SURVEY REPORT

FROM THE JOINT NORWEGIAN/RUSSIAN ACOUSTIC SURVEY OF PELAGIC FISH IN THE BARENTS SEA SEPTEMBER - OCTOBER 2001

Synopsis

The survey was carried out in the period 3rd of September to 4th of October 2001 and was terminated by a meeting in Vadsø 5-7th October. Four research vessels participated in the survey:

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

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. On "Johan Hjort" acoustic experiments on capelin avoidance towards vessel noise were done.

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 was considered satisfactory.

The capelin stock was estimated at 3.6 million tonnes, 0.8 times the estimate obtained last year. About 2.0 million tonnes were assumed to be maturing.

The polar cod stock was estimated at 1.9 million tonnes, about 1.4 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 12 000 tonnes of one-year-olds, 600 000 tonnes of two-year-olds and 160 000 tonnes of three-year-olds were found in the south-eastern parts of the Barents Sea.

In the south-western parts of the Barents Sea young **blue whiting** were observed in considerable amounts, more than 50% belonged to the 2000 year class. A quantitative estimation was not attempted since only a small area of the total distribution area of this species was covered.

Methods

The cruise leaders prior to the survey adopted a general plan for the survey. A team consisting of N.G. Ushakov (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 total 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 and central parts of the Barents Sea whereas "Johan Hjort" and "G.O. Sars" surveyed the north-western, central, and western parts. Altogether, 15500 nautical miles of survey tracks were made, about 5% more than last year.

The two Norwegian vessels worked with EK-500 echo sounders and BEI post processing systems, "AtlantNIRO" and "F. Nansen" used EK-500, "AtlantNIRO" had a BI-500 and "F. Nansen" a SONIS 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 registrations extending to the bottom were included in the stock abundance calculations for capelin and polar cod, as only these were considered representative for the pelagic component of the stocks, which is measured acoustically.

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. On "Johan Hjort", a "HCL Multisampler", a device attached to a pelagic trawl with three cod ends that can be opened and closed by a signal from the vessel, was used when registrations at various depths were found. In total, 343 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 prior to the survey (See Appendix II).

Computations of stock sizes

The computations of number of individuals and biomass per length-and age group were made using a new stock size estimation program "BEAM" built on SAS GIS and developed at IMR. Stock size estimates were also made by the same computer programme as in previous years for comparison. Both programs have been shown to give identical results when run on historic data. This was also confirmed during the present study, when the capelin estimate was made using both programs. A strata system, dividing the Barents Sea in squares of 1^o (latitude) x 2^o (longitude), was used as basis for the calculation.

Sampling

	Norwegian vessels	Russian vessels	Sum
Capelin			
No of samples	144	100	244
Nos. length measured	11460	15318	26778
Nos. aged	6750	1099	7848
Polar cod			
No of samples	68	83	151
Nos. length measured	3451	13051	16502
Nos. aged	1118	500	1618

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 1 day to exchange a member of crew and when "Johan Hjort" returned to port when a member of the crew became ill. One day was also lost when "Johan Hjort" lost a trawl but managed to rescue it. Even though the weather conditions were unfavourable during parts of the survey, with several days of wind force above 15 m/sec, a total coverage of the capelin distribution area was achieved. The present survey, with its east-west transects either 15 or 20 nautical miles apart from 74° (in western areas) and 69° (in the eastern) to 80° is comparable to last year's survey but extends more northerly, and is probably the most complete coverage obtained at any capelin survey in the time series. The new survey design introduced last year and used this year, running east-west courses starting in the south, proved successful. However, since the northern limit of the capelin distribution seems to be more variable than the southern limit, starting the survey in the north should be considered in the future. "Johan Hjort" had dedicated some working time during the first part of the survey to experimental work (see below). This made that vessel's coverage not synoptic with the other vessels during the first week of work.

Capelin

Distribution

The geographical density distribution of the total stock and each age group are shown in Figs. 4 to 8. The distribution area resembled that found last year, but extended 60-100 nautical miles to the north compared to that in 2000. Never since 1975 has the northern limit of the capelin distribution during autumn been found so far north, extending north of 80°N west of Franz Joseph Land. The extension in the east west direction was equal to that found last year, from the Bear Island in the west to Novaja Zemlja in the east. However, this year larger amounts of capelin were found in the Storfjordrenna area south of Spitsbergen. The main concentration stretched out from about 77°30'N, 34-36°E northwards to 79°30'N, 27° - 37°E and up to 80°10'N between 41 and 45°E (Figure 8). In some areas, mainly to the east of about 38° E, the capelin was found together with the polar cod, sometimes in mixed concentrations, sometimes separated into distinct layers. In areas where humpback whales were found in dense aggregations (north of 79°N), capelin were found mainly in dense schools near the bottom. Figure 9 shows an example of such registrations in position 79º18'N–33º00'E. In some areas capelin was found together with polar cod. In such areas, it was difficult to discern between the two types of fish based on the recordings. In Figure 10 is shown an example of such registrations from 78º29'N – 38º58'E, where the species composition was determined by a multisampler haul.

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

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

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:

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

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 2000 estimate is shown on shaded background for comparison.

Year class		Age	Number (10^9)		Mean weight (g)		Biomass (10^3 t)	
2000	1999	1	113.6	449.2	3.3	3.8	374.8	1699.7
1999	1998	2	218.7	110.6	11.0	14.4	2401.1	1591.8
1998	1997	3	30.5	34.1	26.7	27.9	813.8	951.0
1997	1996	4	1.0	0.8	35.5	37.7	37.7	29.5
Total stock in								
2001	2000	1-4	363.9	594.7	10.0	7.2	3630.0	4273.1

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

Details of the 2001 estimate are shown in Table 1 and the estimates by age group of the capelin stock 1 years old and older from 1973-2001 are shown in Table 2.

The total stock is estimated at about 3.6 million tonnes, about 80% of the stock estimated last year. About 56% (2019 thousand tonnes) of this stock is maturing. The 2000 year class (1-group) consists, according to this estimate, of about 114 billion individuals. This estimate is almost one fourth of that obtained for the 1-group last year. The mean weight is estimated at 3.3 g, which is somewhat lower than that measured last year, and 0.2 g below the long-term average. The biomass of the 2000 year class is about 0.4 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 might be more uncertain than that for older capelin. However, based on the findings during the 0-group survey covering the same areas in August, 1-group capelin were not frequently found mixed with 0-group in the surface layers this year.

The estimated number of fish in the 1999 year class (2-group) is about 219 billions, two times higher than the 1998 year class measured last year. The mean weight at this age is 11.0 g (14.4 g in 2000), and consequently the biomass of the two years old fish is about 2.4 million tonnes. The mean weight is lower than in the seven last years but is above the long-term average (Table 2).

The 1998 year class is estimated at about 30 billion individuals with mean weight 26.7 g, giving a biomass of about 813 thousand tonnes. The mean weight is one of the highest on record and is 10g above the long-term average mean weight. The 1997 year class (now 4 years old) is estimated at 1.1 billion individuals. With a mean weight of 37.7 g this age group makes up only about 37 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 “survey-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
2000-2001	1999	449.2	218.7	51	0.72

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 preying on a decreasing stock of capelin. The mortalities calculated for the period 1996-2001 varied between 27 and 52% and 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. During a Norwegian trawl survey for Greenland halibut during late August-early September in the areas north of Spitsbergen, considerable amounts of polar cod was caught in bottom trawl in the studied areas. 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 Novaja Zemlja south of 72ºN. East, south and west of Spitsbergen dense local concentrations were registered.

Abundance estimation

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

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

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 2000 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)	
2000	1999	1	77.1	33.8	9.2	8.0	709.0	269.4
1999	1998	2	15.7	20.0	27.7	21.6	434.5	432.4
1998	1997	3	12.5	14.6	47.1	40.9	589.3	597.6
1997	1996	4	2.3	0.8	58.2	57.6	132.1	48.4
Total stock in								
2001	2000	1-5	107.7	69.2	17.4	19.5	1869.6	1347.8
Based on TS value: 21.8 log L - 72.7, corresponding to σ = $6.7 \cdot 10^{-7} \cdot L^{2.18}$								

The 2000 year class (the one-year-olds) is 2.3 times as numerous as the one-group measured last year, and their mean weight is 1.2 gram higher. The biomass is, therefore, 2.6 times larger than that of the one-year-olds measured last year. The size of the 1999 year class (the two-year-olds) is somewhat lower than that of the two-group found last year but with higher mean weight. The biomass is, therefore, equal to that of the 1998 year class estimated last year. The three-years-old fish (1998 year class) is also less numerous than the three-group estimated last year but has a much higher mean weight. Consequently, the biomass of this age group is about equal to that for the corresponding age group during the 2000 survey. The four-year-olds (1997 year class) are scarcely found. The total stock, estimated at 1.9 million tonnes, is almost 1.4 times larger than that estimated last year, and is the highest on record. It should be noted that the area west of Spitsbergen, which contained more than 200 000 t of polar cod was not covered last year. In addition, the coverage extended further north to the east of Spitsbergen this year. Therefore, a part of the increase in the estimate might stem from the increase in area coverage of the stock.

The text tables below show the "survey-mortality rates" of polar cod of the year classes 1984 to 1999.

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
2000-2001	1999	33.8	15.7	54	0.77

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
2000-2001	1998	20.0	12.5	38	0.47

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 5 000 and 50 000 tonnes of polar cod, in 1998 the catch was negligible. In 1999 the catch was about 20 000 tonnes and 35 000 tonnes in 2000. 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 probably only partly covered. The main registration of the one- to -three-year-old fish was observed in the southern part of the

Barents Sea (Fig. 20). The south-western border of its distribution was not determined due to deficit of time and since herring is not among the target species in this survey. Northwards herring were distributed up to 76° 00' N, which is unusual for the herring autumn distribution.

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. In addition, the presence of 0-group herring during autumn may cause difficulties when distributing s_A-values on age groups of herring. For these reasons, the stock size estimates obtained during the autumn may be unrealistic, but may indicate the relative strength of the year classes. Therefore, it was decided to present a stock size estimate for 1- 2- and 3-group herring as an additional source of information to that obtained during the May survey.

The stock abundance estimate by age, number, and weight was calculated using the same computer program 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 12.8 billion specimens (Table 5). One-year-old fish constituted 0.5 billion specimens, two-year-old fish 10.5 billion specimens, and three-year-old fish 1.7 billion specimens. The total biomass of young herring amounted to 776 000 tonnes, a decrease of about 20% from last years autumn survey. The estimates of one- and two-year-olds were somewhat higher than those obtained during the Russian survey in May 2001, while the estimate of the three-year-olds was considerably lower. This estimate of the 1998 year class confirms, however, that the size of this year class may be considerably lower than estimated during May 2000. The 0-group herring was estimated at 24.3 billion individuals, with a mean weight of 5.4g.

Blue whiting

In the south-western parts of the Barents Sea young blue whiting were observed in considerable amounts, more than 50% belonged to the 2000 year class. A quantitative estimation was not attempted since only a small area of the total distribution area of this species was covered. The geographical distribution of blue whiting inside the surveyed area is shown in figure 21.

Hydrographical conditions

Temperature charts in 0, 50, 100, 200m, and bottom depths are shown in Figs. 22-26. In September the cooling of surface waters has begun in the north of the Barents Sea because of earlier and more intensive decrease of air temperature there for this period. From August to September the surface temperature decreased by on average 0.5-1.0°C. However, it increased (by 0.5°C) in the southwest of the sea, where heating continued. The thickness of the upper mixed layer was mainly about 15-25 m in the east of the region and about 5-10 m in the southeastern and northern parts.

The maximum horizontal temperature gradients (0.2°C per nautical mile) were observed in the western part of the sea in the Polar Front at 50 m depth. This area of the frontal zone had sharper gradients than the other ones, for example, than the central one. Here the gradient was more eroded. A sharpened frontal zone was also found at the same depth near Novaja Zemlja (Coastal Branch of Novaja Zemlja current).

The surface water temperature was on average 1.5°C higher than the long-term mean in the western and southern parts of the region and 2.7°C in the eastern part.The maximum positive anomalies (up to +3.0°C) were observed in the east of the Barents Sea (Novaja Zemlja current and its branches). The bottom temperature was close to normal. The surface water temperature differences between 2001 and 2000 were on average +1.0°C for the western, central and eastern, +2.0°C for the northern, and -0.7°C for the southern parts of the area. The bottom temperature was the same as last year except for the south of the sea, where it was on average 1.0°C lower.

Acoustic experiments

During the first part of the survey, some acoustic experiments were undertaken on board "Johan Hjort". The BAB (Bergen Acoustic Buoy) was deployed at two instances in areas of clean capelin registrations, and the reactions of the capelin were observed when "Johan Hjort" approached and passed the buoy at short distance. By visual inspection of the echograms from the buoy echo sounder, it was not possible to detect any reaction even when the depth of the capelin registrations was only 20m, during neither daytime nor nighttime. However, calculations of volume backscattering from various depths may show slight reactions not visible on the echograms. The results from these experiments will be presented at the acoustic symposium in Montpellier, France, in June 2002.

Table 1. Acoustic estimate of Barents Sea capelin, September-October 2001.

