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REPORT FROM THE JOINT NORWEGIAN/RUSSIAN ACOUSTIC SURVEY OF PELAGIC FISH IN THE BARENTS SEA, SEPTEMBER-OCTOBER 2002

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Joint IMR-PINRO report

REPORT

FROM THE JOINT NORWEGIAN/RUSSIAN ACOUSTIC SURVEY OF PELAGIC FISH IN THE BARENTS SEA SEPTEMBER-OCTOBER 2002

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REPORT

FROM THE JOINT NORWEGIAN/RUSSIAN ACOUSTIC SURVEY OF PELAGIC FISH IN THE BARENTS SEA SEPTEMBER-OCTOBER 2002

The survey was carried out in the period 6th of September to 6th of October 2002 and was terminated by a meeting in Kirkenes 7-9th October. Five research vessels participated in the survey:

Vessel	Institute	Cruise leader	Date
"Johan Hjort"	IMR, Bergen	H. Gjøsæter	11/9–6/10
"G.O.Sars"	IMR, Bergen	J.H. Nilsen	10/9–19/9
“M. Sars”	IMR, Bergen	J.H. Nilsen	25/9–4/10
"AtlantNIRO"	PINRO, Murmansk	D. Prozorkevich	6/9–21/9
“F. Nansen”	PINRO, Murmansk	I. Dolgolenko	6/9–6/10

Synopsis

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. 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 TS variation with depth 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 2.2 million tonnes, 0.6 times the estimate obtained last year. About 1.3 million tonnes were assumed to be maturing.

The polar cod stock was estimated at 1.4 million tonnes, a reduction of about 25% from the record high estimate obtained last year.

Practically no **Norwegian Spring Spawning Herring** were found in the surveyed area

Young **blue whiting** were observed in the southwestern parts of the Barents Sea. A quantitative estimation was not attempted.

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 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" were granted permission to work in parts of Russian EEZ, but on terms that could not be accepted by IMR. 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 trawl 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" (from 23. September “M. Sars”) surveyed the north-western, central, and western parts. Altogether, 10725 nautical miles of survey tracks were made, about 30 % less 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 (Norwegian vessels) or fifth nautical mile (Russian vessels) were recorded. The echograms, with their corresponding s_A-values, were scrutinised every day. Contributions from the seabed, false echoes, and noise were deleted. 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, 244 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 the stock size estimation program “BEAM” built on SAS GIS and developed at IMR. 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	87	93	180
Nos. length measured	6539	11189	17728
Nos. aged	4830	807	5637
Polar cod			
No of samples	36	75	111
Nos. length measured	1578	11050	12628
Nos. aged	479	1027	1506

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 10 days and was exchanged with "Michael Sars". The weather conditions were unfavourable during most parts of the survey, with several days of wind force above 15 m/sec, and the vessels had to wait out a couple of storms. In spite of this, an almost total coverage of the capelin distribution area was achieved. Only a small area in the southern Barents Sea where capelin may have been present was left uncovered because of lack of time. This lack of coverage will only affect the estimation of the youngest age group of capelin. 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, and is probably the most complete coverage obtained at any capelin survey in the time series. The survey design used in recent years, running east-west courses starting in the south, was abandoned in favour of starting in the north. Since the northern limit of the capelin distribution seems to be more variable than the southern limit, starting the survey in the north ensures that enough time can be allocated to the most important parts of the survey area. "Johan Hjort" had dedicated some working time during the first part of the survey to experimental work (see below).

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, extending north to 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 52-55° in the east, and in addition, small amounts of capelin were found in the Storfjordrenna area south of Spitsbergen. The main concentration was found between 76° and 77°N and from 28° to 38°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 observed (north of 77°N), capelin were found mainly in dense schools near the bottom. Figure 9 shows an example of such registrations in position 78º30'N–35º13'E. In some areas capelin was found together with polar cod. In such areas, it was difficult to discern between the two species of fish based on the recordings. In Figure 10 is shown an example of such registrations from 73º50'N – 40º00'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

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

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 2001 estimate is shown on shaded background for comparison

Year class		Age	Number (10^9)		Mean weight (g)		Biomass (10^3 t)	
2001	2000	1	59.7	113.6	3.9	3.3	234.3	374.8
2000	1999	2	90.8	218.7	10.1	11.0	918.6	2401.1
1999	1998	3	50.2	30.5	20.7	26.7	1037.1	813.8
1998	1997	4	1.0	1.0	35.0	35.5	20.2	37.7
Total stock in								
2002	2001	1-4	201.3	363.9	11.0	10.0	2210.2	3630.0
Based on TS value: 19.1 log L - 74.0, corresponding to $\sigma = 5.0 \cdot 10^{-7} \cdot L^{1.91}$								

Details of the 2002 estimate are shown in Table 1 and the estimates by age group of the capelin stock 1 years old and older from 1973-2002 are shown in Table 2.

The total stock is estimated at about 2.2 million tonnes, about 60% of the stock estimated last year. About 58% (1291 thousand tonnes) of this stock is above 14 cm and considered to be maturing. The 2001 year class (1-group) consists, according to this estimate, of about 60 billion individuals. This estimate is only about half of that obtained for the 1-

group last year. The mean weight is estimated at 3.9 g, which is somewhat higher than that measured last year, and 0.3 g below the long-term average. The biomass of the 2001 year class is about 0.2 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.

The estimated number of fish in the 2000 year class (2-group) is about 90 billions, only 40 % of the size of the 1999 year class measured last year. The mean weight at this age is 10.1 g (11.0 g in 2001), and consequently the biomass of the two years old fish is about 0.9 million tonnes. The mean weight is lower than in the eight last years and is at the long-term average (Table 2).

The 1999 year class is estimated at about 50 billion individuals with mean weight 20.7 g, giving a biomass of about 1 million tonnes. The mean weight is considerably lower than last year (26.7 g) and is 2.3 g above the long-term average mean weight. The 1998 year class (now 4 years old) is estimated at 0.6 billion individuals. With a mean weight of 35.0 g this age group makes up only about 20 thousand tonnes. 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 "surveymortality" 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
2001-2002	2000	113.6	90.8	20	0.22

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. This coincided with a considerable increase in the stock size caused by the rich 1989 year class. 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 rapidly decreasing stock of capelin. The mortalities calculated for the period 1996-2002 varied between 20 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 76ºN and 78ºN, east of 40ºE. East and south of Spitsbergen 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:

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

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 2001 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)	
2001	2000	1	8.4	77.1	6.7	9.2	56.8	709.0
2000	1999	2	34.8	15.7	25.2	27.7	875.9	434.5
1999	1998	3	6.4	12.5	44.4	47.1	282.2	589.3
1998	1997	4	2.3	2.3	61.7	58.2	143.2	132.1
Total stock in								
2002	2001	1-5	52.2	107.7	26.4	17.4	1377.2	1869.6
Based on TS value: 21.8 log L - 72.7, corresponding to $\sigma = 6.7 \cdot 10^{-7} \cdot L^{2.18}$								

The 2001 year class (the one-year-olds) is only 11% of the abundance of the one-group measured last year, and their mean weight is 2.5 gram lower. The biomass is, therefore, 8% of that of the one-year-olds measured last year. The abundance of the 2000 year class (the two-year-olds) is more than twice as high as that of the two-group found last year but with lower mean weight. The biomass is, therefore, two times higher that of the 1999 year class estimated last year. The three-years-old fish (1999 year class) is about half as numerous as the three-group estimated last year and has somewhat lower mean weight. Consequently, the biomass of this age group is less than half of that for the corresponding age group during the 2001 survey. The four-year-olds (1998 year class) are scarcely found. The total stock, estimated at 1.4 million tonnes, is 26% lower than that estimated last year, which was the highest on record. It should be noted that the area west of Spitsbergen, which contained more than 200 000 t of polar cod last year was not covered this year. Therefore, a part of the decrease in the estimate might stem from the decrease in area coverage of the stock.

The text tables below show the "survey-mortality rates" of polar cod of the year classes 1984 to 2000

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
2001-2002	2000	77.1	34.8	55	0.80

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
2001-2002	1999	15.7	6.4	59	0.90

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, in 2000 35 000 tonnes and in 2001 41 200 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

No herring other than the 0-group was encountered during the survey.

Blue whiting

In the south-western parts of the Barents Sea young blue whiting were observed. A quantitative estimation was not attempted since only a small area of the total distribution area of this species was covered.

Plankton

The abundance of krill (size fraction >2000 µm) from bottom to surface was investigated at "Johan Hjort" during the survey. In this investigation, samples were collected by using WP2 and MOCNESS plankton nets. The WP2 net is 56 cm in diameter, 180 µ mesh size and has mouth area 0,25 m^2. The net was hauled at a speed of 0,5 m/s. The MOCNESS sampler has a 1 m^2 mouth opening and a mesh size of 180 µ. The towing speed of the boat was 0,8-1-0 m/s. The number of stations was 19 for the MOCNESS (90 samples) and 45 for the WP2 (86 samples). For each WP2 and MOCNESS profile, the abundance (individuals per square metre), was calculated by using the number of krill in each sample, the depth interval and the volume of water filtered. The results are shown in the maps of the distribution of total krill (fig.20) and distribution of *Meganyctiphanes norvegica*, taken to be an indicator of warm waters masses (fig.21).

The total krill abundance increased from north to south. Euphausiids were not observed in the plankton samples between 35°E and 40°E. In the northern part of the observation area, krill were represented by two amphiboreal species *Thysanoessa inermis* and *T. longicaudata.* In the central part adults, juveniles and *furcilia* stages concentrated in the depth interval 50-25 m. In addition, in the central part the arctoboreal species *T. raschii* and the shelf species *Meganyctiphanes norvegica* appeared. The highest abundance of total krill was recorded in the southern region of the investigated area, and samples included all four species of euphausiids of the Barents Sea. Here, amphiboreal species dominated. In the deep layers of the southernmost stations a high abundance of small krill was observed.

Sea Mammals

During survey observations on sea mammals were carried out. Whales, seals and dolphins were seen over the whole of observed areas, and more often in places of capelin concentration. Distribution of sea mammals is shown in Fig. 22.

Hydrographical conditions

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

In September the cooling of surface waters had begun. From August to September the average surface temperature decreased by 1.5-2.0°C.

The thickness of the upper mixed layer was mainly about 35-45 m for the regions influenced by warm currents and up to 20 m northwards from 78°30'N.

The maximum horizontal temperature gradients (0.2°C per nautical mile) were observed in the western part of the sea for the Polar Front at 50 m depth. The frontal zone was sharper in this area than for example in the central area, where it was more eroded.

The surface water temperature was on average 1.0-1.5°C lower than the long-term mean in the eastern and central parts of the region, and 0.5-1.0°C higher than usually for the northern region. The maximum positive anomalies (up to +2.0°C) were observed in the western parts of the Barents Sea. The bottom temperature was close to the long-term mean.

In 2002 the surface water temperature was significantly lower (on average 3.0-4.0°C) than in the same period in 2001 for the eastern part of the area. In the northern area the difference between surface water temperature in 2002 and 2001 was at average –1.0°C. The bottom temperature was insignificantly lower than last year.

Acoustic experiments

During the first part of the survey, some acoustic experiments were undertaken on board "Johan Hjort". A specially designed transducer (38 kHz) was lowered to various depths inside clean capelin registrations, and the TS *in situ* of the capelin were observed. Clear indications of a depth dependent TS were found. An experiment where a small area was covered repeatedly during day and night was also done. In this case, it was observed that higher s_A-values were obtained during night, when the capelin were found near surface, than during daytime, when capelin was found deeper down. These results will be published elsewhere.

