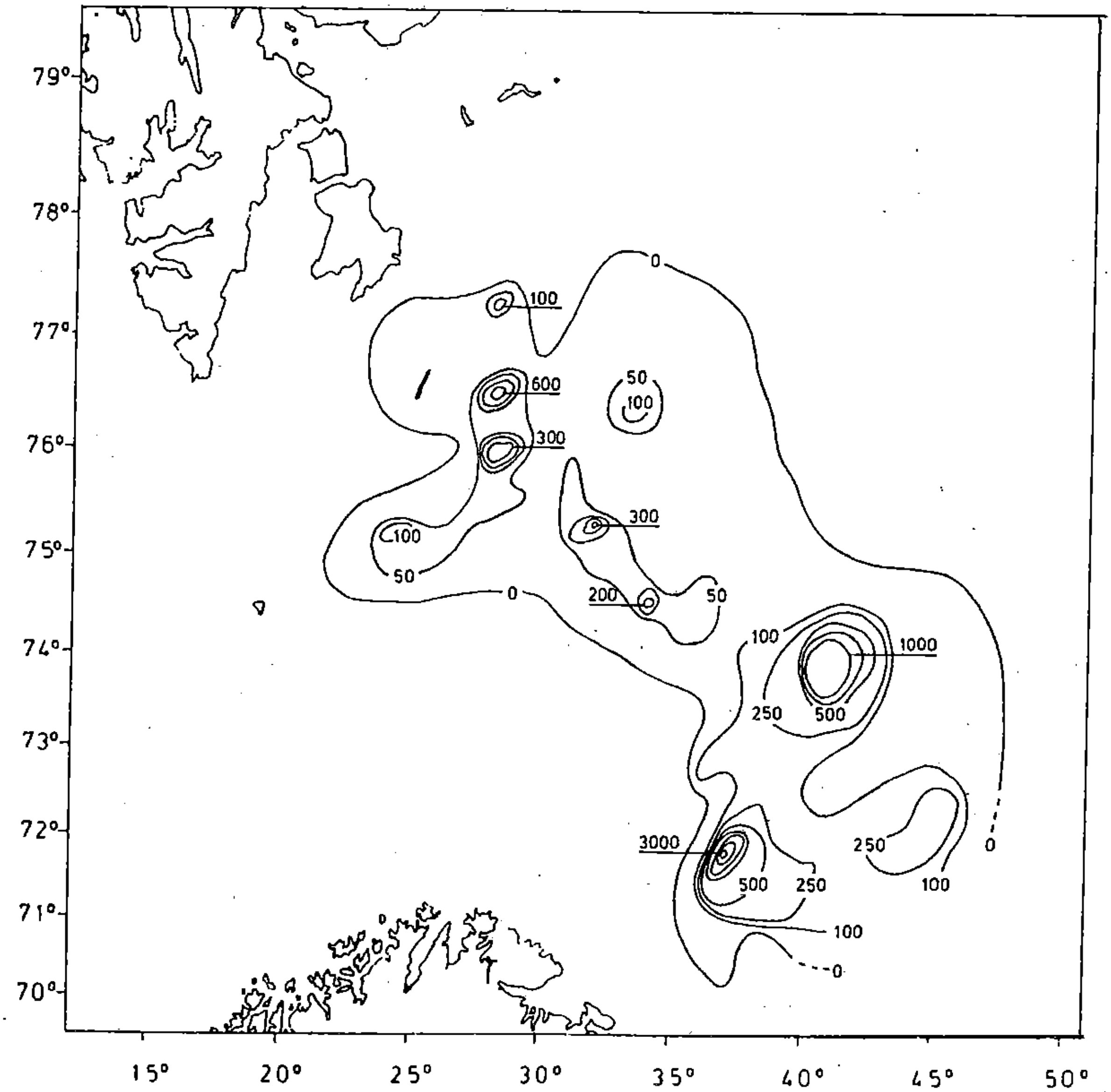
App.II, Figure 10. Distribution of temperature (t°C) in 50 m depth.



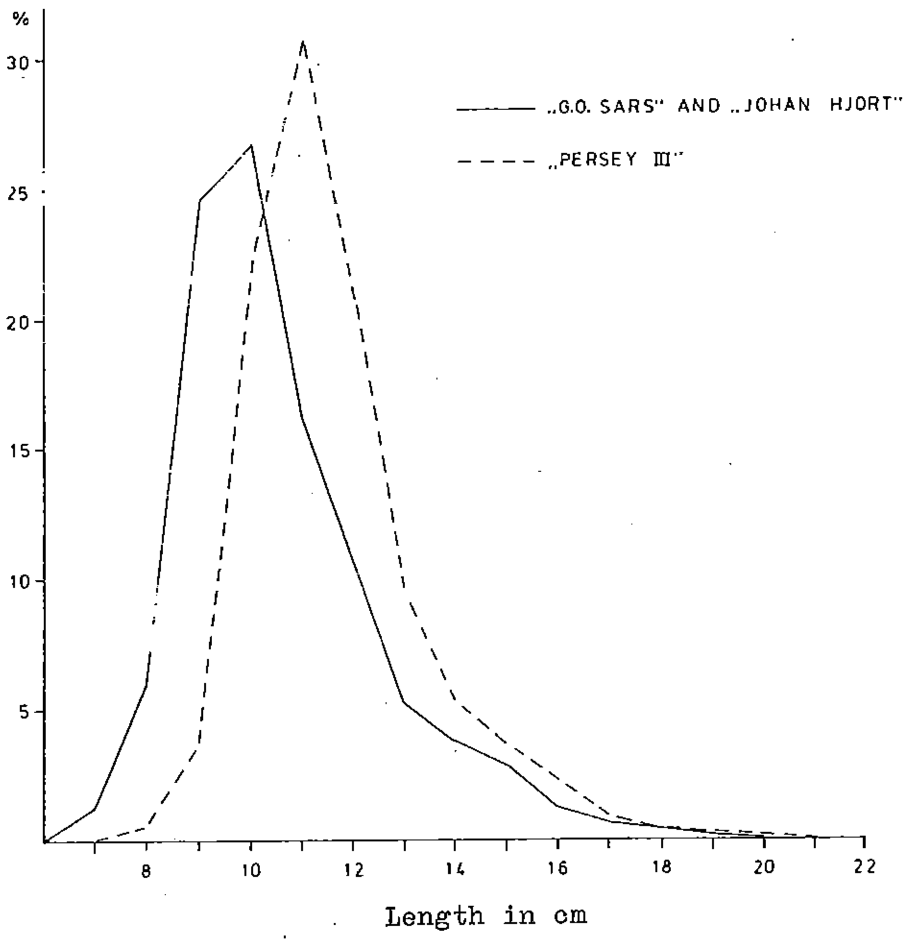
<u>App.II, Figure 11.</u> Distribution of temperature (t°C) in 100 m depth.



App.II, Figure 12. Distribution of temperature (t°C) in 200 m depth.



App.II, Figure 13. Geographical distribution of Polar cod (mm integrator deflection, values from "G. O. Sars", "Johan Hjort" and "Persey III").



App.II, Figure 14. Length distribution of Polar cod.

Annex to Appendix II

Work Note
3.10.1981

REPORT ON THE INTERCALIBRATION OF THE ECHO INTEGRATORSYSTEMS ON R/V "G. O. SARS" AND R/V "PERSEY III" DURING THE JOINT CAPELIN SURVEY IN SEPTEMBER-OCTOBER 1981

The intercalibration took place during the night between 27 September - 28 September 1981. The starting point of the intercalibration was 76°10'N, 28°00'E. During the first part of the intercalibration the vessels steamed 360°, but due to pitching the course was changed to 180° after 10 nautical miles.

Annex, Figure 1 shows the position of the vessels during the intercalibration. As it can be seen the distance between the vessels was 0.5 nautical mile, and "G. O. Sars" was positioned 10° to the starboard ahead of "Persey III". The navigational log on "G. O. Sars" was used asa reference of distance, and information on the log counter's showing was passed on to "Persey III" by help of VHF communication. Each time the log-counter on "G. O. Sars" passed 0.5 nautical mile, a signal was transmitted to "Persey III" where the integrator was reset immediately. The resetting of the integrator on "G. O. Sars" was done every time a full mile was passed on the log-counter. Consequently, since the distance between the vessels was 0.5 nautical mile, the resetting of the integrators on both vessels occurred at approximately the same positions. Thus, the corresponding nautical miles on the recording papers on the vessels would include comparable echo recordings and integrator values. Annex, Figure 2 shows examples of corresponding nautical miles of echo recordings. The intercalibration was carried out on a dense layer of capelin, and the distance covered was 40 n. miles. The settings of the instruments on both vessels are given in Annex, Table 1.

Corresponding integrator values (running means 5 n.miles) obtained for "G. O. Sars" and "Persey III" are given in Annex, Figure 3. In Annex, Figure 4 these values are plotted with "G. O. Sars" values on the ordinate, and "Persey III" values on the abscissa. Scrutinizing of the recording papers from both vessels revealed that for a few corresponding nautical miles, the echo recordings were not comparable. These were not included in the calculation of the regression lines.