Length (cm)	Age/Year class 1 2000	2 1999	3 1998	4 1997	5 1996	Sum (10^6)	Biomass (10^3 t)	Mean weight (g)
5.0 - 5.5	34					34	0.0	0.5
5.5 - 6.0								
6.0 - 6.5	296					296	0.3	0.9
6.5 - 7.0	1199					1199	1.3	1.1
7.0 - 7.5	2592					2592	2.8	1.1
7.5 - 8.0	3756					3756	5.0	1.3
8.0 - 8.5	5134					5134	9.7	1.9
8.5 - 9.0	9207					9207	21.0	2.3
9.0 - 9.5	17351	3				17353	46.1	2.7
9.5 - 10.0	23350	42				23391	74.3	3.2
10.0 - 10.5	25616	381				25998	93.5	3.6
10.5 - 11.0	15014	2457				17471	77.2	4.4
11.0 - 11.5	7086	8039				15125	80.6	5.3
11.5 - 12.0	2815	24258				27073	169.2	6.3
12.0 - 12.5	85	32271	6			32362	236.9	7.3
12.5 - 13.0	29	32591	63			32683	266.2	8.1
13.0 - 13.5		28541	52			28592	275.7	9.6
13.5 - 14.0	23	21965	89			22078	251.3	11.4
14.0 - 14.5		21221	209	19		21450	282.4	13.2
14.5 - 15.0		17545	372			17917	270.2	15.1
15.0 - 15.5		9455	2430			11885	199.0	16.7
15.5 - 16.0		7900	3588	50		11538	223.8	19.4
16.0 - 16.5		4619	4476	7		9102	200.6	22.0
16.5 - 17.0		3888	6355	7		10250	259.6	25.3
17.0 - 17.5		2315	4657	280		7253	213.8	29.5
17.5 - 18.0		1024	3171	59		4253	139.9	32.9
18.0 - 18.5		119	3685	198		4002	146.8	36.7
18.5 - 19.0		44	860	351	61	1316	54.4	41.3
19.0 - 19.5		60	463	46		569	24.7	43.4
19.5 - 20.0			25	34		59	2.9	49.1
20.0 - 20.5				11		11	0.5	48.0
TSN (10^6)	113587	218737	30500	1063	61	363948		
TSB (10^3 t)	374.8	2401.1	813.8	37.7	2.5		3630.0	
Mean length (cm)	9.80	13.40	16.80	18.00	18.80	12.60		
Mean weight (g)	3.3	11.0	26.7	35.5	41.4			10.0
SSN (10^6)	0	68190	30291	1062	61	99605		
SSB (10^3 t)	0	1167	812	38	3		2019	

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 1973-2001. 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
2001	0.37	3.3	2.40	11.0	0.81	26.7	0.04	35.5	+	41.4	3.25
Average	0.71	3.5	1.45	9.2	0.85	16.6	0.29	20.7			2.56

[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 2001

	Age/Year class							
Length (cm)	1	2	3	4	5	Sum	Biomass	Mean
	2000	1999	1998	1997	1996	(10^6)	(10^6)	weight (g)
6.5 - 7.0	149					149	0.3	2.1
7.0 - 7.5	573					573	1.5	2.6
7.5 - 8.0	1801					1801	5.9	3.3
8.0 - 8.5	3818					3818	13.6	3.6
8.5 - 9.0	5363					5363	22.1	4.1
9.0 - 9.5	7343					7343	39.2	5.3
9.5 - 10.0	7101					7101	44.5	6.3
10.0 - 10.5	9002					9002	66.4	7.4
10.5 - 11.0	8883					8883	74.1	8.3
11.0 - 11.5	8056	137				8192	79.7	9.7
11.5 - 12.0	8328	136				8464	93.4	11.0
12.0 - 12.5	4900	248				5148	67.4	13.1
12.5 - 13.0	4734	233	1			4968	73.6	14.8
13.0 - 13.5	3285	342				3626	64.4	17.7
13.5 - 14.0	2071	653				2724	53.5	19.6
14.0 - 14.5	1189	1042				2231	47.9	21.5
14.5 - 15.0	348	1485	49			1883	41.9	22.3
15.0 - 15.5	203	2197	210			2611	61.7	23.6
15.5 - 16.0		1984	184			2168	60.8	28.1
16.0 - 16.5		1963	569			2532	69.1	27.3
16.5 - 17.0		1823	161		84	2068	65.5	31.7
17.0 - 17.5		1258	414	41		1712	57.4	33.5
17.5 - 18.0		982	663			1645	62.8	38.2
18.0 - 18.5		699	1400			2099	82.8	39.4
18.5 - 19.0		34	1786	159		1979	90.0	45.5
19.0 - 19.5		381	1570	372		2323	109.6	47.2
19.5 - 20.0		98	1575	119		1792	86.9	48.5
20.0 - 20.5			1669	105	1	1775	92.4	52.0
20.5 - 21.0			893	296		1189	71.6	60.2
21.0 - 21.5			453	508		961	60.1	62.5
21.5 - 22.0			351	177		529	32.3	61.0
22.0 - 22.5			275	91		366	21.5	58.8
22.5 - 23.0			203	90		293	22.2	75.8
23.0 - 23.5				211		211	19.7	93.7
23.5 - 24.0			29	72		101	5.1	50.2
24.0 - 24.5			34	27		61	5.6	91.4
24.5 - 25.0			8			8	0.9	110.0
25.0 - 25.5				4	14	18	1.7	92.1
25.5 - 26.0					3	3	0.3	106.0
26.0 - 26.5								
26.5 - 27.0								
27.0 - 27.5					2	2	0.3	164.0
TSN (10^6)	77144	15694	12499	2271	104	107713		
TSB (10^3 tonnes)	709.0	434.5	589.3	132.1	4.8		1869.6	
Mean length (cm)	10.70	15.80	19.20	20.90	18.40	12.7		
Mean weight (g)	9.2	27.7	47.1	58.2	45.6			17.4

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 1986-2001. TSN and TSB is 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	67.0	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
2001	77144	709.0	15694	434.5	12499	589.3	2271	132.1	107713	1869.6
Average	29838	229.4	9914	210.2	4028	145.4	438	22.1	44263	609.5

Table 5. Acoustic estimate of young herring by age in September-October 2001. 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 2000	2 1999	3 1998	Sum (10^6)	W (10^3)	Mean weight (g)
12.0-12.5	3.9			3.9	0.0	10.8
12.5-13.0	4.2			4.2	0.1	13.3
13.0-13.5	24.1			24.1	0.4	15.1
13.5-14.0	32.3			32.3	0.5	16.5
14.0-14.5	60.8			60.8	1.2	20.2
14.5-15.0	104.1			104.1	2.2	20.8
15.0-15.5	199.6			199.6	4.6	23.0
15.5-16.0	81.4			81.4	2.4	30.0
16.0-16.5		196.0		196.0	5.6	28.7
16.5-17.0		37.4		37.4	1.2	31.5
17.0-17.5		107.1		107.1	4.2	39.3
17.5-18.0	14.2	14.2		28.4	1.1	38.3
18.0-18.5		273.9		273.9	10.2	37.2
18.5-19.0		410.2		410.2	18.1	44.1
19.0-19.5		1581.2		1581.2	73.4	46.4
19.5-20.0		1572.2		1572.2	80.8	51.4
20.0-20.5		2687.6		2687.6	162.3	60.4
20.5-21.0		1272.2	141.4	1413.5	86.9	61.5
21.0-21.5		1245.9		1245.9	81.7	65.6
21.5-22.0		466.3		466.3	32.4	69.5
22.0-22.5		322.4	263.8	586.2	43.7	74.5
22.5-23.0		173.1	173.1	346.2	28.1	81.3
23.0-23.5		106.8	229.1	335.9	29.8	88.8
23.5-24.0		15.8	265.7	281.5	26.7	94.9
24.0-24.5		38.2	203.4	241.6	25.1	103.9
24.5-25.0		23.6	165.2	188.8	20.6	109.1
25.0-25.5			185.6	185.6	21.6	116.6
25.5-26.0			51.1	51.1	6.4	124.4
26.0-26.5			28.3	28.3	3.7	130.1
26.5-27.0			1.5	1.5	0.2	138.1
27.0-27.5			4.6	4.6	0.7	146.4
27.5-28.0			1.5	1.5	0.2	155.0
TSN (10^6)	524.5	10544.1	1714.4	12783		
TSB (10^3 tonnes)	11.96	604.33	159.95		776.25	
Mean length (cm)	14.9	20.15	23.49	20.38		
Mean weight (g)	22.8	57.3	93.3			60.72

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

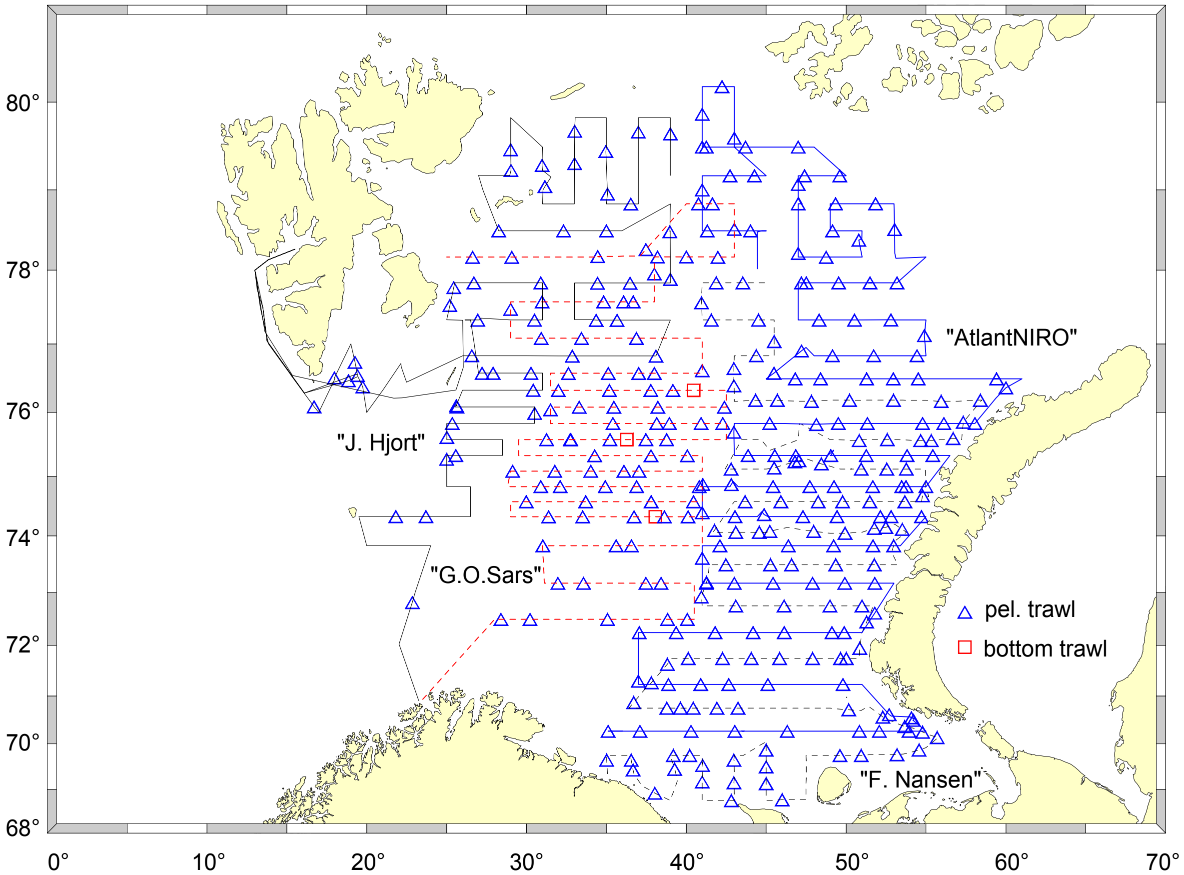

Figure 1 Survey routes and trawl stations for "G.O. Sars", "Johan Hjort", "AtlantNIRO" and "F. Nansen" September - October 2001

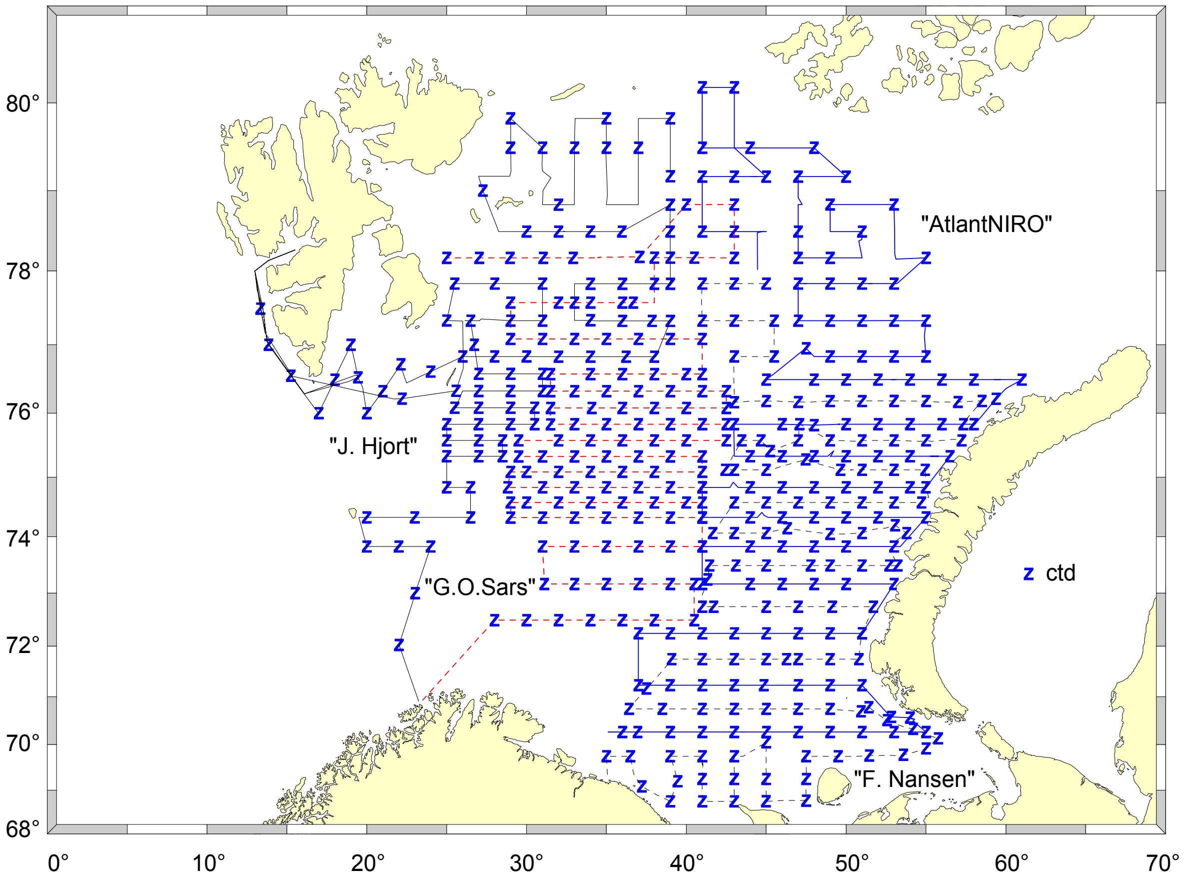

Figure 2 Survey routes and hydrographic stations for "G.O. Sars", "Johan Hjort", "AtlantNIRO" and "F. Nansen" September - October 2001