Table 1. Acoustic estimate of Barents Sea capelin, September-October 2002

Length (cm)	Age/Year class 1 2001	2 2000	3 1999	4 1998	Sum (10^6)	Biomass (10^3 t)	Mean weight (g)
6.5 - 7.0	2				2	0.0	1.0
7.0 - 7.5	214				214	0.3	1.6
7.5 - 8.0	1674				1674	2.6	1.6
8.0 - 8.5	8844				8844	18.1	2.0
8.5 - 9.0	7407				7407	18.8	2.5
9.0 - 9.5	6206				6206	19.6	3.2
9.5 - 10.0	4797				4797	16.7	3.5
10.0 - 10.5	7130	55			7185	30.5	4.2
10.5 - 11.0	10471	758			11229	53.5	4.8
11.0 - 11.5	8102	2594			10697	58.4	5.5
11.5 - 12.0	4033	9706			13738	87.5	6.4
12.0 - 12.5	451	17173	61		17684	138.0	7.8
12.5 - 13.0	26	17854	286		18166	162.5	8.9
13.0 - 13.5	204	14255	1486		15945	158.0	9.9
13.5 - 14.0	78	11089	2076		13243	154.4	11.7
14.0 - 14.5	64	8470	5812		14346	190.0	13.2
14.5 - 15.0		3824	6503		10327	155.3	15.0
15.0 - 15.5		2578	6422		9000	155.2	17.2
15.5 - 16.0		916	6284	9	7209	142.8	19.8
16.0 - 16.5		392	6248	48	6688	152.6	22.8
16.5 - 17.0		424	5274	32	5730	146.3	25.5
17.0 - 17.5		292	4007	47	4346	122.8	28.3
17.5 - 18.0		355	3193	91	3639	115.7	31.8
18.0 - 18.5		61	1735	86	1882	67.5	35.8
18.5 - 19.0			642	134	776	29.8	38.3
19.0 - 19.5			181	58	239	10.3	43.0
19.5 - 20.0				60	60	2.6	43.0
20.0 - 20.5				8	8	0.4	51.1
20.5 - 21.0				2	2	0.1	55.8
TSN (10^6)	59704	90794	50211	577	201286		
TSB (10^3 t)	234.3	918.6	1037.1	20.2		2210.2	
Mean length (cm)	9.90	13.10	15.80	18.20	12.80		
Mean weight (g)	3.9	10.1	20.7	35.0			11.0
SSN (10^6)	64	17312	46301	575	64252		
SSB (10^3 t)	0.8	273.1	995.5	20.1		1291.4	

Based on TS value: 19.1 log L - 74.0, corresponding to $\sigma = 5.0 \cdot 10^{-7} \cdot L^{1.9}$

Table 2. Acoustic estimates of the Barents Sea capelin stock by age in autumn 1973-2002 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
2002	0.23	3.9	0.92	10.1	1.04	20.7	0.02	35.0			1.98
Average	0.71	3.6	1.44	10.3	092	18.4	0.27	24.4			2.55

[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 2002

Length (cm)	1 2001	2 2000	3 1999	4 1998	5+ 1997-	Sum (10^6)	Bio-mass (10^3)	Mean weight (g)
6.5 - 7.0	115					115	0.2	2.0
7.0 - 7.5	92					92	0.2	2.3
7.5 - 8.0	312					312	0.9	2.9
8.0 - 8.5	834	33				867	3.1	3.6
8.5 - 9.0	1091	0				1091	4.8	4.4
9.0 - 9.5	1534	10				1544	8.1	5.2
9.5 - 10.0	1178	89				1267	7.7	6.1
10.0 - 10.5	1163	118				1280	9.3	7.2
10.5 - 11.0	584	614				1198	10.7	8.9
11.0 - 11.5	496	538				1035	10.9	10.5
11.5 - 12.0	434	677	16			1127	12.7	11.2
12.0 - 12.5	444	1200				1645	21.8	13.3
12.5 - 13.0	69	1633	58			1761	25.7	14.6
13.0 - 13.5	8	2581	11			2599	44.8	17.2
13.5 - 14.0	75	2752	47			2873	53.8	18.7
14.0 - 14.5		3249	177			3426	71.1	20.7
14.5 - 15.0		3552	71			3623	81.1	22.4
15.0 - 15.5		4115	56			4170	104.7	25.1
15.5 - 16.0		3278	34			3312	93.8	28.3
16.0 - 16.5		2830	320			3150	97.9	31.1
16.5 - 17.0		2471	236	4		2712	90.2	33.3
17.0 - 17.5		2412	212	4		2627	96.6	36.8
17.5 - 18.0		950	1128	3		2080	82.1	39.5
18.0 - 18.5		916	703	3		1622	68.2	42.1
18.5 - 19.0		341	965	20	2	1328	59.3	44.6
19.0 - 19.5		224	554	230		1008	49.9	49.5
19.5 - 20.0		216	393	346	2	956	51.8	54.2
20.0 - 20.5		25	665	147		837	46.0	55.0
20.5 - 21.0		1	116	498	80	695	39.5	56.8
21.0 - 21.5			85	360	79	523	33.3	63.6
21.5 - 22.0			235	284		519	33.5	64.6
22.0 - 22.5			118	138	58	314	21.9	69.7
22.5 - 23.0			120	12	37	169	12.5	74.0
23.0 - 23.5			32	90	33	154	12.0	78.3
23.5 - 24.0				114		114	9.2	80.6
24.0 - 24.5				7		7	0.6	94.8
24.5 - 25.0				12		12	1.2	104.3
25.0 - 25.5				53		53	6.1	115.3
25.5 - 26.0					1	1	0.1	101.0
TSN (10^6)	8431	34824	6350	2322	291	52218		
TSB (10^3 tonnes)	56.8	875.9	282.2	143.2	19.1		1377.2	
Mean length (cm)	9.80	15.00	18.50	21.10	21.70	14.90		
Mean weight (g)	6.7	25.2	44.4	61.7	65.8			26.4

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 1986-2002. 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
2002	8431	56.8	34824	875.9	6350	282.2	2322	143.2	52218	1377.2
Average	28578	219.3	11380	249.3	4164	153.4	549	29.2	44731	654.7

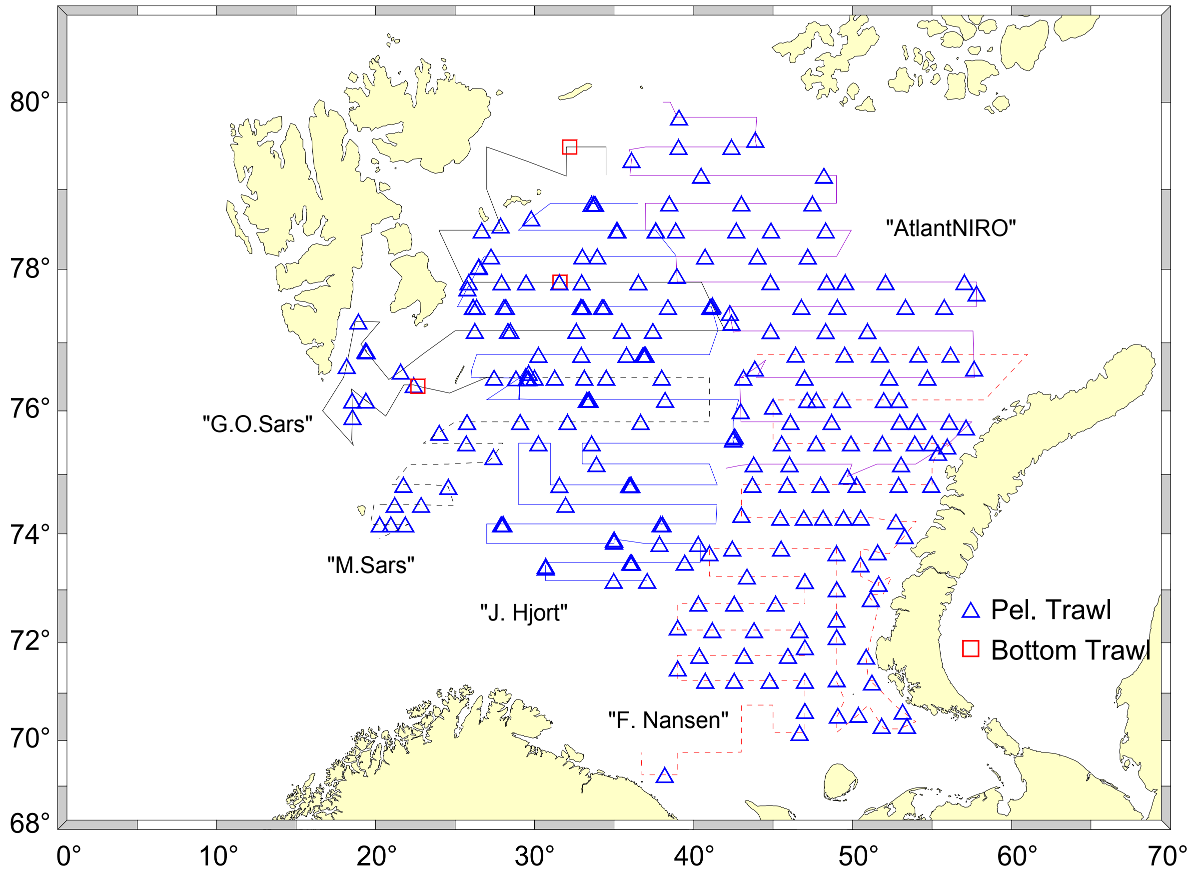

Figure 1 **Survey routes and trawl stations for "G.O. Sars", "Johan Hjort", "Michael Sars" "AtlantNIRO" and "F. Nansen" September -October 2002**

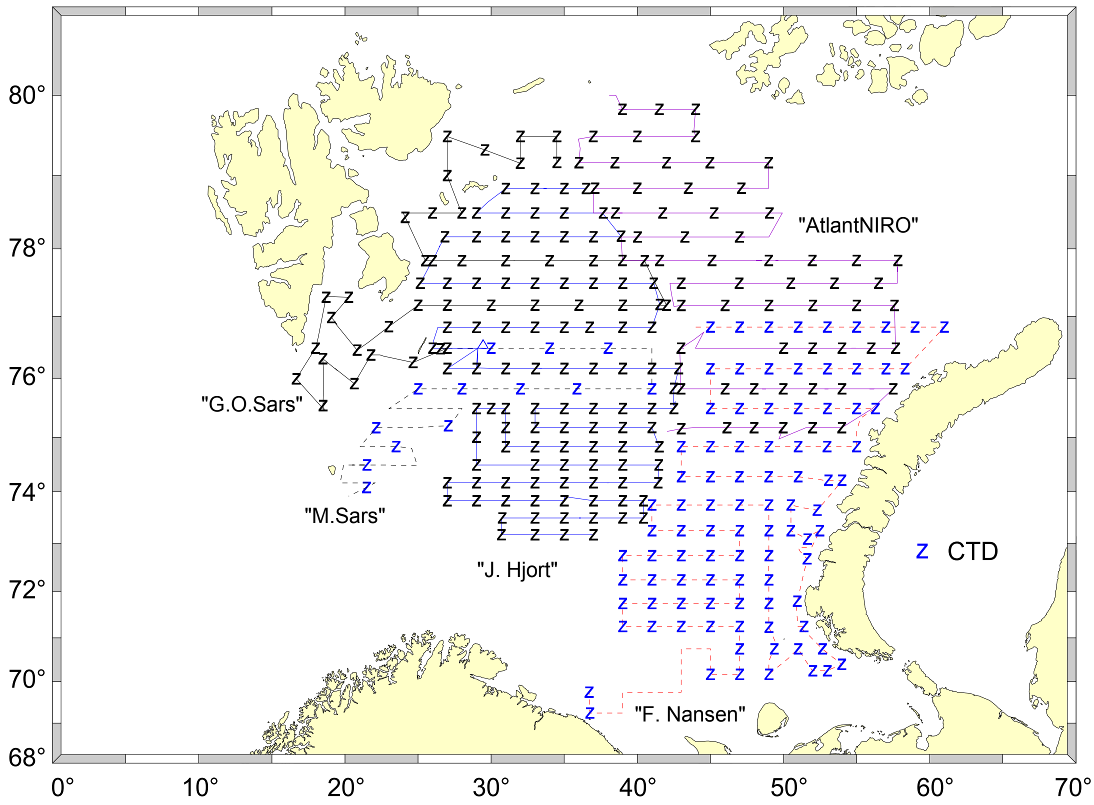

Figure 2 **Survey routes and hydrographic stations for "G.O. Sars", "Johan Hjort", "Michael Sars" "AtlantNIRO" and "F. Nansen" September-October 2002**

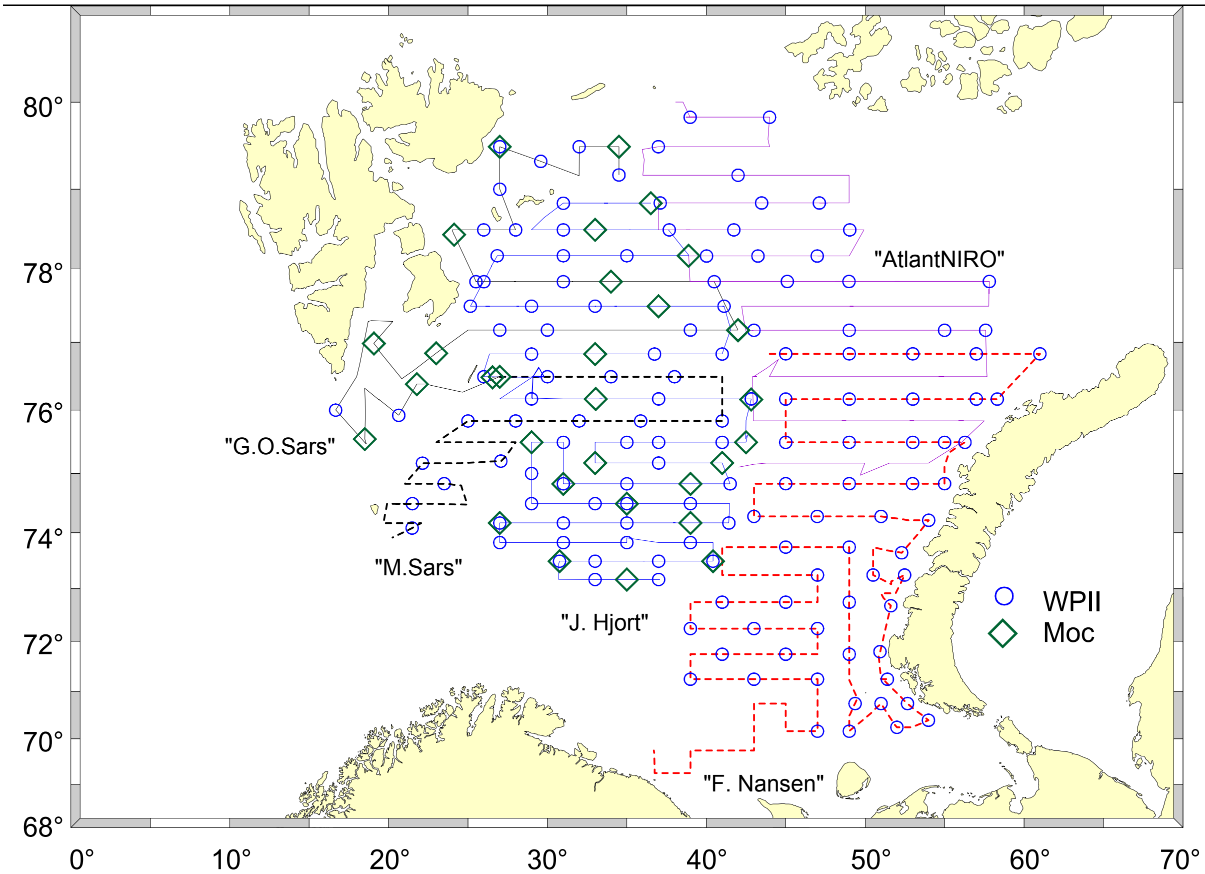

Figure 3 **Survey routes and plankton stations for "G.O. Sars" and "Johan Hjort" September-October 2002**