The following regression line was calculated from all values in Annex, Figure 4, based on the method of least squares:

$$M_{G.O.S.} = 0.21 \quad M_{PERSEY\ III} - 32 \qquad (r = 0.96)$$

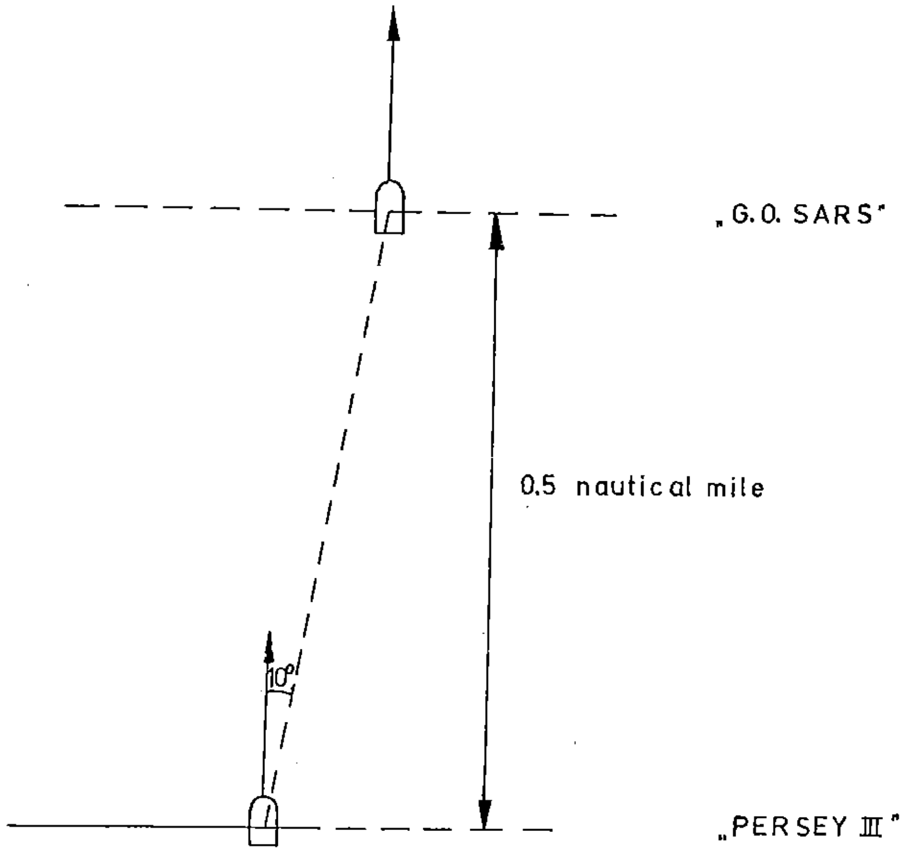
Due to lack of low values in channel 1, values from the second and third channels were used as a basis for the calculation of an equation to be used for values less than 500 Persey III-units. The regression was:

$$M_{G.O.S.} = 0.156 \quad M_{PERSEY\ III} - 4.8 \qquad (r = 0.96)$$

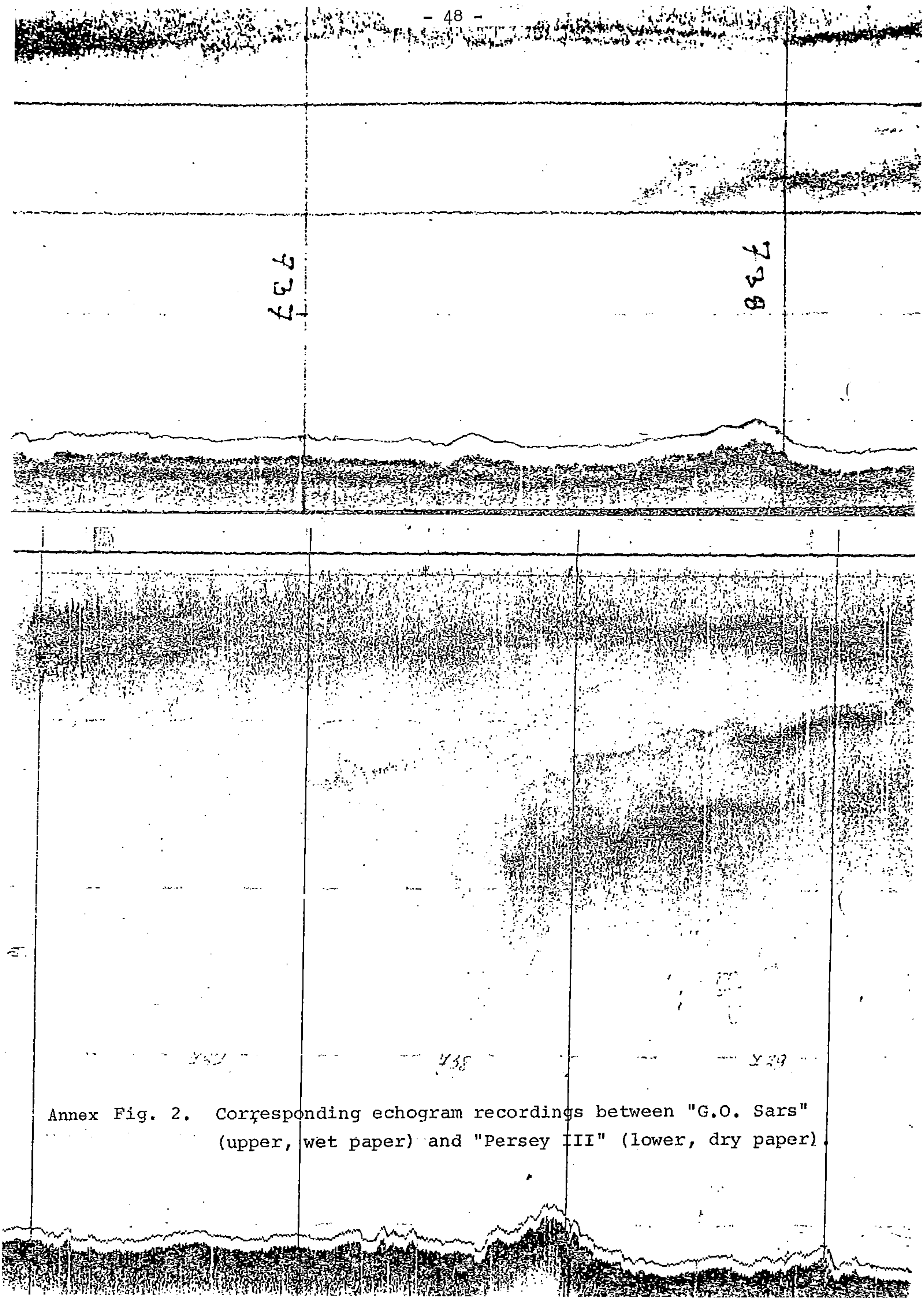
However, after a close study of the echo recordings in channel 2 and 3, it was decided that for all practical reasons, a conversion factor of $M_{G.O.S.} = 0.15\ M_{PERSEY\ III}$ could be used for integrator values below 500 Persey III units. This line is also included in Annex, Figure 4.

Annex Table 1. Instrument settings during intercalibration.

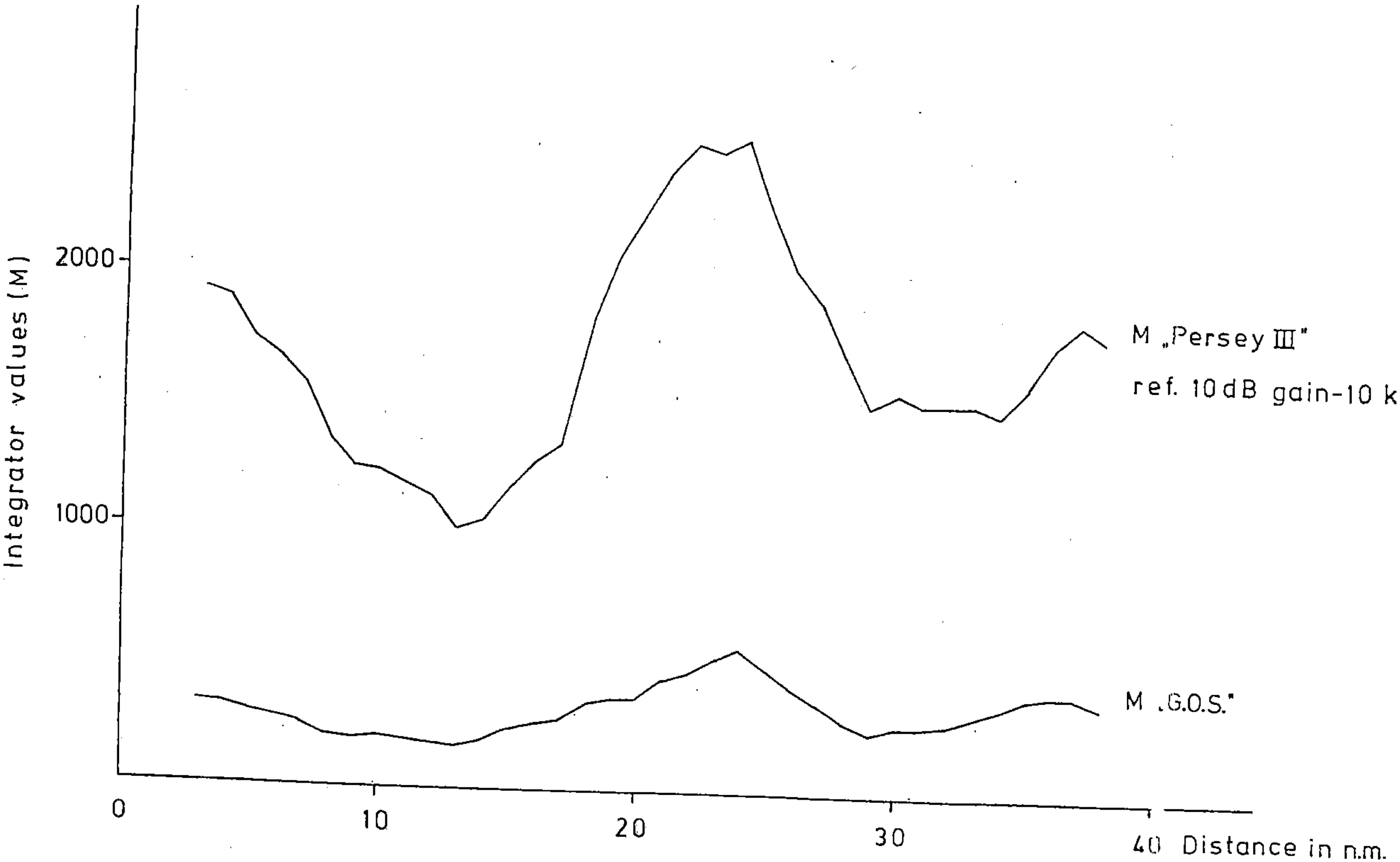
	"G. O. Sars"	"Persey III"
Echo sounder	EK 38 AR	EKS 38
Transducer	45x48 cm	30x30 cm
	5x5,5°stab.	8°x8° ceramic
Power	10 kw transmitter	4.8 kw transmitter
TVG/Gain		
Bandw./Pulslength	3 kHz-0.6 ms	3kHz - 0.6 ms
Range	0 - 250 m	0 - 250 m
Integrator	Digital N-10	Digital AIS 8
Gain (ref.output)	40 dB	15 dB
Threshold	10 mV	32 mV
Intervals	10 - 50 m	10 - 50 m
	50 - 100 m	50 - 100m
	100 - 150 m	100 - 150m



