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SURVEY REPORT FROM THE JOINT NORWEGIAN/RUSSIAN ACOUSTIC SURVEY OF PELAGIC FISH IN THE BARENTS SEA, SEPTEMBER - OCTOBER 2000

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Polar Research Institute of Marine Fisheries and Oceanography - PINRO

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SURVEY REPORT

FROM THE JOINT NORWEGIAN/RUSSIAN ACOUSTIC SURVEY OF PELAGIC FISH IN THE BARENTS SEA SEPTEMBER - OCTOBER 2000

Synopsis

The survey was carried out in the period 4th of September to 3rd of October 2000 and was terminated by a meeting in Vadsø 4-6th October. Four research vessels participated in the survey:

Vessel	Institute	Cruise leader	Date
"Johan Hjort"	IMR, Bergen	H. Gjøsæter	8/9 – 3/10
"G.O.Sars"	IMR, Bergen	J. Røttingen	8/9 – 3/10
"AtlantNIRO"	PINRO, Murmansk	D. Prozorkevitch	4/9 – 3/10
“F. Nansen”	PINRO, Murmansk	I. Dolgolenko	5/9 – 3/10

The main aim of the survey was to estimate the sizes of two pelagic fish stocks in the Barents Sea, the capelin and the polar cod, in addition to studying their biology and geographical distribution. An estimate was also made of a third pelagic species in the area, the young herring. The survey on pelagic species formed a part of a multipurpose survey, with aim to study fish, environmental features, and plankton.

This report mainly concerns the results on the pelagic fish species, but includes a general description of the hydrographical situation in the area. A list of the scientific members on all vessels is given in Appendix I.

The coverage of the stock of capelin and polar cod was considered satisfactory. The young stages of Norwegian spring spawning herring were observed in the south-eastern part of the area. A total coverage of the herring, especially the 0-group, was not attempted during this survey.

The capelin stock was estimated at 4.3 million tonnes, 1.6 times higher than the estimate obtained last year. About 2.1 million tonnes were assumed to be maturing.

The polar cod stock was estimated at 1.3 million tonnes, about 1.2 times higher than that measured last year and the highest estimate on record.

The young stages of the **Norwegian Spring Spawning Herring** were partly covered during the survey. About 380 000 tonnes of one-year-olds and 560 000 tonnes of two-year-olds were found in the south-eastern parts of the Barents Sea. No attempt was made to assess the number or biomass of 0-group herring.

Methods

The cruise leaders prior to the survey adopted a general plan for the survey. A team consisting of A. Krysov (PINRO) and H. Gjøsæter (IMR) on board "Johan Hjort" conducted a joint leadership over the whole survey. This implied a day-to-day planning of survey grid, assessment of acoustic data from all vessels, calculations of stock sizes for the target species, and preparing of the joint report. "AtlantNIRO" was adopted as “hydrographic vessel”, with the responsibility to gather and process all hydrographic data. Data on cruise tracks, hydrography, integrator values etc. were exchanged by use of satellite or radio telex, and these data were used during the day-to-day planning of the survey.

This way of organising the survey enabled the survey leaders to control the day to day coverage of the area and to improve the total coverage by a daily revision of the sailing routes, thus optimising the total outcome of the effort put into the survey.

The survey area was chosen based on general knowledge of the distribution of the target species, and on information about fish distribution from the International 0-group survey preceding the present survey.

"G.O. Sars" and "Johan Hjort" was granted permission to work in a small area in the northern part of Russian EEZ. The two Russian vessels, therefore, had to cover the rest of the Russian EEZ. A relatively good coverage of the total capelin distribution area was obtained.

Survey routes and stations are shown in Fig. 1, 2 and 3. The main distribution area of capelin was surveyed with course lines 15 and 20 nautical miles apart, while most other areas were surveyed with course lines 30 or more nautical miles apart. "AtlantNIRO" and "F. Nansen" surveyed the eastern parts of the Barents Sea whereas "Johan Hjort" and "G.O. Sars" surveyed the northwestern, central, and western parts. Altogether, more than 14500 nautical miles of survey tracks were made.

The two Norwegian vessels worked with EK-500 echo sounders and BEI post processing systems, "AtlantNIRO" and "F. Nansen" used EK-500, but only “AtlantNIRO” had a BI-500 post processing system. Echo intensities were integrated continuously, and mean values per nautical mile were recorded for each fifth nautical mile. The echograms, with their corresponding s_A-values, were scrutinised every day. Contributions from the seabed, false echoes, and noise were deleted, and corrections were made in case of the presence of a bubble layer. The two Norwegian vessels are equipped with transducers on adjustable keels that can be lowered in rough weather to avoid the damping effect of bubbles.

The corrected values for integrated echo intensity were allocated to species according to the trace pattern of the echograms and the composition of the trawl catches. Only data from pelagic trawl hauls and bottom trawl hauls set on capelin registrations extending to the bottom were included in the stock abundance calculations for capelin, as only these were considered representative for the pelagic component of the stock, which is measured acoustically. For polar cod, samples from both pelagic and bottom trawl hauls were included in the calculations.

The echo sounders were watched continuously, and trawling was carried out whenever the recordings changed their characteristics and/or the need for biological data made it necessary. Trawling was thus carried out both for identification purposes and to obtain biological observations, i.e., length, weight, maturity stage, stomach data, and age. In total, 331 trawl hauls were made during the survey.

The vessels gave the s_A-values in absolute terms based on sphere calibrations, that is, as scattering cross section in m^2 per square nautical mile. The acoustic equipment of the vessels was calibrated by a standard copper sphere (See Appendix II).

Computations of stock sizes

The computations of number of individuals and biomass per length-and age group were made by the same computer programme as in previous years. Nakken and Dommasnes (1975) describe the method. The modified WMO strata system, dividing the Barents Sea in squares of 1^o (latitude) x 2^o (longitude), was used as basis for the calculation.

The mean s_A-values in the squares were calculated using the GIS-system “MapInfo”. The output files from the BEI-systems and from the BI500 systems were imported into the computer program, the position of the midpoint of each five nautical mile was shown, and the mean value of all five-miles having the midpoint inside each square was automatically calculated. This method gives a more accurate allocation of five-miles to squares than the manual methods.

Stock size estimates were also made using a new stock size estimation program “BEAM” built on SAS GIS and developed at IMR. These estimates were comparable to the ones made using the traditional method.

Results and discussion

Area coverage

The total vessel time this year allocated to the survey was almost equal to that last year. Some working days were lost when "G.O. Sars" returned to port after 3-4 days to exchange a member of crew and when "AtlantNIRO" returned to the coast after 5 days for refuelling. However, under the favourable weather conditions, experienced during most of the survey, with few days of wind force above 15 m/sec, a total coverage of the capelin and polar cod distribution area was achieved. The present survey, with its east-west transects either 15 or 20 nautical miles apart from 72° (in western areas) and 69° (in the eastern) to 78° is probably the most complete coverage obtained at the capelin survey. The new survey design used this year, running east-west courses starting in the south, proved successful.

Capelin

Distribution

The geographical density distribution of the total stock and each age group are shown in Figs. 4 to 8. The distribution area was larger this year compared to last year. The distribution did not extend as far north as last year, but in few years have the northern limit of the distribution, which this year was located at about 78°N, been found further to the north. The southernmost limit of the capelin distribution area was found further south than in recent years reaching almost the coast of Russia east of 40°E. The extension in the east west direction was notably larger than last year and extended from the Bear Island in the west to Novaya Zemlya in the east. The main concentration stretched out from about 73°N, 45°E northwestwards to 77°30’N, 25° - 40°E (Figure 8). To the east of about 40° E, the capelin was found together with the polar cod, sometimes in mixed concentrations, sometimes separated into distinct layers. Figure 9 shows an example where capelin and polar cod was observed in separate layers in position 74º50’N–45º00’E. Capelin was found in an upper layer, while polar cod was found near the bottom. Typical to the northern area was capelin distributions extending from near-bottom depths to 100-150 m above the bottom. In Figure 10 is shown an example of such registrations from 77º10'N – 35º40'E.

Abundance estimate and size by age

The mean s_A-value in each basic square was converted to fish area density ρ_A using the relation

$$\rho_A = \frac{s_A}{\sigma}$$

and number of fish was found by multiplying with the area of the square. Numbers were converted to biomass by multiplying with observed mean fish weight in each length group.

The target strength relation for capelin is given by:

$$TS = 10 \cdot \log(\frac{\sigma}{4\pi}) = 19.1 \cdot \log L - 74.0$$

corresponding to a σ-value of $5.00 \cdot 10^{-7} \cdot L^{1.91}$

The results of the estimation are given in the text table below. The 1999 estimate is shown on shaded background for comparison.

Year class		Age	Number (10^9)		Mean weight (g)		Biomass (10^3 t)	
1999	1998	1	449.2	155.9	3.8	4.2	1699.7	651.6
1998	1997	2	110.6	101.5	14.4	13.6	1591.8	1383.5
1997	1996	3	34.1	26.5	27.9	26.9	951.0	714.3
1996	1995	4	0.8	0.9	37.7	29.3	29.5	25.4
Total stock in								
2000	1999	1-4	594.7	284.8	7.2	9.7	4273.1	2774.8
Based on TS value: 19.1 log L - 74.0, corresponding to = $5.0 \cdot 10^{-7} \cdot L^{1.91}$								

Details of the 2000 estimate are shown in Table 1 and the estimates by age group of the capelin stock 2 years old and older from 1973-2000 are shown in Table 2.

The total stock is estimated at about 4.3 million tonnes, 1.5 times larger than the stock estimated last year. About 49% (2098 thousand tonnes) of this stock is maturing. The 1999 year class (1-group) consists, according to this estimate, of about 450 billion individuals. This estimate is almost three times higher than that obtained for the 1-group last year, and is the largest one-group estimate since 1990. It is, however, only 64% the size of the latest strong year class of capelin - the 1989 year class. The mean weight is estimated at 3.8 g, which is somewhat smaller than that measured last year. The biomass of the 1999 year class is about 1.7 million tonnes. It should be kept in mind that, given the limitations of the acoustic method concerning mixed concentrations of small capelin and 0-group fish and near-surface distribution, the 1-group estimate may be more uncertain than that for older capelin.

The estimated number of fish in the 1998 year class (2-group) is about 110 billions, at the same level as in the 1997 year class measured last year. The mean weight at this age is 14.4 g (13.6 g in 1999), and consequently the biomass of the two years old fish is about 1.6

million tonnes. The mean weight is larger than in all previous years except for 1990 and 1996, when mean weights of 15.3 g and 18.6 g respectively were recorded (Table 2).

The 1997 year class is estimated at about 34 billion individuals with mean weight 27.9 g, giving a biomass of about 950 thousand tonnes. The mean weight is the highest on record. The 1996 year class (now 4 years old) is estimated at 0.8 billion individuals. With a mean weight of 37.3 g this age group makes up only about 30 thousand tonnes. Practically no capelin older than four years was found.

Mortality, length-, weight- and age-distributions

The text table below shows the number of fish in the various year classes, and their mortality from age one to two.

Year	Year class	Age 1 (10^9)	Age 2 (10^9)	Total mort. %	Total mort. Z
1984-1985	1983	154.8	48.3	69	1.16
1985-1986	1984	38.7	4.7	88	2.11
1986-1987	1985	6.0	1.7	72	1.26
1987-1988	1986	37.6	28.7	24	0.27
1988-1989	1987	21.0	17.7	16	0.17
1989-1990	1988	189.2	177.6	6	0.06
1990-1991	1989	700.4	580.2	17	0.19
1991-1992	1990	402.1	196.3	51	0.72
1992-1993	1991	351.3	53.4	85	1.88
1993-1994	1992	2.2	3.4	-	-
1994-1995	1993	19.8	8.1	59	0.89
1995-1996	1994	7.1	11.5	-	-
1996-1997	1995	81.9	39.1	52	0.74
1997-1998	1996	98.9	72.6	27	0.31
1998-1999	1997	179.0	101.5	43	0.57
1999-2000	1998	155.9	110.6	29	0.34

As there has been no fishing on these age groups, the figures for total mortality constitute natural mortality only, and probably reflect quite well the predation on capelin. As can be seen from the table, the mortality was high prior to 1988, but then a substantial decrease occurred in 1988-89, probably caused by a diminished predation pressure from cod. From 1990, the mortality again increased, up to 85% in 1992-93. This increase is in accordance with the observation of an increasing stock of cod, which were predating on a decreasing stock of capelin. The mortalities calculated for the period 1996-2000 (52%, 27%, 43% and 29%) indicate a somewhat lower level of mortality. The results of the calculation for the year classes 1988, 1992, and 1994 show, however, that either the one-group are underestimated or the two-group is overestimated these years. Knowing that the measurement of the 1-group is more uncertain than the older age groups due to limitations in the acoustic method, the first mentioned possibility is the most probable.

Length and age distributions for the various age groups are shown in Fig. 11 (for the subareas used in the stock size estimation) and Fig. 12 (for the total area).

Polar cod

As in previous years, the coverage of the polar cod distribution is considered incomplete. In some areas, particularly in the northern, a definite boundary of the polar cod distribution area could not be found within the time allocated to the survey. This situation is common during the autumn, when the polar cod stock is widely distributed in the northern part of the Barents Sea.

Distribution

The densest registrations of polar cod were made in the area between 73ºN and 77ºN, east of 40ºE. Dense occurrences were also extending to coastal waters of Novaya Zemlya south of 72ºN.

Abundance estimation

The stock abundance estimate by age, number, and weight was calculated using the same computer model as for capelin. Echo densities were converted to absolute numbers using the following TS-relation:

$$TS = 10 \cdot \log(\frac{\sigma}{4\pi}) = 21.8 \cdot \log L - 72.7$$

corresponding to a σ-value of $6.7 \cdot 10^{-7} \cdot L^{2.18}$

A detailed estimate based on this TS relation is given in Table 3, and the main results are summarised in the text table below. The 1999 estimate is shown on a shaded background for comparison.

The total geographical density distribution of polar cod by age is shown in Figs. 13-17. Age- and length distribution for the polar cod stock in the subareas used for stock size estimation and for the total area are given in Figs. 18 and 19, respectively.

Year class		Age	Number (10^9)		Mean weight (g)		Biomass (10^3 t)	
1999	1998	1	33.8	59.4	8.0	6.7	269.4	399.6
1998	1997	2	20.0	22.8	21.6	18.7	432.4	426.0
1997	1996	3	14.6	8.8	40.9	32.6	597.6	286.8
1996	1995	4	0.8	0.4	57.6	59.6	48.4	25.9
Total stock in								
2000	1999	1-6	69.2	91.4	19.5	12.5	1347.8	1141.9
Based on TS value: 21.8 log L - 72.7, corresponding to σ = $6.7 \cdot 10^{-7} \cdot L^{2.18}$								

The 1999 year class (the one-year-olds) is less than 60% as numerous as the one-group measured last year, but their mean weight is 1.3 gram higher. The biomass is, therefore, almost 70% of that of the one-year-olds measured last year. The size of the 1998 year class (the two-year-olds) is comparable to that of the two-group found last year but with higher mean weight. The biomass is, therefore, somewhat above that of the 1997 year class estimated last year. The three-years-old fish (1997 year class) is about 1.7 times more numerous than the three-group estimated last year and has a much higher mean weight. Consequently, this age group constitutes almost 600 000 tonnes as compared to less than 300 000 tonnes for the corresponding age group during the 1999 survey. The four-year-olds (1996 year class) are scarcely found but have very high (but somewhat lower than last year) mean weights. The total stock, estimated at 1.3 million tonnes, is almost 1.2 times larger than that estimated last year, and is the highest on record.

The text tables below show the mortality rates of polar cod of the year classes 1984 to 1998.

