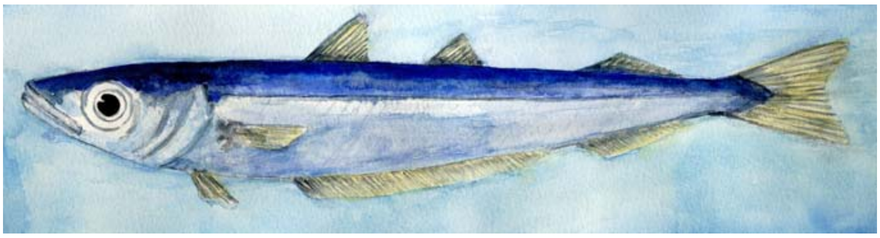
Toktrapport/Havforskningsinstituttet/ISSN 1503-6294/Nr. 26 - 2003

Working Document

to

The Northern Pelagic and Blue Whiting Fisheries Working Group
Copenhagen, Denmark, 27 April–4 May 2004



BLUE WHITING SURVEY DURING SPRING 2004

by

Mikko Heino, Henrik Søiland, Jan Erik Nygaard, Jaime Alvarez, Jan de Lange,
Kirsti B. Eriksen, Jarle Kristiansen, Elna Meland & Øyvind Tangen

Institute of Marine Research, Bergen, Norway

Artyom Oleynik

AtlantNIRO, Kaliningrad, Russia

Rebekka Varne

Trondhjem Biological Station, NTNU, Norway

Rupert Wienerroither

University of Salzburg, Austria

Johan Hjort, Institute of Marine Research, April 2004

Introduction

During the period March 19–April 18 R/V Johan Hjort surveyed the main spawning areas of blue whiting (*Micromesistius poutassou*) west of the British Isles. The survey is a continuation of a series of surveys that goes back to the 1970's. The Northern Pelagic and Blue Whiting Fisheries Working Group (or its predecessors) have used the data from 1981 onwards for tuning the assessment of stock abundance and structure (e.g., ICES 2003). This survey represents the longest continuous time series (only broken by a couple of years) on abundance and distribution of this stock and is as such also an important contributor on knowledge and information about stock dynamics in general.

The Norwegian survey in 2004 was part of the international blue whiting spawning stock survey. In addition to J. Hjort, three other vessels participated in the survey: R/V Fridtjof Nansen (PINRO, Murmansk, Russia), R/V Celtic Explorer (Marine Institute, Ireland) and R/V Tridens (Netherlands Fisheries Research Institute, the Netherlands). The results of the international survey, including inter-calibration of J. Hjort against the other vessels, are presented in a separate report.

Coordination of the international blue whiting spawning stock survey was initiated in the meeting of the Planning Group on Surveys on Pelagic Fish in the Norwegian Sea in August 2003 (ICES 2003). International co-operation allows for wider coverage of the stock and more rational utilisation of resources than isolated national surveys. However, in the aforementioned meeting it was recognized that as the Norwegian survey is currently the only tuning time series that has regularly been updated up to the present year, too drastic changes in this survey could jeopardize its value in tuning the assessment. The coverage of the Norwegian survey was therefore kept broadly similar, but a more regular design of cruise tracks was adopted in order to make coordination of efforts easier. Despite this modification, we consider the survey in 2004 as comparable to the earlier Norwegian blue whiting surveys.

The main purpose of the survey is to assess the abundance of blue whiting in the surveyed area using acoustic assessment methodology. In addition, the survey serves to improve knowledge about the biology and dynamics of this stock, particularly with respect to movements and distribution during and after spawning. This report documents the main results of the survey with the focus on the assessment of stock abundance.

Material and methods

The cruise tracks of Johan Hjort are shown in Figure 1. Traditional zig-zag design along the shelf edge was replaced with a more systematic approach. In comparison to earlier years, coverage in the south was more restricted and coverage in west-north-west more extensive.

The acoustic survey was conducted with Simrad EK 38 and 18 kHz echo sounders. Both sounders were controlled by a standard sphere calibration (Foote et al. 1987) some 4 months before the actual survey, and the calibration in the end of the survey revealed no changes. The 38 kHz echo sounder was used for the assessment, and differences between the two frequencies were used during the scrutinizing process to improve separation of blue whiting from other acoustic scatters. The acoustic recordings were scrutinized once or twice a day using the Bergen Echo Integrator (BEI, Foote et al. 1991). Blue whiting was separated from other recordings using catch information, characteristics of the recordings, and frequency response between 18 and 38 kHz integration. The main settings of the acoustic instruments are given in Appendix 1.

The main sampling tool for identification of the acoustic recordings and for representative biological sampling of the population was a 486 m circumference pelagic trawl (Åkratrål); this is the same pelagic trawl as used in earlier years. Meshes gradually decreasing from 3.2 m in front to 42 mm in the codend. A liner of 22 mm was inserted in the last 5 m of the codend. The rigging, detailed in Appendix 2, gave vertical opening between 25 m and 30 m at trawling speed of about 3 knots. Comparison against survey trawl on R/V Celtic Explorer suggested similar size selectivity but comparison against R/V Fridtjof Nansen showed a selection pattern shifted towards smaller sizes (difference in mean size 1.5 cm, 95 % confidence limits 0.84-2.2 cm). In addition bottom trawl with 4 x 18 m opening equipped with a Rock-hopper ground gear was used occasionally in shelf and bank areas, and a smaller capelin trawl (Harstadtrål) to target mesopelagic fish.

Catch from the trawl hauls was sorted and weighed; fish were identified to species, with a particular attention paid to lanternfishes, and other taxa to higher taxonomic levels. Saithe, herring and argentines were measured for length. Normally a sub-sample of 50 blue whiting were sexed, aged, and measured for length and weight, and their maturity status, stomach content, parasite load and liver size were estimated using established methods (Fotland et al. 2000). An additional sample of 50 fish (occasionally more) was measured for length and weight. Special morphological measurements were carried out for the first 10 fish in a sample. Tissue samples for genetic analyses were taken on most stations from 50 or 100 individuals.

The acoustic data as well as the data from trawl hauls were analysed with BEAM (Totland and Godø 2001) to make estimates of total biomass and numbers of individuals by age and length in the whole survey area and within different sub-areas (i.e., the main areas in the terminology of BEAM). Strata of 1º latitude by 2º longitude were used. The area of a stratum was adjusted, when necessary, to correspond with the area that was covered representatively by the survey track. This was particularly important in the shelf break zone where high densities of blue whiting dropped quickly to zero at depths less than 200 m. The shallow areas were normally not covered and these were excluded from the analysis.

To obtain an estimate of length distribution within each stratum, samples from the focal stratum were used. If the focal stratum was not sampled representatively, also samples from the adjacent strata were used. In such cases, only samples that represented a similar kind of registration that dominated the focal stratum were included. Because this includes a degree of subjectivity, the sensitivity of the estimate with respect to the selected samples was crudely assessed by studying the influence of these samples on the length distribution in the stratum. Length frequency distributions from each sample were weighted with the numbers of fish measured in that sample. The number of fish in the stratum is then calculated from the total acoustic density and the length composition of fish.

The methodology is in general terms described by Toresen et al. (1998). More information on this survey is given by, e.g., Anon. (1982) and Monstad (1986). Traditionally the following target strength (TS) function has been used:

$$TS = 21.8 \log L - 72.8 \text{ dB},$$

where L is fish length in centimetres. For conversion from acoustic density (s_A, m^2/n.mile^2) to fish density (ρ) the following relationship was used:

$$\rho = s_A / \langle\sigma\rangle,$$

where $\langle\sigma\rangle = 6.72 \cdot 10^{-7} L^{2.18}$ is the average acoustic backscattering cross section (m^2). The total estimated abundance by stratum is redistributed into length classes using the length distribution estimated from trawl samples. Biomass estimates and age-specific estimates are calculated for main areas using age-length and length-weight keys that are obtained by using estimated numbers in each length class within strata as the weighting variable of individual data.