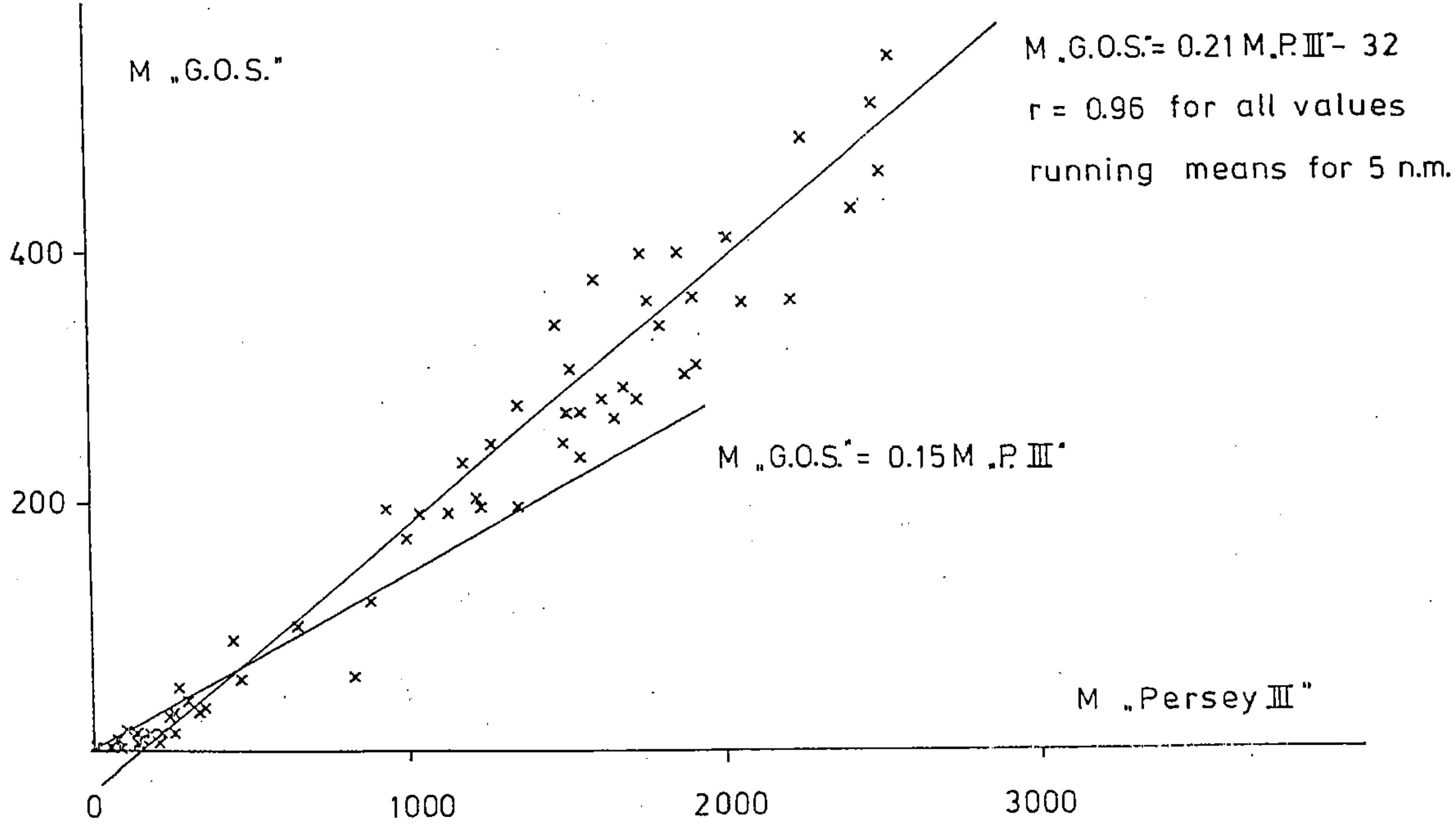
Annex Figure 1. Sailing positions during the intercalibration between "G. O. Sars" and "Persey III".



Annex Fig. 2. Corresponding echogram recordings between "G.O. Sars" (upper, wet paper) and "Persey III" (lower, dry paper).



Annex Figure 3. Corresponding integrator values for „G.O.Sars" and „Persey III"



Annex Figure 4. Integrator values „Persey III" ref. integrator values „G.O. Sars"

APPENDIX III

REPORT ON THE ICELANDIC-NORWEGIAN ACOUSTIC SURVEY OF THE ICELANDIC CAPELIN STOCK IN OCTOBER 1981

Introduction

Through previous surveying by Iceland and Norway it has been established that the best acoustic estimates of the size of the Icelandic stock of capelin are obtained at the end of the feeding period in late autumn - early winter and during the first stages of the spawning migration in January-February before the fish enter the shallow coastal waters at south and southwest Iceland.

As last year, the joint survey was, therefore, carried out during 14-23 October. Two vessels participated: R/V "Bjarni Sæmundsson", Marine Research Institute, Reykjavik,and R/V "G. O. Sars", Institute of Marine Research, Bergen.

An Icelandic survey of the Denmark Strait and adjacent waters, which because of increasing drift ice had been planned to take place during the first 10 days of October, had to be abandoned due to technical difficulties and to bad weather conditions.

Exchange of personnel took place during the survey and information on data collected was exchanged daily. Planning had to take place as work progressed due to varying weather and ice conditions.

Final processing of the data was handled on board R/V "G. O. Sars". The following scientists participated:

On board R/V "Bjarni Sæmundsson": H Vilhjálmsson and A Dommasnes

On board R/V "G. O. Sars": J Hamre, L Midttun and P Reynisson.

Material and Methods

The survey was initiated just north of 69° between 13° and 20°W. From there it covered an area north to 70°45', and along the ice border southwestwards to 66°N. Courselines and stations are shown in Appendix III Figure 1.

Initially the main cruise tracks were spread at 15 nautical miles intervals running in an east-west direction. In order to obtain a better coverage of areas with relatively high concentrations of capelin, spacing of course tracks was decreased to 5-8 n.miles on several occasions.

Echo intensities were integrated continuously using an analog integrator on board R/V "Bjarni Sæmundsson" and a digital set on board the "G. O. Sars". Mean values per 1 nautical mile were recorded for each 5 nautical miles sailed. Integrated values of echo intensities and echograms were scrutinized daily and contributions from bottom, false echoes and noise deleted. The remainder was then attributed to species according to the trace pattern of the catch composition. Trawling was carried out whenever necessitated by changes in the characteristics of the echograms or when needed in order to ensure adequate biological sampling, i.e., to obtain information on length, weight, maturity stage, stomach content and age of the capelin. Hydrographic observations were carried out by means of a CTD zonde and bathythermograph.

Due to reasonably good weather and limited access to the possible distribution area imposed by drift ice over the East Greenland shelf it was possible to cover the main capelin area in the period 14-23 October. The main fishing area at 68°N and 19° to 21°W was covered twice. In order to render the integrated echo intensities comparable, an intercalibration run was conducted in the area 67°N, 20°30'W. Recordings consisted of O-group capelin and plankton. The following relationship was established with a correlation coefficient of 0.98:

$$M_{GOS} = 0.026 \qquad M_{BS} = + 4.9$$

In addition, a standard target calibration (copper sphere, 60 mm in diameter) was carried out at anchor in Isafjordardjup.

Integrated echo intensity simulated over 1 nautical mile gave the following result:

$$\frac{M_{GOS}}{M_{BS}} = 0.027$$

A report on the calibrations is found on page 65.

The echo intensities recorded by the "Bjarni Sæmundsson" were then converted to "G. O. Sars" values using the first equation.

Compilation of numbers of individuals and biomass by length and age groups were obtained by the same standard computer program as previously.

Results

The capelin were recorded in three main areas. Area I between 69°30' and 70°30'N, area II between 67°30' and 68°30'N, and area III between 66°00' and 66°30'N. Distribution of echo intensity in the three areas is shown in App.III Figures 2 and 3. Age and length distribution by areas are given in App.III, Fig. 4.The population in areas I and II was predominantly adults, while juveniles were most abundant in area III.

The northern component of the capelin stock, which has its feeding grounds in the area west of Jan Mayen, was now located between 69°30'N and 70°30'N. This is about 60 nautical miles further to the northeast than its counterpart in 1980. The main concentration was now found between 67°30' and 68°30'N, which is also considerably further to the northeast than last year. A small area, containing mostly immature fish was located between 66°00'N and 66°15'N to the west of the northwestern peninsula of Iceland.

It should be noted that the area between 66°15'N and 67°30'N west of 21°40'W was now covered by drift ice with the exception of the relatively shallow waters from the coast to 40-50 nautical miles offshore. This corresponds to the area where the bulk of the stock was located last year.