Year	Year class	Age 1 (10^9)	Age 2 (10^9)	Total mort. %	Total mort Z
1986-1987	1985	24.0	10.1	58	0.86
1987-1988	1986	15.0	1.5	90	2.30
1988-1989	1987	4.3	1.8	58	0.87
1989-1990	1988	13.5	2.2	84	1.81
1990-1991	1989	3.8	4.2	-	-
1991-1992	1990	23.7	14.0	41	0.53
1992-1993	1991	22.9	18.9	17	0.19
1993-1994	1992	16.3	9.3	43	0.56
1994-1995	1993	27.5	6.5	76	1.44
1995-1996	1994	30.7	10.1	67	1.11
1996-1997	1995	19.4	7.8	59	0.91
1997-1998	1996	15.8	7.6	52	0.73
1998-1999	1997	89.9	22.8	75	1.37
1999-2000	1998	59.4	20.0	66	1.09

Year	Year class	Age 2 (10^9)	Age 3 (10^9)	Total mort. %	Total mort Z
1986-1987	1984	6.3	3.1	51	0.71
1987-1988	1985	10.1	0.7	93	2.67
1988-1989	1986	1.5	0.2	87	2.01
1989-1990	1987	1.8	0.7	61	2.57
1990-1991	1988	2.2	1.9	14	0.15
1991-1992	1989	4.2	0.8	81	1.66
1992-1993	1990	14.0	3.0	78	1.54
1993-1994	1991	18.9	5.0	74	1.33
1994-1995	1992	9.3	1.6	83	1.76
1995-1996	1993	6.5	3.3	51	0.68
1996-1997	1994	10.1	3.1	69	1.18
1997-1998	1995	7.8	4.0	49	0.67
1998-1999	1996	7.6	8.8	-	-
1999-2000	1997	22.8	14.6	36	0.44

The mortality estimates are unstable during the whole period. Although unstable mortalities may indicate errors in the stock size estimation from year to year, the impression remains that there is a considerable total mortality on young polar cod. Prior to 1993, these mortality estimates represent natural mortality only, as practically no fishing took place. In the period 1993 to 1997 the Russian fleet landed between 5 and 50 000 tonnes of polar cod, in 1998 the catch was negligible. In 1999 the catch was about 20 000 tonnes. Since there has been a minimum landing size of 15 cm (from 1998, 13 cm) in that fishery, a considerable amount of this could consist of two- and even one-year-olds, and this may explain some, but only a small part of the high total mortality.

Herring

Coverage and geographical distribution

The area of distribution of young herring was only partly covered. The main registration of the one- and-two-year-old fish was observed in the southern part of the Barents Sea (Figs. 20-22). The southern border of its spreading was not determined due to deficit of time. Northwards herring were mainly distributed up to 74° 00'N. A few single schools of herring were observed more northerly, in water with temperature near to 0^{o}C, which is unusual for the herring autumn distribution. The distribution of a 0-group of herring was wider then that observed during the 0-group survey (see the report from the International 0-group survey in the Barents Sea and adjacent areas carried out just prior to the present survey).

Abundance estimate

Traditionally an acoustic survey of the young herring is conducted in May, when herring behaviour is more near ideal. September is not a good time for young herring survey because in that season herring are migrating to the wintering area and are distributed in the surface layer of sea. For these reasons, the stock size estimates obtained during the autumn may be far from reality, but may indicate the relative strength of the year classes. Therefore, it was decided to present a stock size estimate for 1- and 2-group herring.

The stock abundance estimate by age, number, and weight was calculated using the same computer model as for capelin. Echo densities were converted to absolute numbers using the following TS-relation:

$$TS = 10 \cdot \log\left(\frac{\sigma}{4\pi}\right) = 20.0 \cdot \log L - 71.9$$

corresponding to a σ-value of $8.1 \cdot 10^{-7} \cdot L^{2.00}$

The total amount of the estimated part of the young herring was 26,2 billion specimens (Table 5). One-year-old fish constituted 14,7 billion specimens and two-year-old fish 11,5 billion specimens. Herring older then two-years were not found in the covered area. In this year, the mean length and mean weight of each age group of herring was about 1,9 and 2,0 cm and 11,3 and 17,3 g larger then for the same age groups last autumn. Probable, increasing mean length and weight indicate good feeding conditions in the Barents Sea in year 2000. The total biomass of young herring amounted to 943 000 tonnes, of which the 1998 year class constituted 560 00 tonnes.

Hydrographical conditions

Temperature charts in 0, 50, 100, 200, bottom depths shown in Figs. 23-27.

In September the cooling of surface waters has begun. From August to September the surface water temperature decreased 1.0-1.5^{o}C on average. This process was developed faster in the northern part of the Barents Sea than in the south and central parts due to earlier and more intensive decrease of air temperature at this period.

The thickness of the upper mixed layer was about 20-30 m in the east and north of the surveyed area and about 30-40 m in the streams of warm currents.

The maximum horizontal temperature gradients (0.2^{o} C per nautical mile) were observed in the Polar front at the 50 m depth in the western part of the sea. This area was more sharpened compared with more eroded frontal zone in the south-eastern area. The position of near the north and central branches of the North Cape current, the Murmansk current and the branches of the Novaja Zemlja current displaced to the east and north in comparison with their usual location.

Near the Bear Island the frontal zone spread to the south. Those facts point at more intensive advection of warm waters into the Barents Sea.
The surface water temperature was on average 0.35^{o}C higher than long-term mean in the western part of the region, 1.35^{o}C in the central and 1.75^{o}C in the eastern one. Compared to the 1999 the temperature of surface water differed at an average on -1.55^{o}C for the north-western, +1.05^{o} C for the north-eastern and central areas and +3.05^{o}C for the south-eastern part of the sea.

The maximum positive anomalies (2.0-2.55^{o} C) were observed in the south-eastern part. The bottom temperature was close to the norm except the southeast of the area where the anomaly was at the average +0.45^{o}C. The bottom temperature was higher than last year on average 0.5-1.05^{o} C both in the west and in the east of the Barents Sea.

Table 1. Acoustic estimate of Barents Sea capelin, September - October 2000.

Length (cm)	Age/Year class 1 1999	2 1998	3 1997	4 1996	5 1995	Sum (10^6)	Biomass (10^3 t)	Mean weigth (g)
6.5 - 7.0	2198					2198	2.2	1.0
7.0 - 7.5	9506					9506	11.7	1.2
7.5 - 8.0	16249					16249	24.2	1.5
8.0 - 8.5	31942					31942	59.0	1.8
8.5 - 9.0	56835					56835	128.9	2.3
9.0 - 9.5	60610					60610	168.6	2.8
9.5 - 10.0	58577					58577	192.1	3.3
10.0 - 10.5	66512	73				66585	273.3	4.1
10.5 - 11.0	57780	555				58335	274.7	4.7
11.0 - 11.5	40027	1024				41051	225.9	5.5
11.5 - 12.0	26161	4315				30476	193.5	6.3
12.0 - 12.5	14416	5943				20359	150.3	7.4
12.5 - 13.0	4880	11347				16227	142.6	8.8
13.0 - 13.5	2250	12448				14698	152.2	10.4
13.5 - 14.0	808	13714	198			14720	176.0	12.0
14.0 - 14.5	238	14856	119			15213	208.3	13.7
14.5 - 15.0	177	13677	460			14314	225.3	15.7
15.0 - 15.5		11224	1302	89		12615	228.7	18.1
15.5 - 16.0		8956	3147		56	12159	244.3	20.1
16.0 - 16.5		5482	4241			9723	219.2	22.5
16.5 - 17.0		3756	5850	79		9685	246.9	25.5
17.0 - 17.5		2140	5617			7757	212.1	27.3
17.5 - 18.0		825	5415			6240	198.3	31.8
18.0 - 18.5		217	4397	107		4721	161.9	34.3
18.5 - 19.0			2561			2561	101.2	39.5
19.0 - 19.5			739	333		1072	41.2	38.5
19.5 - 20.0			55	52		107	4.7	44.1
20.0 - 20.5				122		122	5.8	47.7
TSN (10^6)	449166	110552	34101	782	56	594657		
TSB (10^3 t)	1699.7	1591.8	951.0	29.5	1.2		4273.1	
Mean length (cm)	9.90	14.23	17.13	18.59	15.75	11.13		
Mean weight (g)	3.8	14.4	27.9	37.7	21.0			7.2
SSN (10^6)	415	61133	33903	782	56	96289		
SSB (10^3 t)	6	1113	949	28	1		2097	

Based on TS value: 19.1 log L - 74.0, corresponding to $\sigma = 5.0 \cdot 10^{-7} \cdot L^{1.91}$

Table 2. Acoustic estimates of the Barents Sea capelin stock by age in autumn 1973-2000

Biomass (B) in 10^6 tonnes, average weight (AW) in grams. All estimates based on TS = 19.1 Log L -74.0 dB.

Year	Age										
	1		2		3		4		5		Sum 2+
	B	AW	B	AW	B	AW	B	AW	B	AW	B
1973	1.69	3.2	2.32	6.2	0.73	18.3	0.41	23.8	0.01	30.1	3.47
1974	1.06	3.5	3.06	5.6	1.53	8.9	0.07	20.8	+	25.0	4.66
1975	0.65	3.4	2.39	6.9	3.27	11.1	1.48	17.1	0.01	31.0	7.15
1976	0.78	3.7	1.92	8.3	2.09	12.8	1.35	17.6	0.27	21.7	5.63
1977	0.72	2.0	1.41	8.1	1.66	16.8	0.84	20.9	0.17	22.9	4.08
1978	0.24	2.8	2.62	6.7	1.20	15.8	0.17	19.7	0.02	25.0	4.01
1979	0.05	4.5	2.47	7.4	1.53	13.5	0.10	21.0	+	27.0	4.10
1980	1.21	4.5	1.85	9.4	2.83	18.2	0.82	24.8	0.01	19.7	5.51
1981	0.92	2.3	1.83	9.3	0.82	17.0	0.32	23.3	0.01	28.7	2.98
1982[1]	1.22	2.3	1.33	9.0	1.18	20.9	0.05	24.9			2.56
1983	1.61	3.1	1.90	9.5	0.72	18.9	0.01	19.4			2.63
1984	0.57	3.7	1.43	7.7	0.88	18.2	0.08	26.8			2.39
1985	0.17	4.5	0.40	8.4	0.27	13.0	0.01	15.7			0.68
1986	0.02	3.9	0.05	10.1	0.05	13.5	+	16.4			0.10
1987[2]	0.08	2.1	0.02	12.2	+	14.6	+	34.0			0.02
1988	0.07	3.4	0.35	12.2	+	17.1					0.35
1989	0.61	3.2	0.20	11.5	0.05	18.1	+	21.0			0.25
1990	2.66	3.8	2.72	15.3	0.44	27.2	+	20.0			3.16
1991	1.52	3.8	5.10	8.8	0.64	19.4	0.04	30.2			5.78
1992	1.25	3.6	1.69	8.6	2.17	16.9	0.04	29.5			3.90
1993	0.01	3.4	0.48	9.0	0.26	15.1	0.05	18.8			0.79
1994	0.09	4.4	0.04	11.2	0.07	16.5	+	18.4			0.11
1995	0.05	6.7	0.11	13.8	0.03	16.8	0.01	22.6			0.15
1996	0.24	2.9	0.22	18.6	0.05	23.9	+	25.5			0.27
1997	0.42	4.2	0.45	11.5	0.04	22.9	+	26.2			0.49
1998	0.81	4.5	0.98	13.4	0.25	24.2	0.02	27.1	+	29.4	1.25
1999	0.16	4.2	1.01	13.6	0.27	26.9	0.09	29.3			2.12
2000	1.70	3.8	1.59	14.4	0.95	27.9	0.08	37.7			2.57

[1] Computed values based on the estimates in 1981 and 1983

[2] Combined estimates from multispecies survey and succeeding survey with "Eldjarn"

Table 3. Acoustic estimate of polar cod in September-October 2000

Length (cm)	Age/Year class 1 1999	2 1998	3 1997	4 1996	5 1995	6 1994	Sum (10^6)	Biomass (10^6)	Mean weight (g)
7.5 - 8.0	2516						2516	9.7	3.8
8.0 - 8.5	1574						1574	5.0	3.2
8.5 - 9.0	1081	96					1177	5.1	4.3
9.0 - 9.5	3213	127					3340	16.9	5.1
9.5 - 10.0	3635	67					3702	22.3	6.0
10.0 - 10.5	4489	30					4519	31.4	7.0
10.5 - 11.0	4835	152					4987	42.3	8.5
11.0 - 11.5	4712	228					4940	47.8	9.7
11.5 - 12.0	4079	410					4489	49.7	11.1
12.0 - 12.5	2120	647					2767	34.7	12.5
12.5 - 13.0	1190	1237	29				2456	34.2	13.9
13.0 - 13.5	297	1471	159				1927	29.7	15.4
13.5 - 14.0	16	1469	66				1551	25.5	16.4
14.0 - 14.5	37	1878	156				2071	39.4	19.0
14.5 - 15.0		3572	231				3803	79.2	20.8
15.0 - 15.5	15	2363	304				2682	64.5	24.0
15.5 - 16.0	16	2488	379	32			2915	74.6	25.6
16.0 - 16.5		1440	733				2173	60.0	27.6
16.5 - 17.0		1115	1245	37			2397	71.5	29.8
17.0 - 17.5		635	964	74			1673	56.6	33.8
17.5 - 18.0		180	2065	88			2333	86.2	37.0
18.0 - 18.5		271	1698	56			2025	82.1	40.5
18.5 - 19.0		123	2089				2212	98.8	44.7
19.0 - 19.5			1702	23			1725	86.1	49.9
19.5 - 20.0			1218	158			1376	70.4	51.2
20.0 - 20.5			790	18			808	46.9	58.0
20.5 - 21.0			291	72			363	20.9	57.6
21.0 - 21.5			174	29			203	11.4	56.2
21.5 - 22.0			210	2			212	16.2	76.4
22.0 - 22.5				124			124	9.4	76.1
22.5 - 23.0			73	29			102	7.8	76.4
23.0 - 23.5			8	24			32	2.8	86.7
23.5 - 24.0			10	34			44	4.1	92.3
24.0 - 24.5				36			36	3.7	104.0
24.5 - 25.0				1			1	0.1	110.0
25.0 - 25.5			4				4	0.5	134.0
25.5 - 26.0				2			2	0.2	120.0
26.0 - 26.5				1			1	0.1	127.5
TSN (10^6)	33825	19999	14598	840			69262		
Mean length (cm)	10.42	14.68	18.16	20.03			13.40		
TSB (10^3 tonnes)	269.4	432.4	597.6	48.4				1347.8	
Mean weight (g)	8.0	21.6	40.9	57.6					19.5
Condition factor	6.7	6.6	6.6	6.9			6.7		

Based on TS value: 21.8 log L - 72.7, corresponding to $\sigma = 6.7 \cdot 10^{-7} \cdot L^{2.18}$

Table 4. Acoustic estimates of polar cod by age in September-October 1986-2000. TSN and TSB are total stock numbers (10^6) and total stock biomass (10^3 tonnes) respectively. Numbers based on TS = 21.8 Log L - 72.7 dB.

	Age 1		Age 2		Age 3		Age 4		Total	
Year	TSN	TSB	TSN	TSB	TSN	TSB	TSN	TSB	TSN	TSB
1986	24038	169.6	6263	104.3	1058	31.5	82	3.4	31441	308.8
1987	15041	125.1	10142	184.2	3111	72.2	39	1.2	28333	382.8
1988	4314	37.1	1469	27.1	727	20.1	52	1.7	6562	86.0
1989	13540	154.9	1777	41.7	236	8.6	60	2.6	15613	207.8
1990	3834	39.3	2221	56.8	650	25.3	94	6.9	6799	127.3
1991	23670	214.2	4159	93.8	1922	67	152	6.4	29903	381.5
1992	22902	194.4	13992	376.5	832	20.9	64	2.9	37790	594.9
1993	16269	131.6	18919	367.1	2965	103.3	147	7.7	38300	609.7
1994	27466	189.7	9297	161.0	5044	154.0	790	35.8	42597	540.5
1995	30697	249.6	6493	127.8	1610	41.0	175	7.9	38975	426.2
1996	19438	144.9	10056	230.6	3287	103.1	212	8.0	33012	487.4
1997	15848	136.7	7755	124.5	3139	86.4	992	39.3	28012	400.7
1998	89947	505.5	7634	174.5	3965	119.3	598	23.0	102435	839.5
1999	59434	399.6	22760	426.0	8803	286.8	435	25.9	91463	1141.9
2000	33825	269.4	19999	432.4	14598	597.6	840	48.4	69262	1347.8

Table 5. Acoustic estimate of young herring by age in September - October 2000. TSN and TSB are total stock numbers (10^6) and total stock biomass (10^3 tonnes) respectively. Numbers based on TS = 20.0 Log L - 71.9 dB.