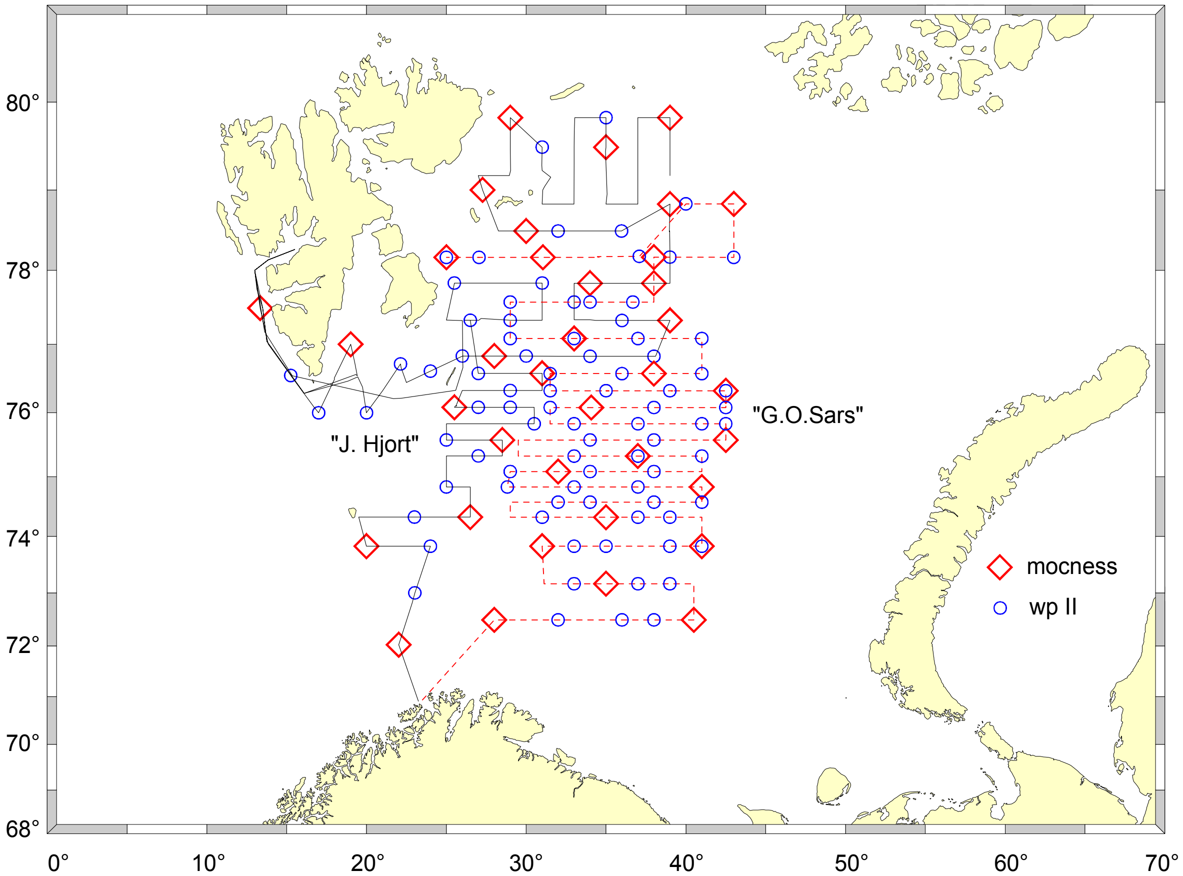

Figure 3 Survey routes and plankton stations for "G.O. Sars" and "Johan Hjort" September - October 2001

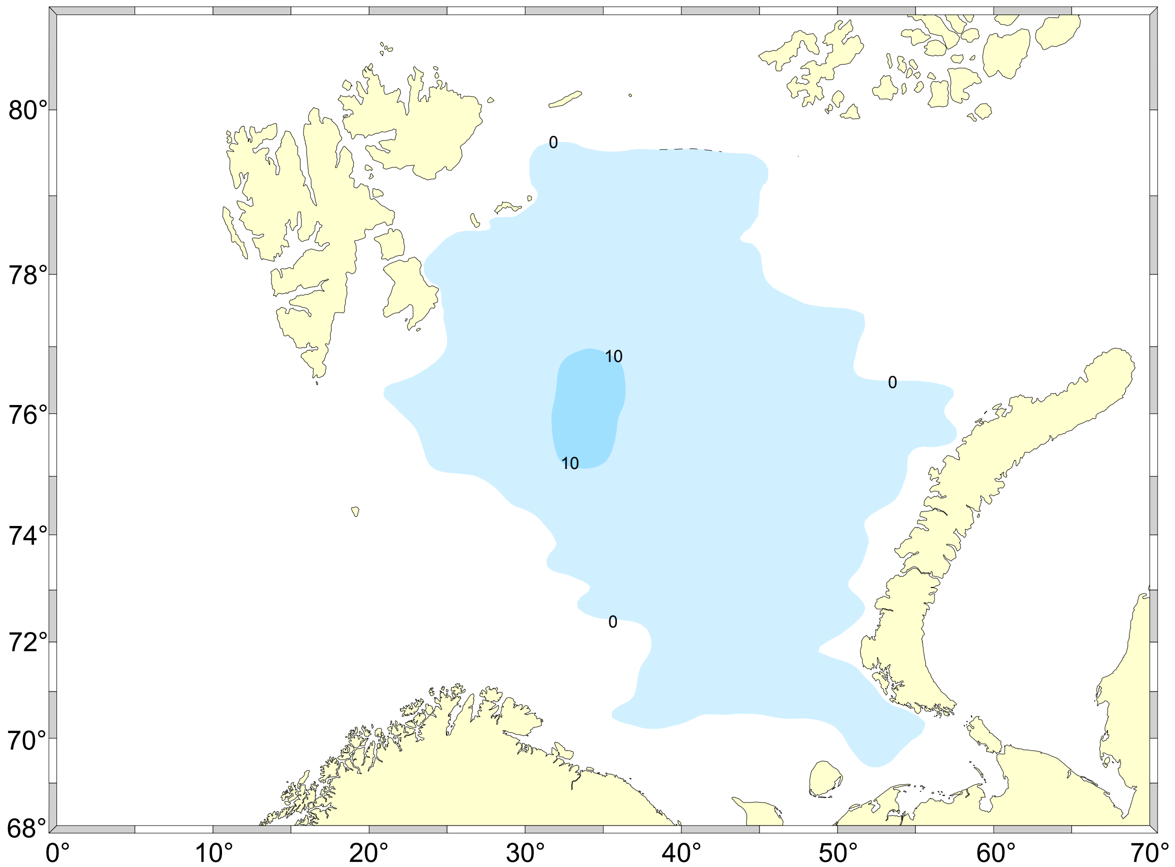

Figure 4 Estimated density distribution of one-year-old capelin (tonnes/square nautical mile) September - October 2001

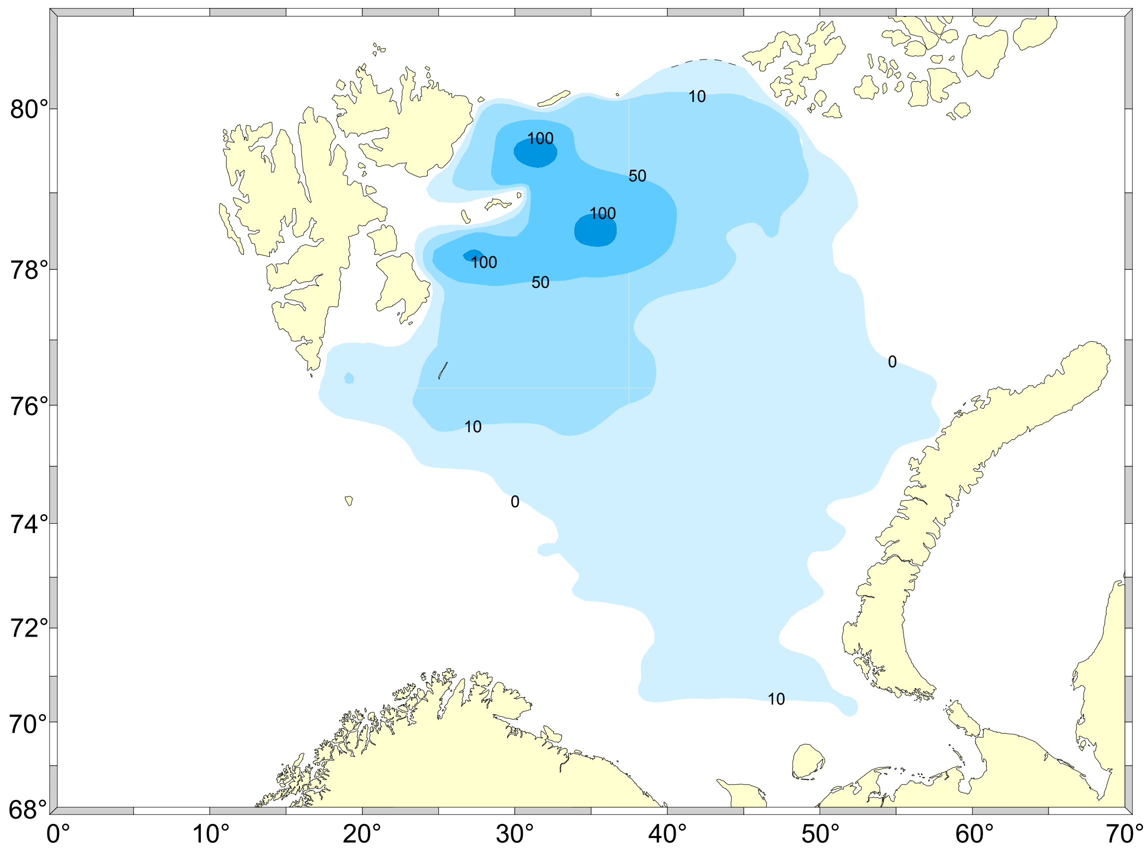

Figure 5 Estimated density distribution of two years old capelin (tonnes/square nautical mile) September - October 2001

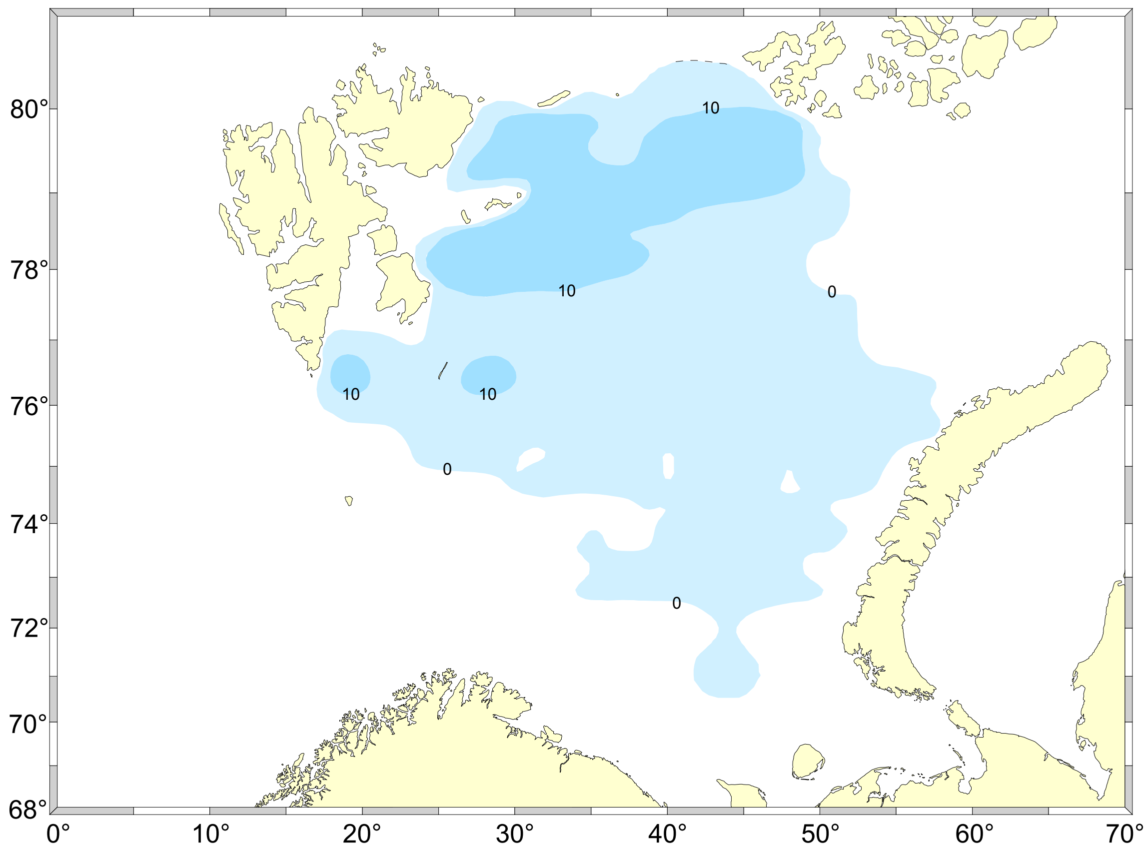

Figure 6 Estimated density distribution of three years old capelin (tonnes/square nautical mile) September - October 2001