BEAM does not distinguish between mature and immature individuals, and calculations dealing with only mature fish were therefore carried out separately after the final BEAM run. Proportions of mature individuals at length and age were estimated with logistic regression by weighting individual observations with estimated numbers within length class and stratum (variable 'popw' in the standard output dataset 'vgear' of BEAM). The estimates of spawning stock biomass and numbers of mature individuals by age and length were obtained by multiplying the numbers of individuals in each age and length class by estimated proportions of mature individuals. Spawning stock biomass is then obtained by multiplication of numbers at length by mean weight at length; this is valid assuming that immature and mature individuals have the same length-weight relationship.

We divided the surveyed area in four sub-areas similarly as in previous years (Fig. 5). Notice that the traditional sub-area I was not covered in the survey this year.

The hydrographical situation in the surveyed area was mapped by a net of 103 CTD stations (Figure 2), including one east-west sections at the western shelf edge of the Porcupine Bank at latitude 53° 30'N and from the Rockall Bank to the shelf edge offshore of the Hebrides at 57°30'N, and a section from the Faroes to Shetland (the Nolsø-Flugga section). The salinity data presented in this report are not calibrated, but the conductivity sensor was newly calibrated. Calibration data from the preceding cruises have shown that the CTD SBE911) on Johan Hjort is very stable and only minor corrections (less than 0.005) have been applied. The CTD data will be calibrated and subject to final quality control after the cruise. In addition surface (~4m) temperature, salinity and fluorescence were recorded continuously along the complete track of the cruise using a ship-mounted thermosalinograph (SBE21).

To study the distribution and development of blue whiting larvae and eggs, plankton samples were collected at about every second CTD stations (Fig. 2) by use of a plankton dip-net (80 cm diameter) lowered to 200 m depth. The samples were immediately fixed in 4 % buffered formaldehyde. Eggs and larvae were counted and identified to species. Blue whiting, mackerel and horse mackerel eggs were classified into developmental stages and larvae were measured for length; for blue whiting the classification of developmental stages followed the scheme adopted from Bailey (1982).

Results

Distribution of blue whiting

Blue whiting were recorded in most of the survey area that covered almost 120 thousand square nautical miles (Fig. 3). Little or know blue whiting were recorded above the deep waters between the Porcupine Bank-Hebrides and Rockall Bank. The highest concentrations were recorded in patches along the shelf edge from northwest of Ireland to the Hebrides. The highest recordings were observed at depths of 450-600 m, sometimes extending to around 300 m depth on the slope areas. Off the shelf break, the recordings often continued towards the ocean as a dense layer of some 50 m in thickness ("the green snake", see, e.g., Fig. 4 in Godø et al. 2002), or as a ribbon-like layer of dense, isolated shoals. This year looser layers of blue whiting in the upper parts of the water column (mostly juveniles) were observed only in the eastern parts of the Faroes sub-area.

When interpreting the results on the distribution and abundance, one should bear in mind that distribution of blue whiting is highly dynamic because of migrations in to and out of the spawning area.

The survey in 2004 took place almost two weeks earlier than in 2003, but only few days earlier than in most other recent years.

In relation to 2003, the distribution in 2004 was broadly similar. However, the densities were higher in the southern areas and lower in the north. This is in accordance with the idea that the shelf edge aggregations of blue whiting area mostly moving northwards during the spawning season.

Stock size

The estimated total abundance of blue whiting for the 2004 Norwegian survey was 11.4 million tonnes, representing an abundance of 137x10^9 individuals (Table 1). In terms of biomass, this estimate is essentially unchanged from the estimates in 2002 and 2003 but is substantially higher than in 2001 and before. In terms of numbers, this is about 15 % less than in 2003, reflecting larger average individual size in the stock. The geographical distribution of biomass by stratum is shown in Figure 4. The spawning stock was estimated at 10.9 million tonnes. This estimate is as high as the record from 2002, and is marginally higher than the estimate for 2003. The table below shows the Norwegian acoustic survey estimates of blue whiting in the spawning area since 1990:

Year	Abundance, 10^9 individuals		Biomass, mill. tonnes		Mean weight,	Mean length,
	total	spawning	total	spawning	g	cm
1990	62.9	56.2	6.3	5.7	100.7	27.1
1991	41.5	40.9	5.1	4.8	115.7	27.8
1992	38.4	36.8	4.3	4.2	111.3	27.5
1993	41.5	39.8	5.2	5.0	124.6	28.6
1994	26.8	26.1	4.1	4.1	152.9	31.1
1995	62.0	45.2	6.7	6.1	108.2	26.9
1996	52.2	36.2	5.1	4.5	94.9	25.5
1997						
1998	79.9	56.6	5.5	4.7	68.3	23.2
1999	120	110	8.9	8.5	74.4	25.0
2000	102	89.8	8.3	7.8	80.7	25.5
2001	96.5	72.1	6.7	5.6	69.0	24.1
2002	176	147	12.2	10.9	69.3	24.2
2003	160	132	11.4	10.4	71.6	24.6
2004	137	128	11.4	10.9	83.2	26.1

The spawning stock estimate obtained in 2004 is equal to the record obtained in 2002 in terms of biomass, but about 15% less in terms of numbers.

The biomass estimates for the Hebrides and Rockall sub-areas were approximately unchanged, with the Hebrides sub-area continuing to host the largest part of the estimated stock biomass. At the Hebrides, coverage was similar to the earlier years. At Rockall, however, the coverage of the survey was much larger than before, which together with the unchanged estimate implies a relatively low overall density. It is clear that this result is influenced by the timing of the survey. Norwegian fishing vessels reported good fishing in the area until early April, but at the time of the survey, most of the fishing fleet had already moved away from the area, after having fished in order of half a million tonnes blue whiting. To what extent this reflected depletion of biomass or movement of fish away from the area remains unclear.

The amount of blue whiting on the Porcupine Bank was about twice as high as observed in 2003 and in most other previous years. This occurred despite relatively small area covered, restricted to the northern parts of the area. This can probably be explained by the relatively early coverage of the area: later in the season the aggregations now recorded in this sub-area would likely have moved to the Hebrides sub-area. Similarly, timing of the survey probably contributed to the decrease in biomass recorded in the Faroes sub-area. However, also the numbers of juvenile blue whiting were lower than before.

Stock composition

Year class 2000 (age 4 years) continues to be the most abundant years class in the stock, both in terms of biomass and numbers (Table 2, Fig. 5). This was also the dominant year class in 2002 and 2003, and appears for third year in row as the strongest one in record for its age. This year class is now fully recruited to the spawning stock, and its number has been reduced by some 30% from 2003. The second and third in dominance were the year classes from 2001 and 2002 (respectively 2 and 1 years of age), followed by year class 1999 (age 5 years) with a very small margin. Whereas the numbers at age 1 and 2 years were moderate and lower than in previous two years and, the abundance of year class 1999 the highest one recorded at this age since 1988 (despite having been reduced in numbers by almost 50% in comparison to 2003). Earlier year classes (blue whiting of age 6 years and older) make only about 9% of the spawning stock.

There is considerable variability among the four sub-areas (Figure 6). Year class 2000 is dominating by a wide margin in the Hebrides and marginally in the Rockall sub-area. In other areas, younger fish are also abundant, namely 2001 year class in the Porcupine Bank and Faroes sub-areas, and 2002 in the Faroes. This picture is consistent with that observed in 2003, with the Hebrides sub-area having the oldest fish and the Faroes youngest.

Mean length and weight of blue whiting in the survey area show an increase from 2003 and 2002 (see the text table above), largely reflecting the increase in the average age. Nevertheless, average individual size continues to be much smaller than it was in the early 1990’s. Both length and weight at age in 2004 are slightly lower than in 2003, such that condition factors at different ages are more or less unchanged.