Geographically, the capelin were thus distributed much further to the north and east than at the same time last year but as then kept to the zero and sub-zero temperatures of the East Greenland Current and adjacent waters.

The total abundance estimate in weight of 1-3 year old capelin amounted to 144 000 tonnes, distributed by areas I, II and III as 11 000 tonnes, 128 000 tonnes and 5 000 tonnes, respectively. Details of the total stock estimate are given in App.III Table 1. An abstract is given in the following text table, together with the corresponding values for 1979 and 1980:

Age	1981		1980		1979	
	Number x 10^{-9}	Tonnes x 10^{-3}	Number x 10^{-9}	Tonnes x 10^{-3}	Number x 10^{-9}	Tonnes x 10^{-3}
1	0.9	5	23.6	171	22.3	141
2	7.0	135	19.6	378	42.4	639
3	0.2	4	4.8	128	7.9	167
Total	8.1	144	48.0	677	72.6	947

Due to insufficient coverage the 1 year old capelin must be very much underrepresented. This, however, is by far the lowest amount observed. Until further information is obtained, the small amounts of 1-group fish should, therefore, be taken as a warning that the 1980 year class may be even weaker than 0-group data have suggested.

As far as the immature stock is concerned, there is a dramatic decrease in biomass even compared to last year.

Hydrography

The hydrography is illustrated by horizontal charts of surface salinity (App.III Figure 5), surface temperatures (App.III Figure 6), and temperatures at 100 m and 200 m respectively (App.III Figures 7 and 8).

The isolines reflect the main features of the general water circulation in the area: the Icelandic coastal water of relatively high salinity and temperature is entering the area from the south and flows eastwards bordered in the north by the Polar waters of the East Greenland Current and its branch, which forms the East Icelandic Arctic Current.

The main concentration of capelin is found in the southern part of the area where the East Icelandic Current branches from the Greenland Current, its southern boundary being the warmer coastal water. App.III Figure 9 shows temperature and salinity in a meridional section along 19°W between 67°30'N and 68°20'N running through some fish concentrations, mainly located in waters with temperatures between -1 and +1°C.

Discussion

As far as the survey grid itself is concerned, coverage must be considered adequate. Errors arising from survey tracks being too sparsely spaced may thus be judged as negligible.

Surveying in the Iceland-Greenland area is, however, often most difficult due to drift ice and rapidly changing ice conditions. In October 1980 the bulk of the capelin stock was concentrated in the deep, cold waters of the strait between northwest Iceland and Greenland. As already pointed out, these waters were impassable due to drift ice during the present survey. Around mid-September, however, an Icelandic capelin fishery was initiated in that area (66°40'N, 26°20'W), the fleet gradually moving northeastwards during the next 3 weeks. The boats were mainly fishing from 67°40' - 68°05'N between 19°00' and 21°30'W during the survey.

In view of the above movements of the fishing fleet as well as diminishing echo intensities towards the ice border, it seems likely that the southwestern border of the distribution of the adult stock has been closely approached.

On the other hand, it should be noted that the distribution of the capelin is often patchy, and concentrations are sometimes left behind underneath drift ice for lengthly periods of time. Thus, the existence of capelin concentrations underneath the present ice cover cannot be excluded.

With the exception of about 24 hours when the ships could not work at all, good weather prevailed throughout the survey, and the echo intensity can only have been influenced by water disturbance to a minor extent, if at all.

Since practically no 1-group fish were encountered except south of the drift ice and on their own, interpretation of the acoustic data was relatively easy. Errors arising from inadequate sampling are, therefore, not thought to affect the acoustic estimates to any significant degree.

Conclusions

As shown in the text table on p.53 the acoustic abundance estimate is much lower this year than that obtained in corresponding surveys in 1980 and 1979. Thus, the present biomass is only 1/6 of the estimated biomass in 1979.

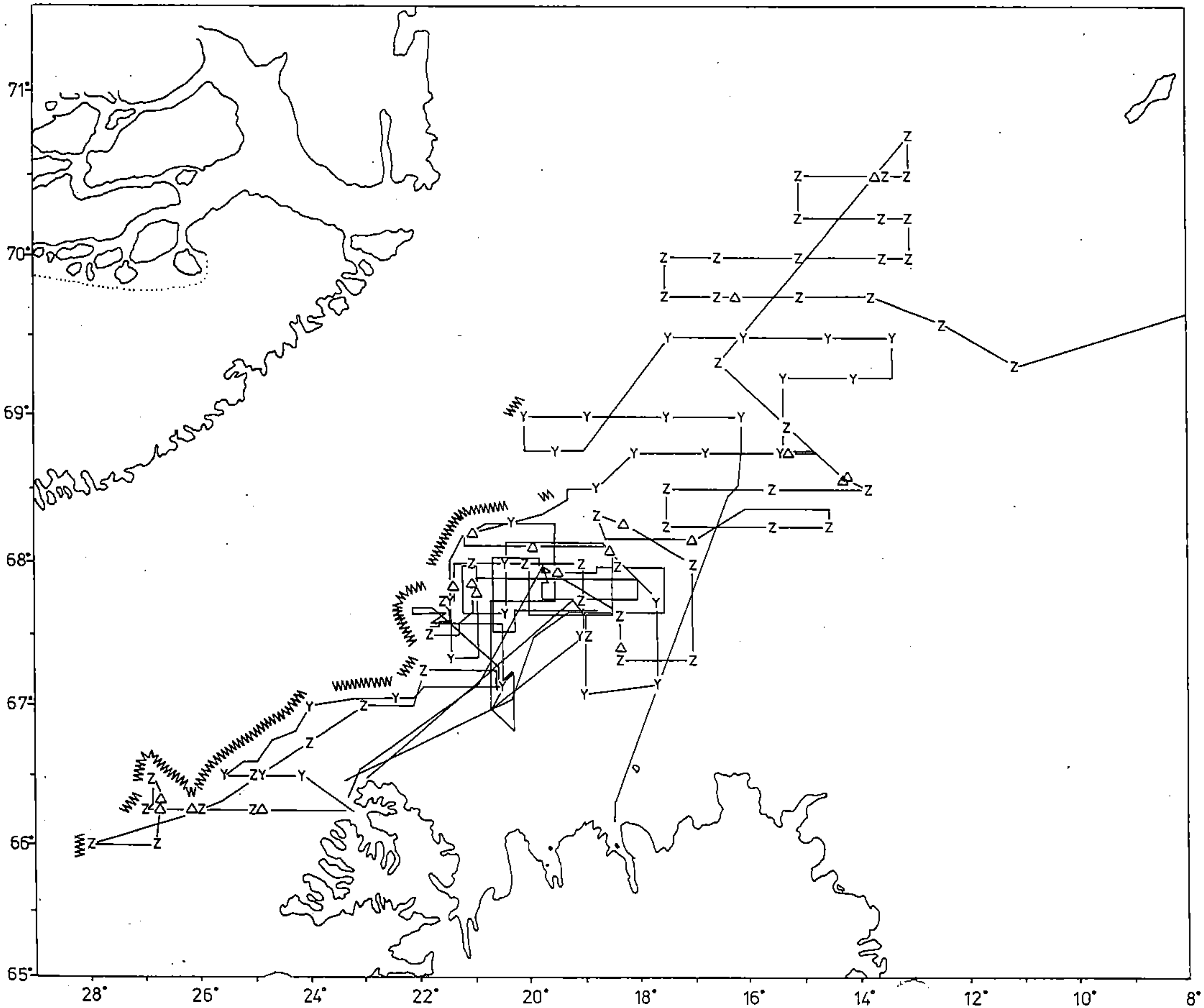
A preliminary TAC of 700 000 tonnes has been agreed between Iceland and Norway. At the time of the survey approximately 350 000 tonnes had been taken by various nations fishing on the stock.

On the basis of the present abundance estimate, it is quite clear that if the remainder of the allocated TAC of about 350 000 tonnes is taken, the spawning stock will be fished out before the spawning season begins. As pointed out in a previous section, the existence of capelin concentrations underneath the present ice cover cannot be excluded. Such concentrations are, however, most unlikely to be of a sufficient magnitude to compensate for the drastic reduction observed in stock abundance. It is, therefore, recommended that the TAC for the present regulation period (autumn fishery 1980 - winter fishery 1981) should be reconsidered as soon as possible.