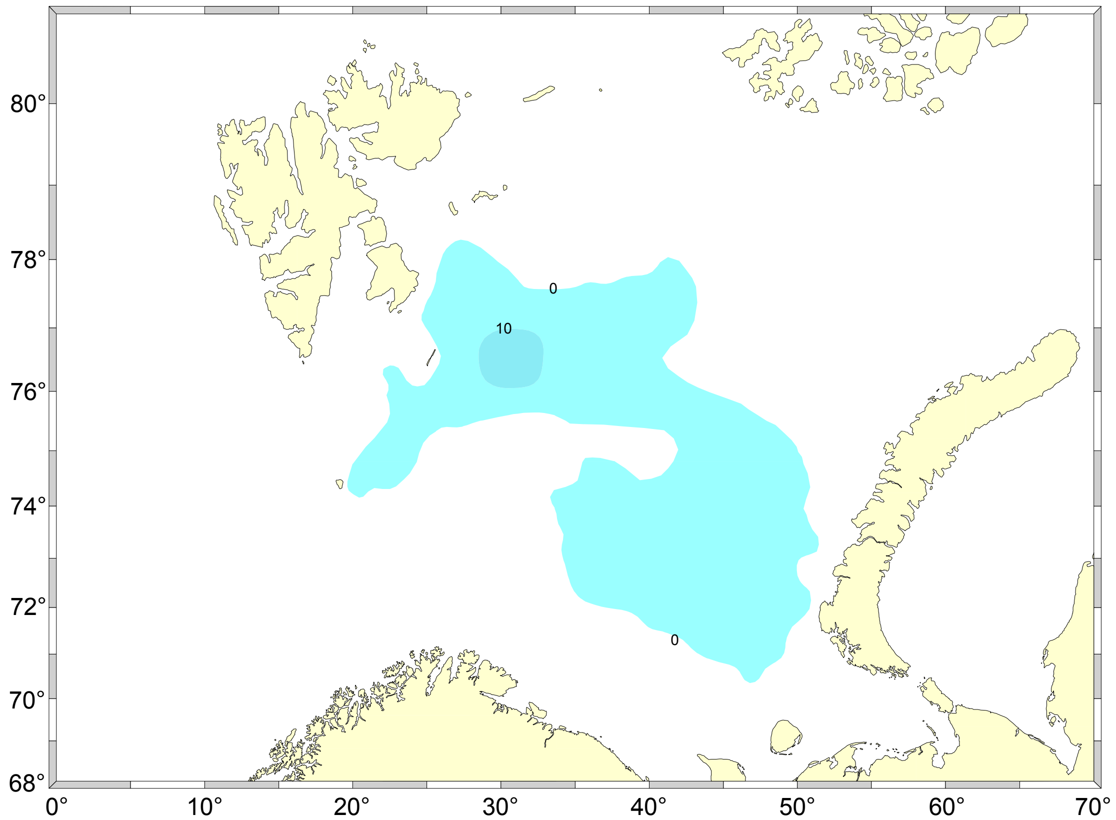

Figure 4 **Estimated density distribution of one-year-old capelin (tonnes/square nautical mile) September-October 2002**

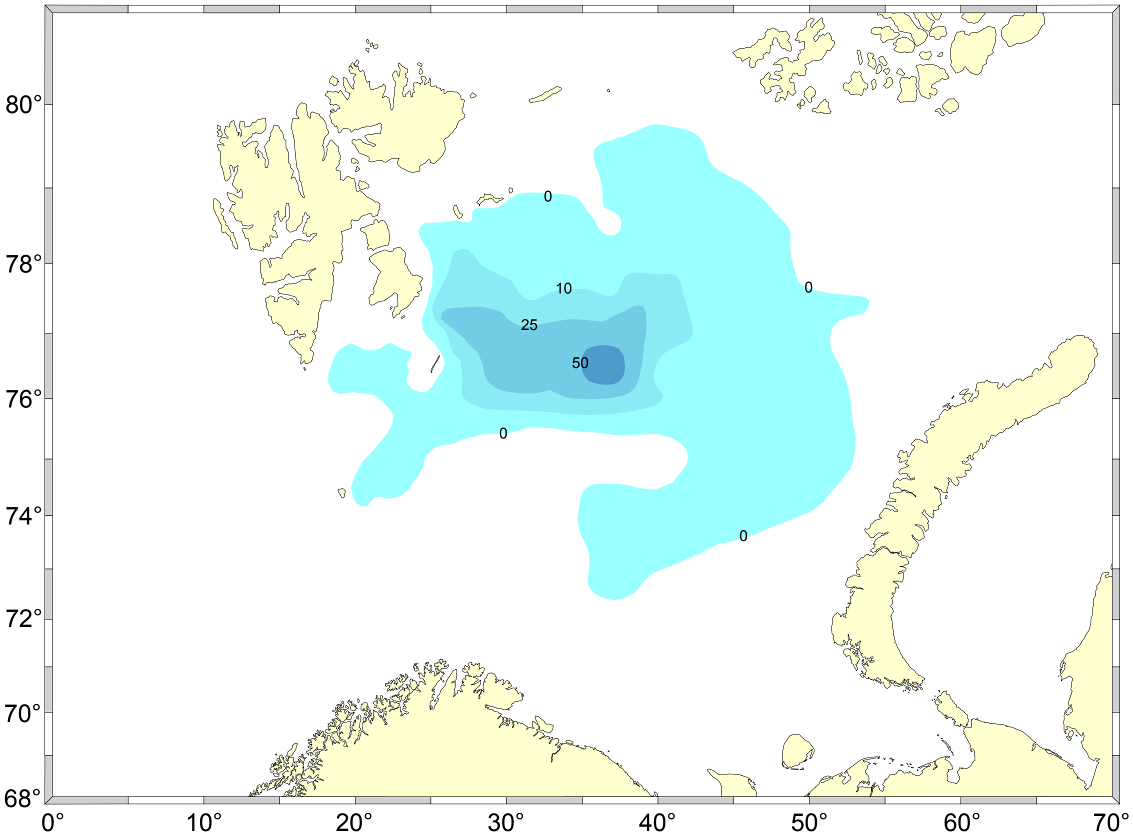

Figure 5 Estimated density distribution of two years old capelin (tonnes/square nautical mile) September-October 2002

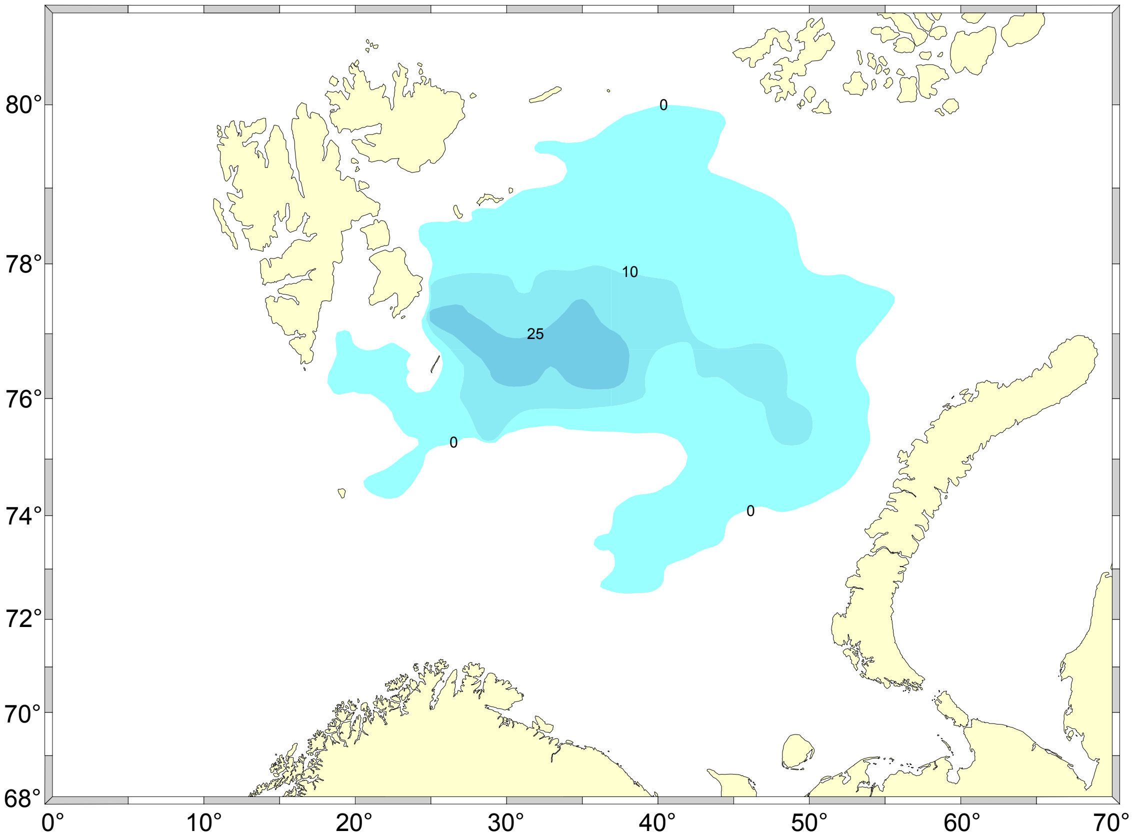

Figure 6 Estimated density distribution of three years old capelin (tonnes/square nautical mile) September-October 2002

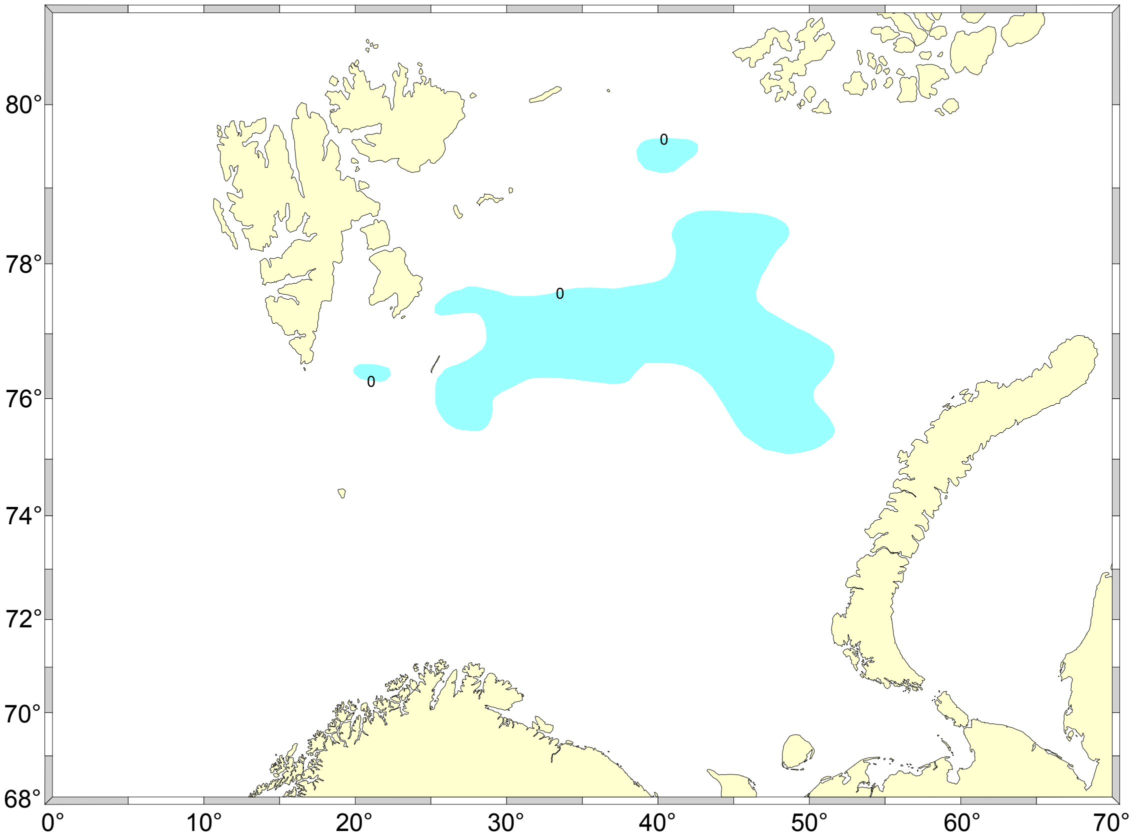

Figure 7 Estimated density distribution of four years old capelin (tonnes/square nautical mile) September-October 2002