Length (cm)	1 1999	2 1998	Sum (10^6)	W (10^3)	Mean weight (g)
11.5-12.0	13		13	0.1	11
12.0-12.5	9		9	0.1	13.5
12.5-13.0	17		17	0.3	15
13.0-13.5	180		180	3.1	17
13.5-14.0	431		431	7.8	18.1
14.0-14.5	1094	41	1135	23.6	20.8
14.5-15.0	2238		2238	50.6	22.6
15.0-15.5	3743	55	3798	94.7	24.9
15.5-16.0	3612		3612	99	27.4
16.0-16.5	2133	184	2317	69.2	29.8
16.5-17.0	755	375	1130	37	32.8
17.0-17.5	405	619	1024	36.6	35.7
17.5-18.0	85	861	946	36.6	38.7
18.0-18.5	16	1732	1748	73	41.7
18.5-19.0		2073	2073	93.9	45.3
19.0-19.5		2104	2104	119.3	56.7
19.5-20.0		1699	1699	92.8	54.6
20.0-20.5		1237	1237	70.9	57.3
20.5-21.0		323	323	20.8	64.5
21.0-21.5		140	140	9.7	69
21.5-22.0		43	43	3	69.5
22.0-22.5		13	13	1	80
TSN (10^6)	14731	11499	26230		
TSB (10^3 tonnes)	382.6	560.3		942.9	
Mean length (cm)	15.44	18.88	16.95		
Mean weight (g)	26	48.7			35.9

Based on: TS value: TS=20.0* log(L) - 71.9,
corresponding to $\sigma = 8.1 \cdot 10^{-7} \cdot L^{2.00}$

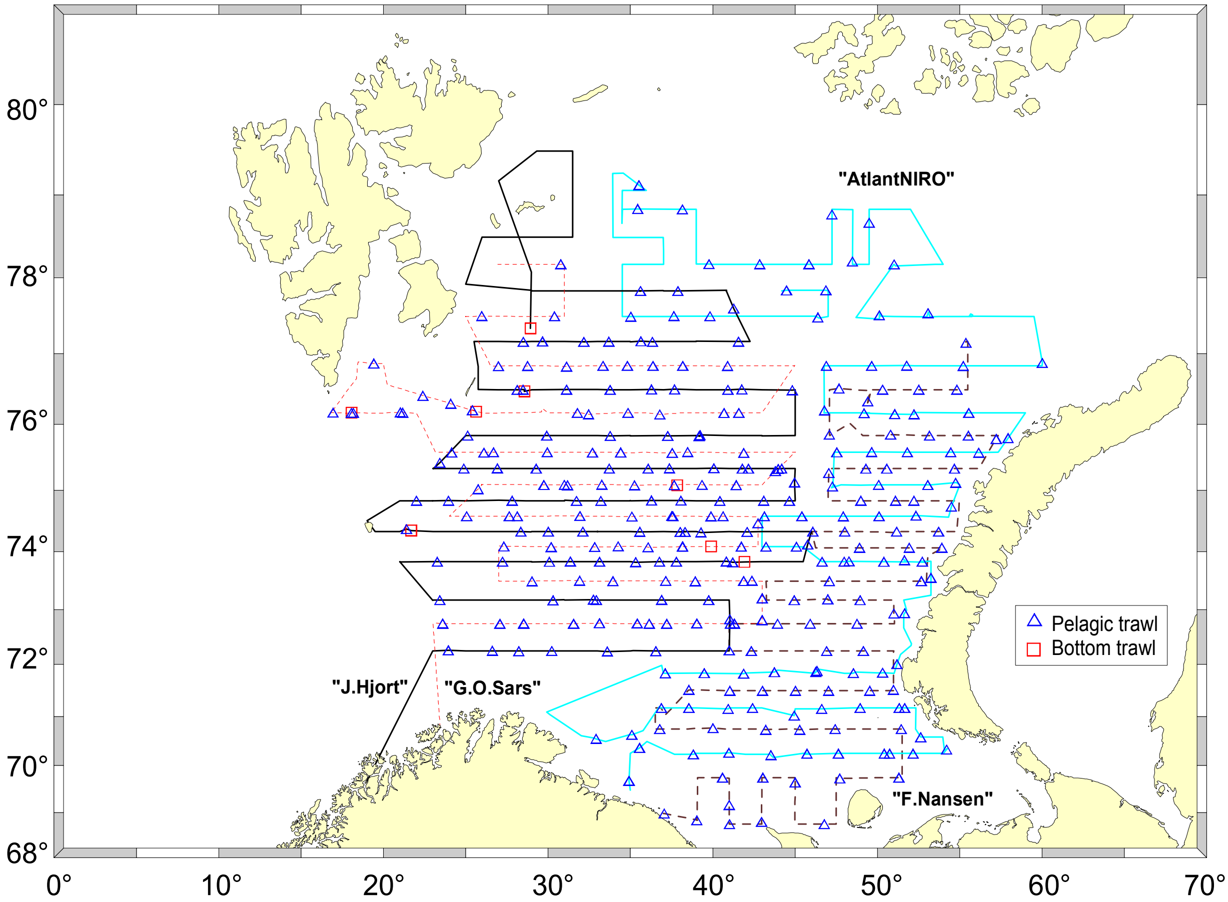

Figure 1 Survey routes and trawl stations for "G.O. Sars", "Johan Hjort", "AtlantNIRO" and "F. Nansen" September - October 2000

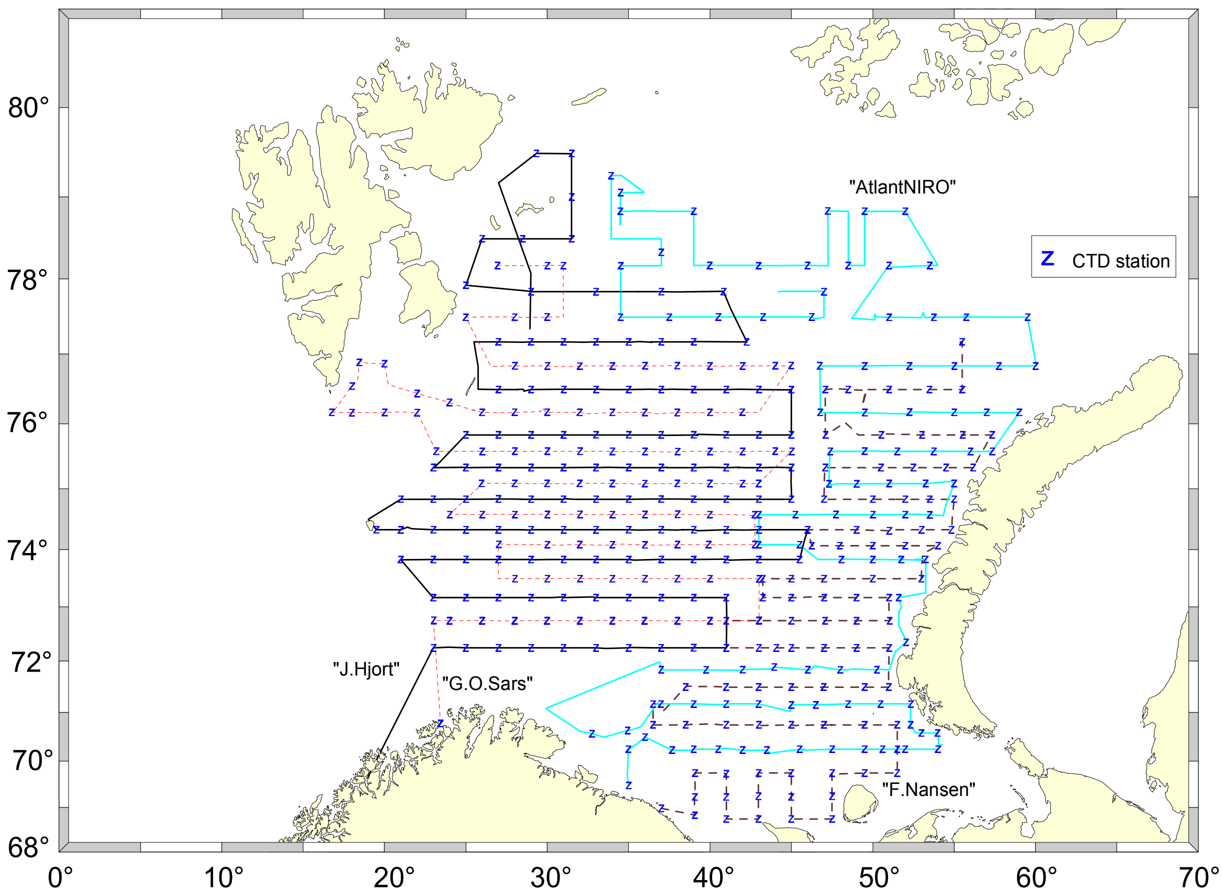

Figure 2 Survey routes and hydrographic stations for "G.O. Sars", "Johan Hjort", "AtlantNIRO" and "F. Nansen" September - October 2000

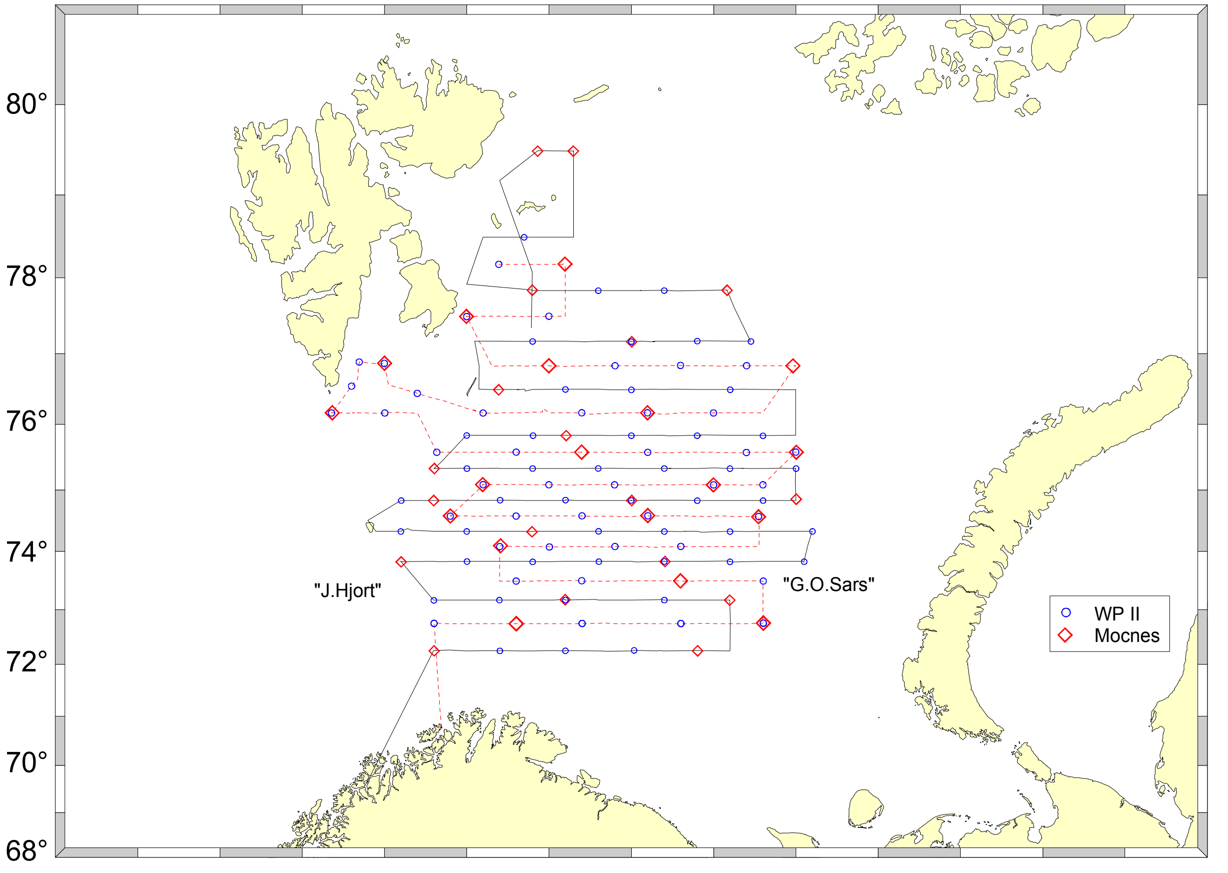

Figure 3 Survey routes and plankton stations for "G.O. Sars" and "Johan Hjort" September - October 2000

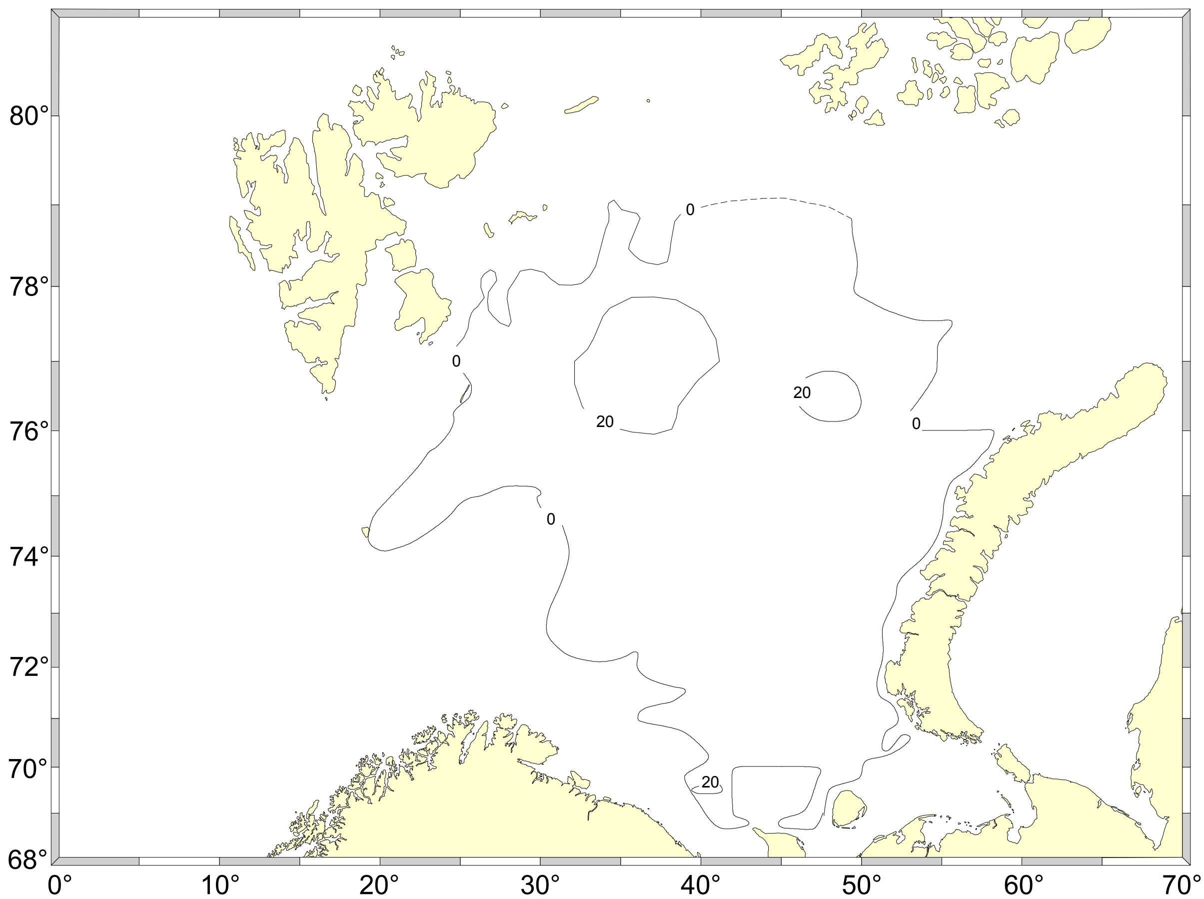

Figure 4 Estimated density distribution of one-year-old capelin (tonnes/square nautical mile) September - October 2000