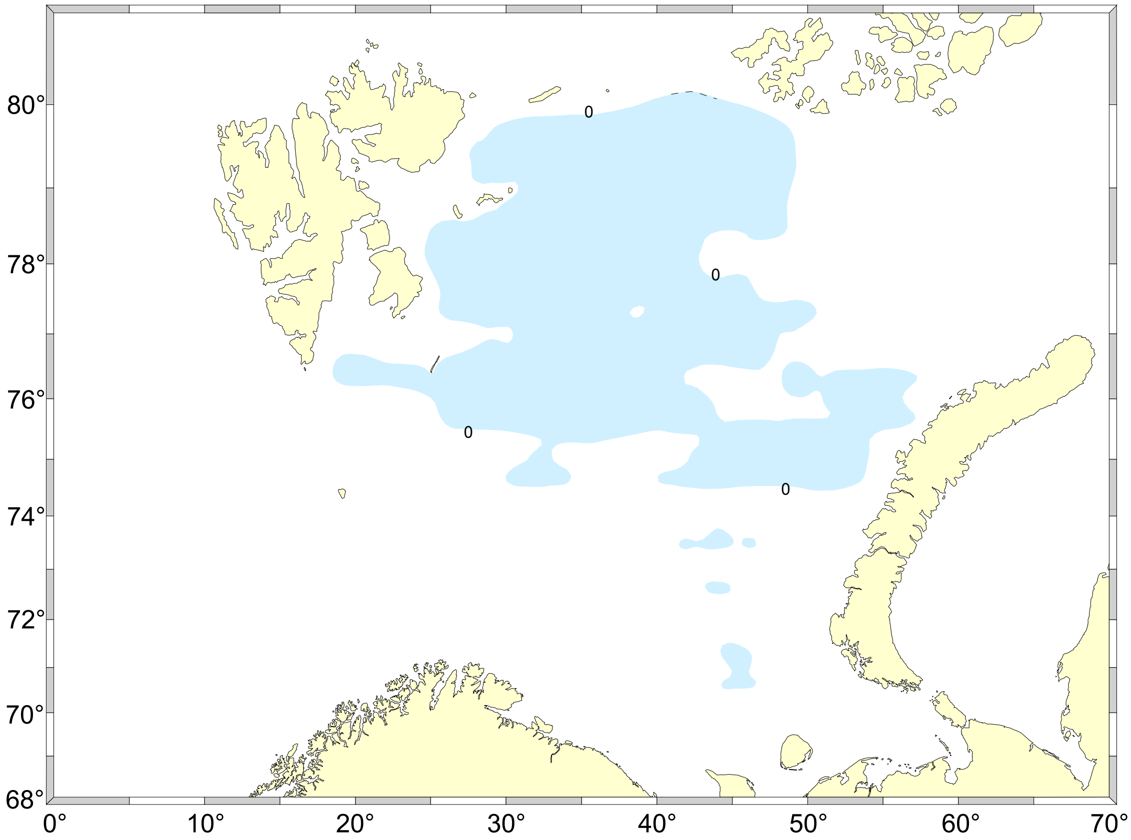

Figure 7 Estimated density distribution of four years old capelin (tonnes/square nautical mile) September - October 2001

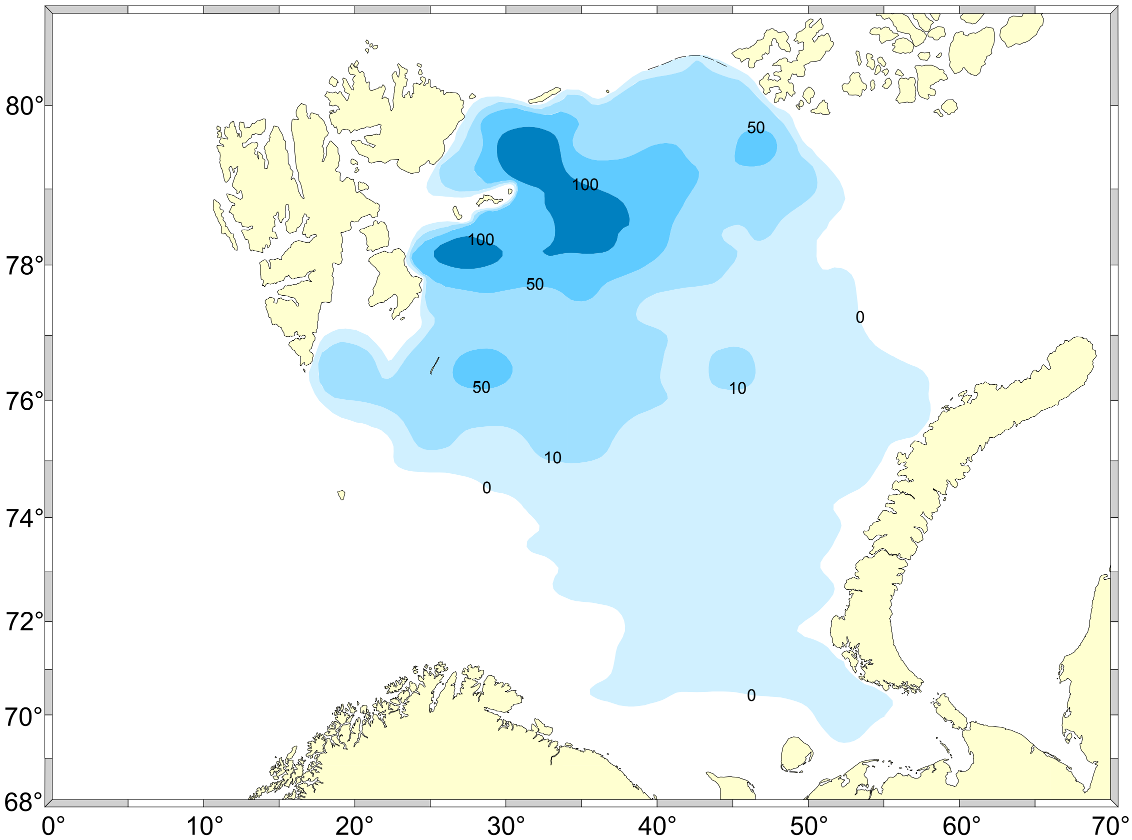

Figure 8 Estimated total density distribution of capelin (tonnes/square nautical mile) September -October 2001

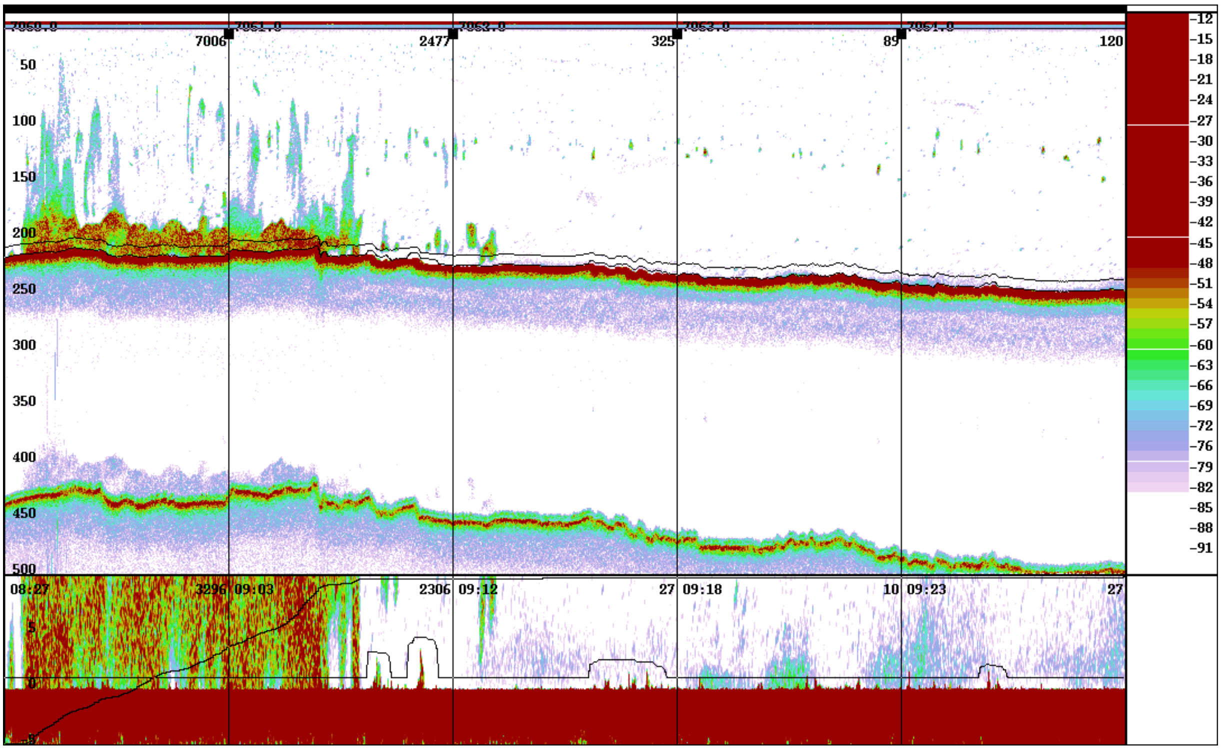

Figure 9 Echogram showing a typical distribution of adult capelin densely packed near bottom in areas where humpback whales were present. Echogram recorded at 79º18'N –33º00'E at 1. October 2001. Depth is 223 m.

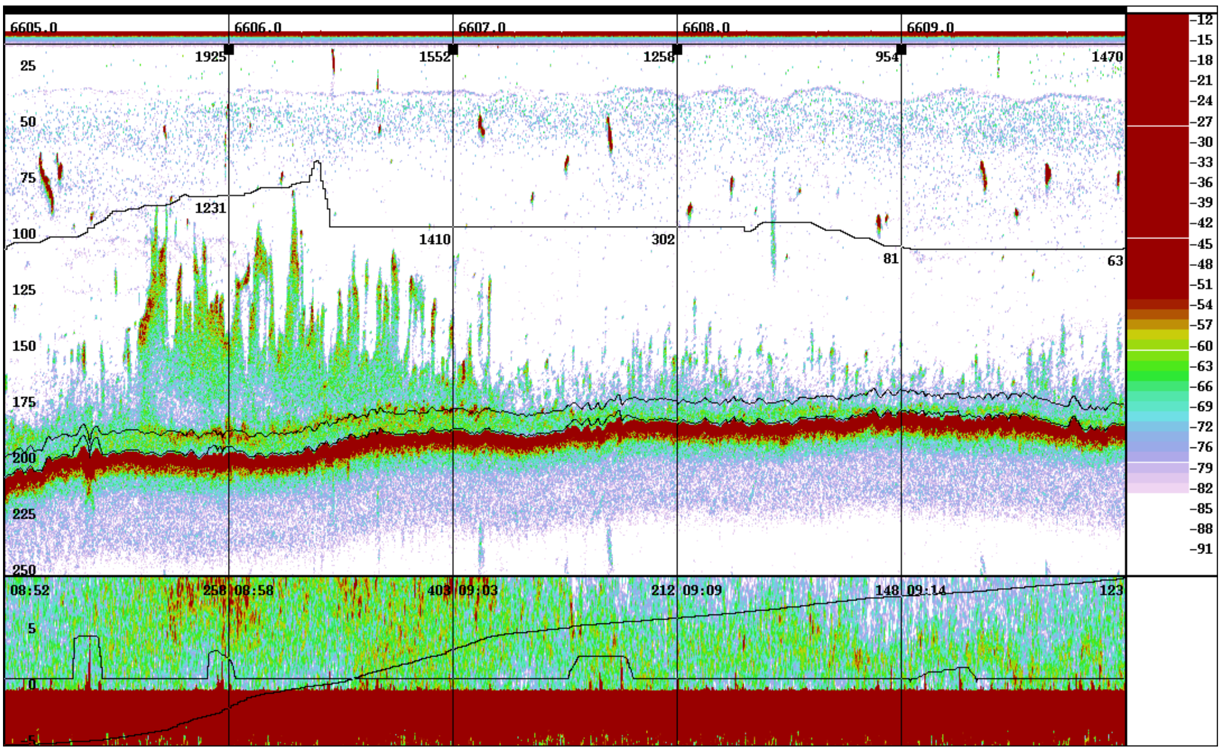

Figure 10 Echogram showing adult capelin distributed in typical schools at all depths, and mixed with polar cod in deeper water. A multisampler haul gave a mixture of polar cod and capelin (50/50) at 180m and at 110m, and capelin at 30-50m. Recorded at 78º29'N –38º58'E at 28 September 2001 07:00-.08:20 UTC.