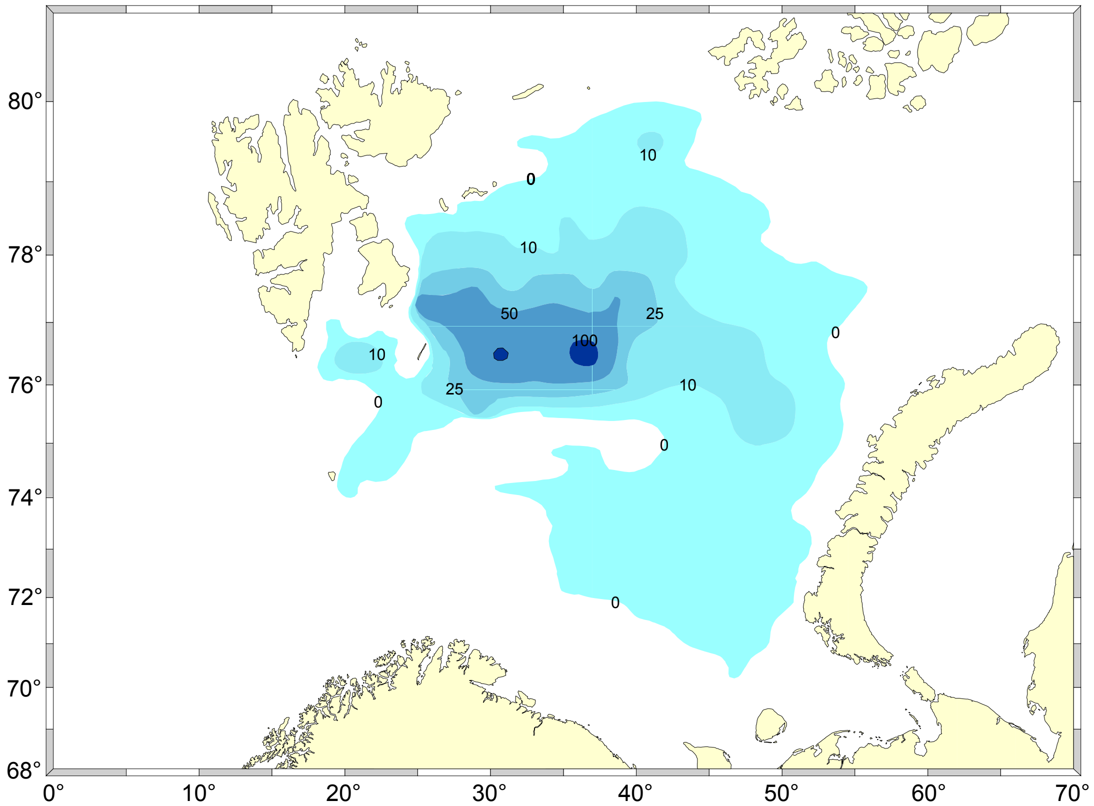

Figure 8 Estimated total density distribution of capelin (tonnes/square nautical mile) September-October 2002

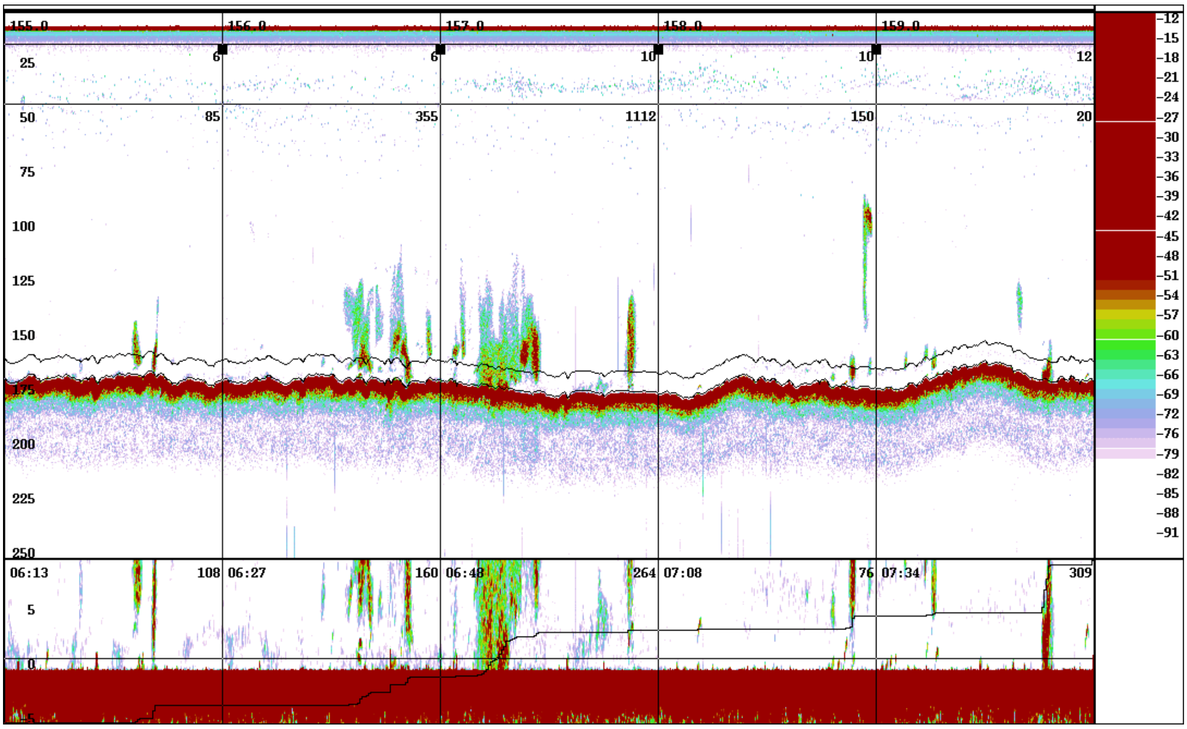

Figure 9 Echogram showing a typical distribution of adult capelin densely packed near bottom in areas where humpback whales were present. Echogram recorded at 78º30'N –35º13'E at 15. September 2002. Depth is 160 m

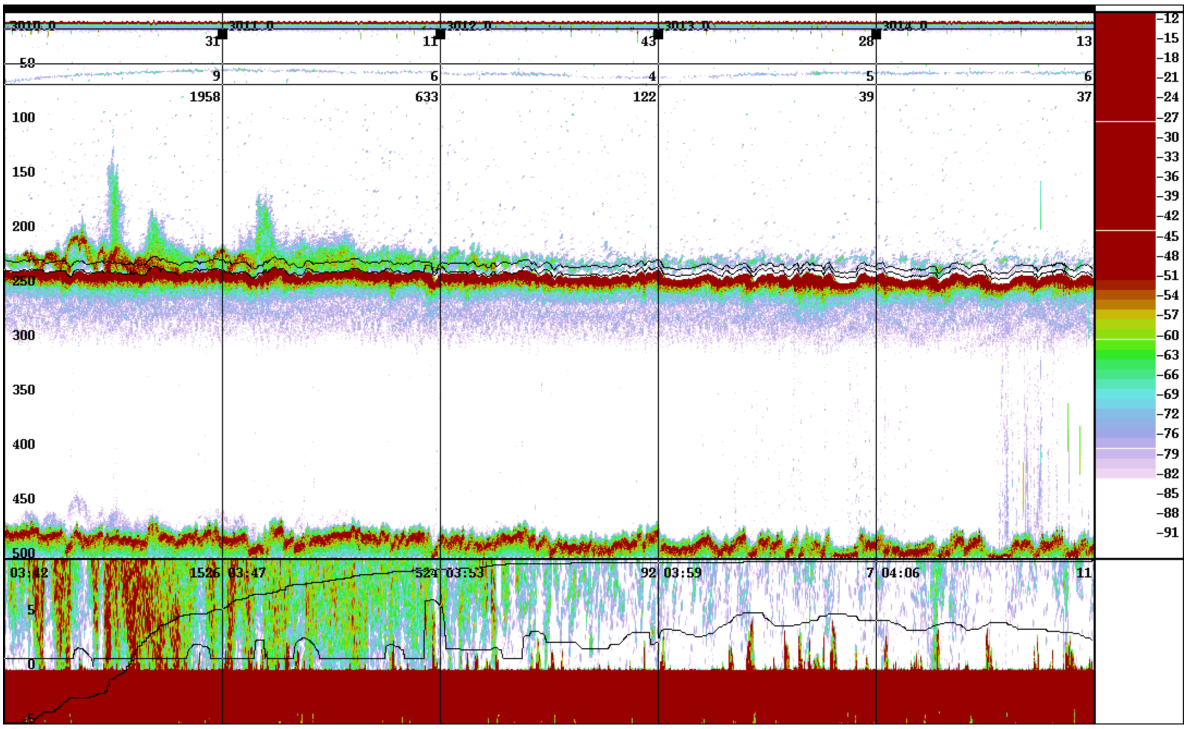

Figure 10 Echogram showing adult capelin mixed with polar cod in deeper water. A trawl haul gave a mixture of polar cod and capelin (10/90) at 200m depth. Recorded at 73º50'N – 40º00'E at 2 October 2002 03:40-.04:10 UTC

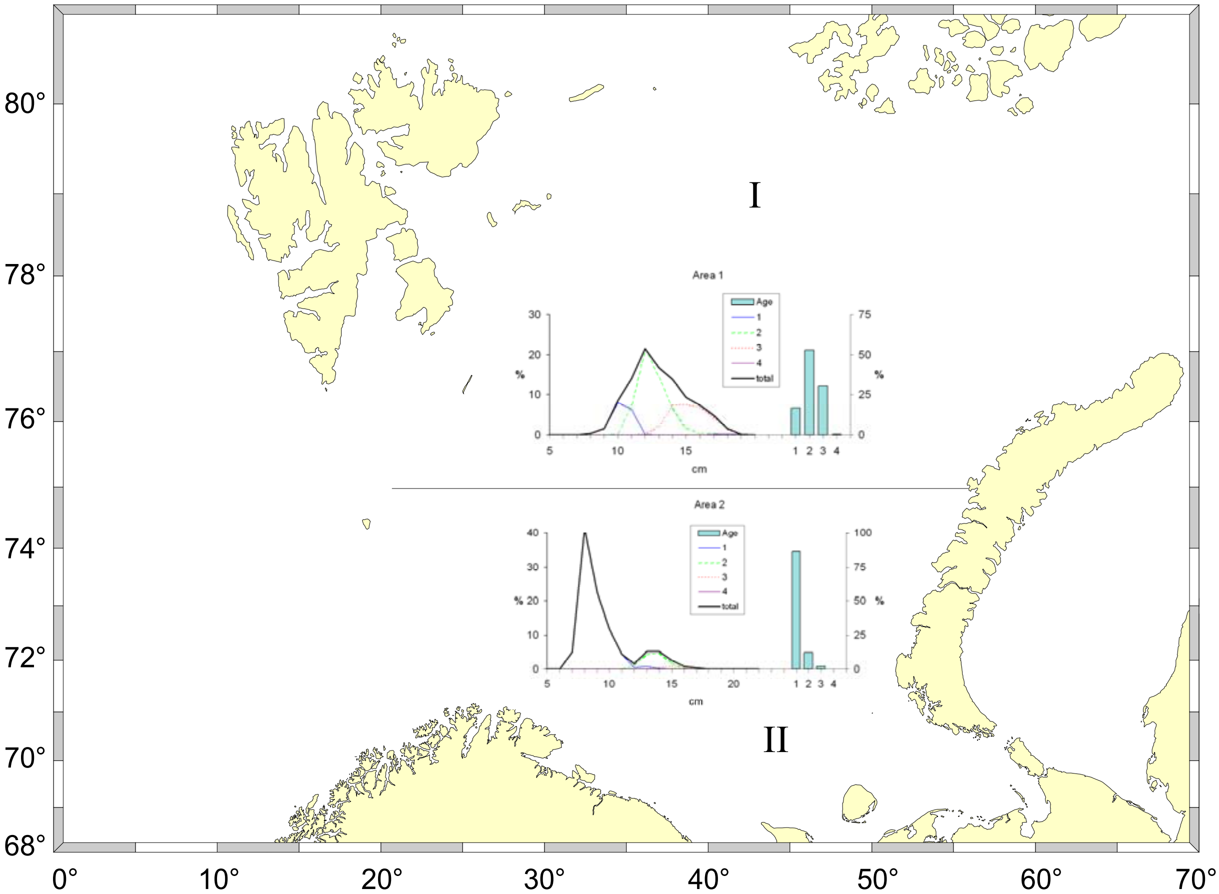

Figure 11 Age and length distribution of capelin in the two sub-areas used for stock size estimation September-October 2002