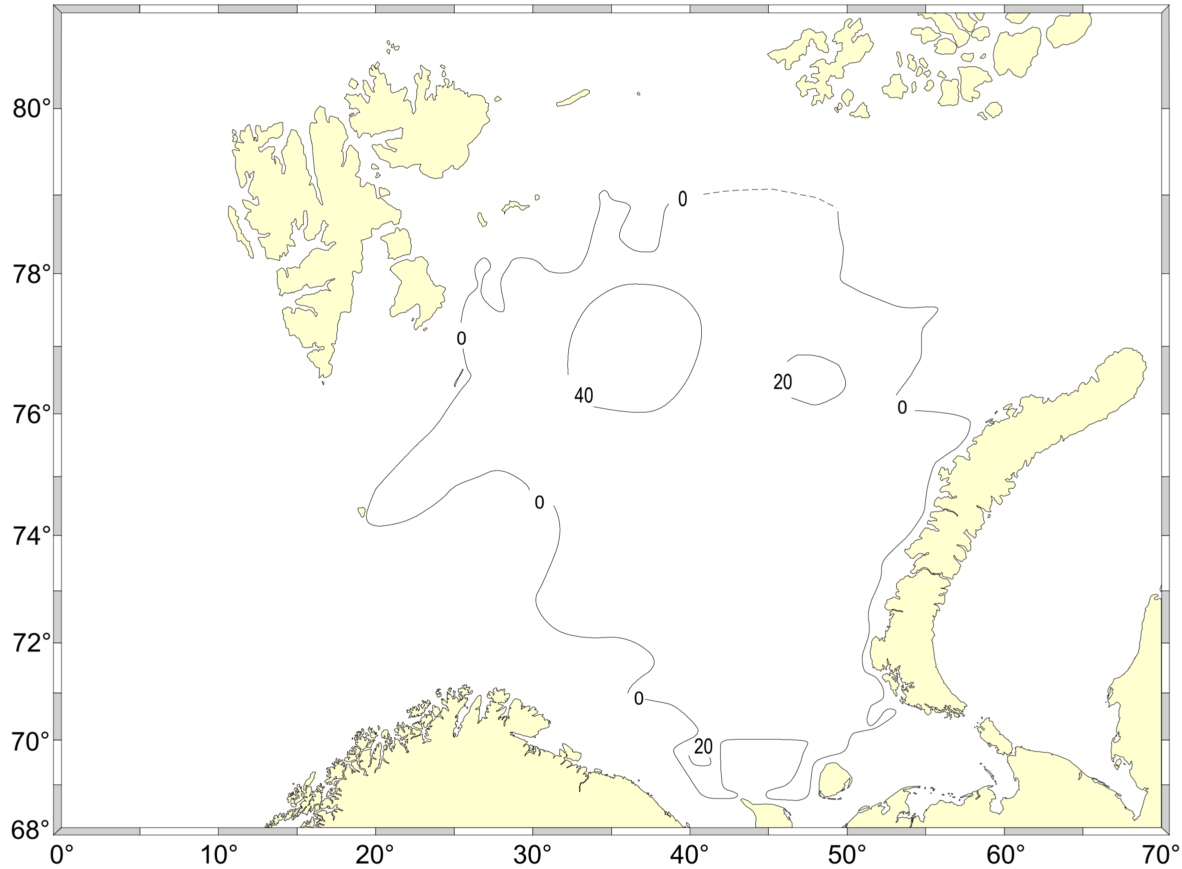

Figure 5 Estimated density distribution of two years old capelin (tonnes/square nautical mile) September - October 2000

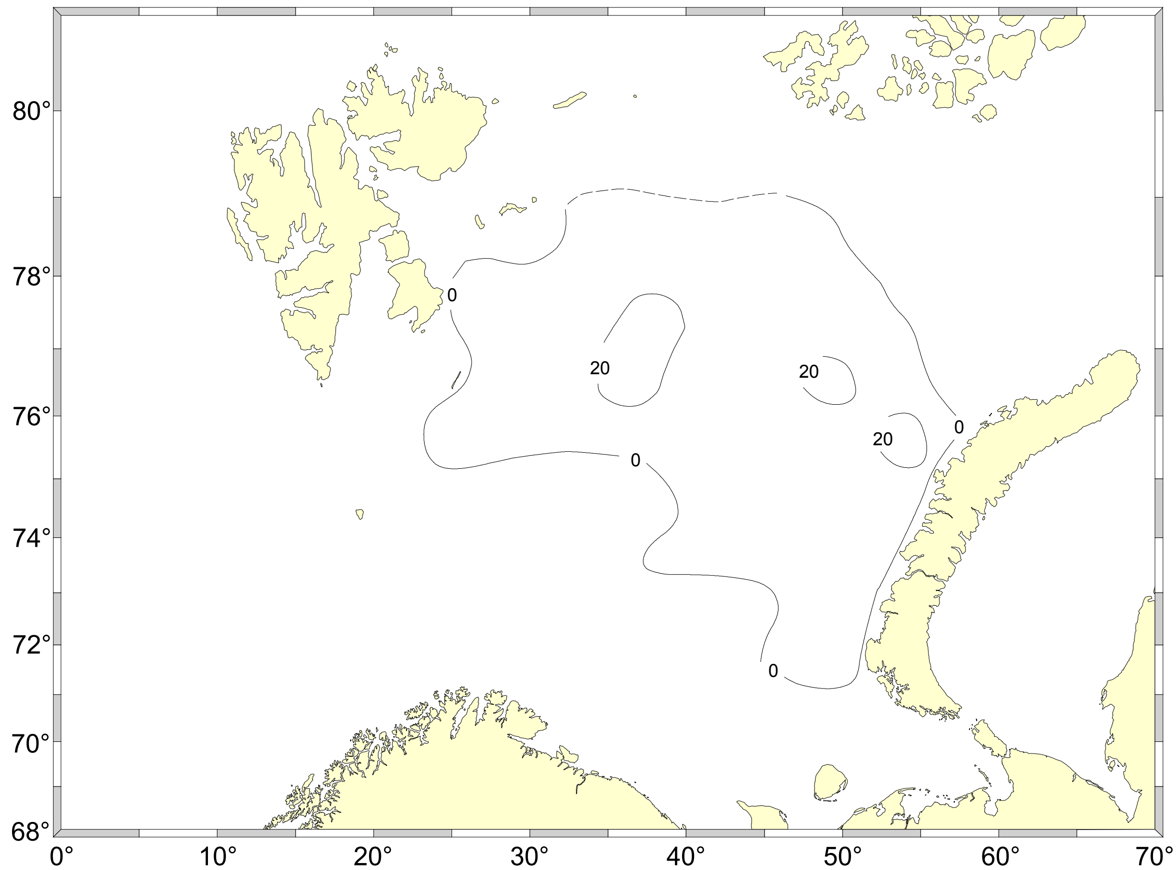

Figure 6 Estimated density distribution of three years old capelin (tonnes/square nautical mile) September - October 2000

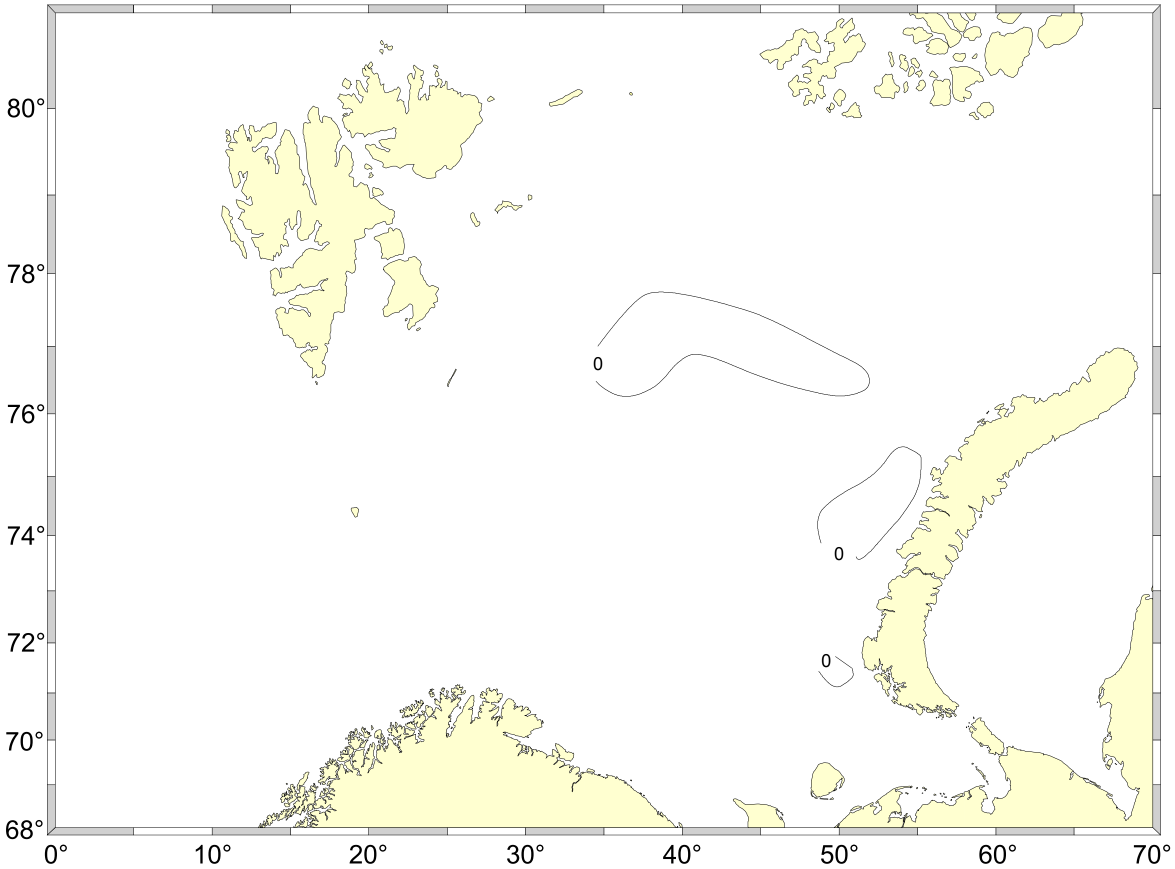

Figure 7 Estimated density distribution of four years old capelin (tonnes/square nautical mile) September - October 2000

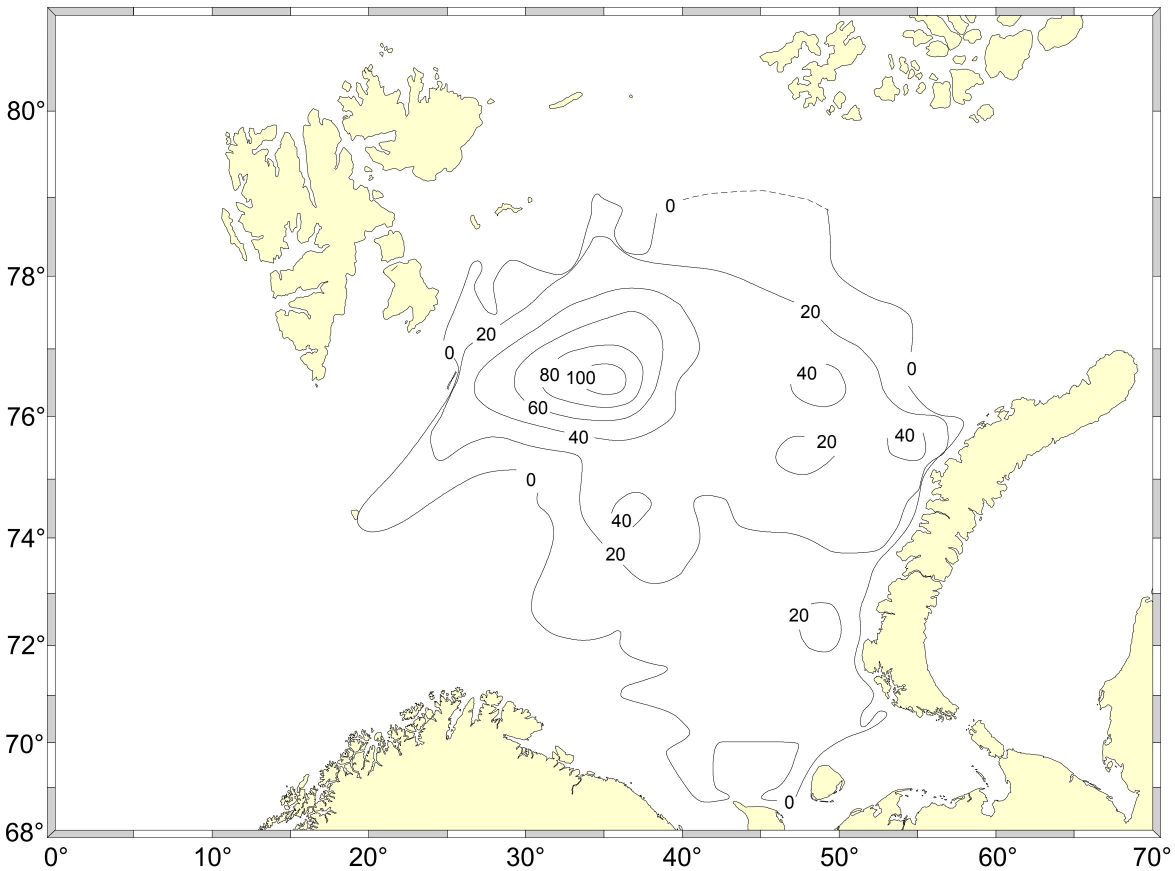

Figure 8 Estimated total density distribution of capelin (tonnes/square nautical mile) September -October 2000

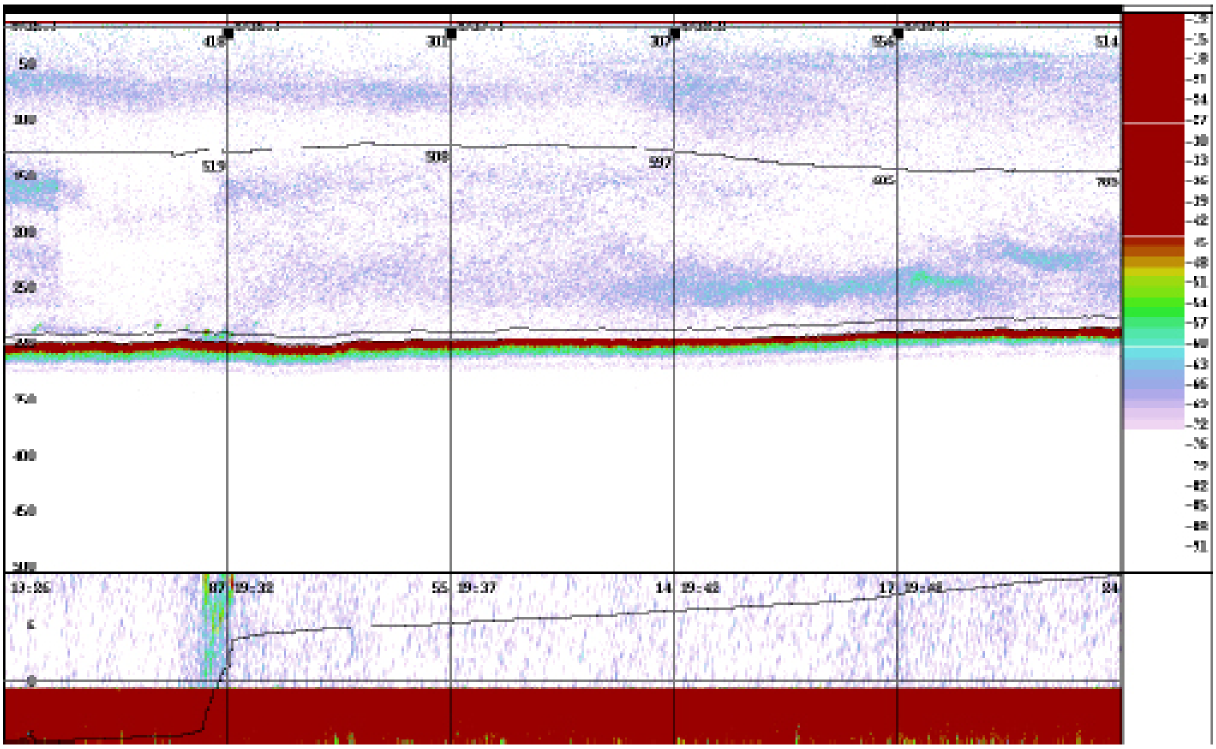

Figure 9 Echogram showing a typical distribution of young capelin (above the dividing line) and polar cod (below the line) recorded at 74°50'N –45°00'E at 20 September 2000.