Eggs and larvae

Plankton samples were taken from 43 stations. Blue whiting was the most numerous species among both fish larvae and eggs. All sample distributions were highly skewed with a few samples containing most of the individuals. Mean numbers of eggs and larvae per sample (with standard deviations) in 2001-2004 were the following:

Year	Blue whiting		Mackerel		Horse mackerel	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
2004	4.5 (11)	9.8 (29)	1.5 (8.8)	0 (0)	0.14 (0.77)	0.023 (0.15)
2003	16.5 (67)	**176** (703)	**20.3** (50)	7.5 (30.3)	**2.7** (7.2)	0.043 (0.21)
2002	1.7 (4.6)	21.9 (48)	**27.8** (98)	0.34 (1.2)	**5.3** (30)	0.054 (0.30)
2001	6.7 (37)	**72.9** (207)	**23.8** (62)	0.20 (0.78)	0.46 (1.4)	0.049 (0.31)

Boldface is here used to mark abundances that are significantly ($p<0.05$) different from the abundance in 2004 as estimated by generalized linear models with logarithmic link and negative binomial error functions.

Abundance of blue whiting larvae was the lowest one recorded in this short time series. In comparison to years 2001 and 2003, this difference is statistically significant ($p<0.001$, see the table above). The number of eggs was low but not as low as in 2002. The numbers of mackerel and horse mackerel eggs and larvae were the lowest on record. However, interpretation of these changes is difficult because of the short time series and highly aggregated distribution of ichthyoplankton. That all components of ichthyoplankton were rare suggests a common explanation. In terms of hydrography (see below), 2004 is not very different from 2004. More turbulent seas in 2004 than in 2003 may also have influenced sampling, either directly by disturbing the operation of the plankton net, or by influencing distribution of ichthyoplankton. It is also obvious that spatial and temporal allocation of sampling effort may have strong influence on the observed variation in abundance. It is thus not possible to say whether the observed rarity of ichthyoplankton is genuine, or caused by changes in sampling in relation to distribution of ichthyoplankton.

Distribution of blue whiting eggs shows no obvious patterns (Fig. 7). Eggs in the late stages of development were dominating. Most of the larvae were encountered near the Porcupine Bank and towards Rockall. Small larvae of 3 mm in length were dominant, which suggests somewhat smaller average size than in the previous years. This is probably related to the core areas having been covered earlier in the season in 2004 than before.

Other fish

Most of the fish were identified to the species level. This revealed altogether 73 species. List of fish species encountered during the survey is given in Appendix 3.

From total of 36 trawl tows, 28 resulted in the capture of myctophid fishes. These were identified to 13 genera and 17 species, and are therefore the most diverse family encountered during this survey, outnumbered only by blue whiting and probably pearlside (*Maurolicus muelleri*).

Benthosema glaciale, *Lampanyctus crocodilus*, *Myctophum punctatum* and *Notoscopelus kroyeri* were dominant within the lanternfishes. Remarkable is the range in standard length of the latter species. Hardly a specimen smaller than 50 mm SL was encountered, most of them measuring more than 100 mm. An influence of the mesh size in the cod end cannot be negated, but the finding of smaller specimens of other species (e.g. the very abundand *B. glaciale*) suggests a distinct population structure of *N. kroyeri* in the investigation area during spring, probably ascribable to its life cycle.

The distribution range of some species may be slightly corrected towards their northern (or northeastern, respectively) extension, although no new species for the area was encountered.

Hydrography

The horizontal distribution of temperature at 10 and 400 meters depths are shown in Figure 8 and 9 respectively. The maps are based on data collected on board Johan Hjort (Figure 2) and CTD data kindly provided by the scientists on board R/V Fridtjof Nansen and R/V Celtic Explorer, who were running simultaneous surveys in the area. The cooperation has given a much better horizontal coverage of the area.

The Wyville Thompson ridge (~60°N) divides the survey area into two very different hydrographic regimes. South of the Wyville Thompson ridge the vertical gradients in temperature are small. In this area the difference in temperature between 10m and 400m are less than 1°C and at 1000m depth the temperatures are between 6 and 9°C, with the lowest temperatures at the Porcupine section (Figure 10) and in the north west. In the Faroe-Shetland channel the situation is very different with a strong thermocline around 500m depth separating a layer of warm saline Atlantic water overlying cold (~-0.5°C), deep waters originating in the Norwegian Sea (See Figure 11, Faroe-Shetland section).

Also the horizontal gradients are generally very small in the area south of the Wyville Thompson ridge; in particular, the north-south gradient is very small. In the Rockall Through the temperature drops by less than 2°C from 50°N to 60°N both at 10m and 400m depths (Figures 8 and 9). Due to a northward flowing shelf edge current, the warmest and most saline water is found in a narrow band along the shelf edge.

Both in 2003 and this year the temperatures in the southern part of the area were above 11°C. In 2003 the 10°C isotherm extended north to about 60°N and water with temperatures above 9.5°C was observed on the Faroe-Shetland section. This year the 10°C isotherm extended north to about 58°N and the warmest water in the Faroe-Shetland channel was just above 9°C. In the south, at 400m depth, the horizontal temperature distribution is very similar to one last year. Thus, in the northern part of the survey area the temperatures at 10m are lower than last year, whereas in the south the differences between this year and last year are small. At 400m depth the temperature distribution was very similar to last year's. At both depths the temperature distributions are similar to what was observed in 2003; compared to earlier years the temperatures are high in the whole area.

At the Porcupine section (Figure 10) the temperature is quite homogeneous down to about 500m with a gradual change in the thermocline between 500m and 1000m. The most conspicuous feature this year is the very high salinities in the upper few hundred meters with salinities above 35.55. If we go back to 2001 the highest salinities were below 35.50, and in 2002 and 2003 we saw an increased presence of water with salinity above 35.50, but this is the first year we have observed salinities above 35.55. Observations from the Celtic Explorer showed salinities above 35.60 just south of the Porcupine Bank. These high salinities indicate a stronger influence of water of Mediterranean origin.

On the Faroe-Shetland section (Figure 11) there is a characteristic wedge shaped core of Atlantic water on the eastern slope, but with Atlantic water in the upper hundred meters across the whole channel. The isotherms and isohalines have a characteristic dome shape, with the intermediate (S<34.90) water of Norwegian Sea origin extending up to about 450m in the central part of the section. The 0°C isotherm is found at 500m depth at the western side and it slopes downward to nearly 700m at the eastern side. Last year the 0°C isotherm was found at 700-800m depth. The extent of the Atlantic is smaller and the temperature in the core of the Atlantic water is slightly lower than last year, but still warm compared to previous years. However, salinities above 35.40 are observed and that have only been seen in 2003 and 2004.

The high temperatures and salinities are confirmed by a study of the temperatures and salinities on all blue whiting cruises from 1983 through 2004. Since the hydrographic surveys have been dependent on the fishery surveys, the CTD stations have been distributed along the shelf edge and have in general not been in the same positions from year to year. In order to compile a time series, the data were grouped in boxes with horizontal dimensions of 2° latitude times 2° longitude, and for each year the mean temperature and salinity from 50 to 600m of all the stations in deep water (bottom depth>600m) in each box was calculated. Some of the boxes had good coverage nearly every year, while others had many years missing. However, in general the same variation from year to year was seen in the boxes along the shelf edge south of the Wyville Thompson ridge. The box with limits 52° to 54°N and 16° to 14°W had few gaps; the time series of mean temperature and salinity for this box is shown in Figure 12. The pattern seen is that after some years with temperatures around 10.1°C in the 1980s, it dropped to a minimum in 1994 (~9.8°C). After 1994 an increase in temperature is seen, and in 1998 temperature reached a local maximum (~10.5°C) with the three following years a few tenths of a degree colder. 2002 was a warm year with ~10.7°C, and in 2003 the temperature dropped to the same as in 1998. 2004 is slightly warmer than 2002, making the warmest year in record.