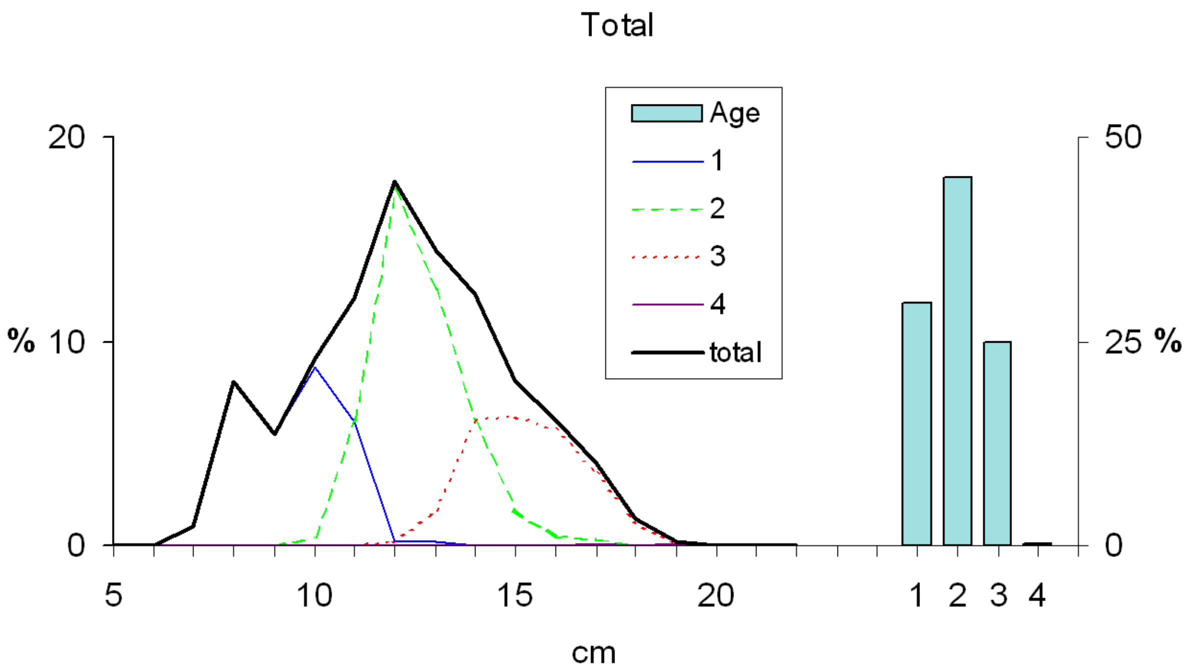

Figure 12 Total length and age distribution of capelin September-October 2002

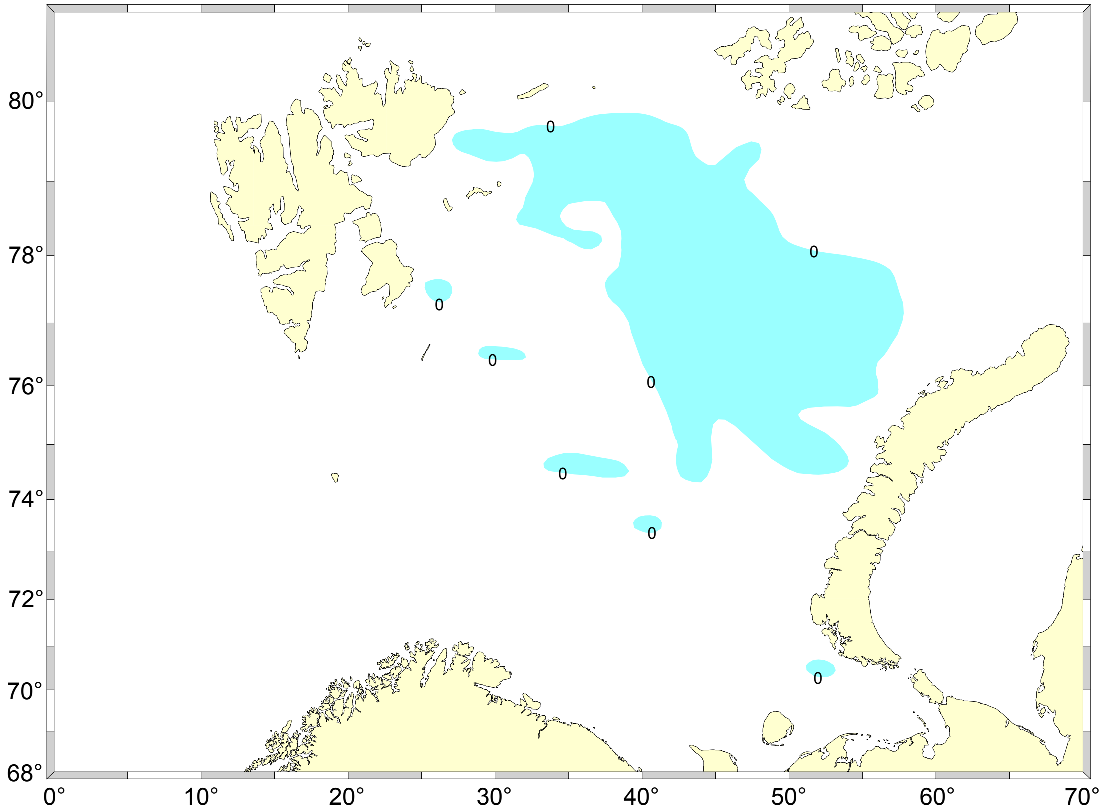

Figure 13 **Estimated density distribution of one year old polar cod (tonnes/square nautical mile) September-October 2002**

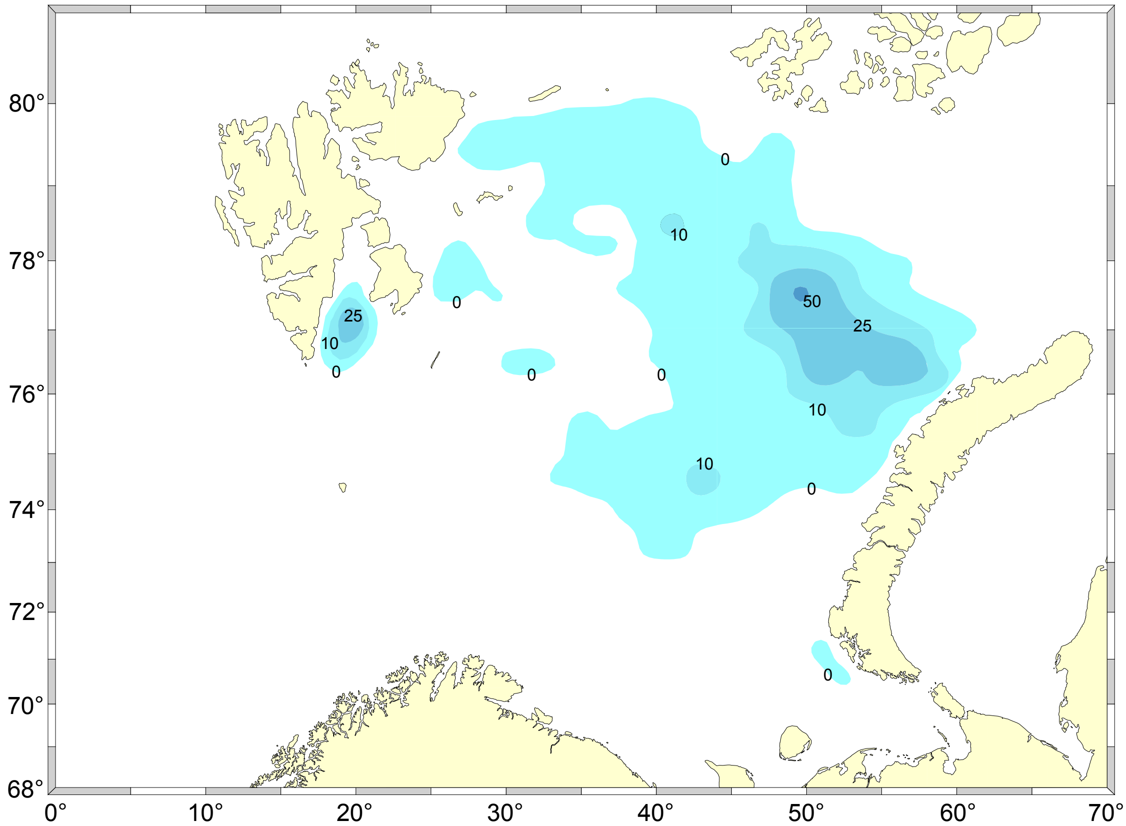

Figure 14 **Estimated density distribution of two years old polar cod (tonnes/square nautical mile) September-October 2002**

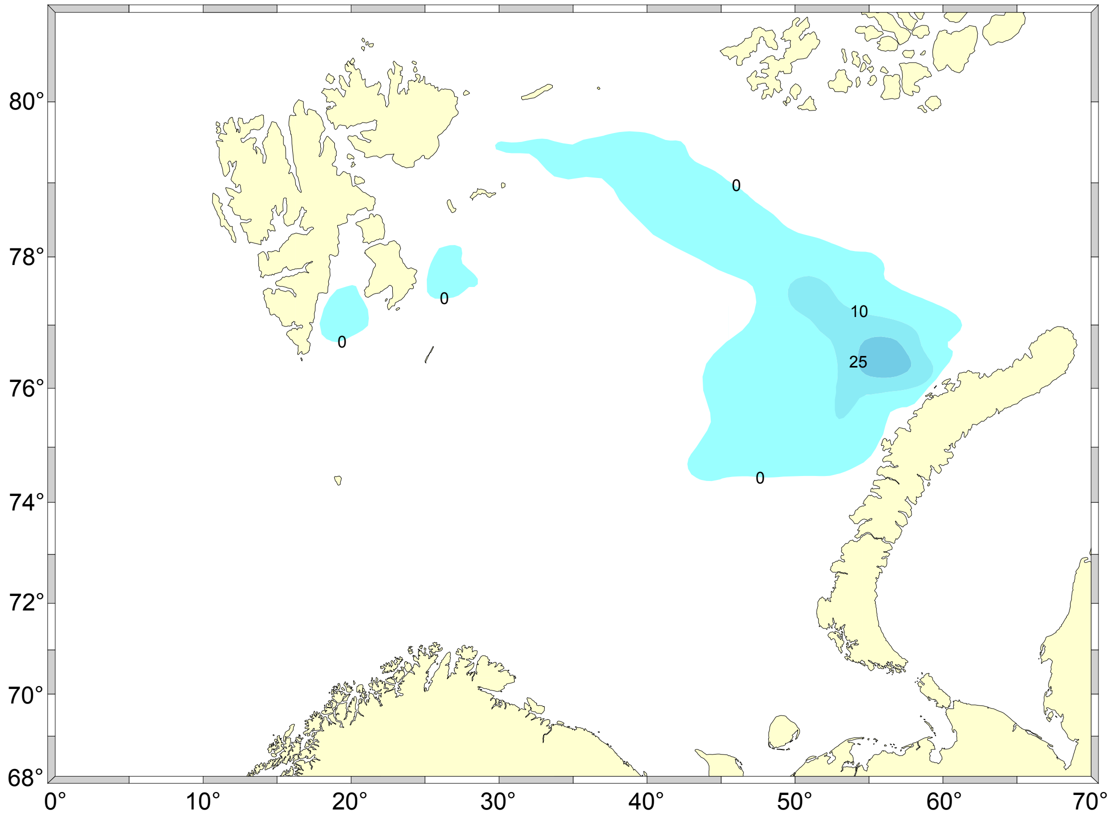

Figure 15 Estimated density distribution of three years old polar cod (tonnes/square nautical mile) September-October 2002