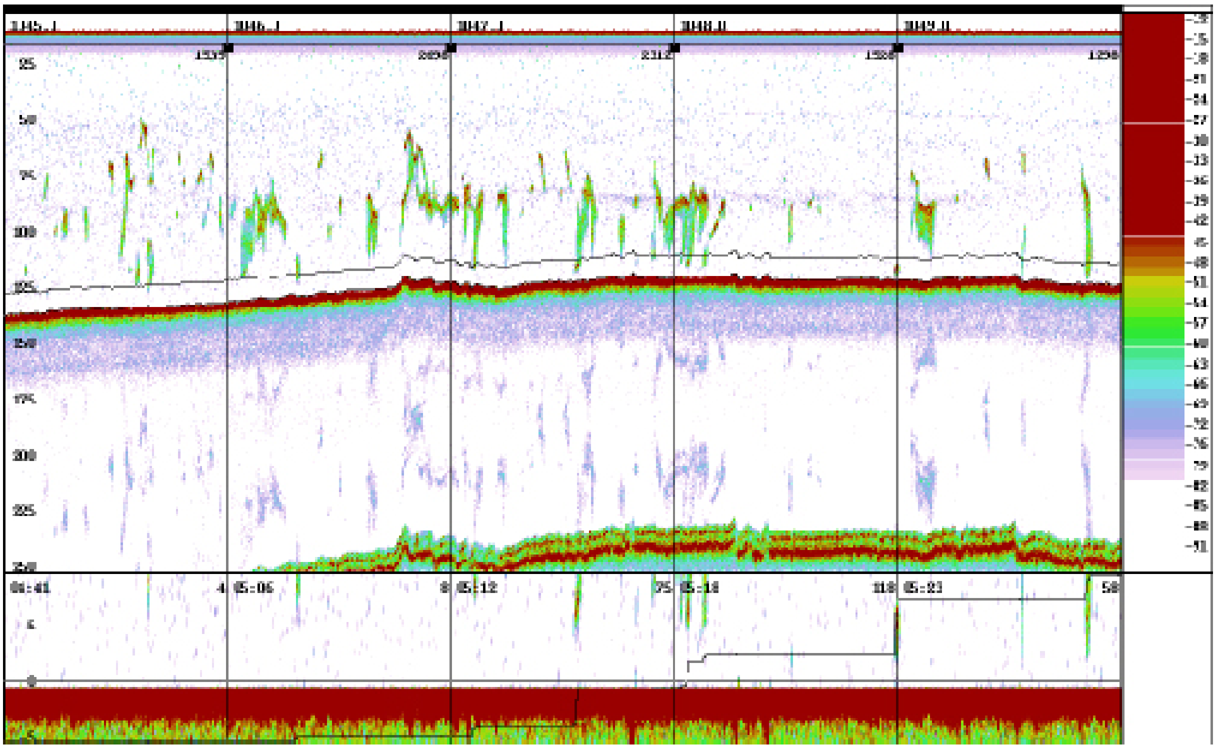

Figure 10 Echogram showing adult capelin distributed in typical schools extending from about 5 meters above the bottom and 100-150m into the pelagic zone. Recorded at 77°10'N –35°40'E at 28 September 2000.

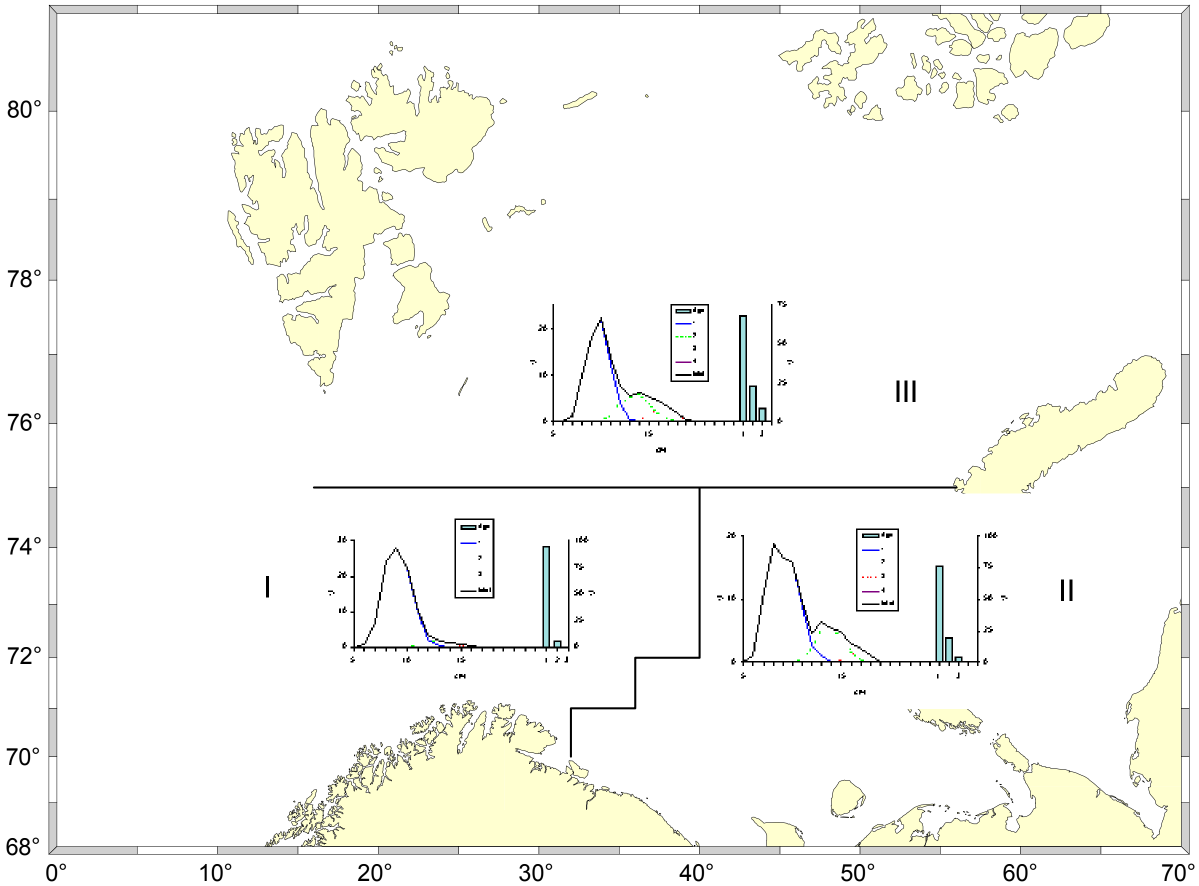

Figure 11 Age and length distribution of capelin in the three sub-areas used for stock size estimation September - October 2000

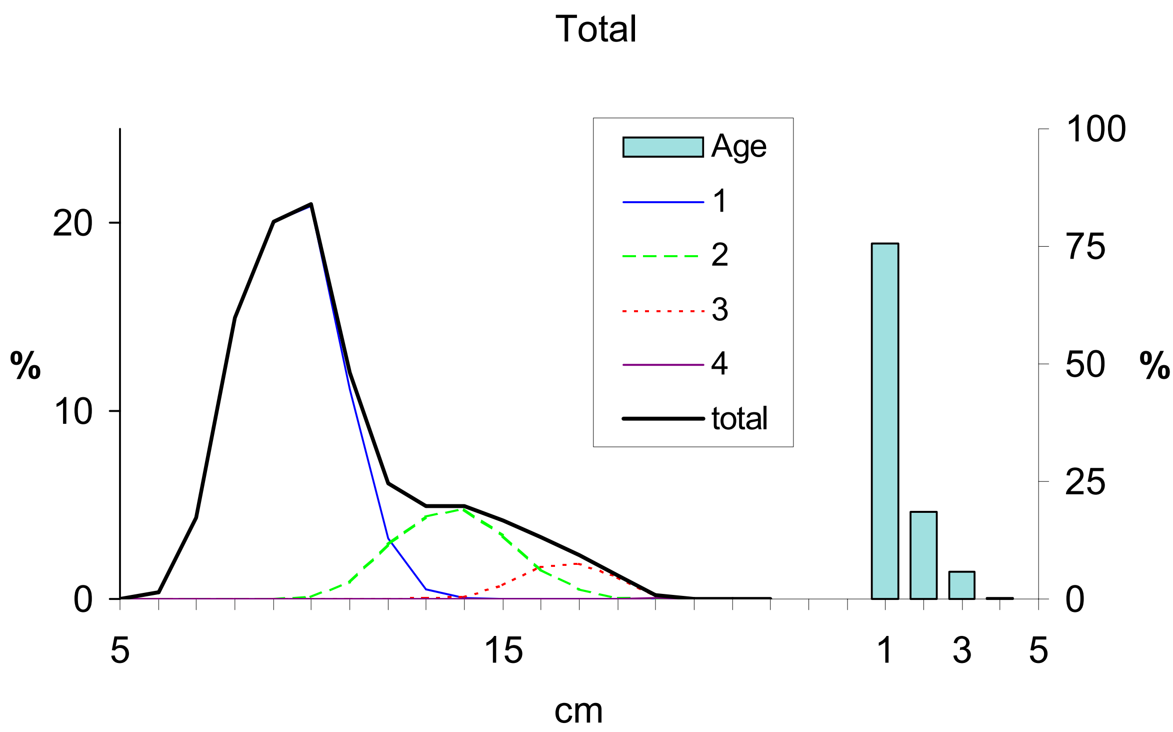

Figure 12 Total length and age distribution of capelin September - October 2000

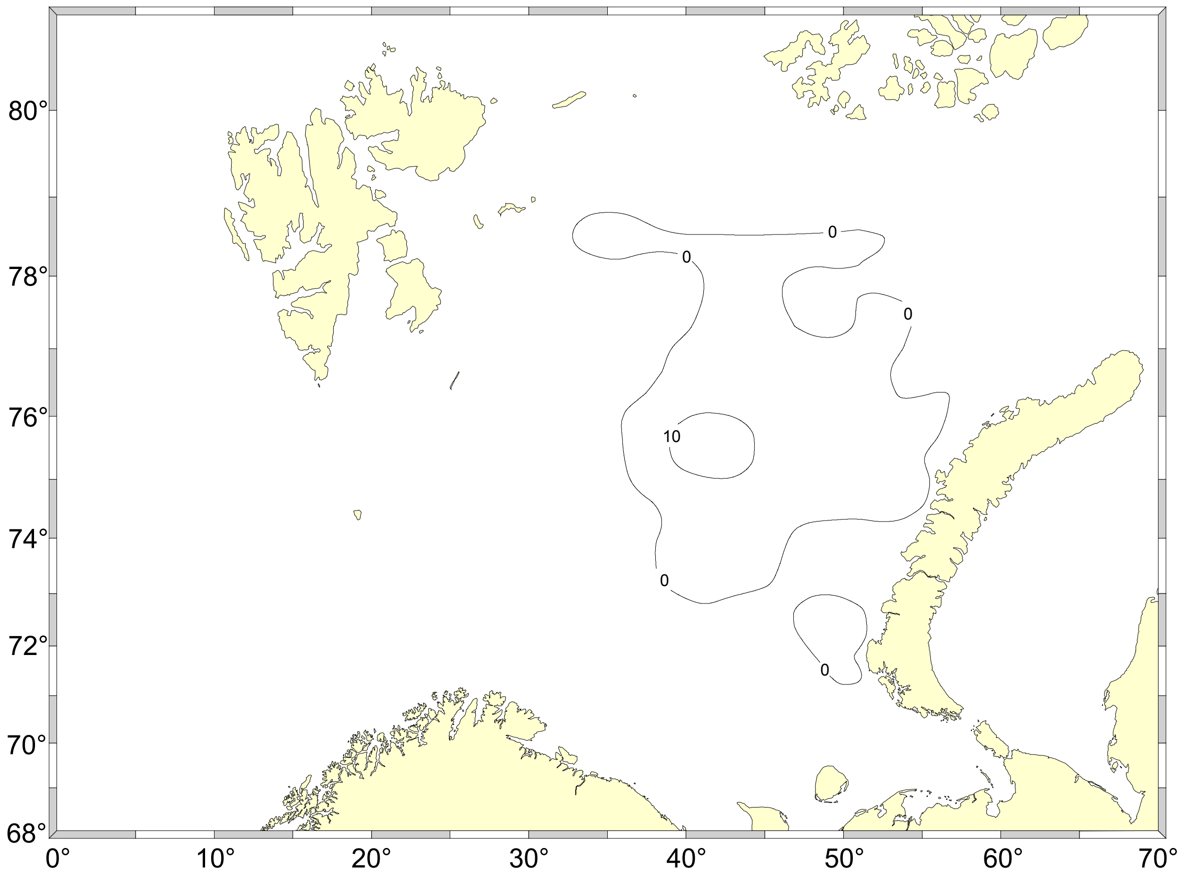

Figure 13 Estimated density distribution of one year old polar cod (tonnes/square nautical mile) September - October 2000

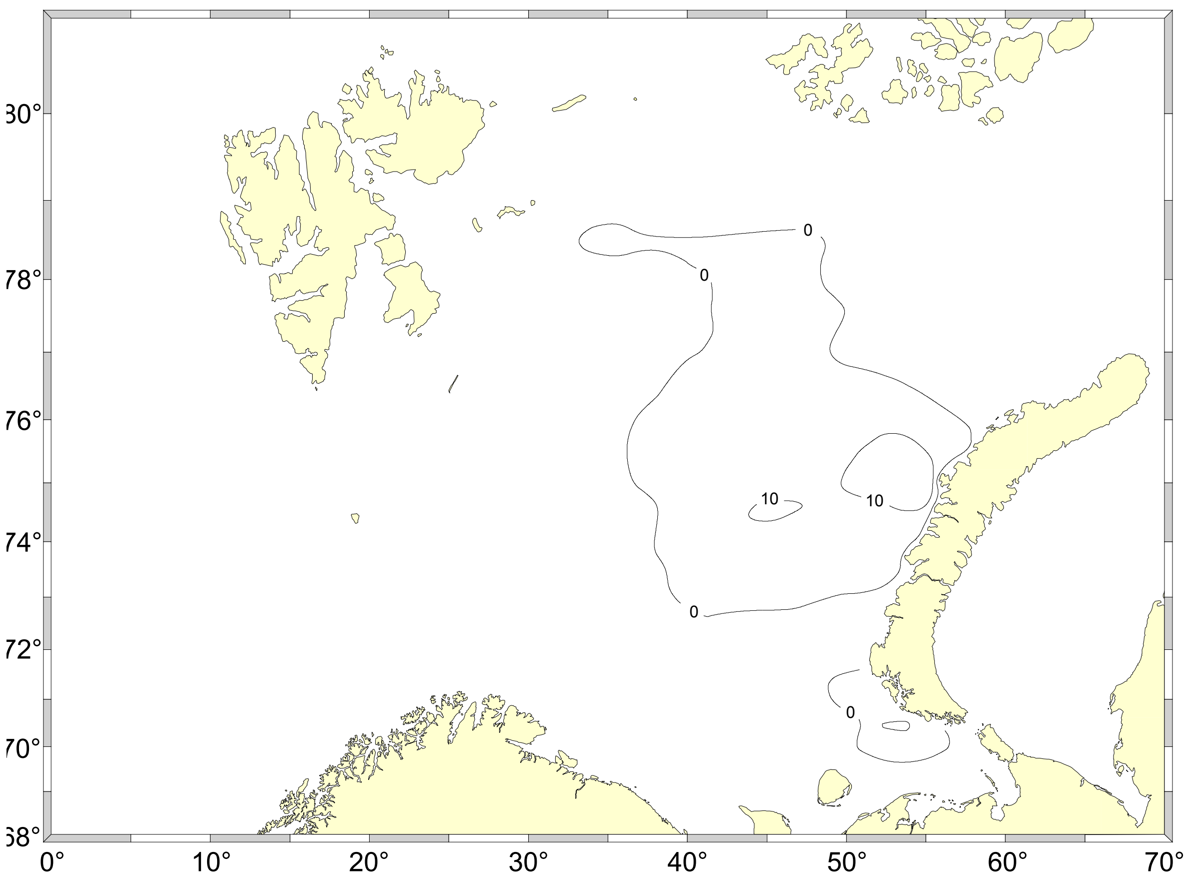

Figure 14 Estimated density distribution of two years old polar cod (tonnes/square nautical mile) September - October 2000