The salinity has also increased over the years, and 2004 was the first year with mean salinity in the box off Porcupine Bank with salinity above 35.50. Also in the boxes further north, where a decrease in temperature from last year was seen, the salinity increased.

In the boxes along the continental shelf in the Rockall Through a similar pattern as described above is seen, but the temperatures did not drop from 2002 to 2003. 2004 was a bit colder than 2003, but still a warm year. All in all, the years 2002-2004 stand out as three consecutive warm years with high temperatures and salinities in the upper 600m in the Rockall Through.

Concluding remarks

It is important to emphasize that the acoustic estimates of blue whiting stock, although traditionally expressed in numbers and biomass, should be understood as relative rather than absolute measures of stock abundance. The estimates are based on a target strength relationship that is known to give too low values. As a consequence, the biomass estimate for the survey are is too high (the actual bias is not known but may be as high as about 40%, see Godø et al. 2002, Heino et al. 2003). On the other hand, it is clear that the coverage of the spawning stock by the survey is not complete. Some other sources of uncertainty in this survey are discussed in Heino (2004).

The survey results on blue whiting spawning stock in spring 2004 suggest a marginal decrease in numbers and a marginal increase in biomass in comparison to 2003. These results should be judged against changes in survey coverage, which was by about 40% larger in 2004 than in 2003. However, much of the increased coverage comes from areas west of Rockall, where relatively low densities were recorded and which thereby do not contribute very much to the total biomass estimate.

While the estimates of total and spawning stock biomass of blue whiting in the survey area west of the British Isles in 2004 show no significant change from 2003, there is a significant change in the age structure of the spawning stock. The year class 2000, probably one of the strongest year classes in record, continues to dominate the spawning stock (39% of spawning stock biomass is attributed to this year class). The year class 2001 is also abundant (28% of SSB). In addition, year class 1999 has a share of 15%; in terms of numbers, this the highest value observed in the survey for 5-yr old fish since 1988. It is importance to appreciate that the spawning stock biomass is to an increasing degree maintained by growth of mature fish in the stock, as opposed to new recruiting year classes (as has been the case for two previous years).

Norwegian survey in 2004 was carried out in co-operation with three vessels (from Ireland, the Netherlands and Russia). Preliminary results of the international survey are in agreement with the Norwegian results with respect to stock abundance, but suggest somewhat higher proportions of large (and old) blue whiting. This is probably related to the relatively small survey trawl employed on R/V Johan Hjort in comparison to the other vessels.

Despite record high exploitation level in the recent years, abundance of blue whiting appears remarkably stable. This is most likely due to exceptionally good recruitment during the period 1995-2000, in particular in 1999-2000. While year class 2001 appears somewhat stronger than previous indications had suggested, its abundance is well below the big year-classes from 1999 and 2000.

Year class 2002 appears even smaller, although this year class is only partially recruited to the spawning stock and thereby not well covered by the survey. Thus, with no incoming year-classes to match the big ones from 1999 and 2000, one can not expect that the current catch levels can be maintained from year to year without reducing the abundance of the spawning stock.

Acknowledgements

We would like to express our gratitude to the officers and the crew of R/V Johan Hjort for their good will and professional contribution to the investigations throughout the survey.

References

Anon. (Monstad et al.), 1982. Report of the International acoustic survey on blue whiting in the Norwegian Sea, July/August 1982. ICES CM 1982/H5.

Bailey, R. S. 1982. The population biology of blue whiting in the north Atlantic. Adv. Mar. Biol. 19: 257-355.

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report, 144: 1-57.

Foote, K.G., H.P. Knudsen, R.J. Korneliussen, P.E. Nordbø and K. Røang 1991. Postprocessing system for echo sounder data. The Journal of the Acoustical Society of America, 90:37-47.

Godø, O. R., Heino, M., Søiland, H., Alvarez, J., Dahl, M., de Lange, J., Gullaksen, O., Tangen, Ø. & Torkelsen, T. 2002. Blue whiting survey during spring 2002. Working Document to The Northern Pelagic and Blue Whiting Fisheries Working Group, Vigo, Spain, 29 April-8 May 2002. 27 pp. ICES CM 2002/ACFM19.

Heino, M. 2004. Norwegian acoustic surveys on blue whiting spawning stock. In: Improvement of instrumental methods for stock assessment of marine organisms. Proceedings of the Russian-Norwegian Workshop on Hydroacoustics, 11-14 November 2003, Murmansk, Russia (ed. Chernook, V.), pp. 76-83. PINRO Press, Murmansk.

Heino, M., Godø, O. R., Søiland, H., Nygaard, J. E., Alvarez, J., de Lange, J., Drivenes, L., Gullaksen, O., Tangen, Ø. and Torkelsen, T. 2003. Blue whiting survey during spring 2003. Working Document to The Northern Pelagic and Blue Whiting Fisheries Working Group, Copenhagen, 29 April-8 May 2003.

ICES 2003a. Report of the Northern Pelagic and Blue Whiting Working Group. ICES CM 2003/ACFM:23.

ICES 2003b. Report of the Planning Group on Surveys on the Pelagic Fish in the Norwegian Sea. ICES CM 2003/D:10, Ref. ACFM, ACE.

Mjanger, H., Alvsvåg, J., Hestenes, K., Svendsen, B. V. and De Lange Wenneck, T. 2000. Prøvetaking av fisk og krepsdyr. Version 3.14. Institute of Marine Research, Bergen. 151 pp.

Monstad, T., 1986. Report of the Norwegian survey on blue whiting during spring 1986. ICES CM 1986/H53.

Toresen, R., Gjøsæter, H. and Barros de, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus* Müller) and herring (*Clupea harengus* Linné) in the Barents Sea. Fisheries Research, 34: 27–37.

Totland, A. and Godø, O.R. 2001. BEAM – an interactive GIS application for acoustic abundance estimation. *In* T. Nishida, P.R. Kailola and C.E. Hollingworth (Eds): *Proceedings of the First Symposium on Geographic Information System (GIS) in Fisheries Science*. Fishery GIS Research Group. Saitama, Japan.

Table 1. Assessment factors of blue whiting, spring 2004.

Subarea			Numbers (millions)			Biomass (1000 tonnes)			Mean weight	Mean length	Density
		n.mile^2	Mature	Total	%mature	Mature	Total	%mature	g	cm	t/n.mile^2
I+II	Porcupine Bank	19 721	18 380	18 520	99.3	1 484	1 491	99.6	80.5	26.2	76
III	Hebrides	34 917	76 160	76 530	99.5	6 484	6 496	99.8	84.9	26.6	186
IV	Faroes/Shetland	23 003	19 330	25 825	74.9	1 776	2 175	81.6	84.2	25.4	95
V	Rockall	39 588	14 090	16 426	85.8	1 178	1 258	93.7	76.6	25.3	32
Total		117 228	128 000	137 300	93.2	10 920	11 420	95.6	83.2	26.1	97

Table 2. Stock estimate of blue whiting, spring 2004.