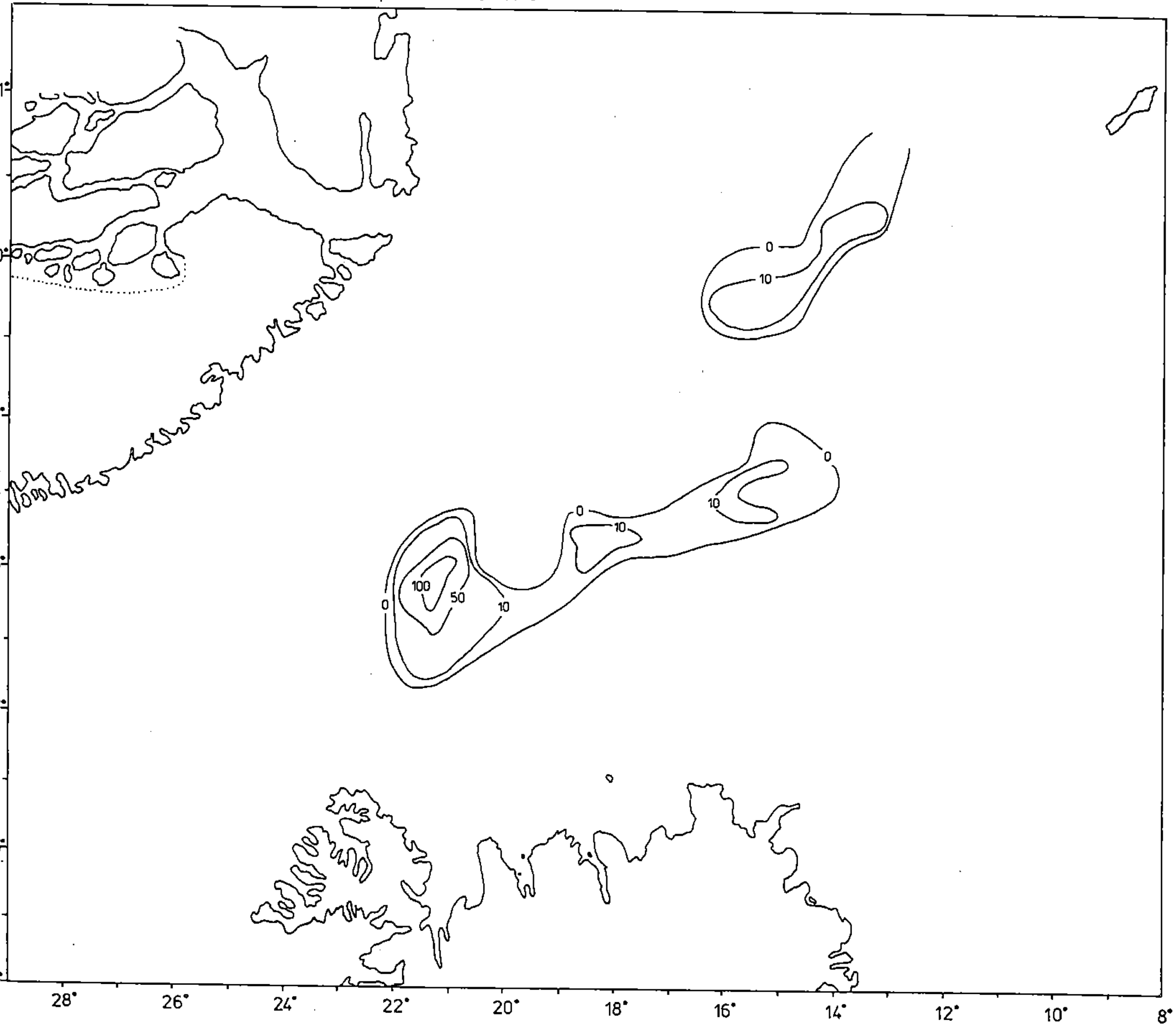
Appendix III, Table 1. Acoustic estimate of the capelin in the Iceland - Jan Mayen - Greenland area in October 1981.

Total length (cm)	Age 1	Age 2	Age 3	Age 4	Total number x 10^{-7}	Biomass tonnes x 10^{-3}	Mean volume (ml)
09.5 - 09.9	5				5	0.2	3.1
10.0 - 10.4	10				10	0.4	3.6
10.5 - 10.9	17				17	0.7	4.1
11.0 - 11.4	17				17	0.8	4.8
11.5 - 11.9	10				10	0.6	5.5
12.0 - 12.4	5				5	0.3	6.5
12.5 - 12.9	11	2			13	1.0	8.0
13.0 - 13.4	3	8			11	1.0	9.4
13.5 - 13.9	7	23			30	3.3	11.0
14.0 - 14.4	1	42	4		47	5.8	12.4
14.5 - 14.9	1	73	4		78	11.0	14.1
15.0 - 15.4		118	3		121	19.5	16.1
15.5 - 15.9		125	3		128	23.1	18.0
16.0 - 16.4		95			95	19.8	20.9
16.5 - 16.9		101	4		105	24.9	23.7
17.0 - 17.4		71	3		74	19.7	26.7
17.5 - 17.9		28	1		29	8.6	29.7
18.0 - 18.4		8	1		9	3.0	33.1
18.5 - 18.9		1			1	0.3	32.3
Number x 10^{-7}	87	695	23		805		
Mean length (cm)	11.60	15.85	15.82		15.39		
Biomass (tonnes x 10^{-3})	5.0	134.6	4.4			144.0	
Mean volume (ml)	5.8	19.4	19.0		17.9		

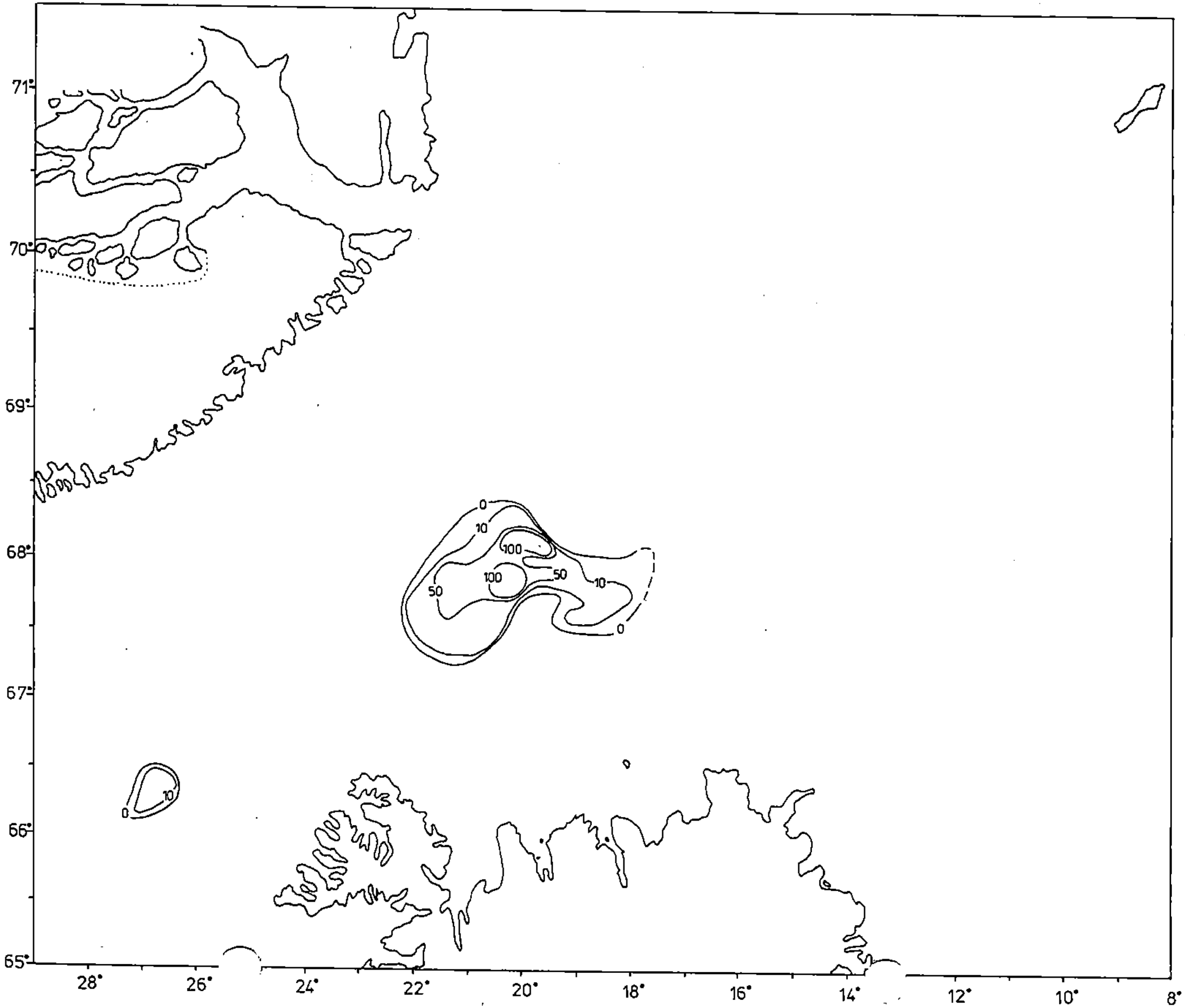
<u>App.III Figure 1.</u> Cruise tracks for "Bjarni Sæmundsson" and "G. O. Sars" 14-23 October 1981



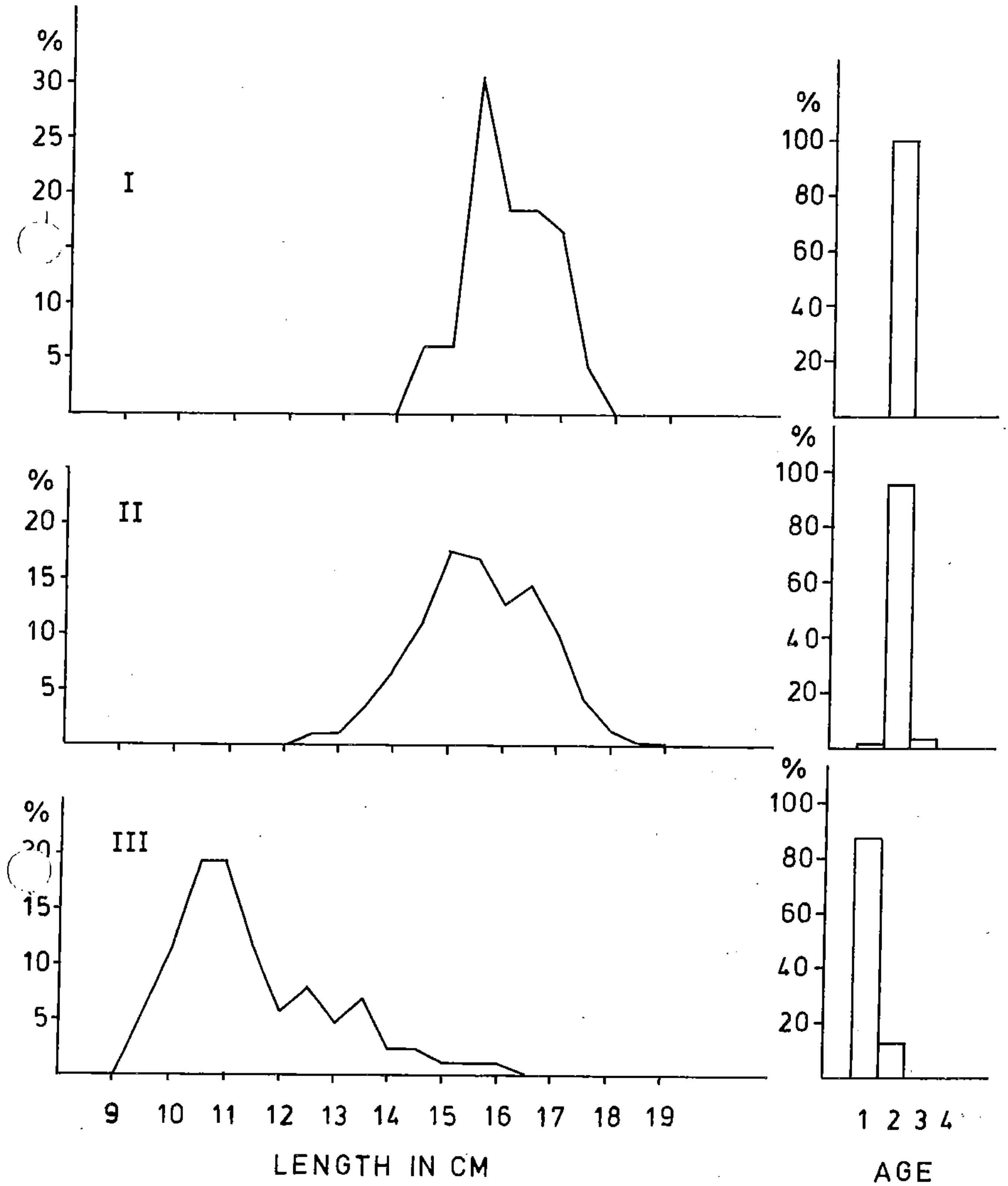
App.III Figure 2. Density distribution of capelin during the first coverage 14-18 October.