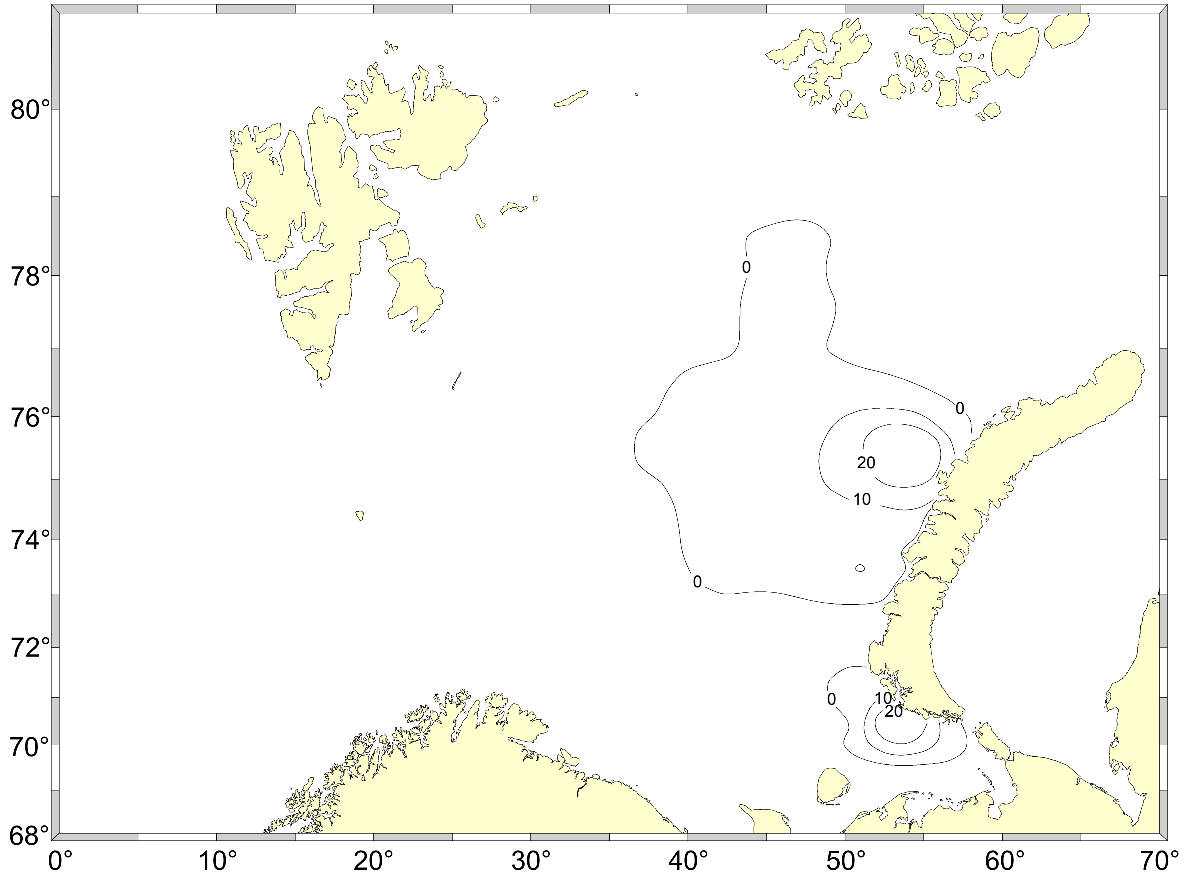

Figure 15 Estimated density distribution of three years old polar cod (tonnes/square nautical mile) September - October 2000

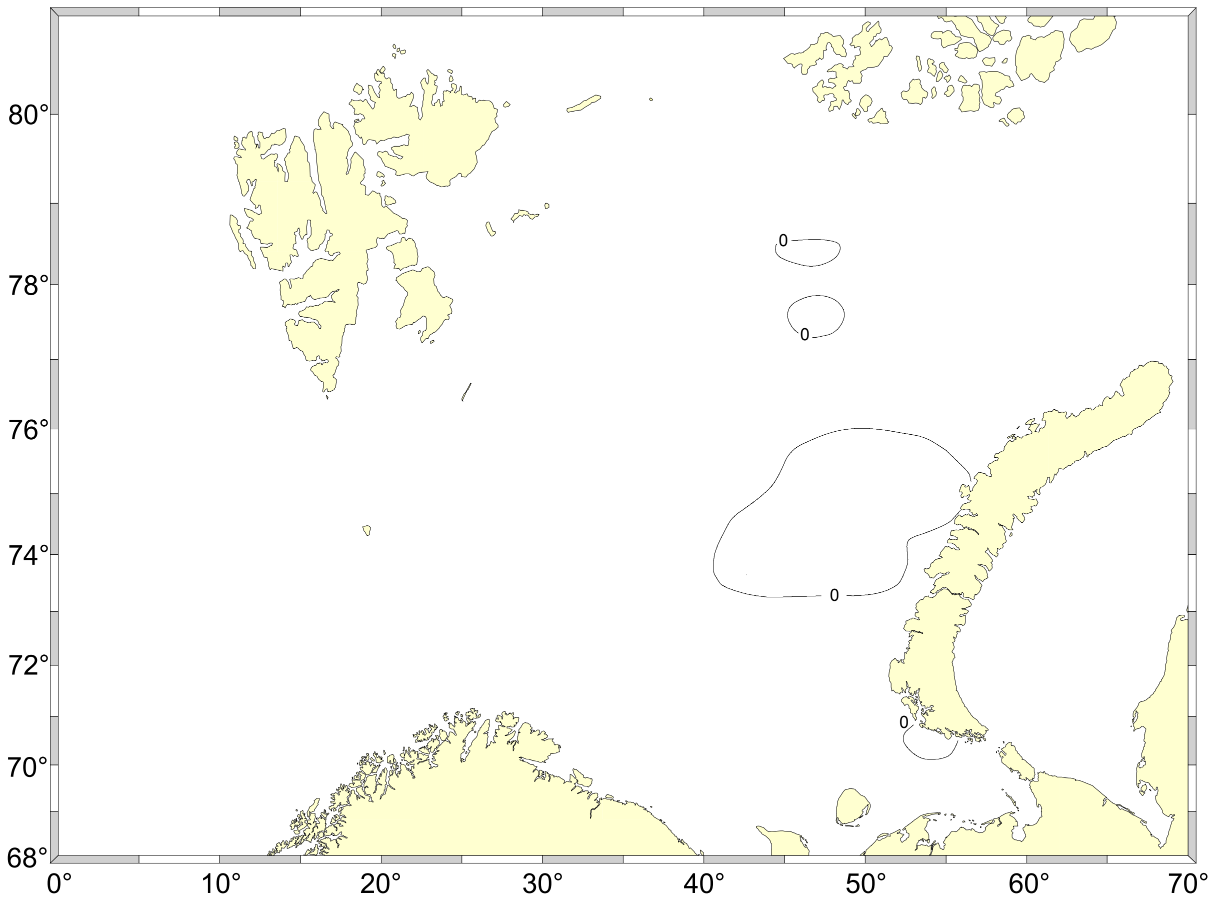

Figure 16 Estimated density distribution of four years old polar cod (tonnes/square nautical mile) September - October 2000

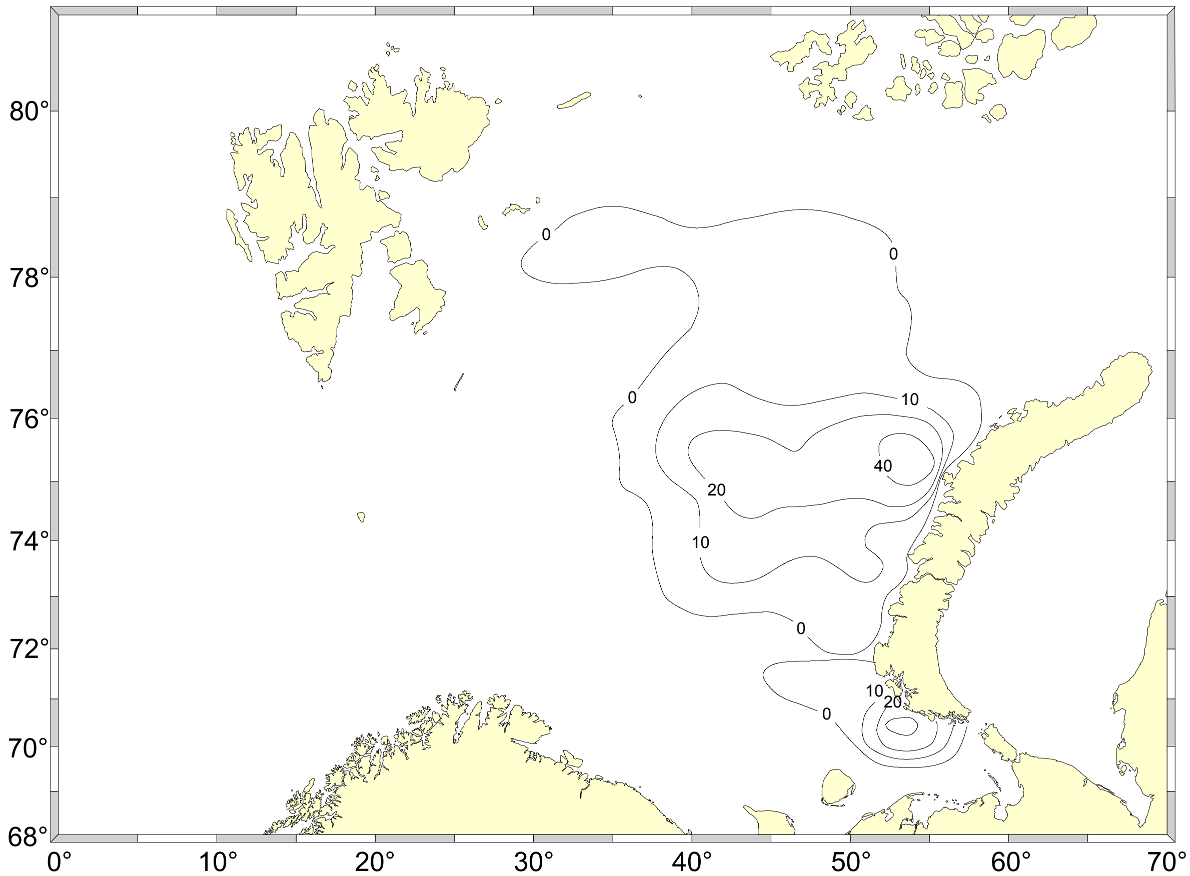

Figure 17 Estimated total density distribution of polar cod (tonnes/square nautical mile) September - October 2000

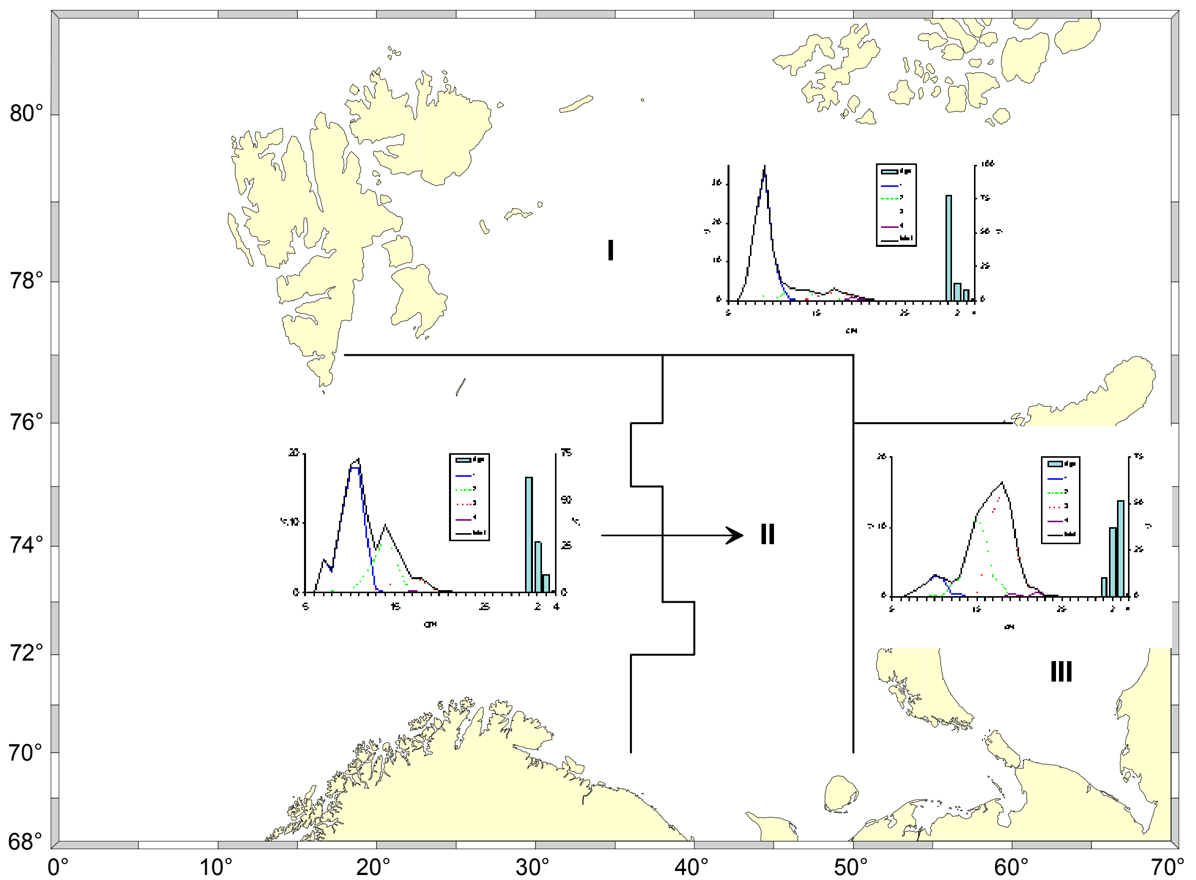

Figure 18 Length and age distribution of polar cod in the four sub-areas used for stock size estimation September - October 2000