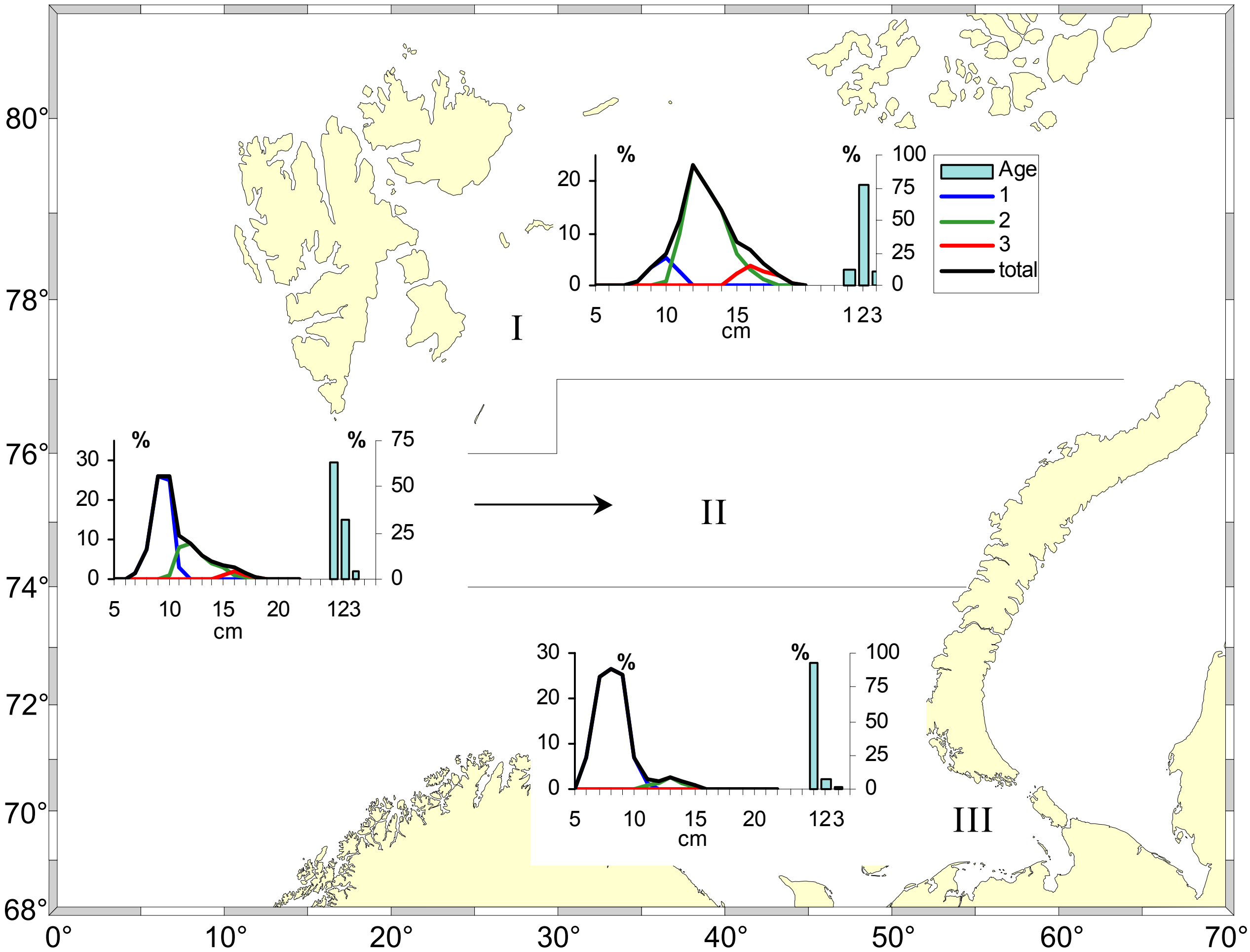

Figure 11 Age and length distribution of capelin in the three sub-areas used for stock size estimation September - October 2001

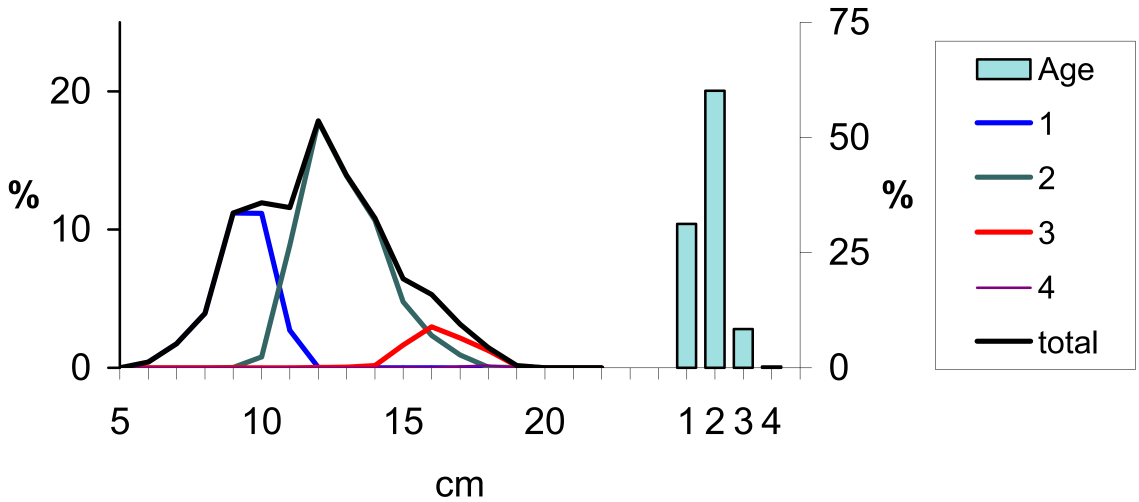

Figure 12 Total length and age distribution of capelin September - October 2001

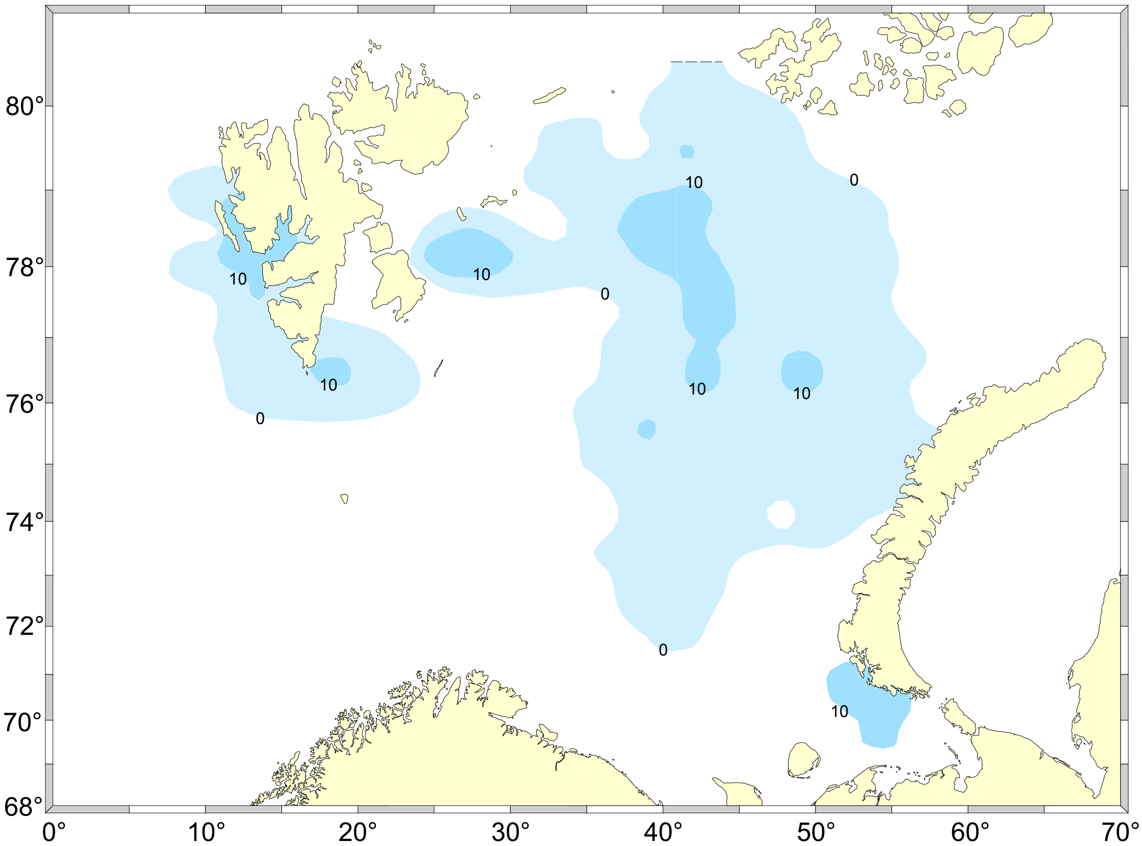

Figure 13 Estimated density distribution of one year old polar cod (tonnes/square nautical mile) September - October 2001

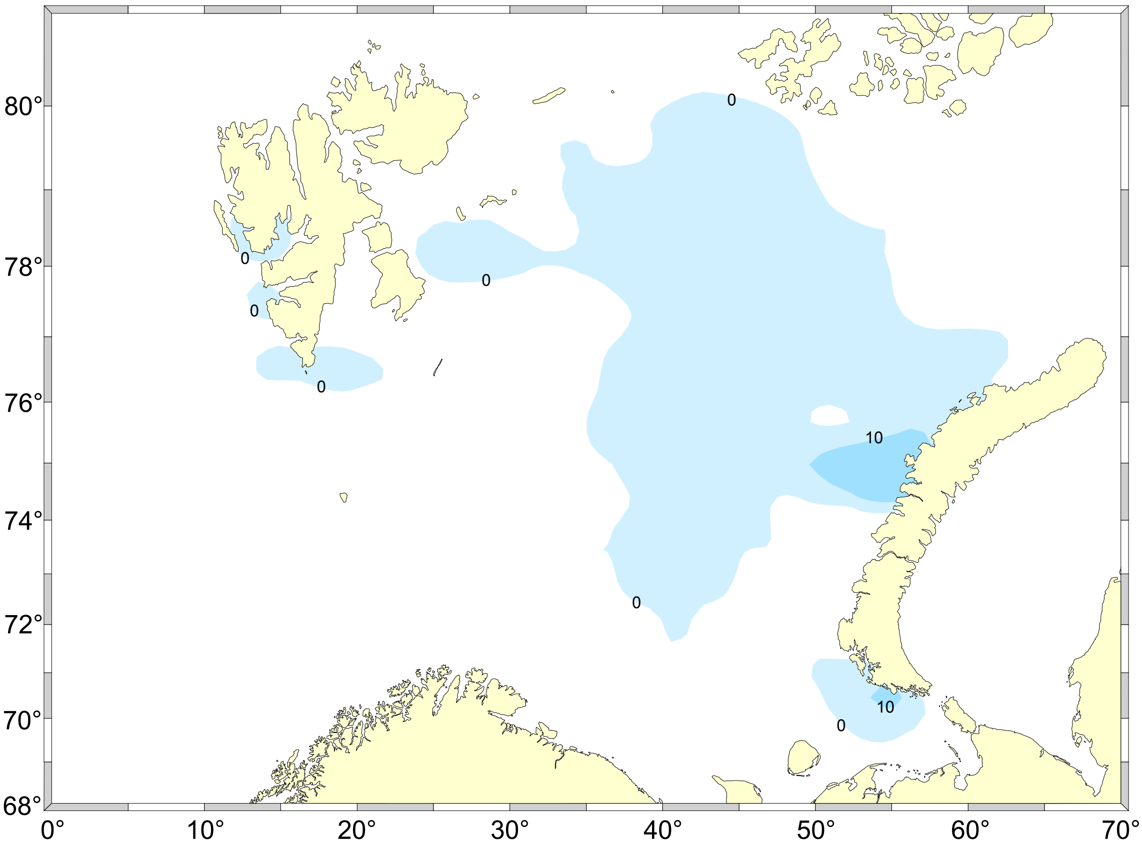

Figure 14 Estimated density distribution of two years old polar cod (tonnes/square nautical mile) September - October 2001