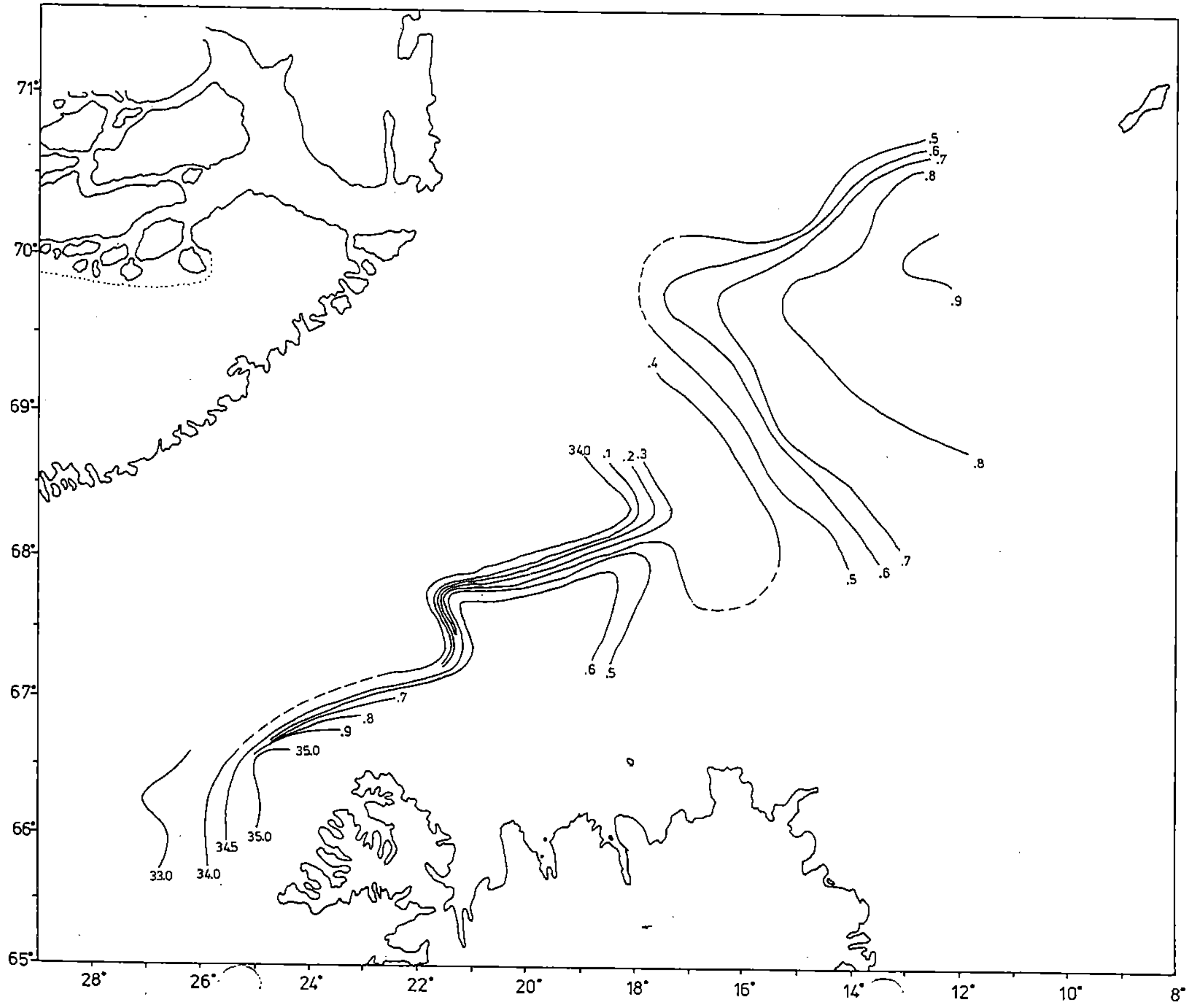
App.III, Figure 3. Density distribution of capelin during the second coverage 20-24 October.



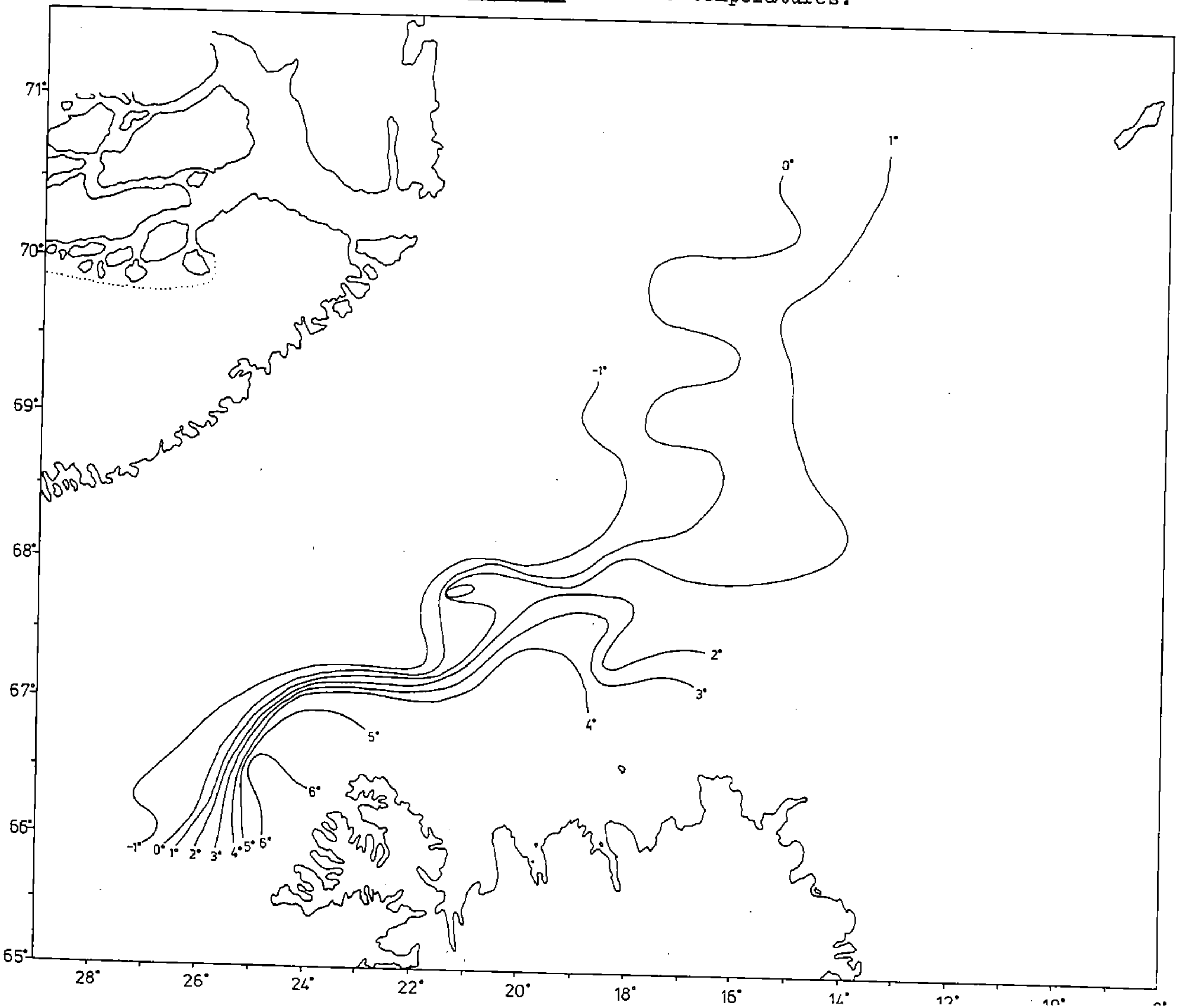
App.III, Figure 4. Length and age distribution for capelin in areas I, II and III, respectively. (Area I between 69°30' and 70°30'N, area II between 67°30' and 68°30'N, and area III between 66°00' and 66°30'N).