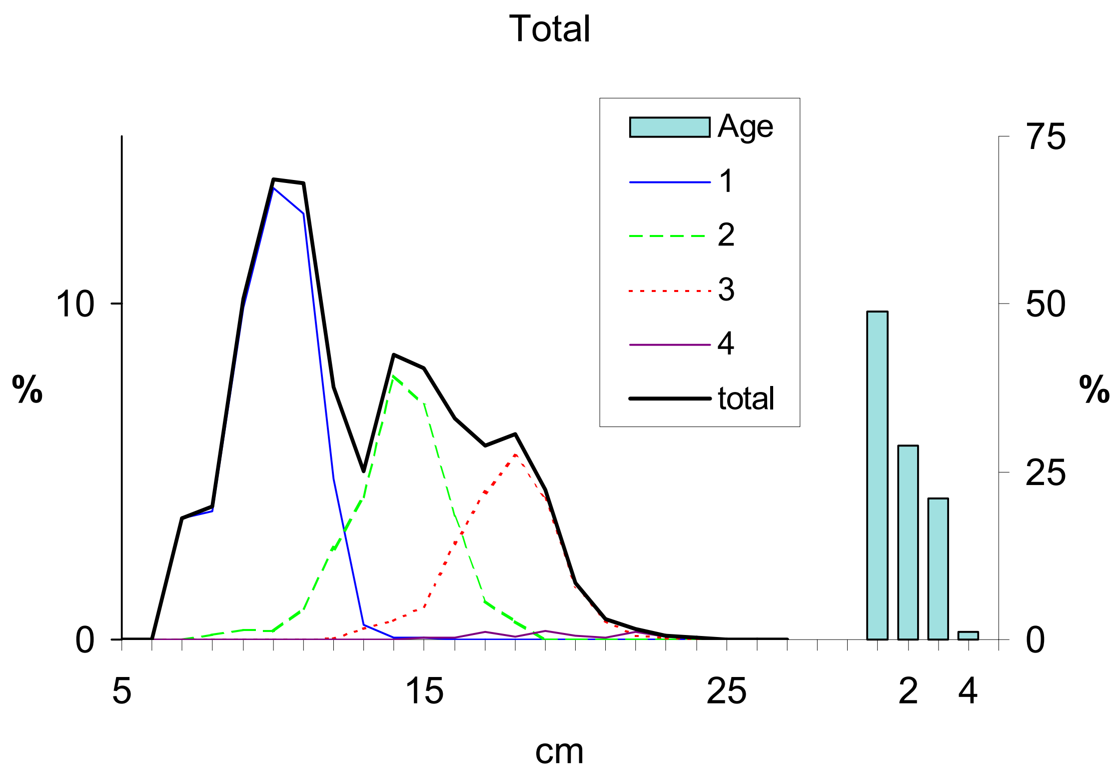

Figure 19 Total length and age distribution of polar cod September - October 2000

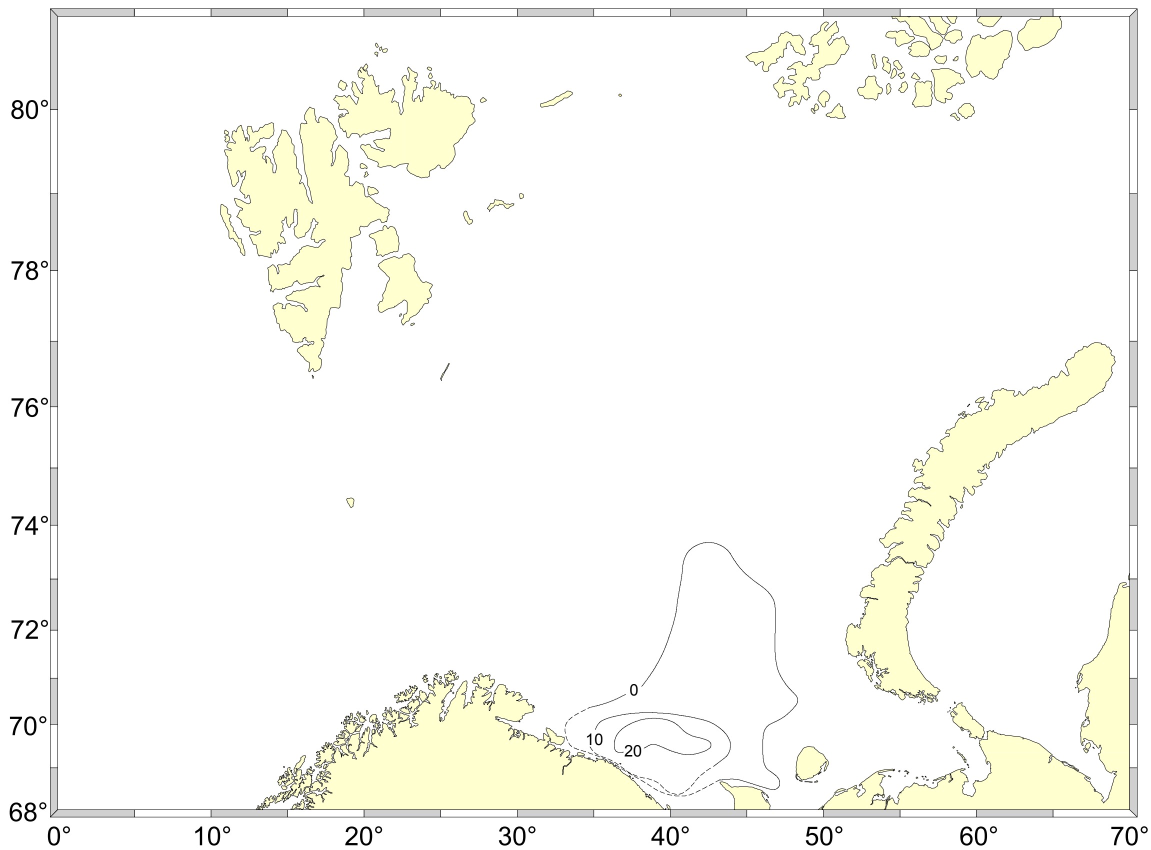

Figure 20 Estimated density distribution of 1-group herring (tonnes/square nautical mile) September - October 2000

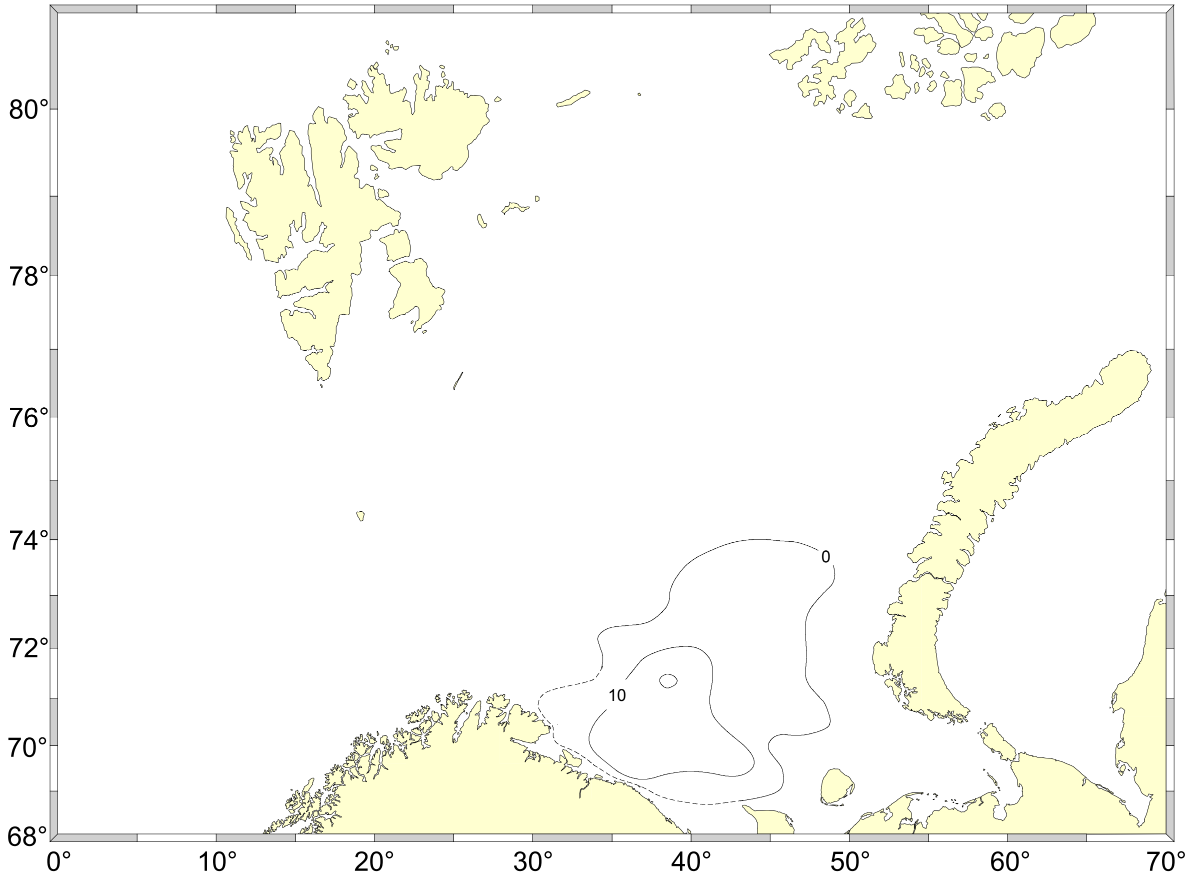

Figure 21 Estimated density distribution of 2-group herring (tonnes/square nautical mile) September - October 2000

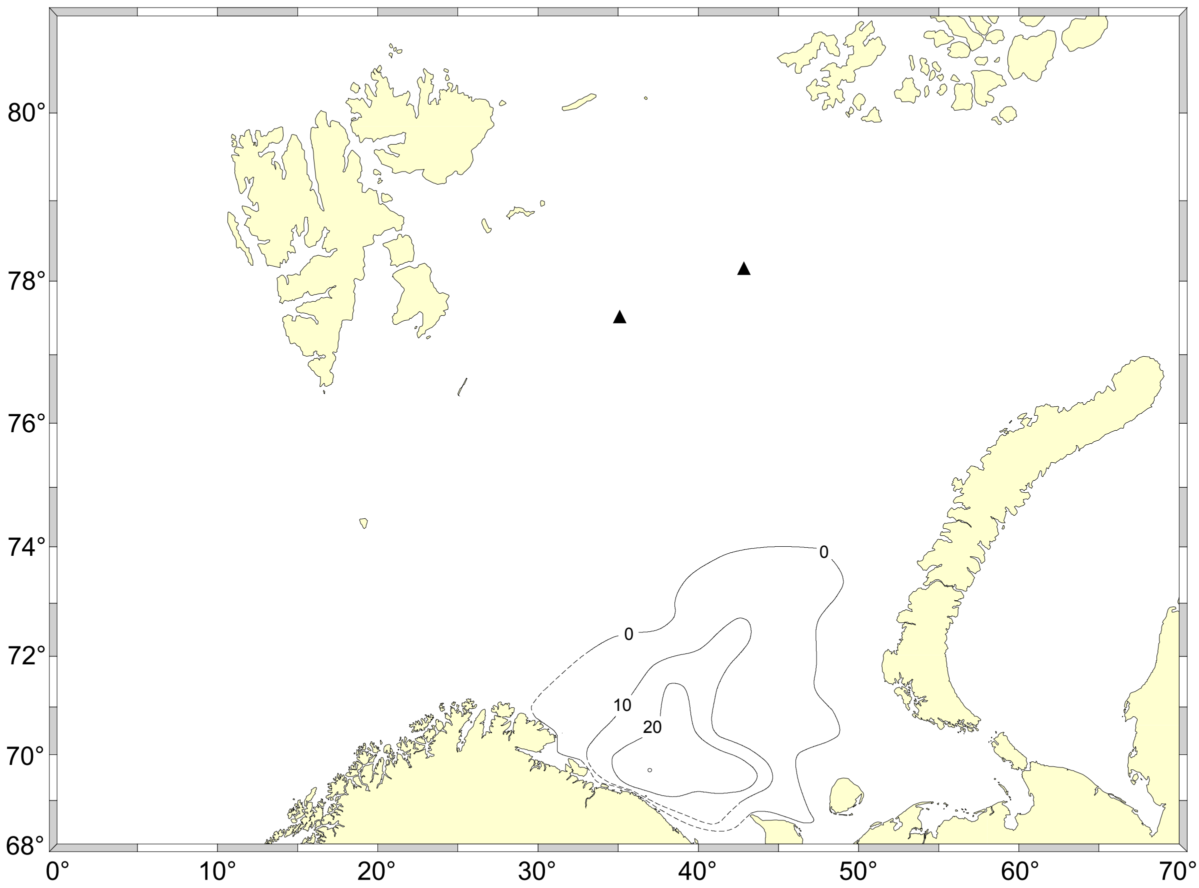

Figure 22 Estimated total density distribution of herring (tonnes/square nautical mile) September - October 2000. Triangles denote trawl observations of herring in the northern area.