Length	Age in years (year class)									Numbers	Biomass	Mean	Proportion
	1	2	3	4	5	6	7	8	9				
(cm)	2003	2002	2001	2000	1999	1998	1997	1996	1995	(10^6)	(10^6 kg)	weight, (g)	mature
14.0 - 15.0	87	0	0	0	0	0	0	0	0	87	1.3	14.5	0
15.0 - 16.0	243	0	0	0	0	0	0	0	0	243	5.2	21.3	0
16.0 - 17.0	373	0	0	0	0	0	0	0	0	373	9.1	24.4	0
17.0 - 18.0	704	0	0	0	0	0	0	0	0	704	21	29.8	0
18.0 - 19.0	763	0	0	0	0	0	0	0	0	763	24.7	32.4	0
19.0 - 20.0	759	0	0	0	0	0	0	0	0	759	29.1	38.3	0
20.0 - 21.0	272	1036	0	0	0	0	0	0	0	1308	51.7	39.6	41
21.0 - 22.0	350	1173	701	0	0	0	0	0	0	2224	108.2	48.7	57
22.0 - 23.0	49	3046	1169	259	0	0	0	0	0	4523	260	57.5	69
23.0 - 24.0	239	5854	3403	1593	64	0	0	0	0	11152	694.9	62.3	86
24.0 - 25.0	21	3925	8592	8205	601	394	0	0	0	21738	1508	69.4	95
25.0 - 26.0	0	2201	12453	10563	1178	0	42	0	0	26437	1973.1	74.6	98
26.0 - 27.0	0	784	6616	9476	2661	80	0	42	0	19657	1614.9	82.2	99
27.0 - 28.0	0	270	3933	9797	2147	661	0	78	58	16944	1540.4	90.9	100
28.0 - 29.0	0	166	2845	5180	2861	585	312	460	103	12512	1294.2	103.4	100
29.0 - 30.0	0	114	476	2559	2477	893	427	149	29	7125	791.6	111.1	100
30.0 - 31.0	0	0	348	1798	1387	1081	302	75	0	4991	618.3	123.9	100
31.0 - 32.0	0	0	27	597	1369	410	525	97	0	3025	414.6	137.1	100
32.0 - 33.0	0	0	18	109	682	178	418	292	0	1697	262.3	154.6	100
33.0 - 34.0	0	0	0	0	114	89	144	55	32	434	71.5	164.6	100
34.0 - 35.0	0	0	88	0	0	0	19	19	0	126	16.8	133.8	100
35.0 - 36.0	0	0	0	0	0	83	0	0	103	186	38.2	205.2	100
36.0 - 37.0	0	0	0	0	108	0	0	0	0	108	25.9	240.5	100
37.0 - 38.0	0	0	0	0	0	0	0	0	62	62	15.6	250.7	100
38.0 - 39.0	0	0	0	0	0	0	29	29	0	58	13	223	100
39.0 - 40.0	0	0	0	0	0	0	0	19	39	58	16.1	279	100
TSN (10^6)	3860	18569	40669	50137	15649	4454	2218	1313	426	137295			
TSB (10^6 kg)	138	1211	3136	4267	1631	510	290	166	71	11420			
Mean length (cm)	18.8	23.8	25.6	26.6	28.5	29.3	30.9	30.4	32.8	26.1			
Mean weight (g)	35.6	65.2	77.1	85.1	104.2	114.5	130.7	126.1	167.6	83.2			
Condition	5.4	4.8	4.6	4.5	4.5	4.6	4.4	4.5	4.7	4.7			
% mature	8	78	97	99	100	100	100	100	100	93.2			
% of SSB	0	9	28	39	15	5	3	2	1				

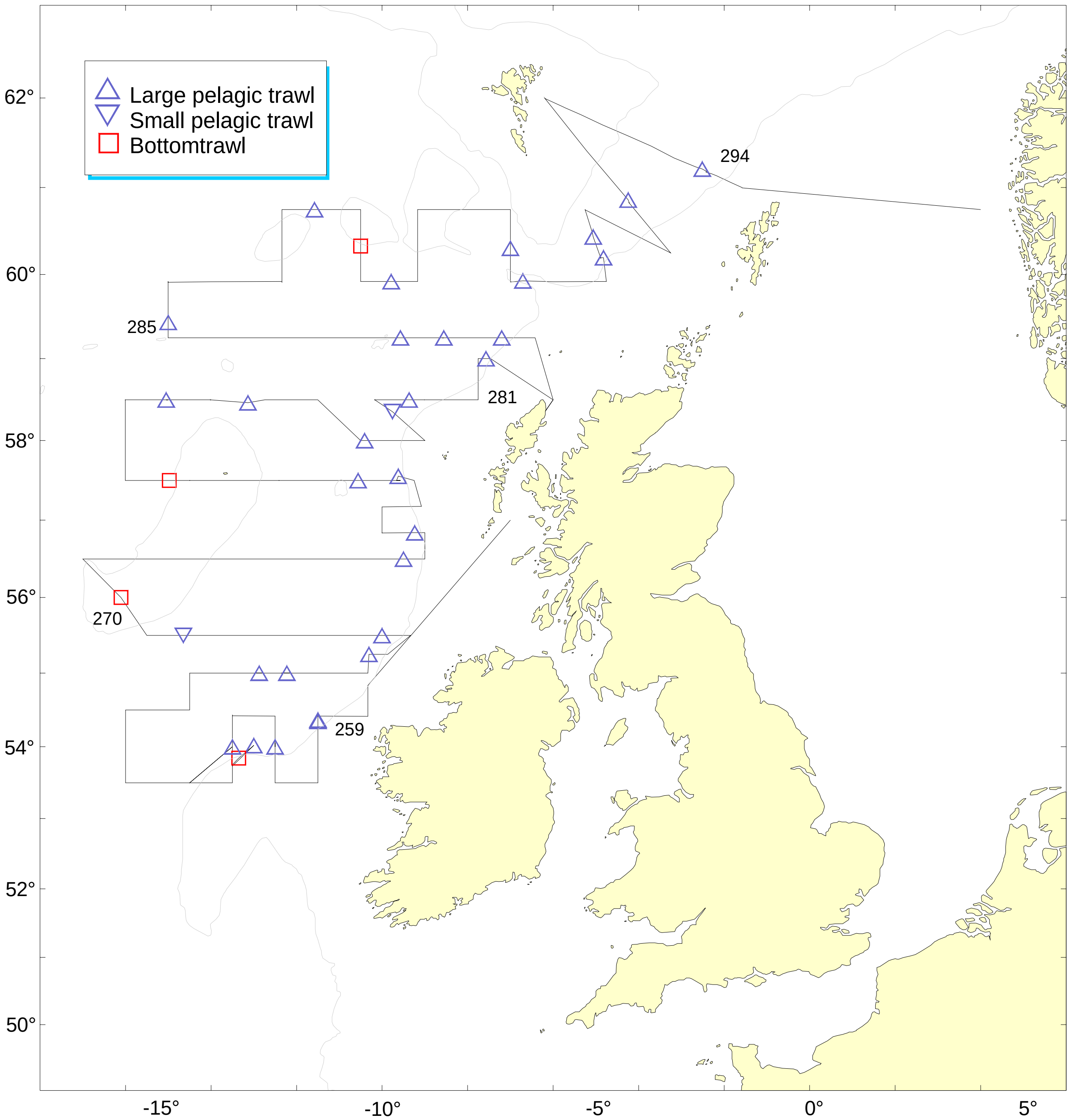


Figure 1. Cruise tracks with trawl stations, R.V. “Johan Hjort” 19 March–18 April 2004.