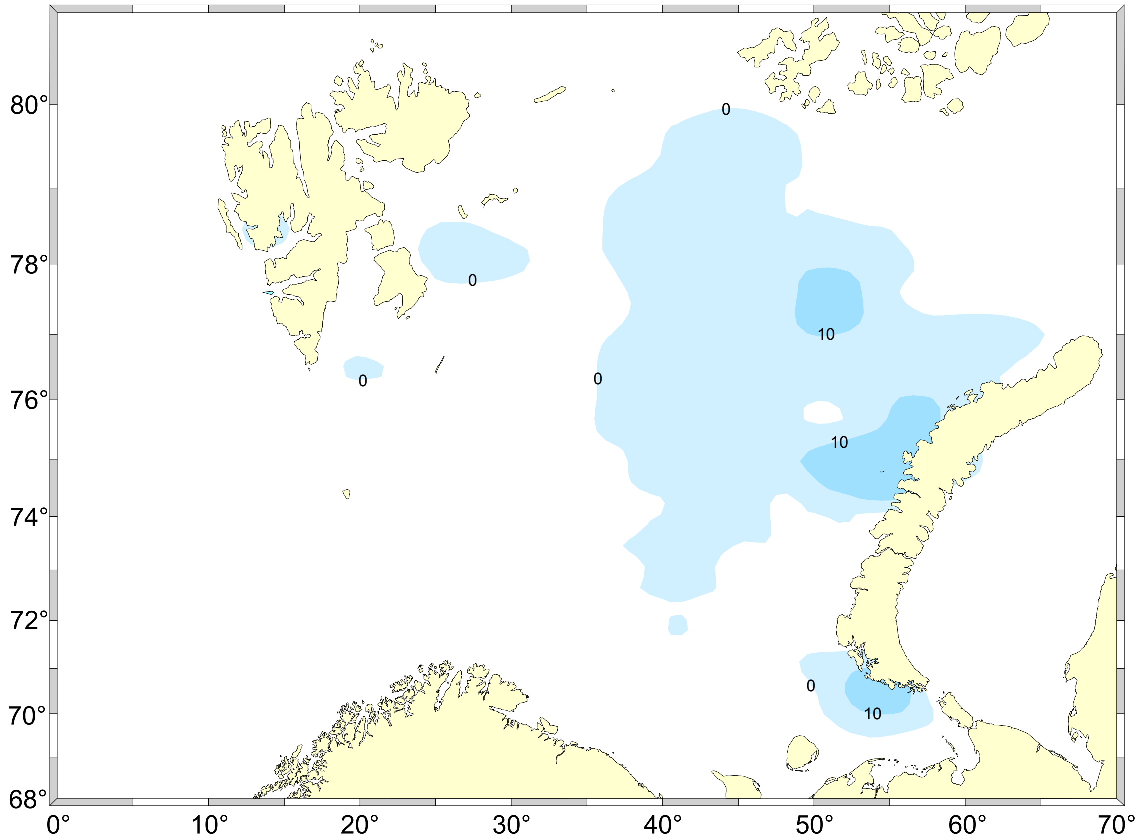

Figure 15 Estimated density distribution of three years old polar cod (tonnes/square nautical mile) September - October 2001

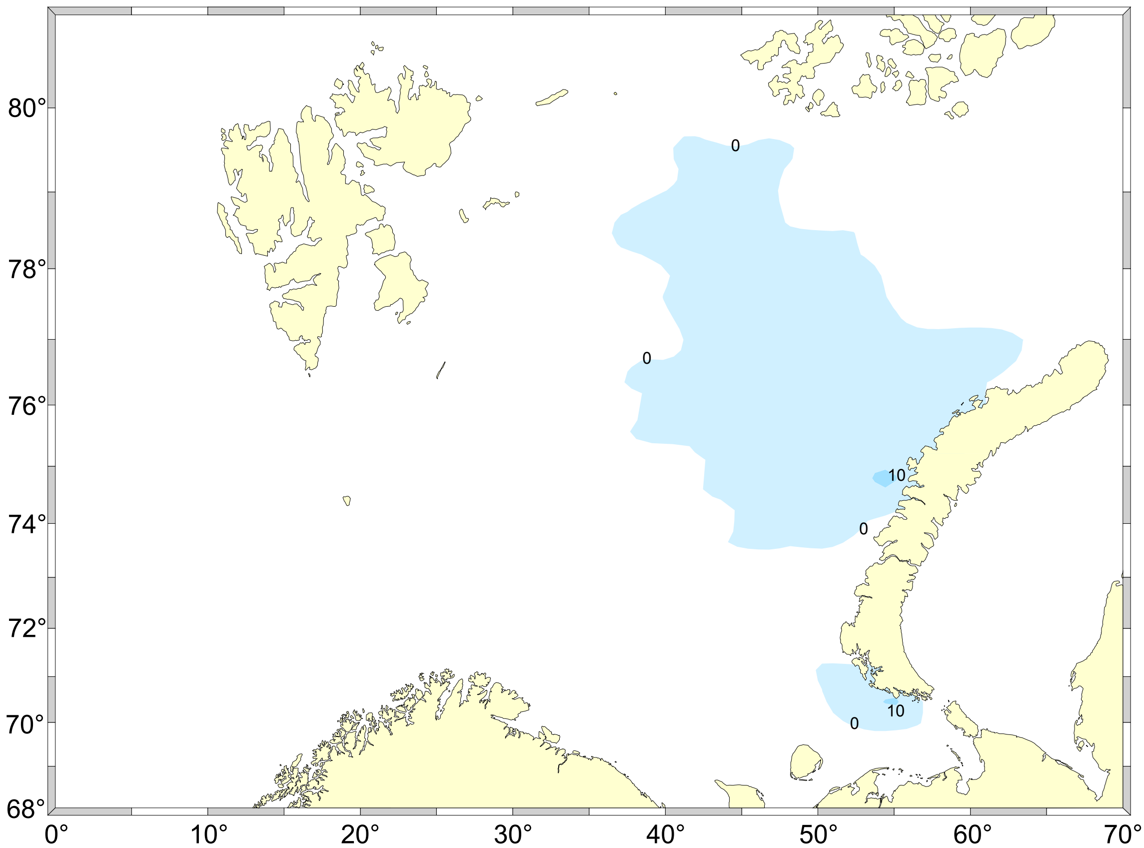

Figure 16 Estimated density distribution of four years old polar cod (tonnes/square nautical mile) September - October 2001

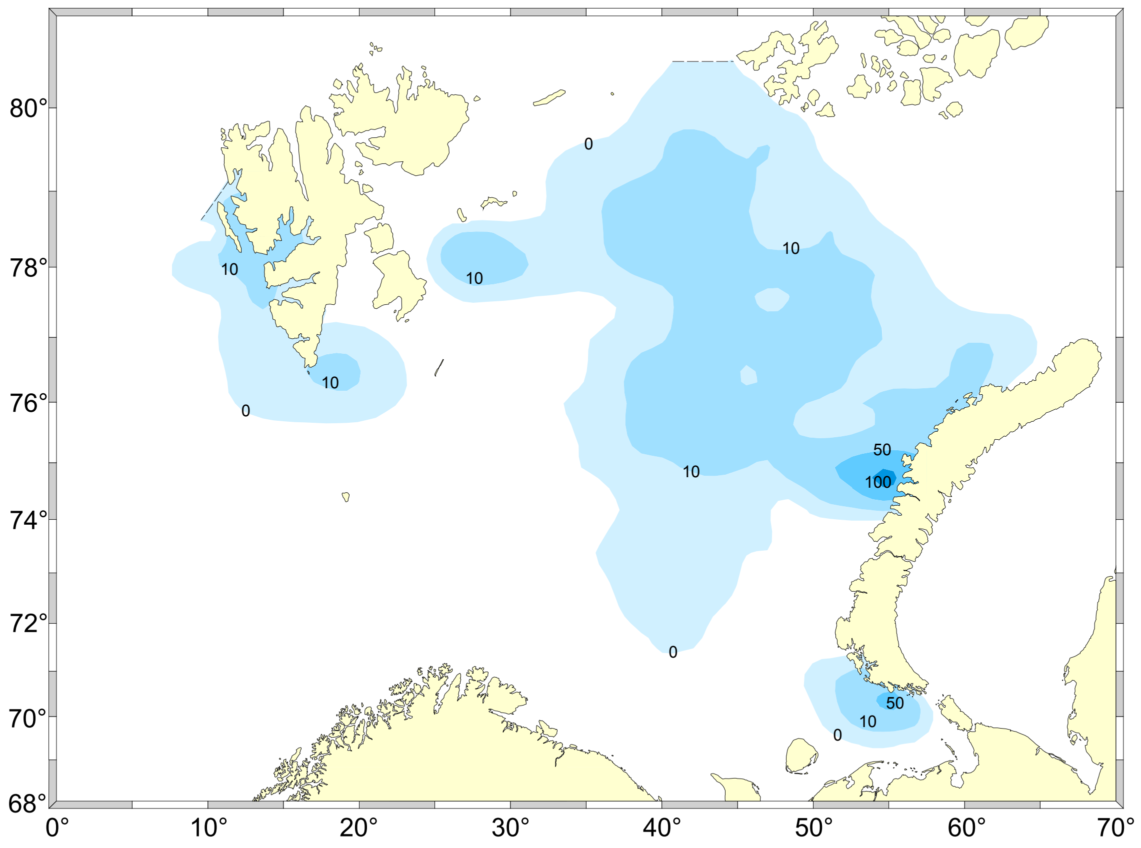

Figure 17 Estimated total density distribution of polar cod (tonnes/square nautical mile) September - October 2001

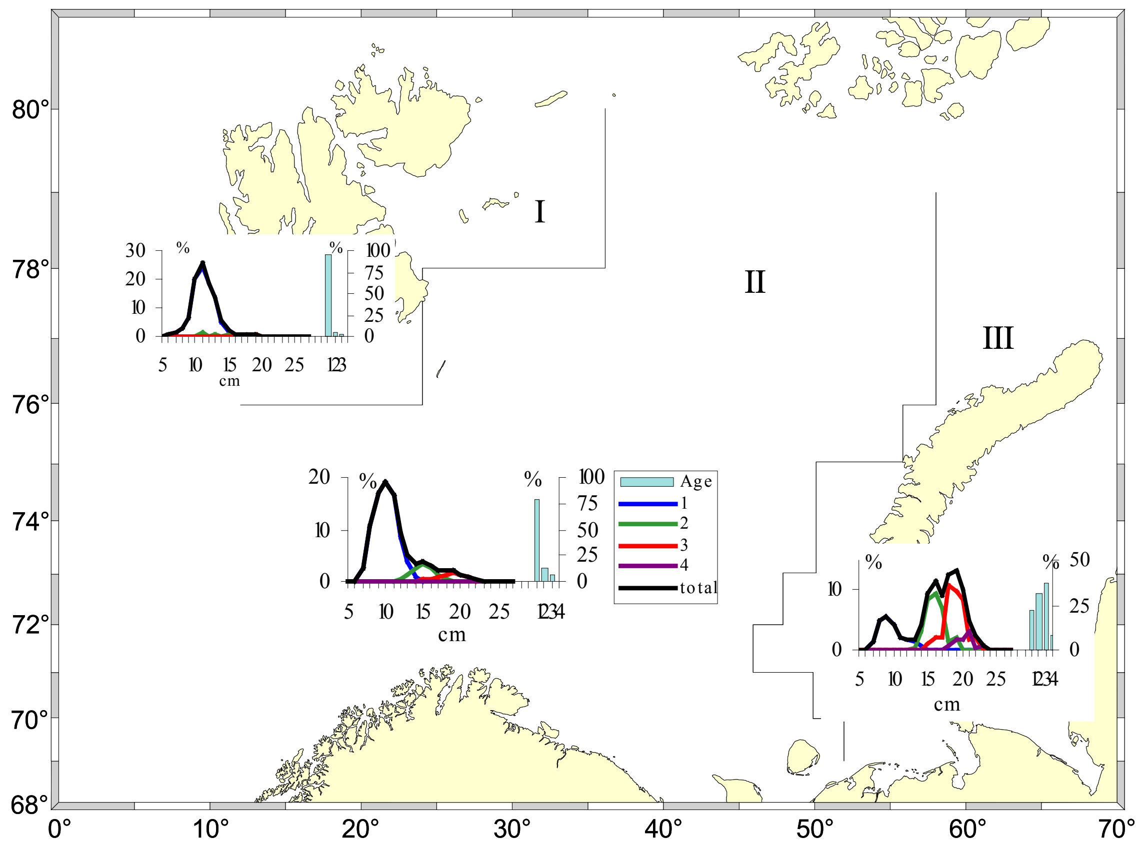

Figure 18 Length and age distribution of polar cod in the three sub-areas used for stock size estimation September- October 2001

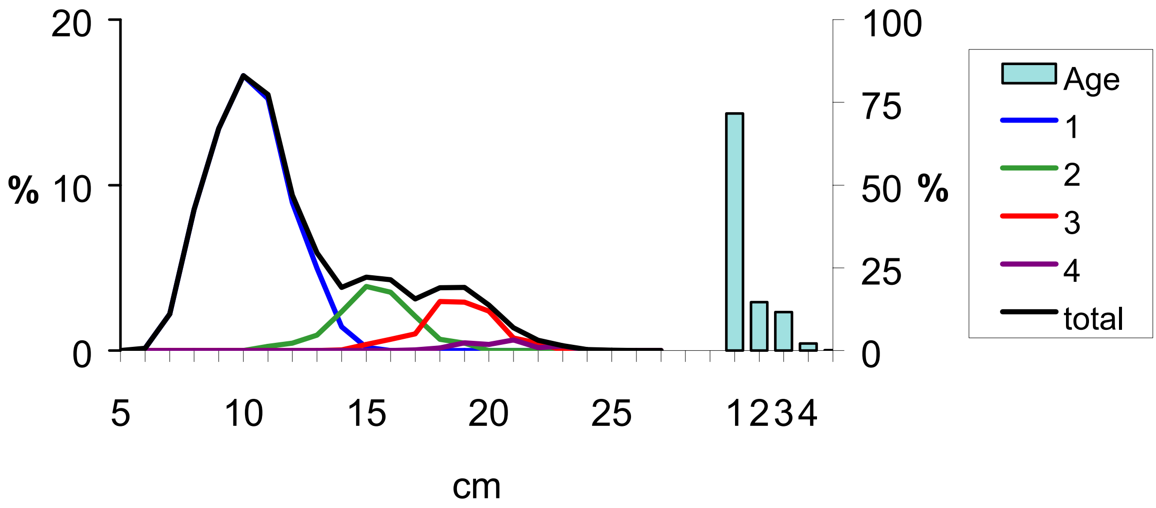

Figure 19 Total length and age distribution of polar cod September - October 2001