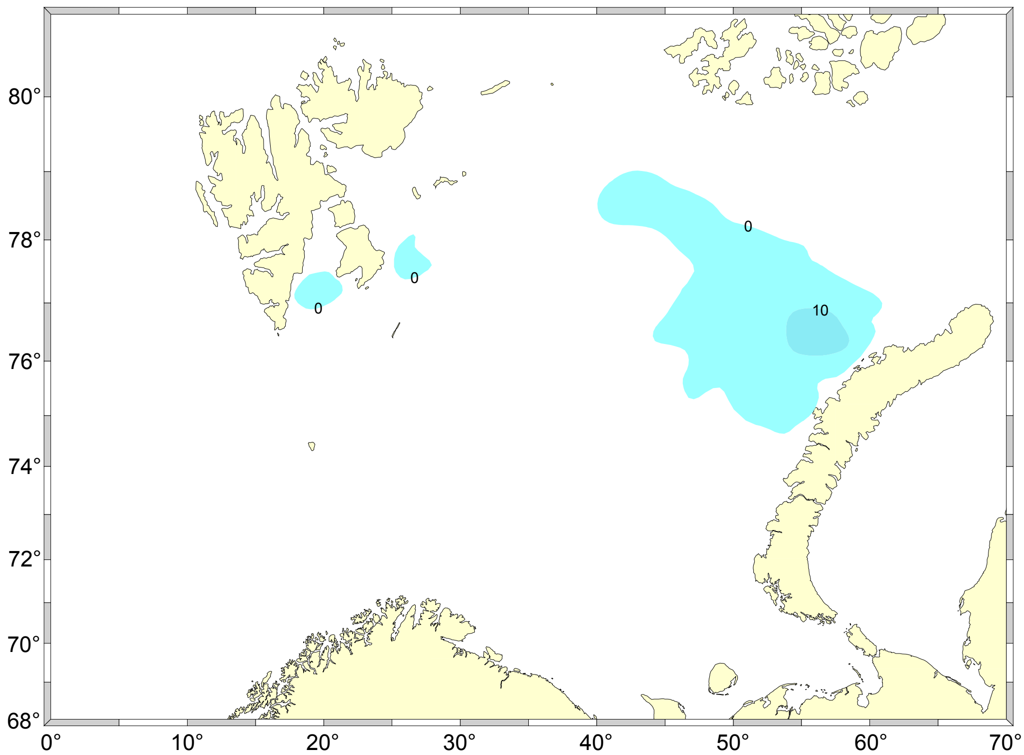

Figure 16 Estimated density distribution of four years old polar cod (tonnes/square nautical mile) September-October 2002

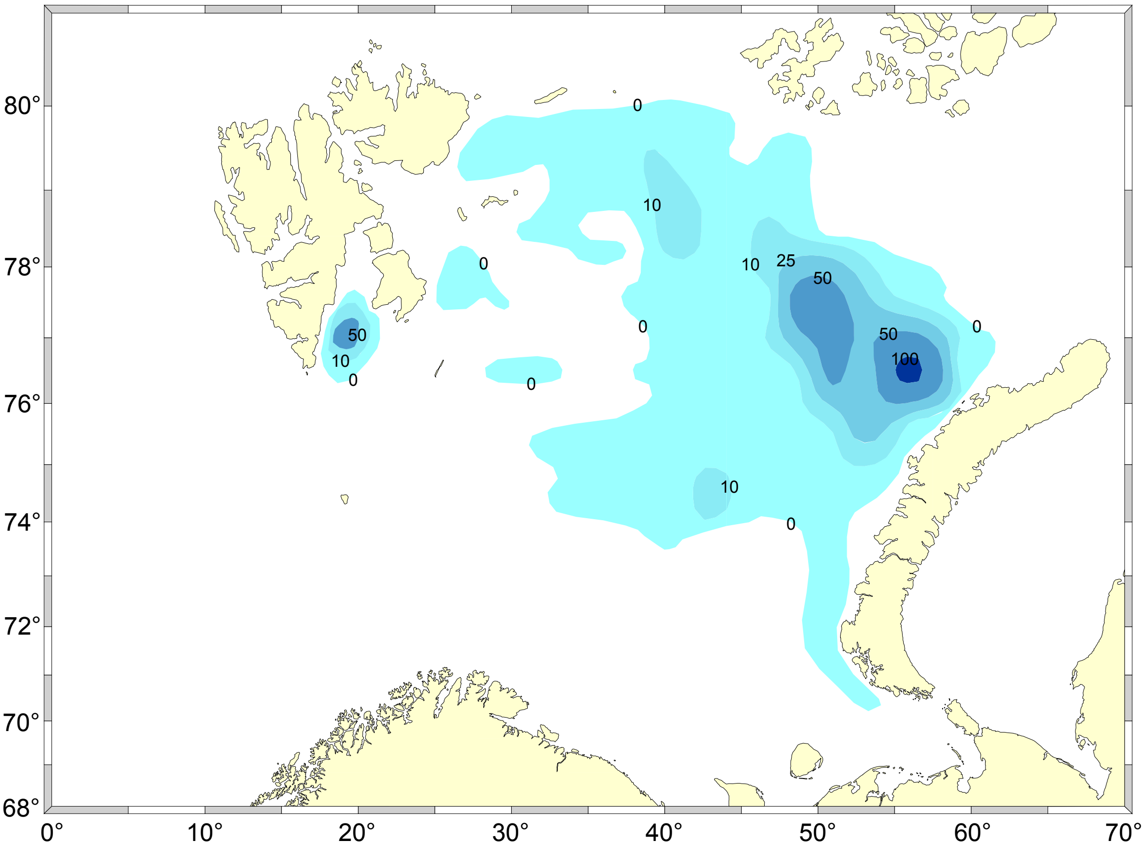

Figure 17 Estimated total density distribution of polar cod (tonnes/square nautical mile) September-October 2002

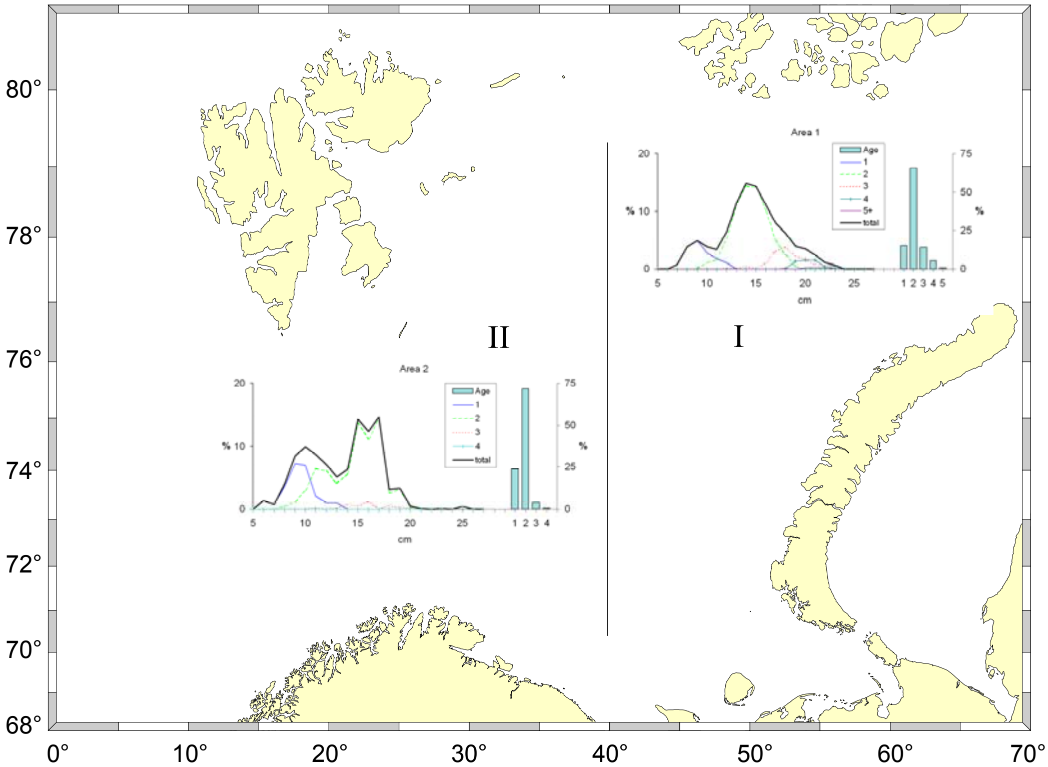

Figure 18 Length and age distribution of polar cod in the two sub-areas used for stock size estimation September-October 2002

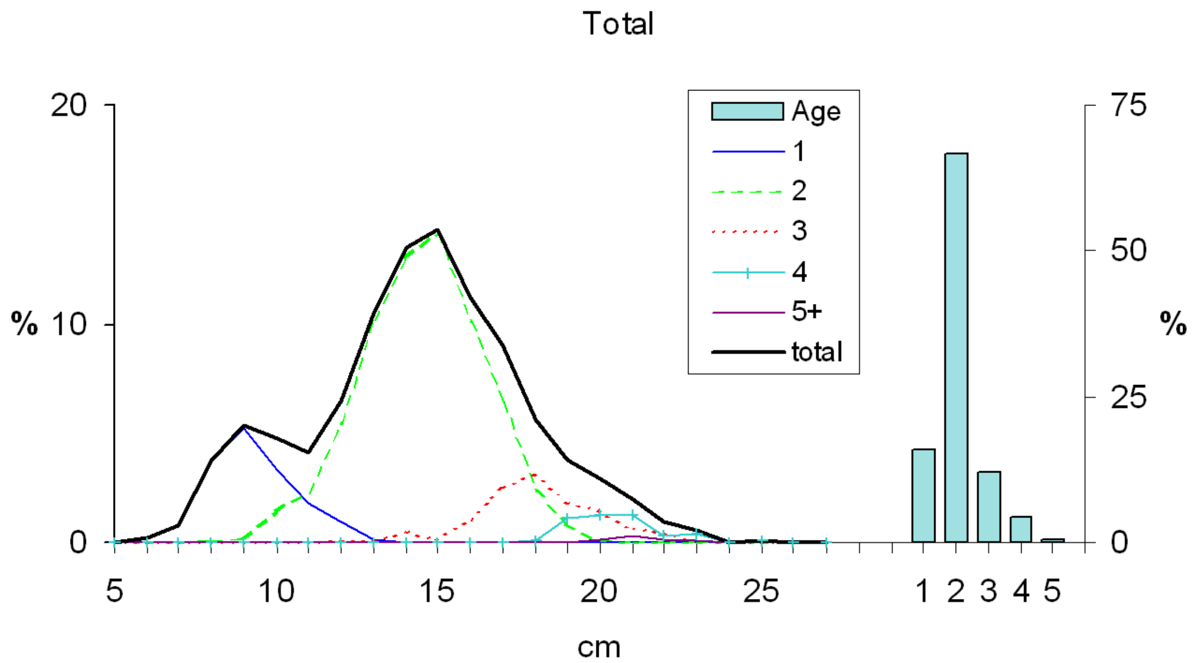

Figure 19 **Total length and age distribution of polar cod September-October 2002**

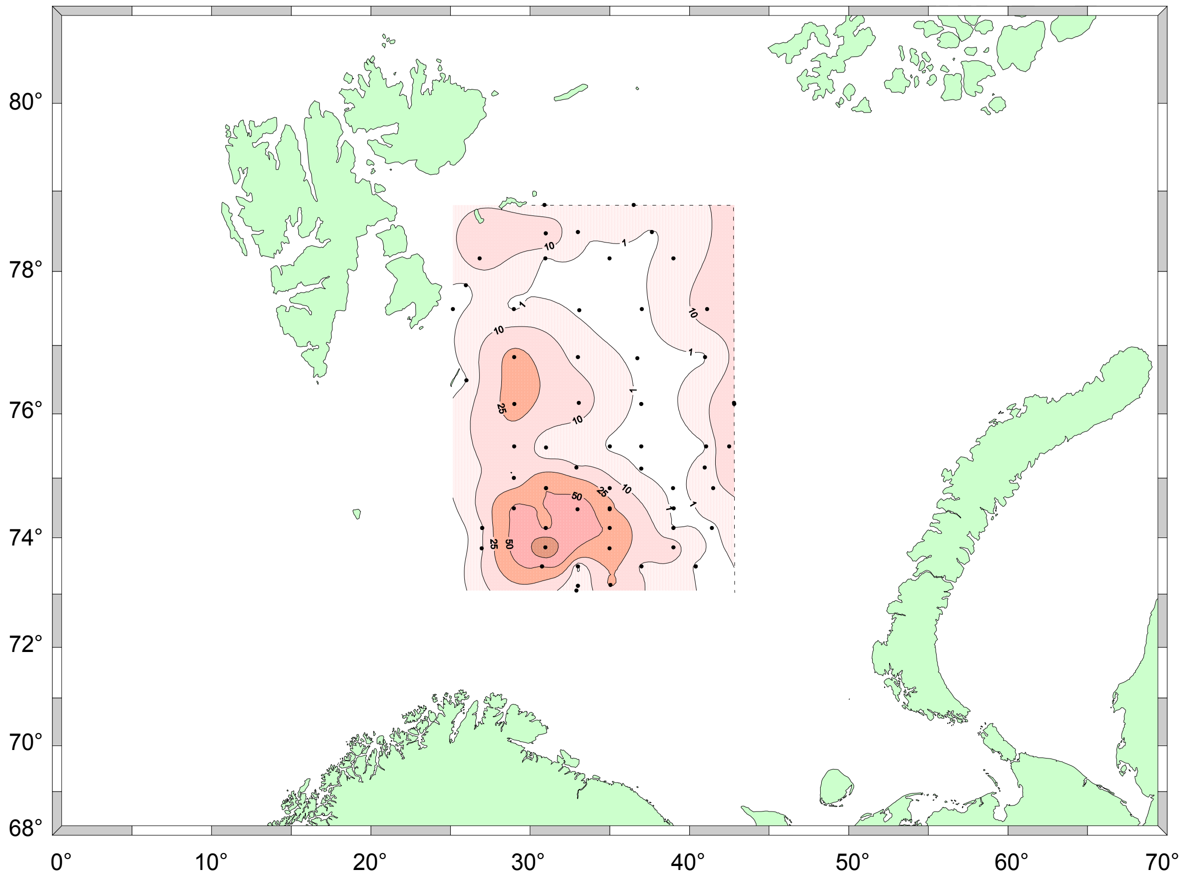

Figure 20 **Total distribution of krill (size fraction > 2000 µm) from bottom to surface in the area surveyed by "Johan Hjort" in September-October 2002**