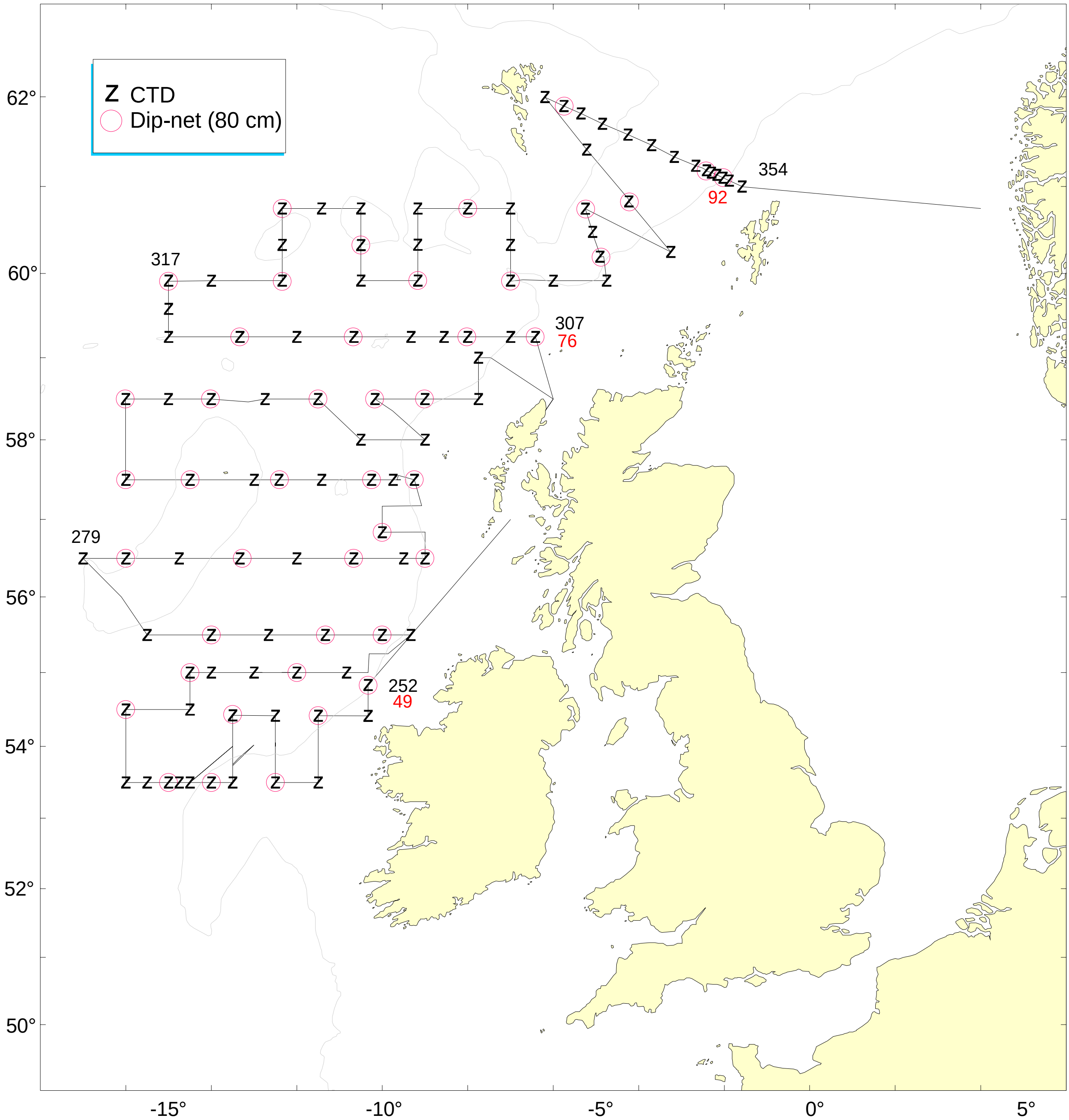


Figure 2. Cruise tracks with CTD and plankton stations, R.V. "Johan Hjort" 19 March–18 April 2004.

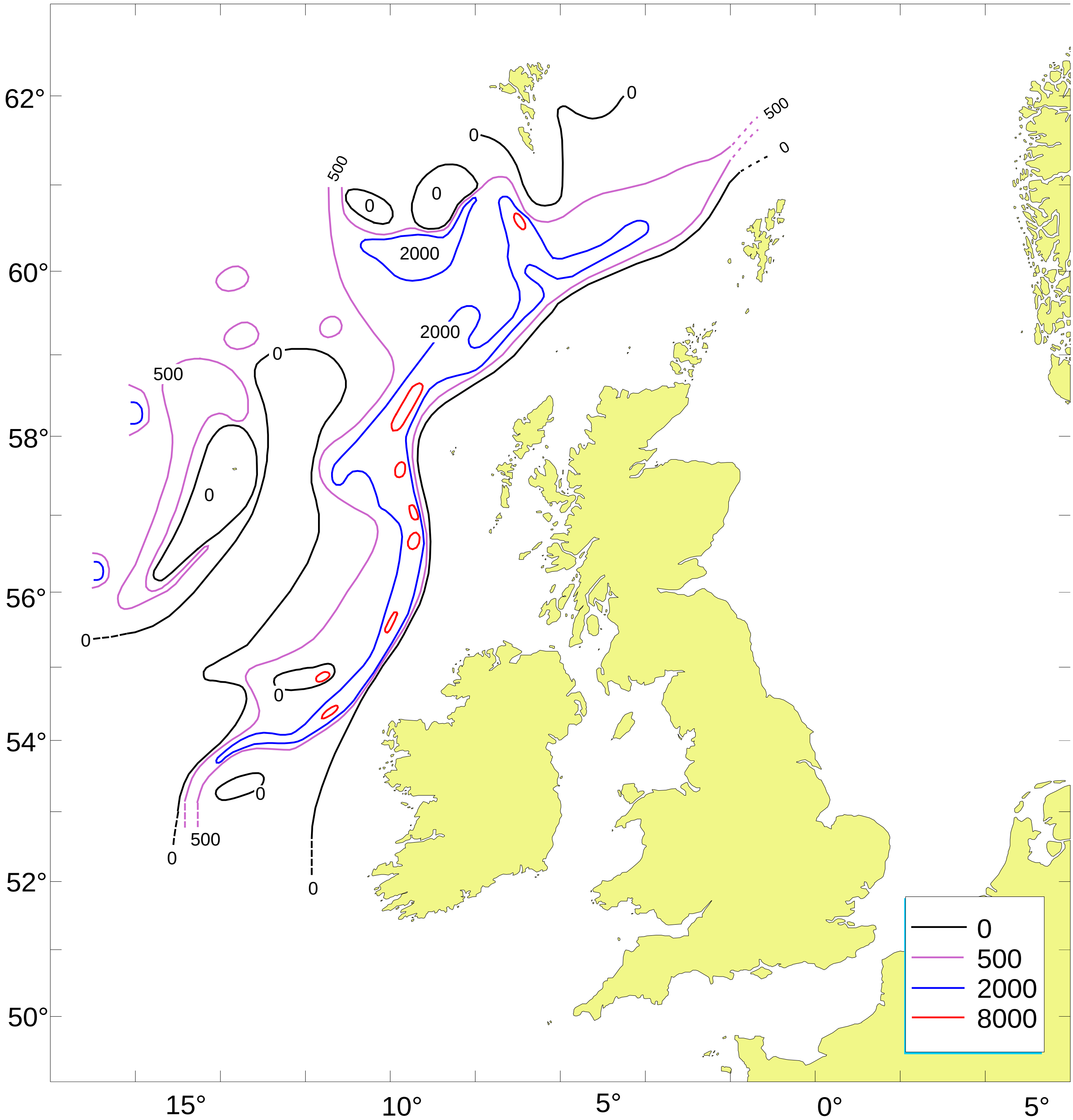


Figure 3. Distribution of blue whiting in spring 2004 in terms of echo intensity (s_A-values, m^2/n.mile^2). The map is primarily based on observed echo intensities along the cruise track (Fig. 1) and knowledge on bottom topography and its influence on distribution of blue whiting. In the margins also observations from R/V Celtic Explorer and R/V Fridtjof Nansen were used.