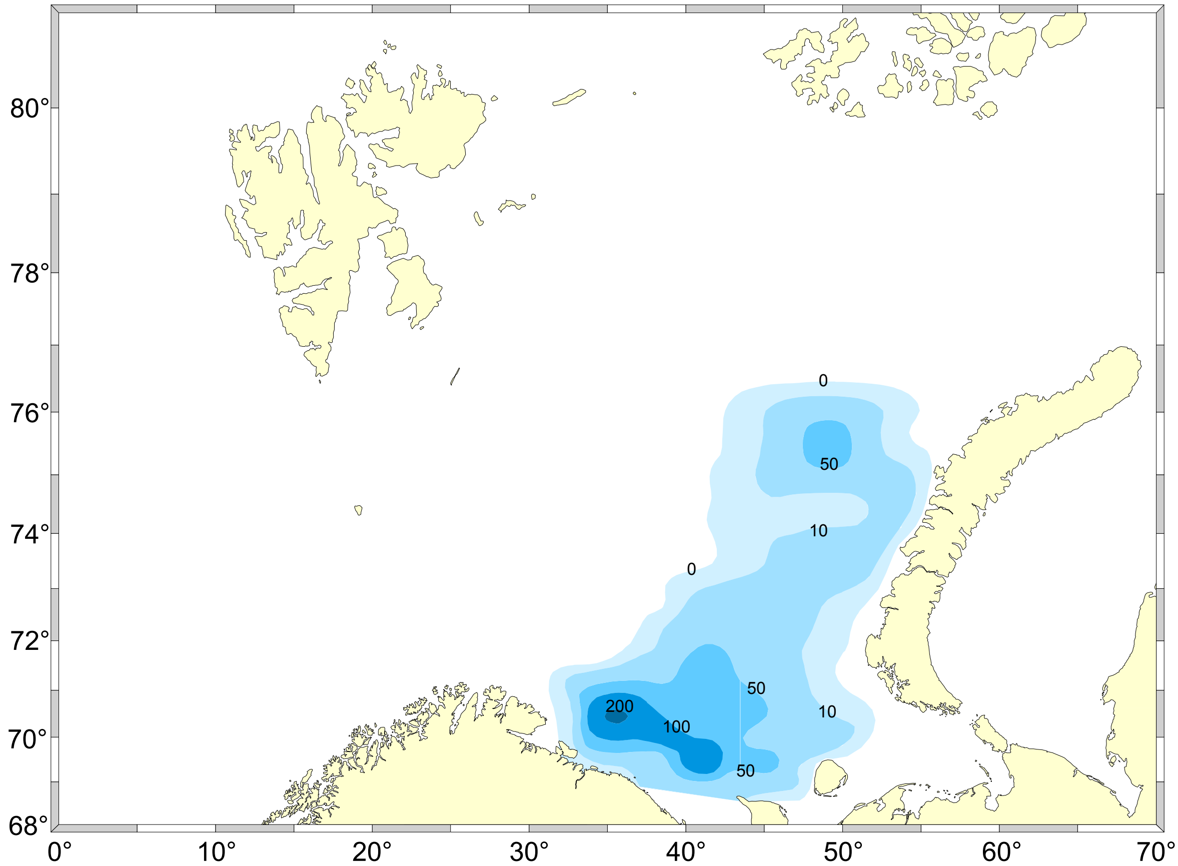

Figure 20 Estimated density distribution of 1- 3group herring (s_A/square nautical mile) September - October 2001

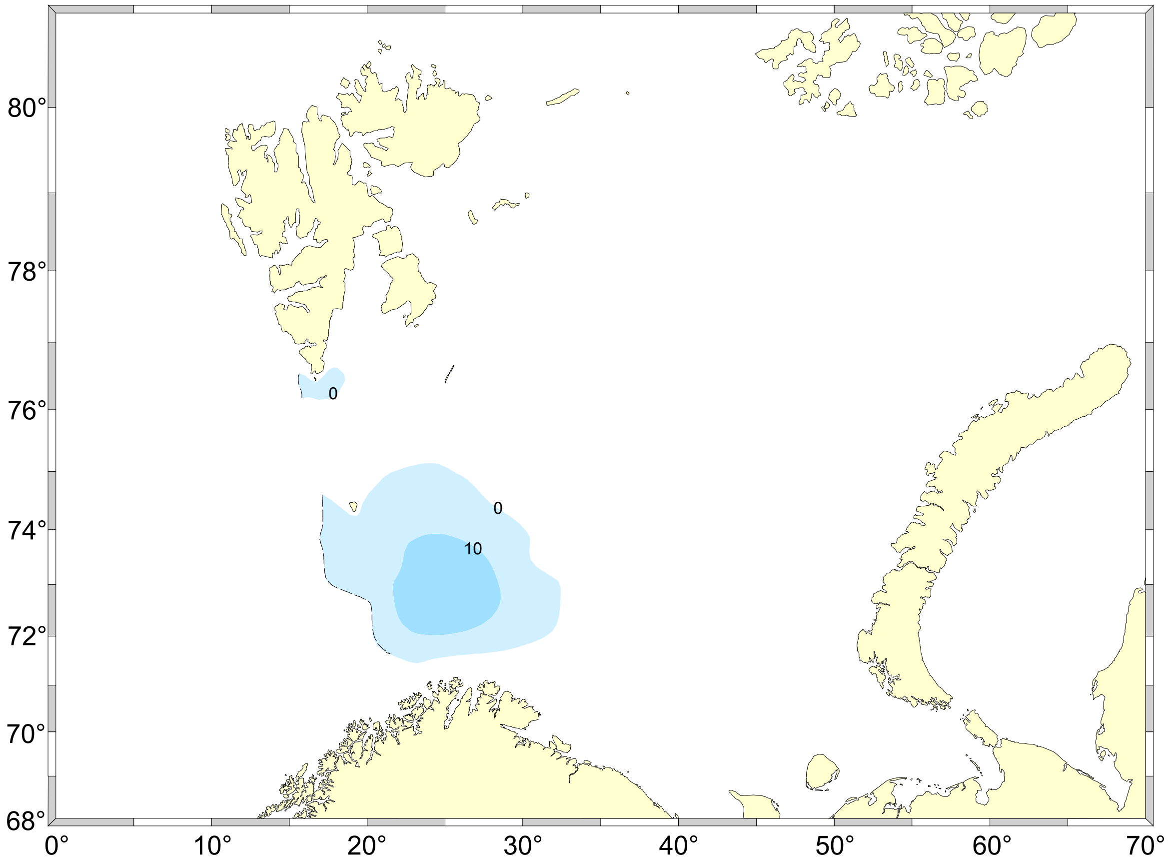

Figure 21 Estimated density distribution of young blue whiting (tonnes/square nautical mile) September - October 2001