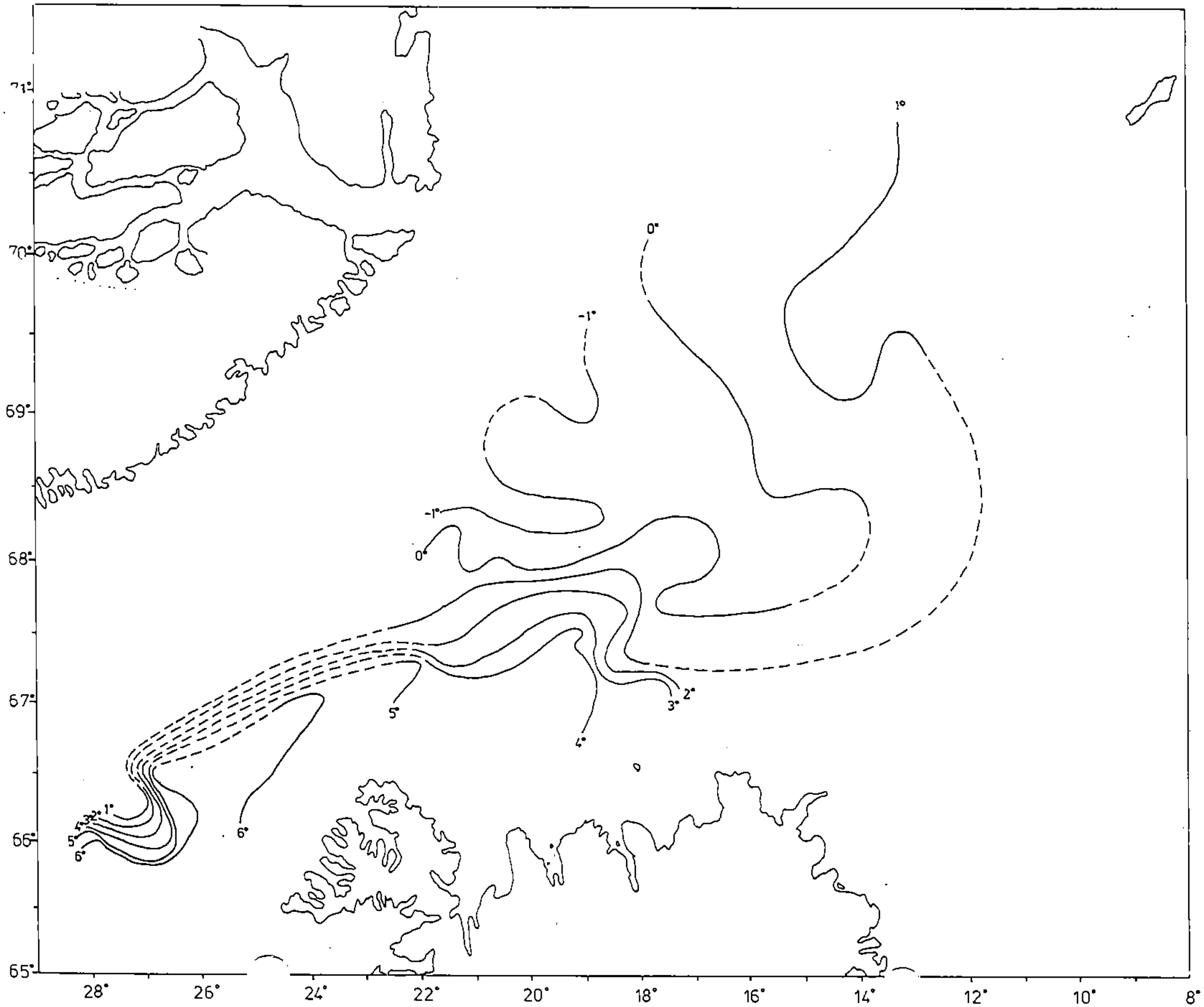
<u>App.III, Figure 5.</u> Surface salinity.



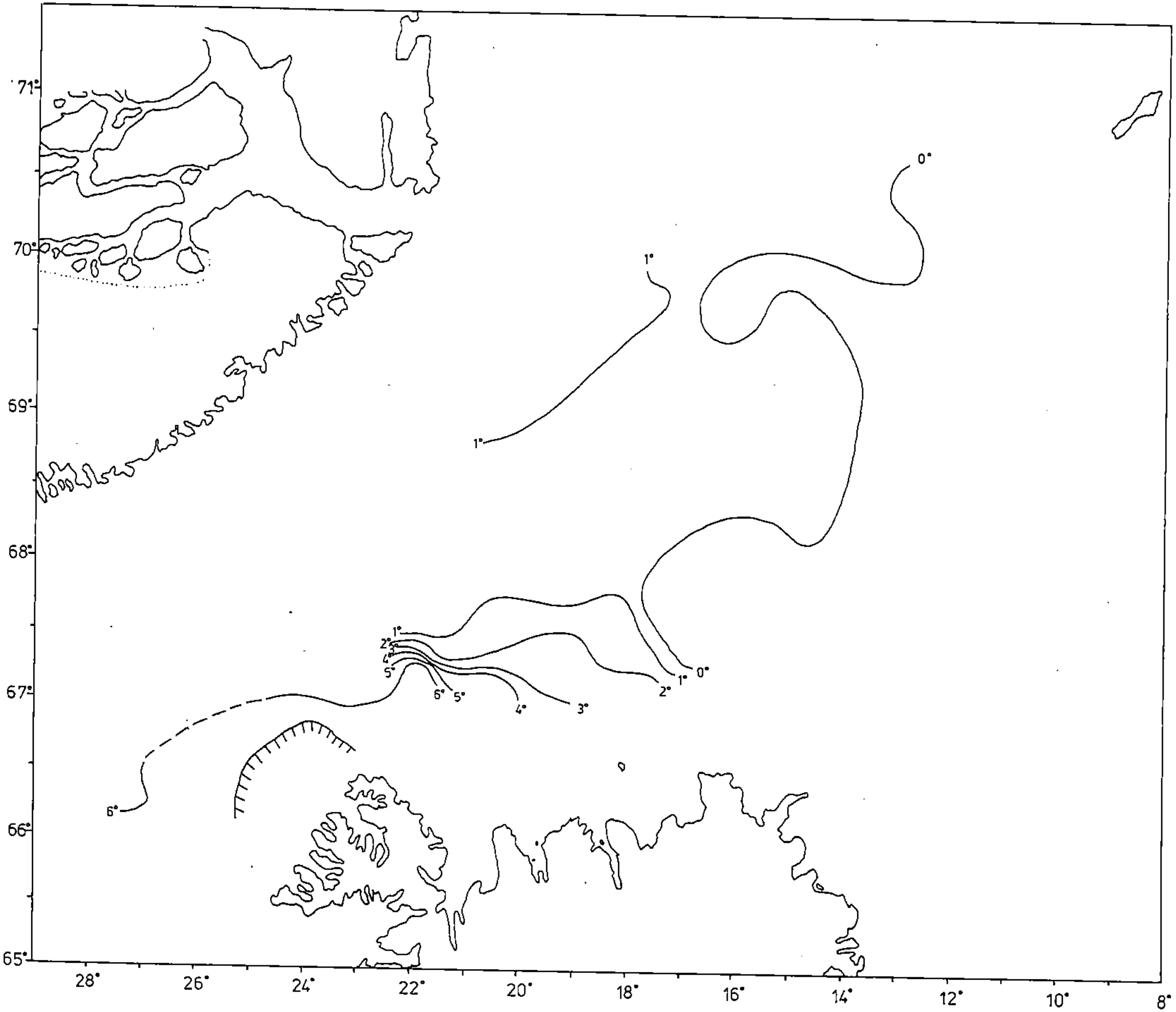
App.III, Figure 6. Surface temperatures.



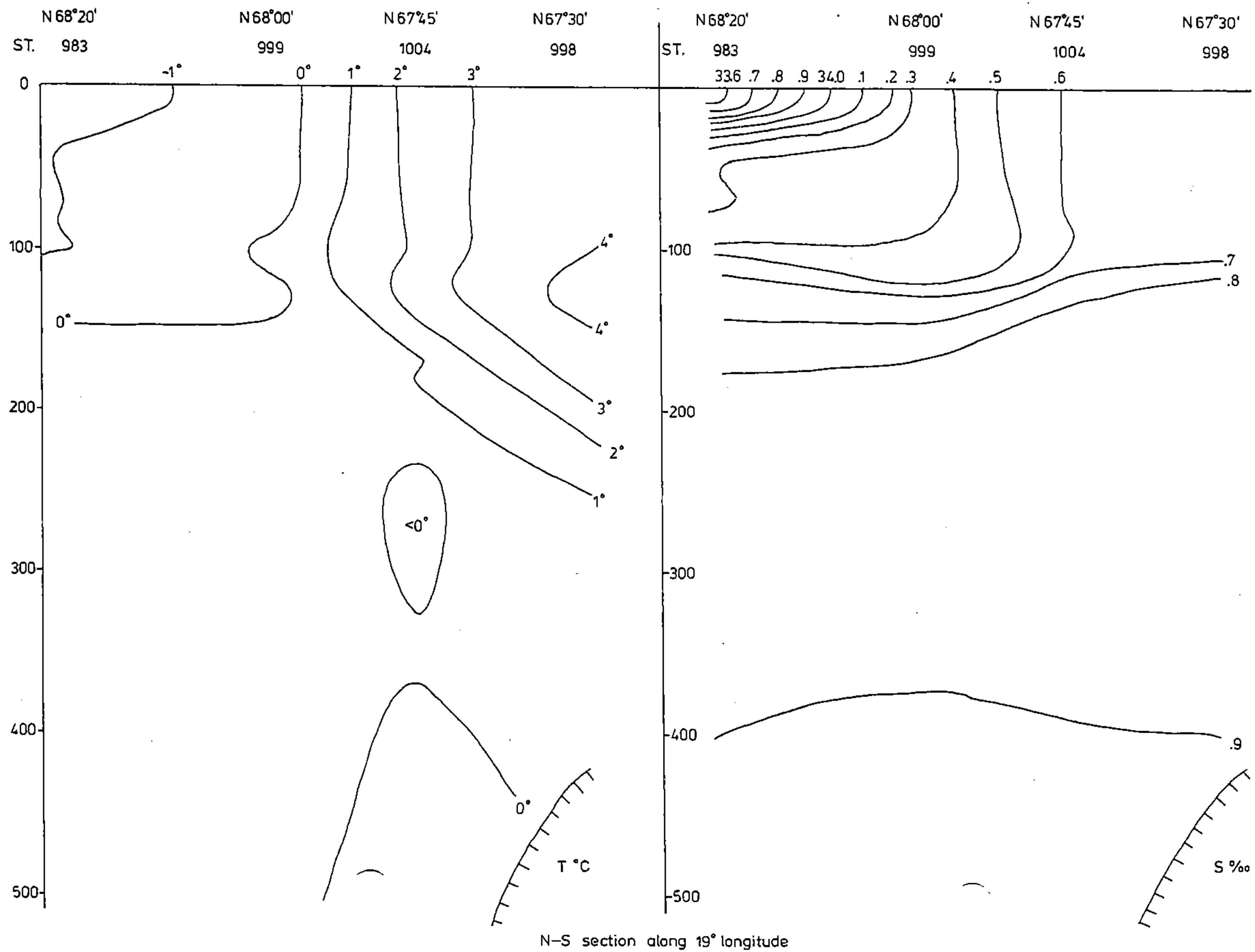
App.III, Figure 7. Temperature at 100 m.