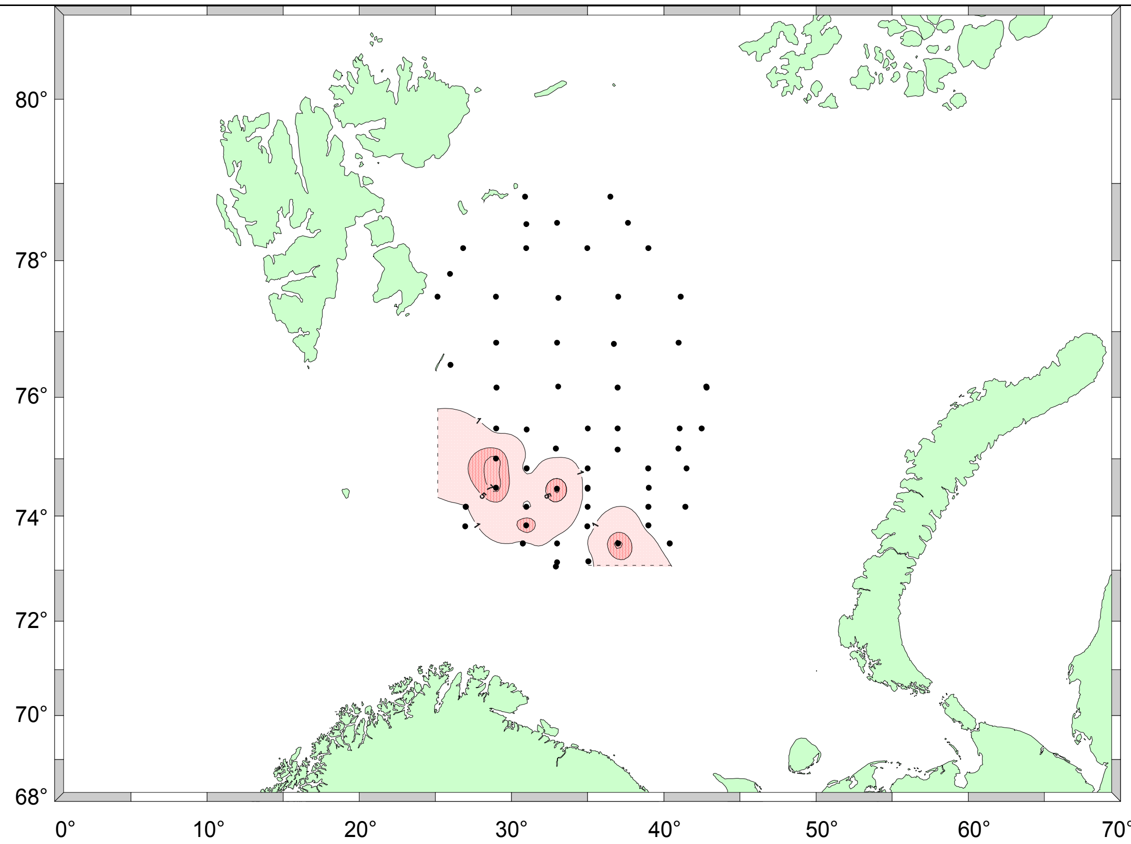

Figure 21 **Distribution of the warm water species *Meganyctiphanes norvegica* (size fraction > 2000 µm) from bottom to surface in the area surveyed by "Johan Hjort" in September-October 2002**