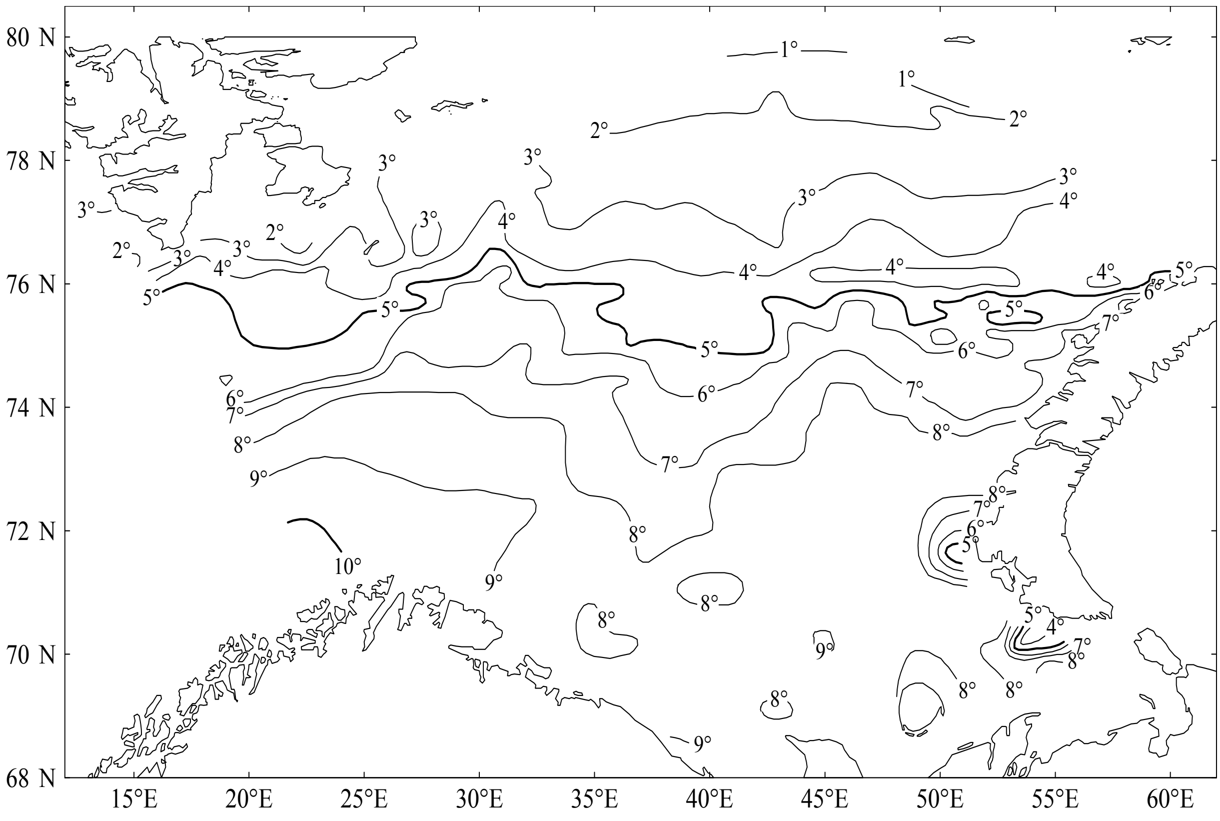

Figure 22 Temperature at the surface September - October 2001

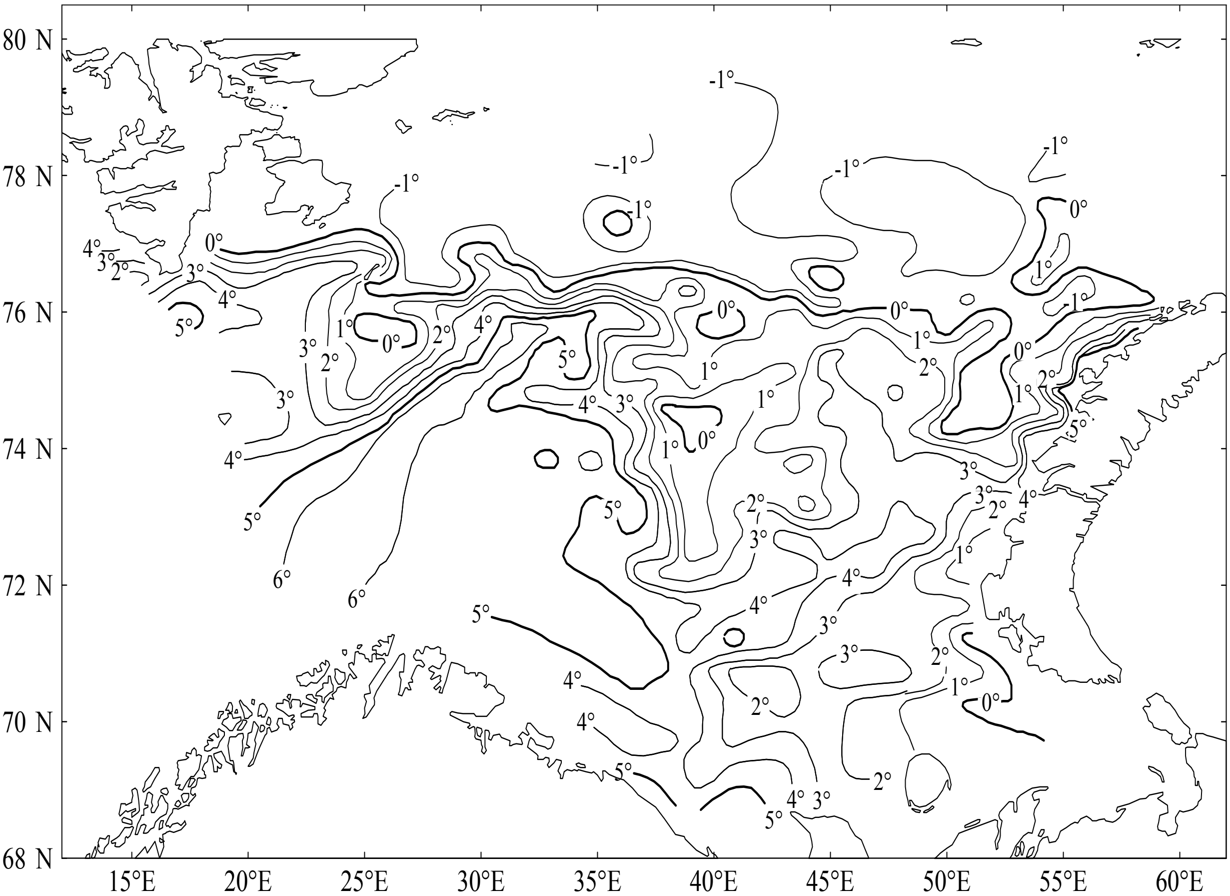

Figure 23 Temperature at 50 m September - October 2001

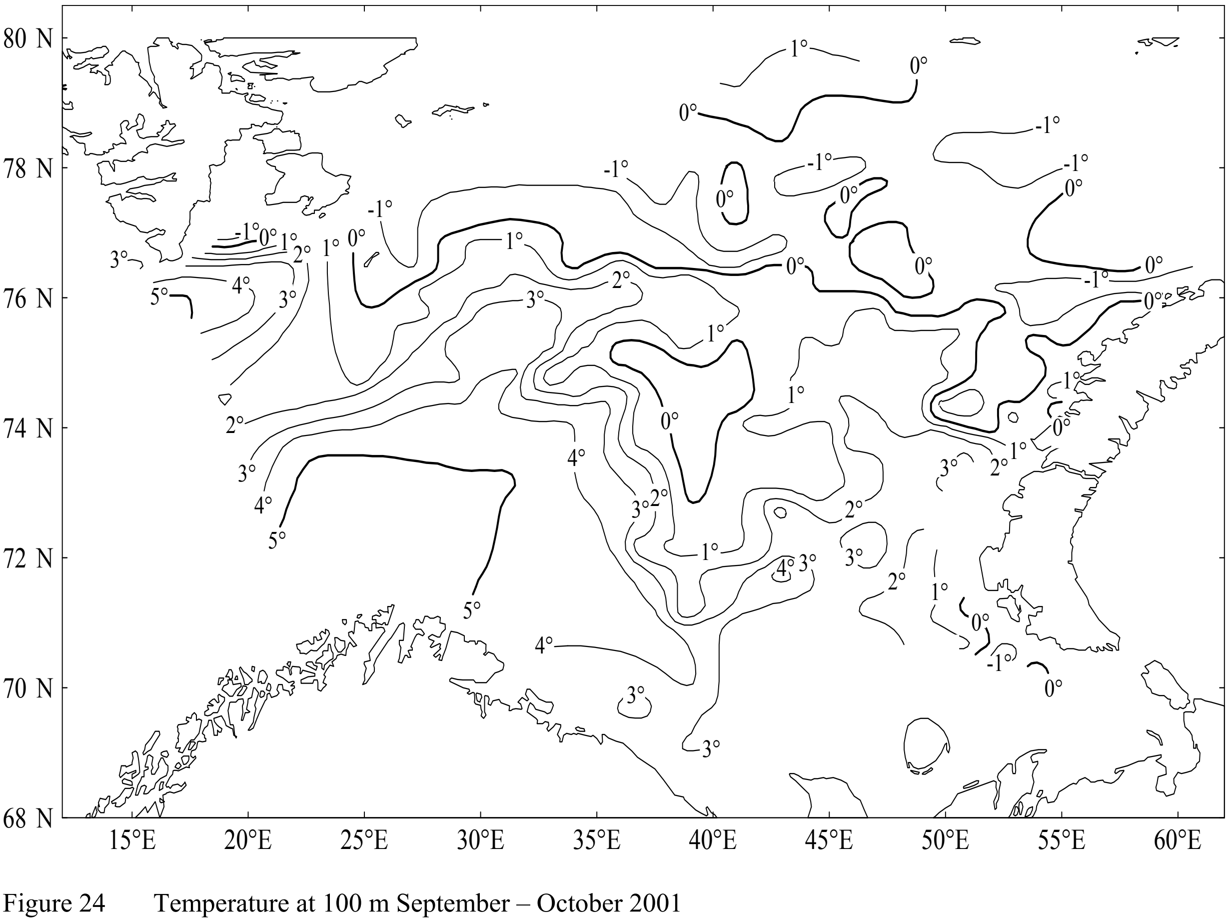

Figure 24 Temperature at 100 m September – October 2001

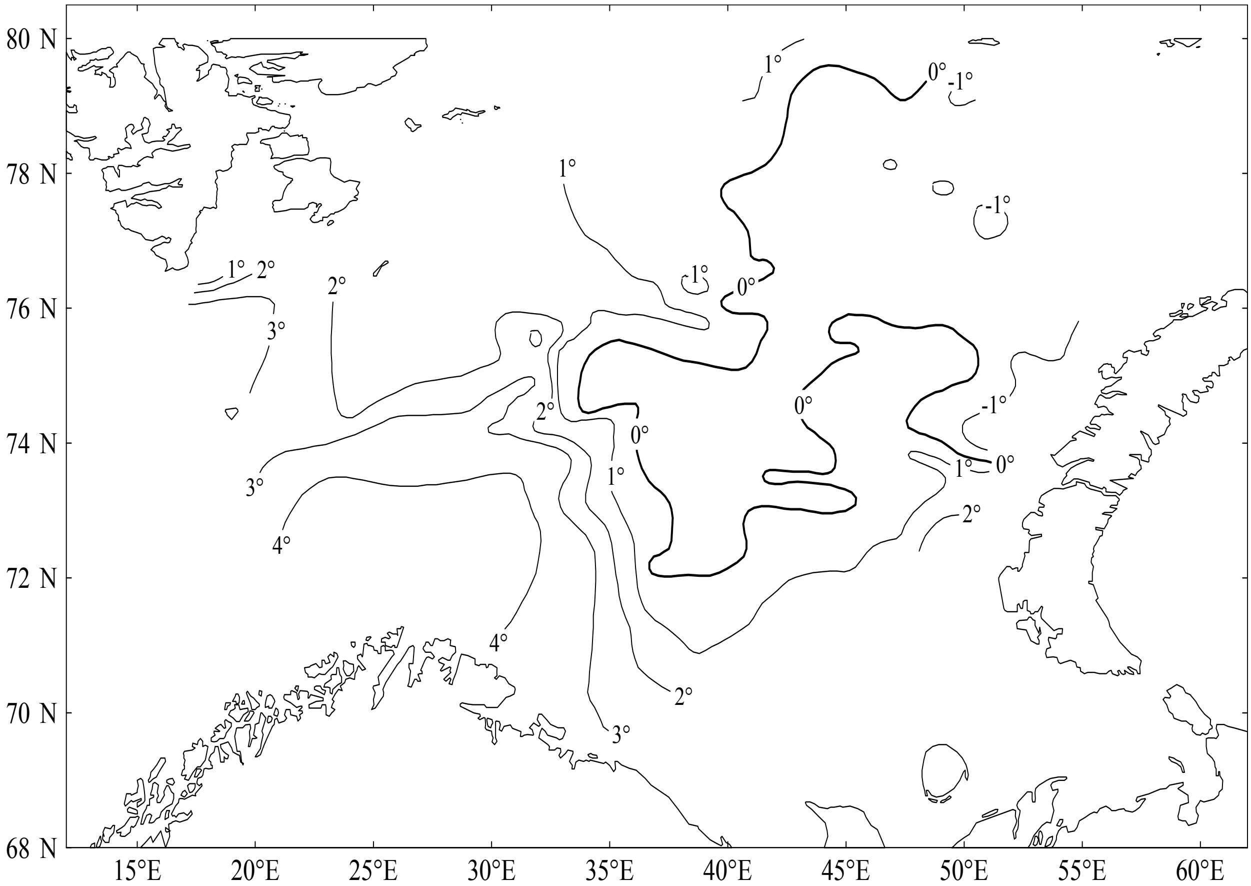

Figure 25 Temperature at 200 m September - October 2001

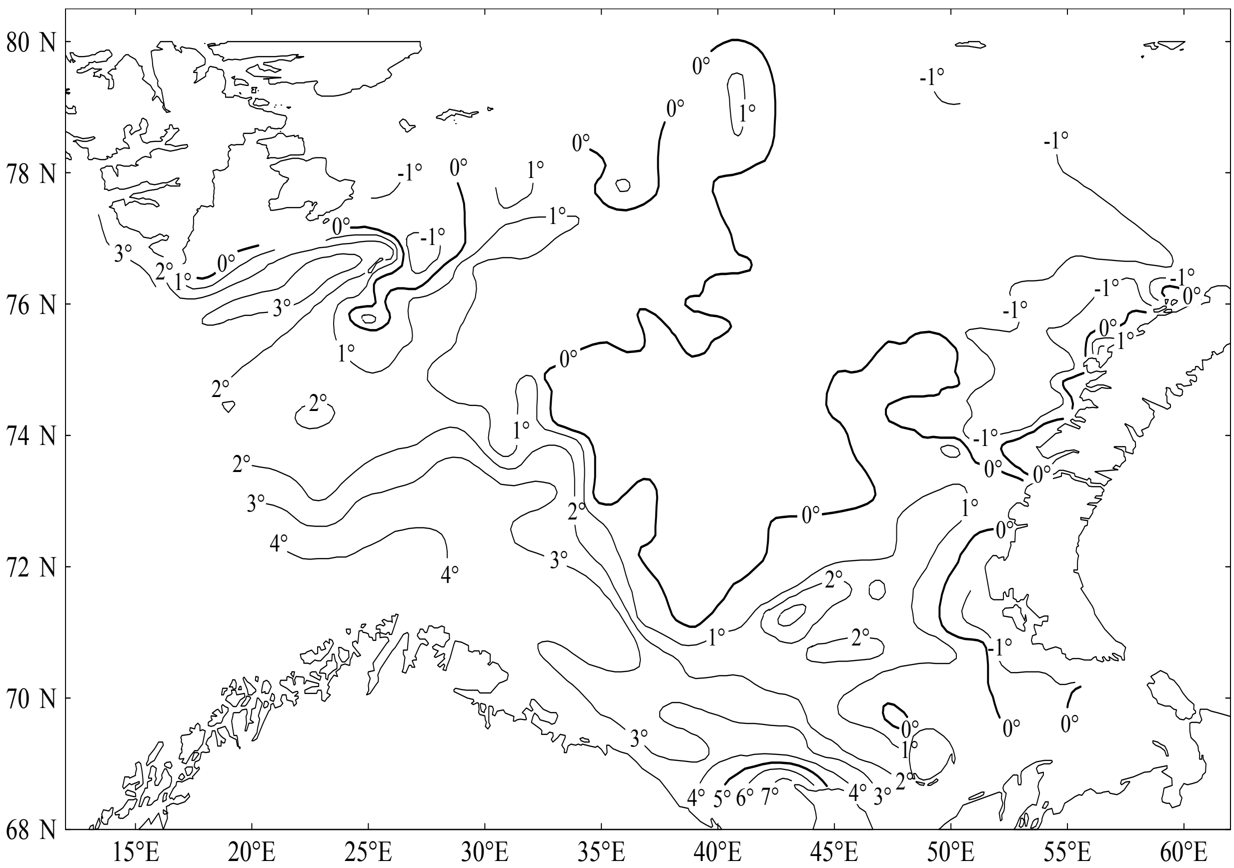

Figure 26 Temperature at bottom depths September - October 2001

Appendix I

Research vessel	Participants
"G. O. Sars"	V. Anthonypillai, J. de Lange, J. H. Nilsen (cruise leader), B. Skjold, B.V. Svendsen, B. Endresen, M. Johannesen, M. Sædberg, J. Kristiansen
"Johan Hjort"	J. Alvarez, E. Eriksen[1], H. Gjøsæter (cruise leader), K. Hansen, I. Henriksen[1], E. Hermansen, K. Hestenes[1], J. Johannesen, R. Johannesen (instrument chief), L. Rey, B.S. Røttingen, J. Røttingen, R. Skeide[1], N.G. Ushakov (PINRO), R. Jørgensen (NFH)[1], K. Olsen (NFH)[1]
"AtlantNIRO"	A. Bendik, O. Dolgaja, T. Gavrilik, S. Ivanov, T. Prokhorova, D. Prozorkevich (cruise leader), S. Ratushnyy, M. Rybakov, T. Sergeeva, A. Trofimov
"F. Nansen"	A. Astakhov, I. Dolgolenko (cruise leader), J. Garbut, V. Guzenko, V. Kapralov, S. Kharlin, S. Rusyaev, V. Sergeev, I. Shevelev, O. Vavilina

[1] Part time

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	11.09.01	11.09.01	14.09.01	03.09.01
Place	Balsfjord	Akkarfjord	Hornsund, Spitsbergen	G. Orlovka
Bottom depth (m)	51	52	90	50
Temperature (°C)	8.5	9.34	3.0	8.5
Salinity (‰)	33.6	33.6	33.0	34.0
Transducer type	ES38B-SK	ES38B-SK	ES38B-SK	ES38
Transducer depth (m)	7	0		
Real sphere depth (m)	18	15.8	17.0	19.2
Sound velocity (m/sec)	1483	1486	1460	1482
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)	27.43	27.07	27.10	25.20
Adjusted TS Transducer Gain (dB)	27.62	27.13	27.10	25.25
3-dB Beamwidth Alongship (deg.)	7.0	7.0	6.8	6.8
3-dB Beamwidth Athwartship (deg.)	6.8	6.9	6.8	6.9
Alongship (fore/aft.) Offset (deg.)	-0.08	0.00	-0.03	0.01
Athwartship Offset (deg.)	-0.06	0.01	-0.07	0.44
Theoretical Sa (m^2/nm^2)	7361	9488	8009	6619
Measured Sa (m^2/nm^2)	6841	9848	7169	6793
	$Sa= \sigma * 1852^2/(r^2 \psi)$		$\sigma = 4\pi * 10^{0,1\,TS}$	