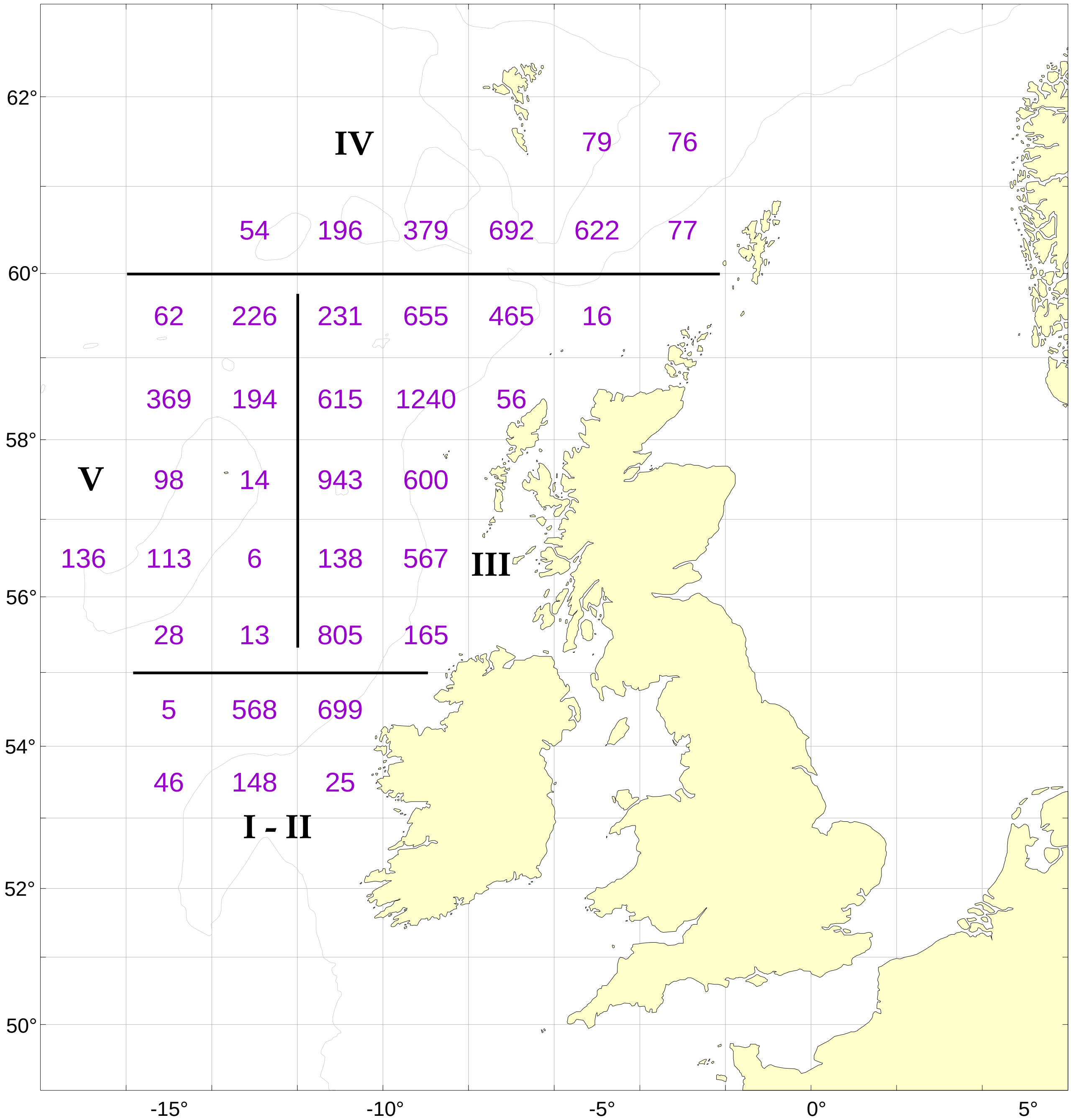


Figure 4. Blue whiting biomass in 1000 tonnes, spring 2004. Marking of sub-areas I-V used in assessment.

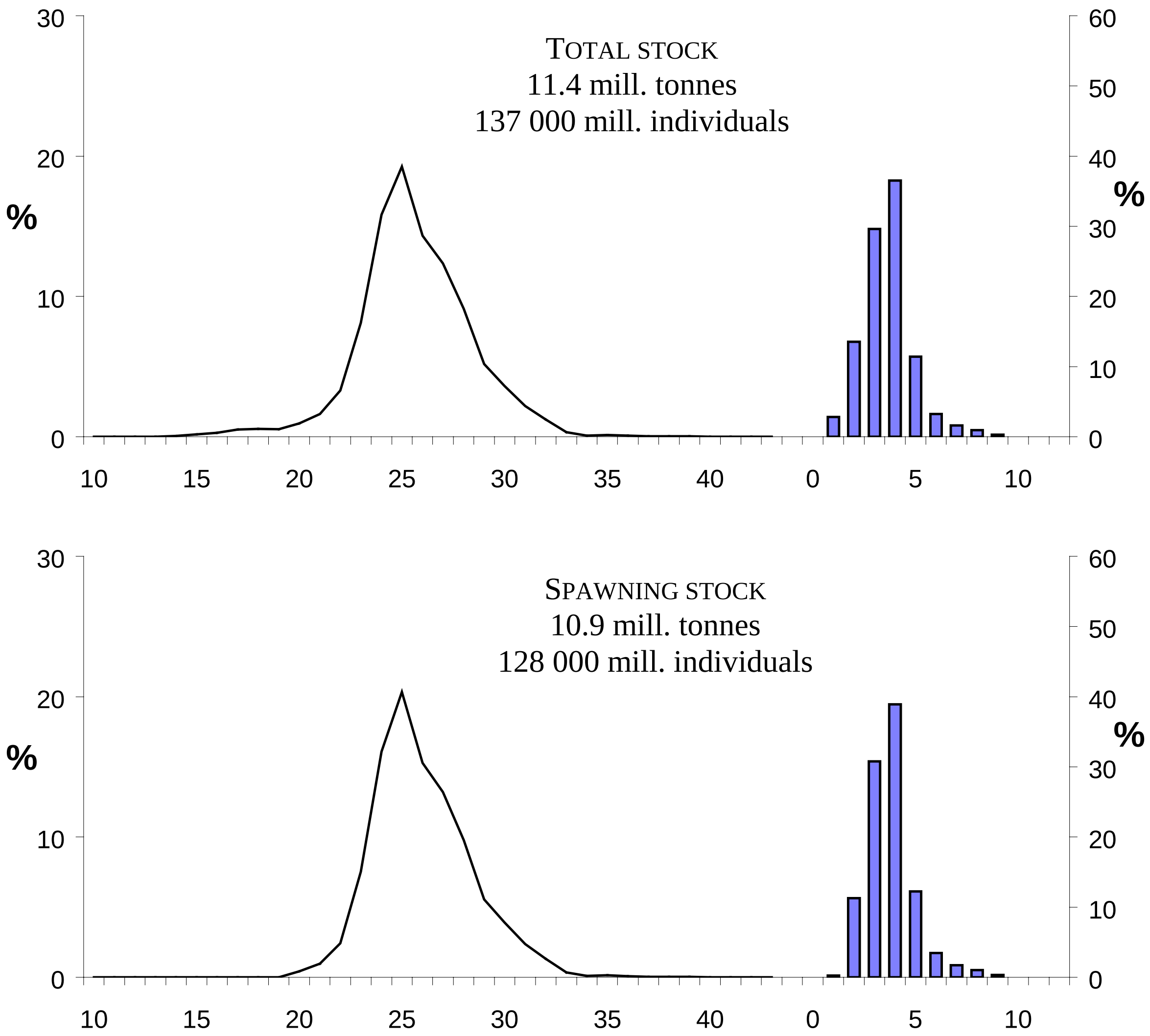


Figure 5. Length and age distribution in the total and spawning stock of blue whiting in the area to the west of the British Isles, spring 2004.