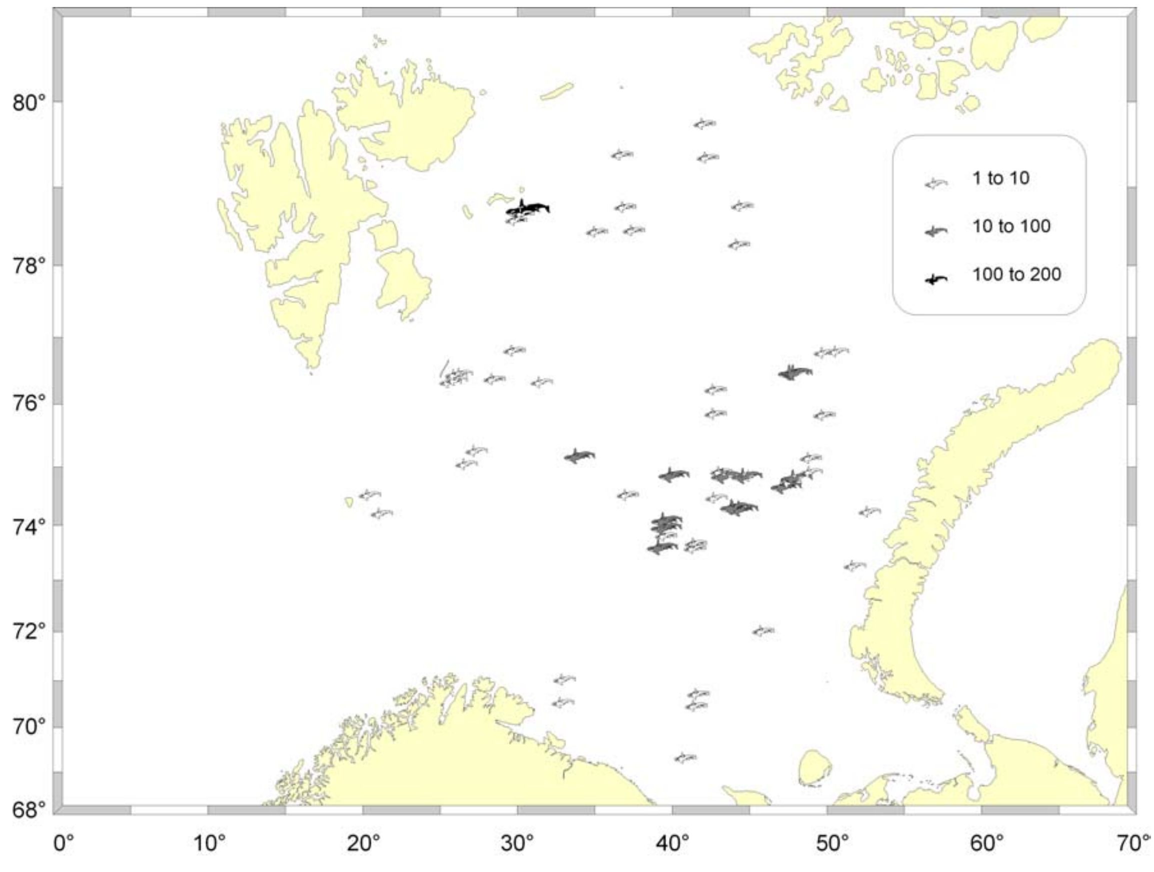

Figure 22 **Distribution of marine mammals September-October 2002**

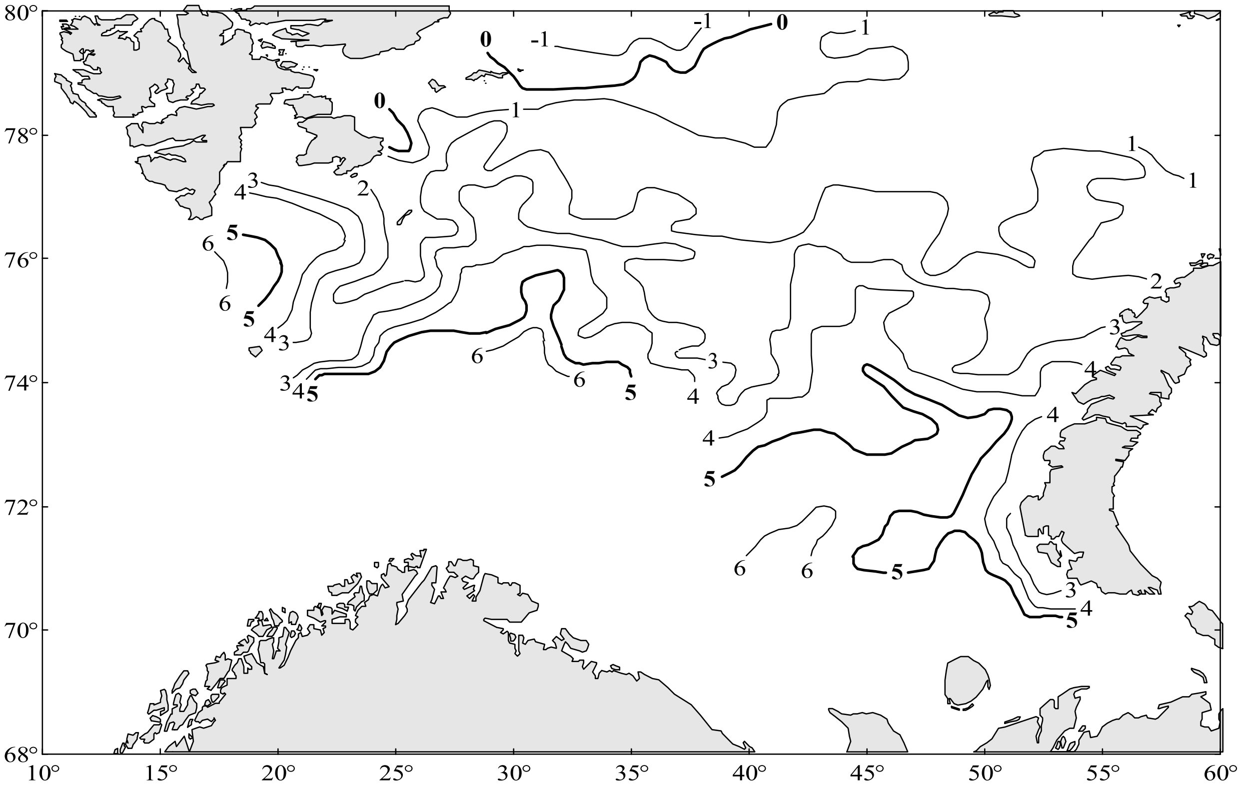

Figure 23 Temperature at the surface September-October 2002

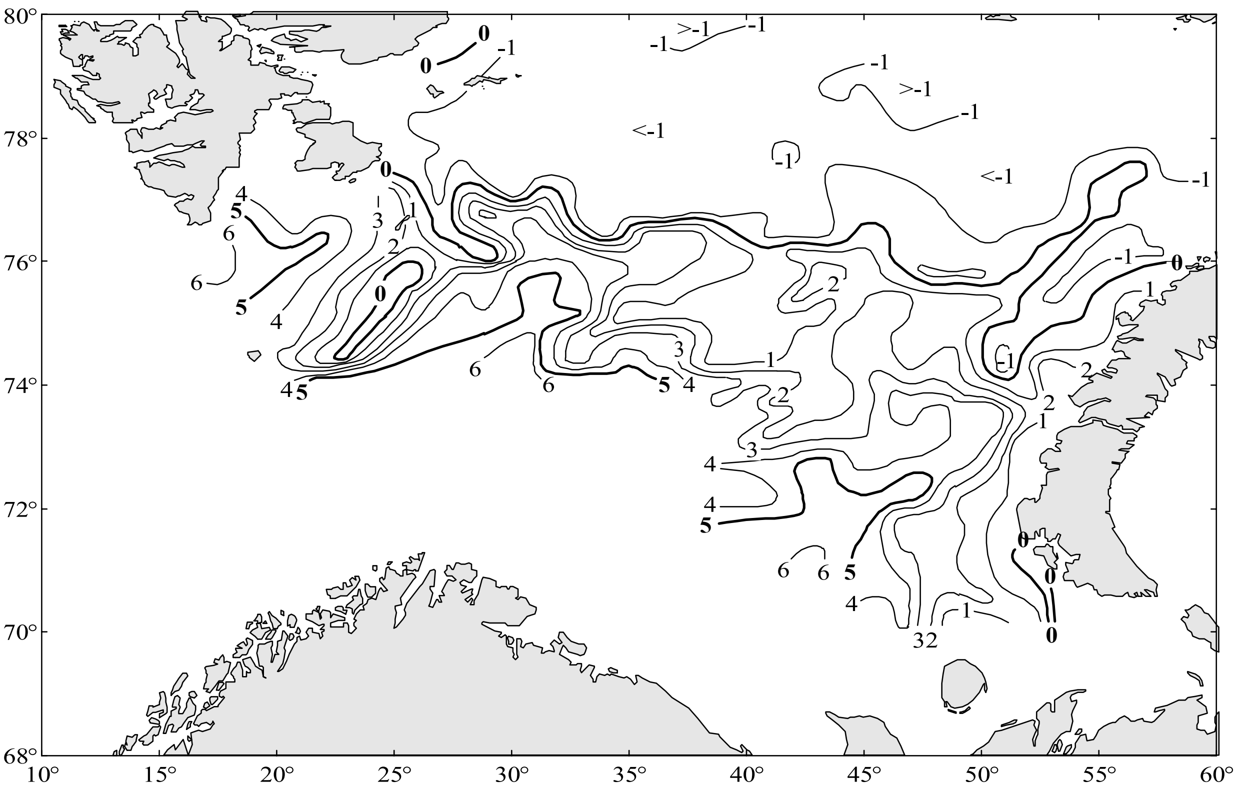

Figure 24 Temperature at 50 m September-October 2002

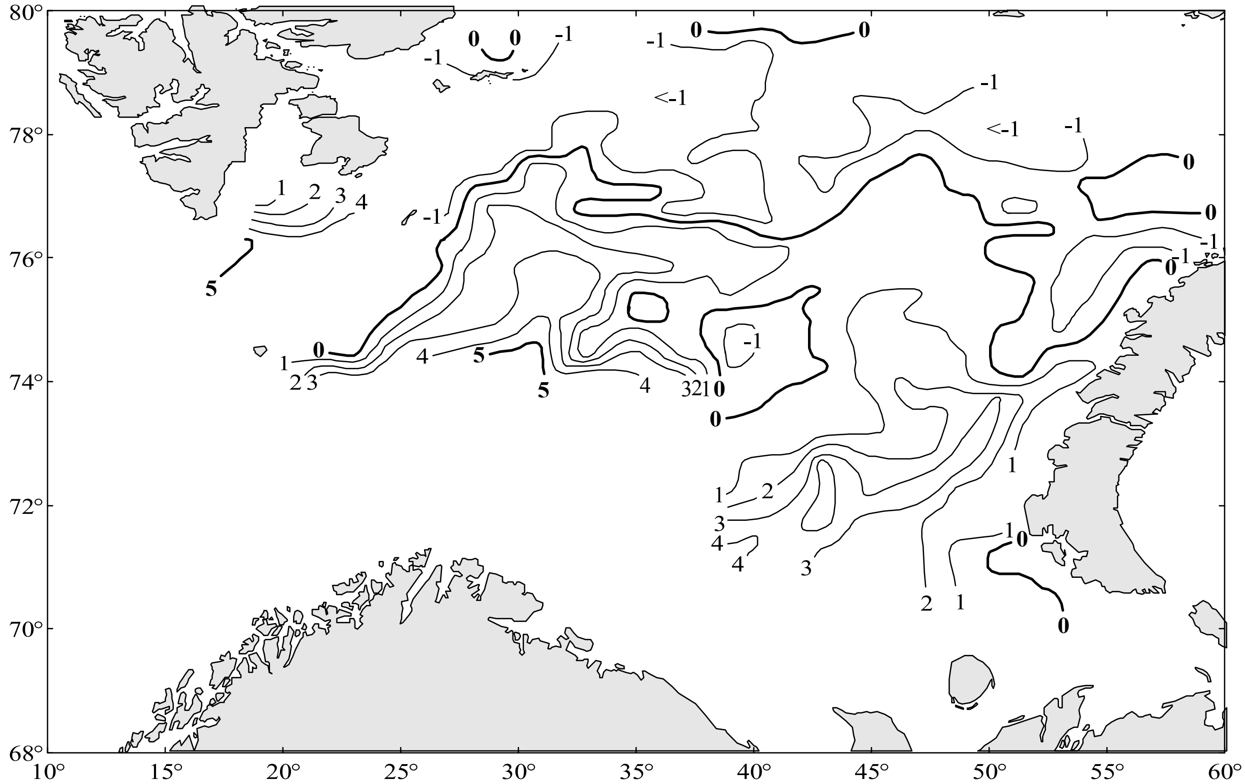

Figure 25 Temperature at 100 m September – October 2002

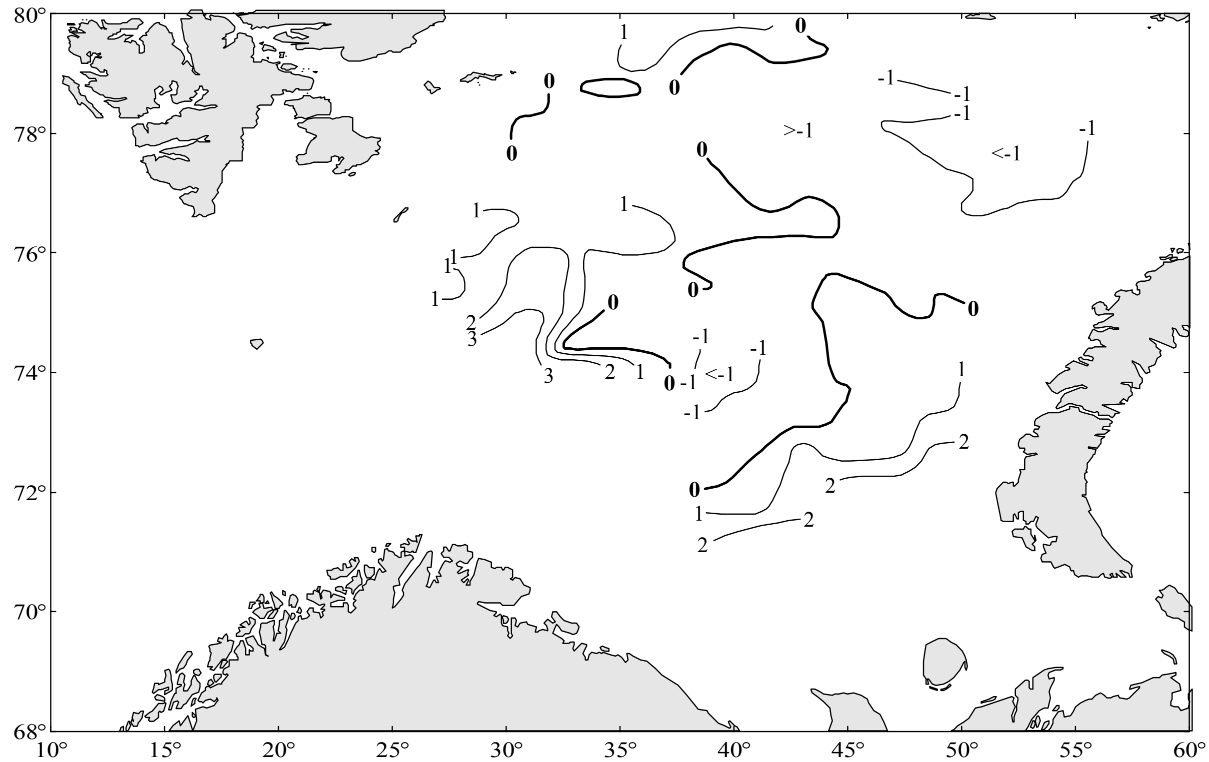

Figure 26 Temperature at 200 m September-October 2002

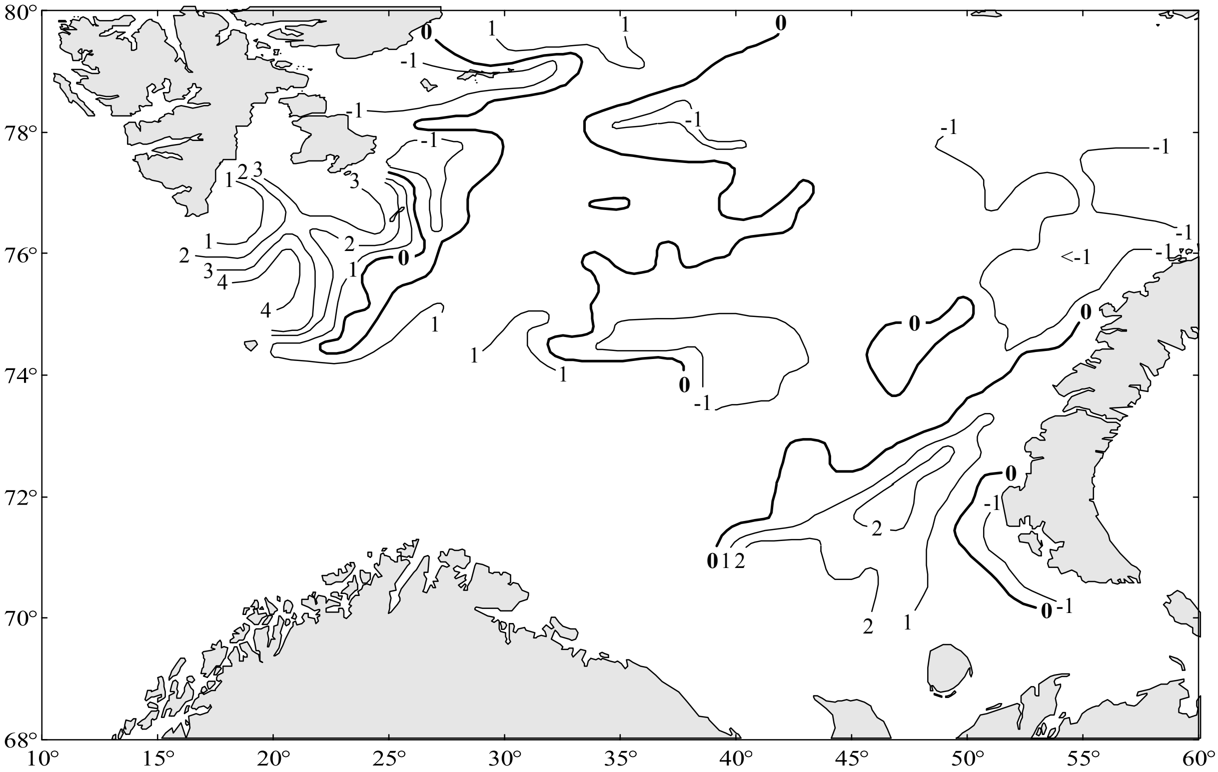

Figure 27 **Temperature at bottom depths September-October 2002**

Appendix I

Research vessel	Participants
“AtlantNIRO”	O. Dolgaja, M. Kalashnikova, V. Mamylov, R. Maslova, T. Prokhorova, D. Prozorkevich (cruise leader), S. Ratushnyy, E. Timokhin, A. Trofimov, O. Vavilina, N.Zujkova
“Fridtjof Nansen”	I. Dolgolenko (cruise leader), Yu. Garbut, V. Kapralov, S. Kharlin, V. Kiselev, A. Lukmanov, S. Nemchinov, A. Nikiforov, S. Rusjaev, V. Sergeev, F. Shevchenko, T. Yusupov
“G.O. Sars”	L. Drivenes, E. Hermansen, A.L. Johnsen, J. de Lange, J. H. Nilsen (cruise leader), B.V. Svendsen, K. Hansen, L. Rey, A. Romslo
“J. Hjort”	J. Alvarez, O.S. Fossheim, H. Gjøsæter (cruise leader), M. Johannessen, R. Johannesen, R. Jørgensen, R. Pettersen, B. Røttingen, J. Røttingen, B. Skjold, Ø. Tangen, N. Ushakov, N. Zhukova
”Michael Sars”	L. Drivenes, E. Hermansen, J. H. Nilsen (cruise leader), A. Nødtvedt, B.V. Svendsen, K. Hansen, L. Rey, A. Romslo

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	11.09.02	10.09.02	09.08.02	04.05.02
Place	Langefjord	Langefjord	Bøkfjord	N6935, E3332
Bottom depth (m)	47	51	44	142
Temperature (°C)	11.8	11.9	9.0	4.0
Salinity (‰)	32.9	32.9	33.5	34.3
Transducer type	ES38B-SK	ES38B-SK	ES38B	ES38B
Transducer depth (m)	0	0	0	
Real sphere depth (m)	19.3	16.5	19.6	19.5
Sound velocity (m/sec)	1493	1494	1484	1464
Absorption coefficient (dB/km)	10	10	10	10
Pulse length (Short/Med./Long, ms)	Med	Med	Med	Med
Bandwidth (Wide/Narrow)	Wide	Wide	Auto	Auto
Maximum power (W)	2000	2000	2000	2000
Transmit power (W)	Normal	Normal	Normal	2000
Angle sensitivity	21.9	21.9	21.9	21.9
2-way Beam Angle (10lgψ, dB)	-21.0	-21.0	-21.0	-20.9
Adjusted Sv Transducer Gain (dB)	27.56	27.05	27.35	25.1
Adjusted TS Transducer Gain (dB)	27.81	27.12	27.50	25.15
3-dB Beamwidth Alongship (deg.)	7.1	7.11	6.84	6.8
3-dB Beamwidth Athwartship (deg.)	6.8	6.97	6.73	6.9
Alongship (fore/aft.) Offset (deg.)	-0.09	-0.08	0.01	0.01
Athwartship Offset (deg.)	-0.06	0.09	-0.03	0.44
Theoretical Sa (m^2/nm^2)	6447	8700	6140	5948
Measured Sa (m^2/nm^2)	6552	8701	6034	5918
	$Sa = \sigma * 1852^2/(r^2 \psi)$		$\sigma = 4\pi * 10^{0,1\ TS}$	

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