App.III, Figure 8. Temperature at 200 m.



App.III, Figure 9. Temperature and salinity in a meridional section along 19°W between 67°30'N and 68°20'N.



REPORT ON INTERCALIBRATION BETWEEN R/V "G. O. SARS" AND R/V "BJARNI SÆMUNDSSON"

In October 1981 a joint acoustic survey was carried out on the Norwegian and Icelandic research vessels "G. O. Sars" and "Bjarni Sæmundsson", for estimating the stock of capelin between Iceland and Jan Mayen.

In the course of the survey intercalibration of the acoustic systems on board the ships was done in two different ways: measurements on the source level and voltage response with a sphere of known target strength and integration on 0-group capelin recordings.

Calibration with sphere:

On 20 October both acoustic systems were calibrated with a copper sphere with diameter = 60 mm and TS = -33.7 dB. The echo from the sphere was integrated in a 4 meters interval for 6 minutes on the 250 meters range. The resultant echo intensities gave:

$$M_{GOS}/M_{BS} = 0.027$$

Comparing the measured sums of source level and voltage response (134.9 dB and 141.8 dB ref. 0 dB for "Bjarni Sæmundsson" and "G. O. Sars" respectively) and taking into account the difference in pulse length, one gets the same result.

Here the difference in directivity of the transducers has not been considered. In Urick (1975) an equivalent two-ways beam with (Ψ) in logarithmic units is given as

$$10 \log \Psi = 10 \log \frac{\theta 1 \times \theta 2}{4} - 31.6$$

where θ is the beam angle, in degrees. By using the beam angles given by Simrad, the ratio will be

$$M_{GOS}/M_{BS} = 0.030$$

Calculation of Ψ from the measured polar diagram (0 dB to -25 dB) gives

$$M_{GOS}/M_{BS} = 0.022$$

In these considerations the threshold effect of the systems has not been taken into account. The polardiagrams were measured 7 and 10 years ago.

Intercalibration:

The intercalibration took place during the night between 21 October and 22 October 1981. The starting position was 67°08'N 20°34'W. During the first part the vessels steamed 045°.

The intercalibration was carried out in a traditional way, with "Bjarni Sæmundsson" 0.5 nautical mile ahead and 10° to starboard of "G. O. Sars". The integrator reset function on "Bjarni Sæmundsson" was manually operated, and was reset on a signal on radio from "G. O. Sars". It is assumed that the recordings during the intercalibration consist of 0-group capelin, which were recorded from 10 to 100 meters depth with various densities. Instrument settings are given in Addendum Table 1. Corresponding integrator values obtained for "G. O. Sars" and "Bjarni Sæmundsson" are shown in Addendum Figure 1.

The total sailed distance was 41 nautical miles, and the integrator values were noted every mile. In Addendum Figure 2 integrator values for both ships are plotted with "G.O.Sars" values on the abscissa and "Bjarni Sæmundsson" values on the ordinate.

Five integrator values were not used because the recordings seemed to be different when the echo sounder papers from the two vessels were compared. By use of the method of least square, the following equation was established:

$$M_{GOS} = M_{BS} \times 0.026 + 4.9$$

with correlation coefficient = 0.98.

This equation has been used to convert the integrator values of "Bjarni Sæmundsson" to "G. O. Sars" values.

Reference

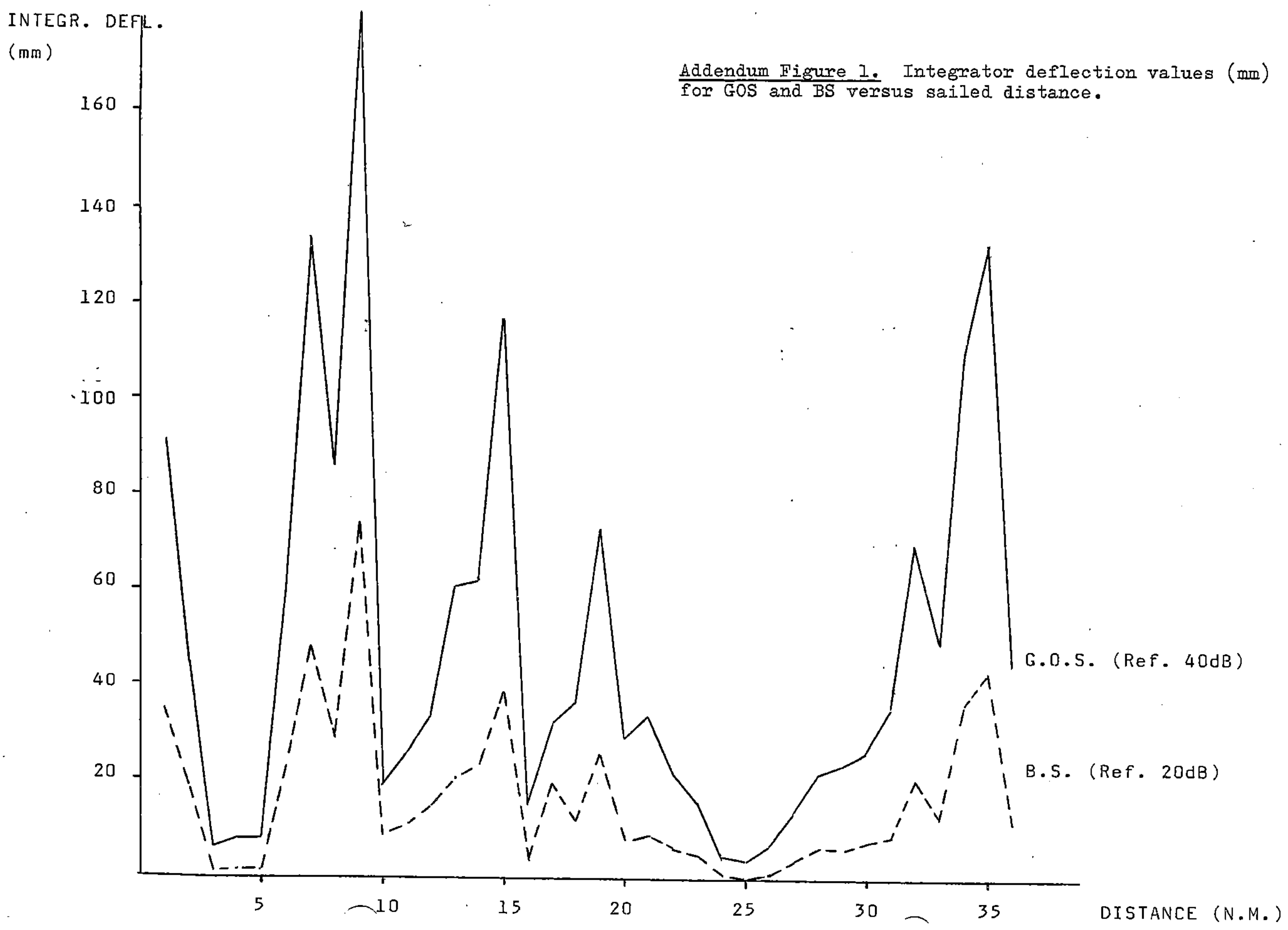
Urick, R J. 1975. Principles of underwater sound. (Mc Graw-Hill, NY, 1975), pp.217.

"G. O. Sars" 24.10.1981

I Svellingen P Reynisson

Addendum Table 1. Instrument settings during intercalibration.

	"G.O.S."	"Bj.Sæm."
Echo sounder	EK-R	EK 400
Freq.	38 kHz	38 kHz
Transducer	69C(5^ox5^o stab.)	69C($4,5^o$x5^o)
Transmitter	Ext.	2,5 kw
TVG/GAIN	20 logR-20dB	20 logR-0dB
Bandw./Pulsl.	3 kHz-0.55ms	3,3kHz-1ms
Recordergain	8	7
Range	0-250 m	0-250 m
Integrator:	N-10	QM MKII
Gain(ref. output)	40 dB	10 dBx10
Threshold	9mv	1
Intervall	8-100m	10-100m



<u>Addendum Figure 1.</u> Integrator deflection values (mm) for GOS and BS versus sailed distance.

Addendum Figure 2. Linear regression of the integrator values.