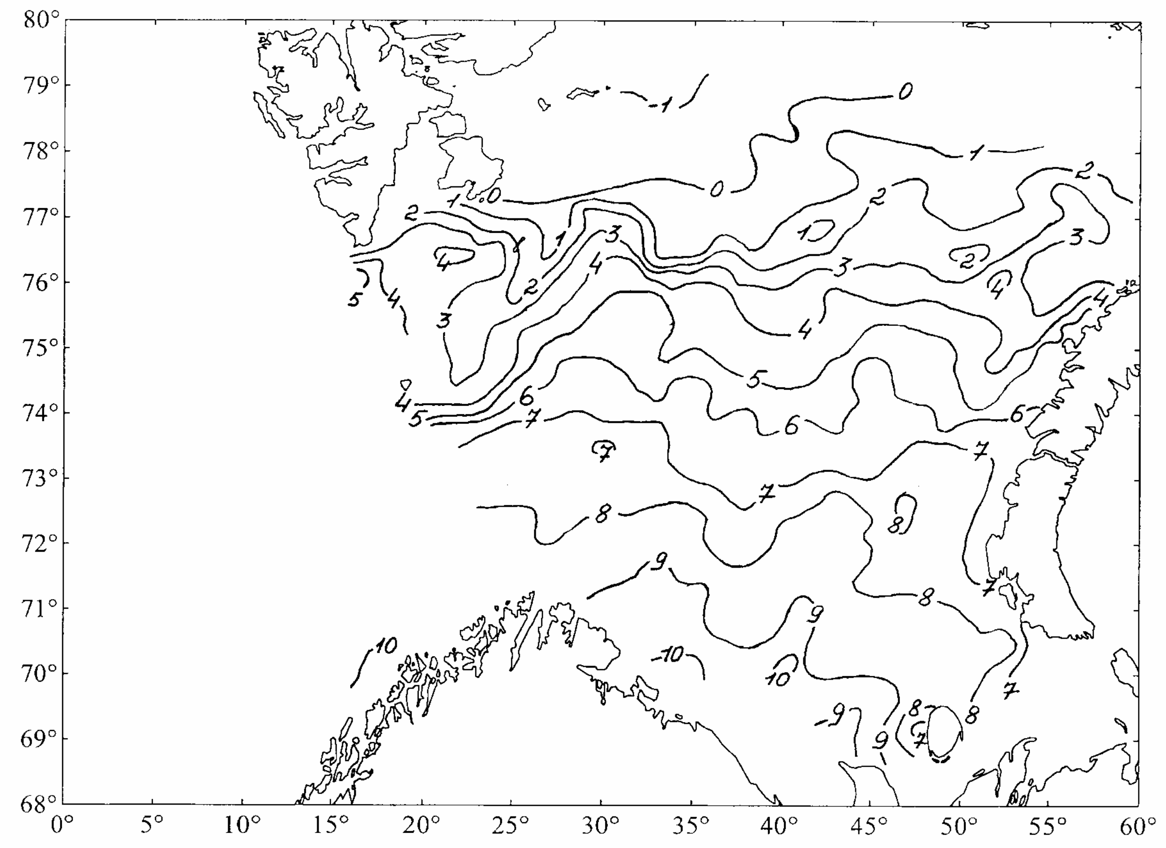

Figure 23 Temperature at the surface September - October 2000

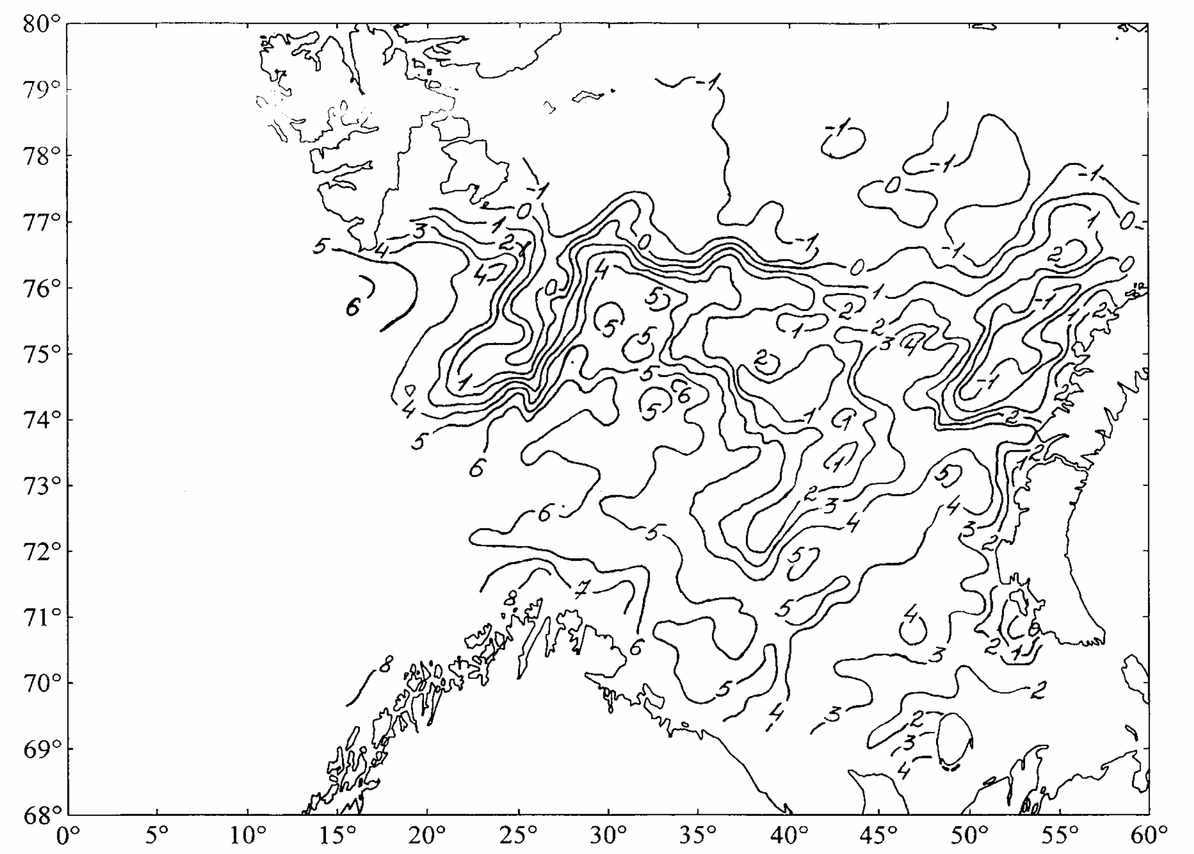

Figure 24 Temperature at 50 m September - October 2000

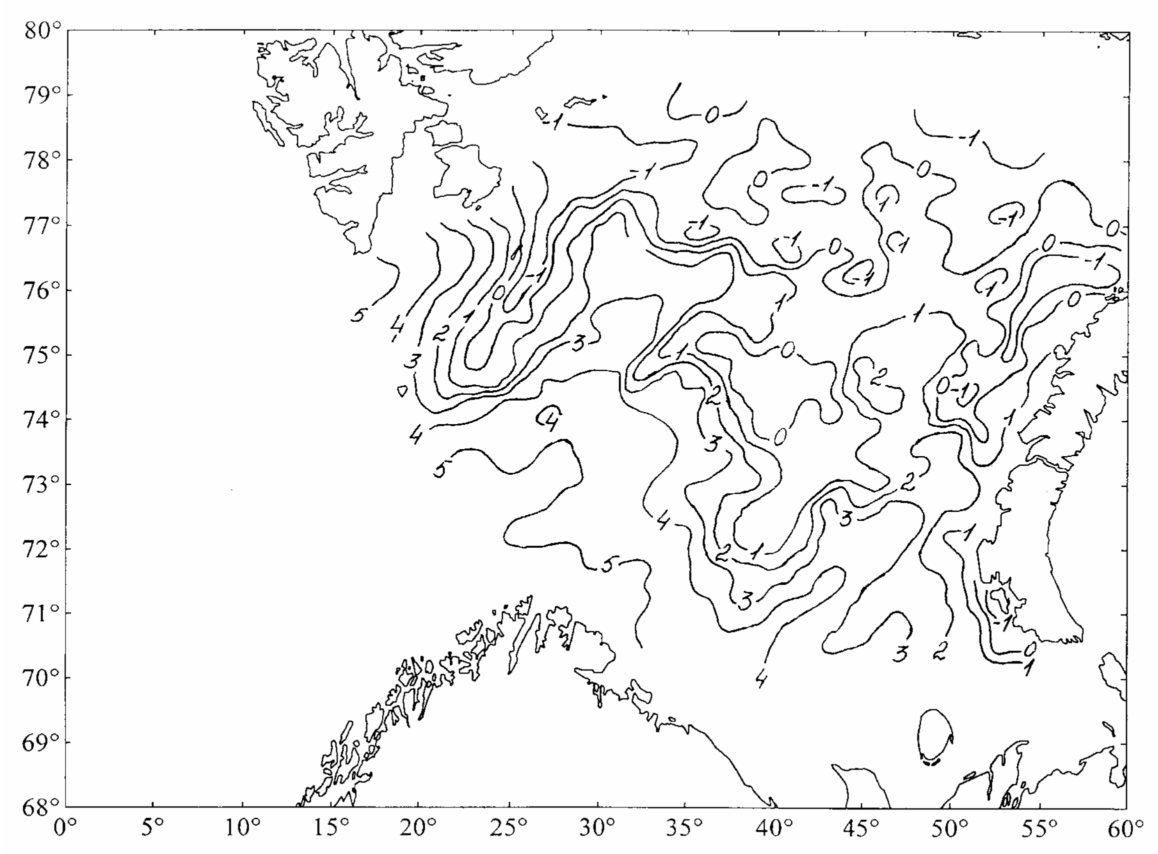

Figure 25 Temperature at 100 m September – October 2000

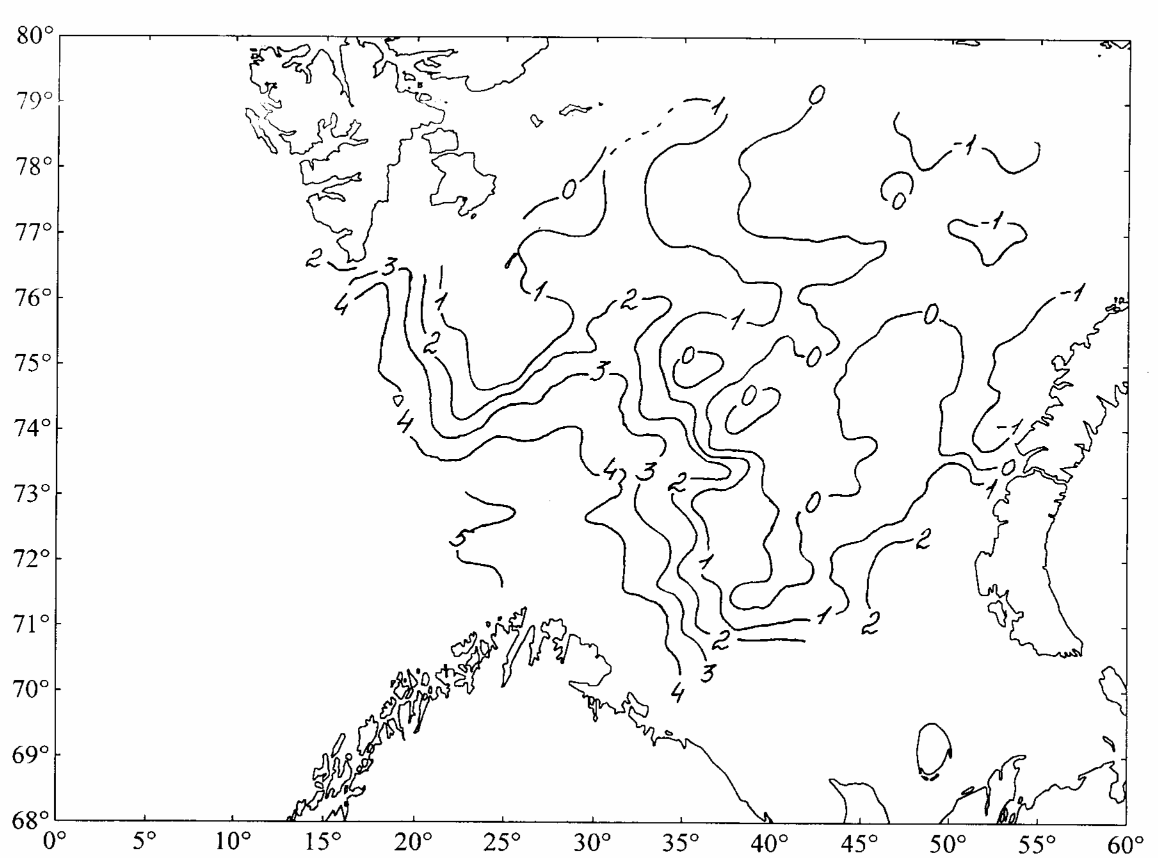

Figure 26 Temperature at 200 m September - October 2000

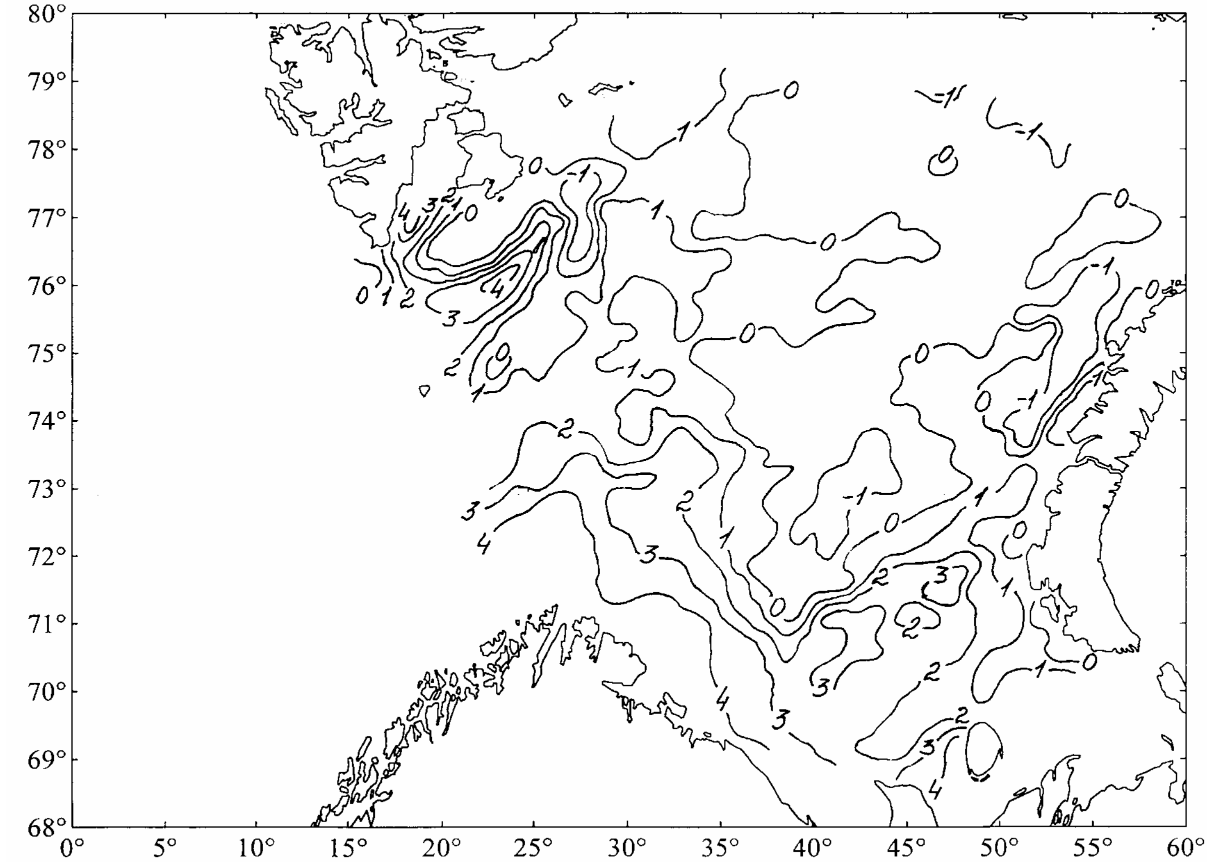

Figure 27 Temperature at bottom depths September - October 2000

Appendix I

Research vessel	Participants
"G. O. Sars"	T. Haugland, M. Haugland, E. Hermansen, M. Johannesen, R. Pettersen, J. Røttingen (cruise leader), B. Skjold, B.V. Svendsen
"Johan Hjort"	J. Alvarez, V. Anthonypillai, H. Gjøsæter (cruise leader), K. Hansen, E.S. Meland, M. Mjanger, L. Rey, B.S. Røttingen, J. Wangensten, A. Krysov (PINRO), R. Jørgensen (NFH)
"AtlantNIRO"	D. Prozorkevich (cruise leader), S. Ratushniy, T. Usupov, V. Mamylov, T. Gavrilik, M. Kalashnikova, A. Rudoy, A. Bendik, A. Trofimov.
"F. Nansen"	I. Dolgolenko (cruise leader), T. Sergeeva, O. Vavilina, V. Guzenko, V. Iliin, V. Kapralov, V. Sergeev, A. Astakhov, T. Prokhorova

Appendix II

SPHERE CALIBRATION OF ECHOSOUNDERS EK-500
(on copper sphere CU60, TS=33,6 dB, at frequency 38 kHz)

Research vessel	JOHAN HJORT	G.O.SARS	AtlantNIRO	F. Nansen
Date	22.07.00	09.09.00	10.08.00	13.08.00
Place	Akkarfjord	Akkarfjord	Bøkfjord	B. Volokovaja
Bottom depth (m)	51	59	54	42
Temperature (°C)	8.5	8.4		
Salinity (‰)	33.6	33.8		
Transducer type	ES38B-SK	ES38B-SK	ES38B-SK	ES38B-SK
Transducer depth (m)	7	0		
Real sphere depth (m)		24.9	20.7	19.2
Sound velocity (m/sec)	1487	1483	1473	1488
Absorption coefficient (dB/km)	10	10	10	10
Pulse length (Short/Med./Long, ms)	Med	Med	Med	Med
Bandwidth (Wide/Narrow)	Wide	Wide	Wide	Wide
Maximum power (W)	2000	2000	2000	2000
Transmit power (W)	Normal	Normal	Normal	Normal
Angle sensitivity	21.9	21.9	21.9	21.9
2-way Beam Angle (10lgψ, dB)	-21.0	-21.0	-21.0	-21.0
Adjusted Sv Transducer Gain (dB)	27.59	27.08	27.55	25.20
Adjusted TS Transducer Gain (dB)	27.73	27.23	27.53	25.10
3-dB Beamwidth Alongship (deg.)	6.9	6.9	6.8	6.8
3-dB Beamwidth Athwartship (deg.)	6.8	6.8	6.8	6.8
Alongship (fore/aft.) Offset (deg.)	0.01	0.06	-0.03	0.03
Athwartship Offset (deg.)	0.01	0.03	-0.07	0.02
Theoretical Sa (m^2/nm^2)	5886	3820	5528	6425
Measured Sa (m^2/nm^2)		3833	5522	6123
	$Sa = \sigma * 1852^2 / (r^2 \psi)$		$\sigma = 4\pi * 10^{0,1\,TS}$	

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REPORT