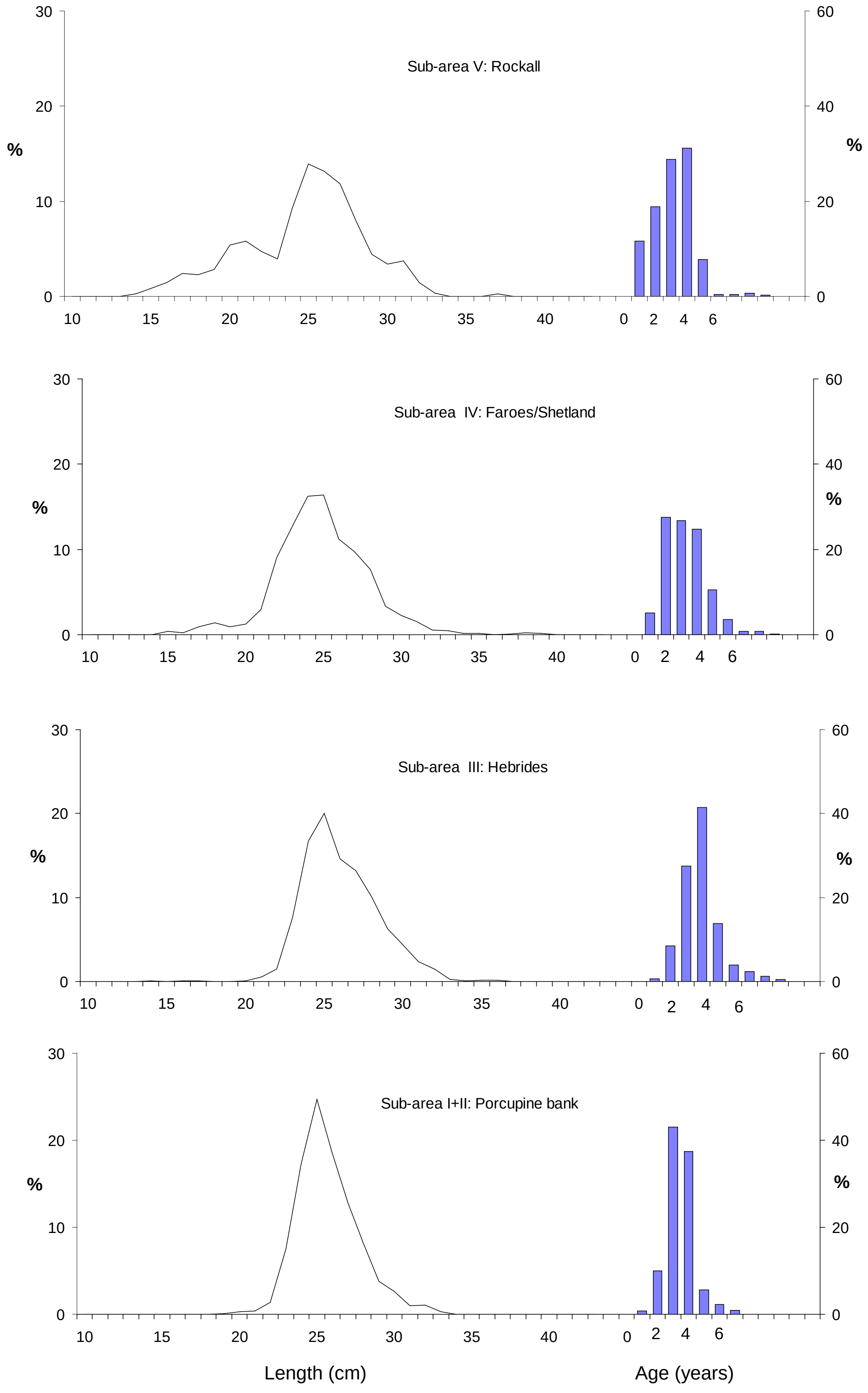


Figure 6. Length and age distribution of blue whiting by sub-areas (I-V), spring 2004.

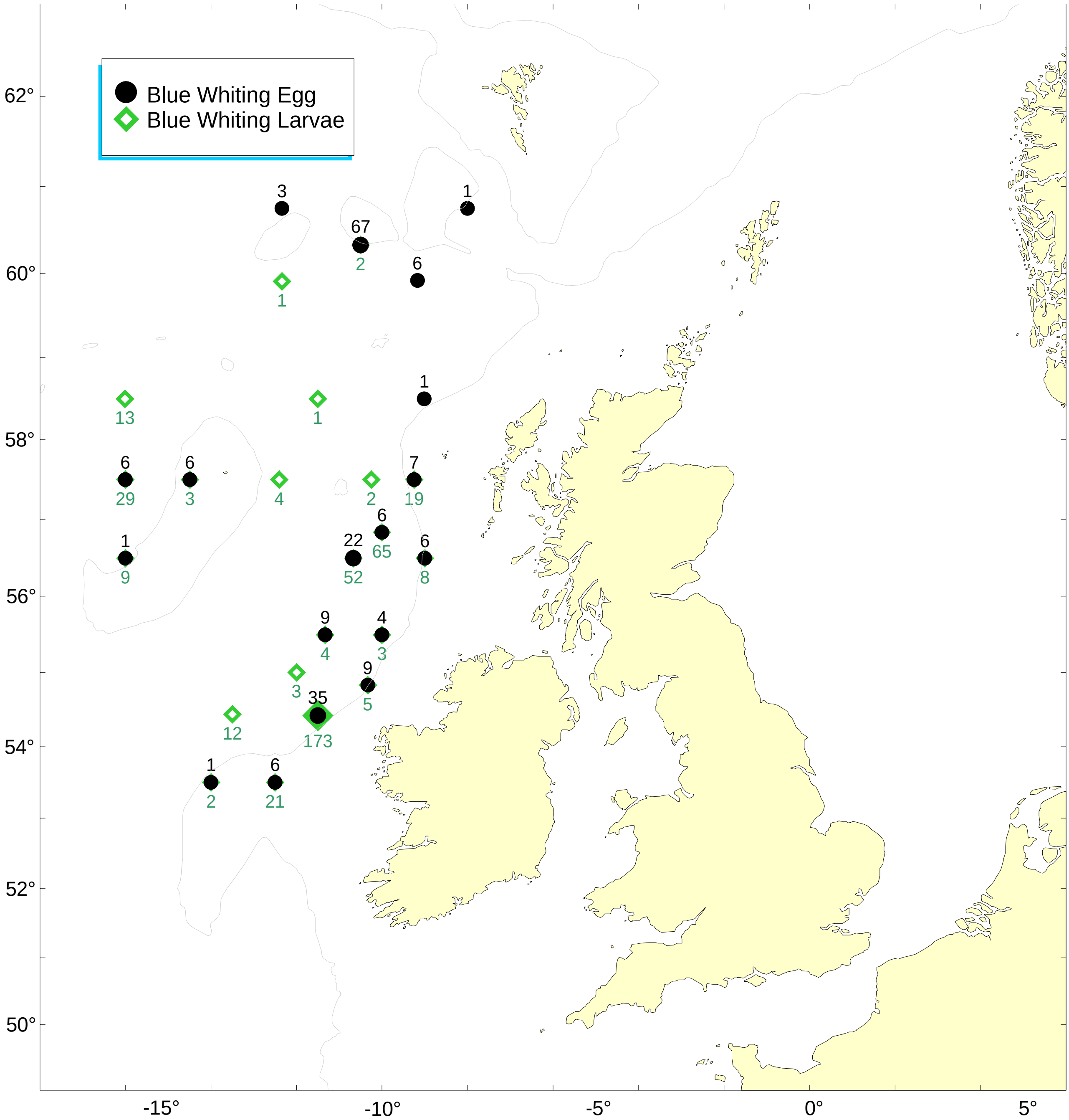


Figure 7. Distribution of blue whiting eggs and larvae in spring 2004. Number of individuals is also inserted (eggs on the top, larvae on the bottom).

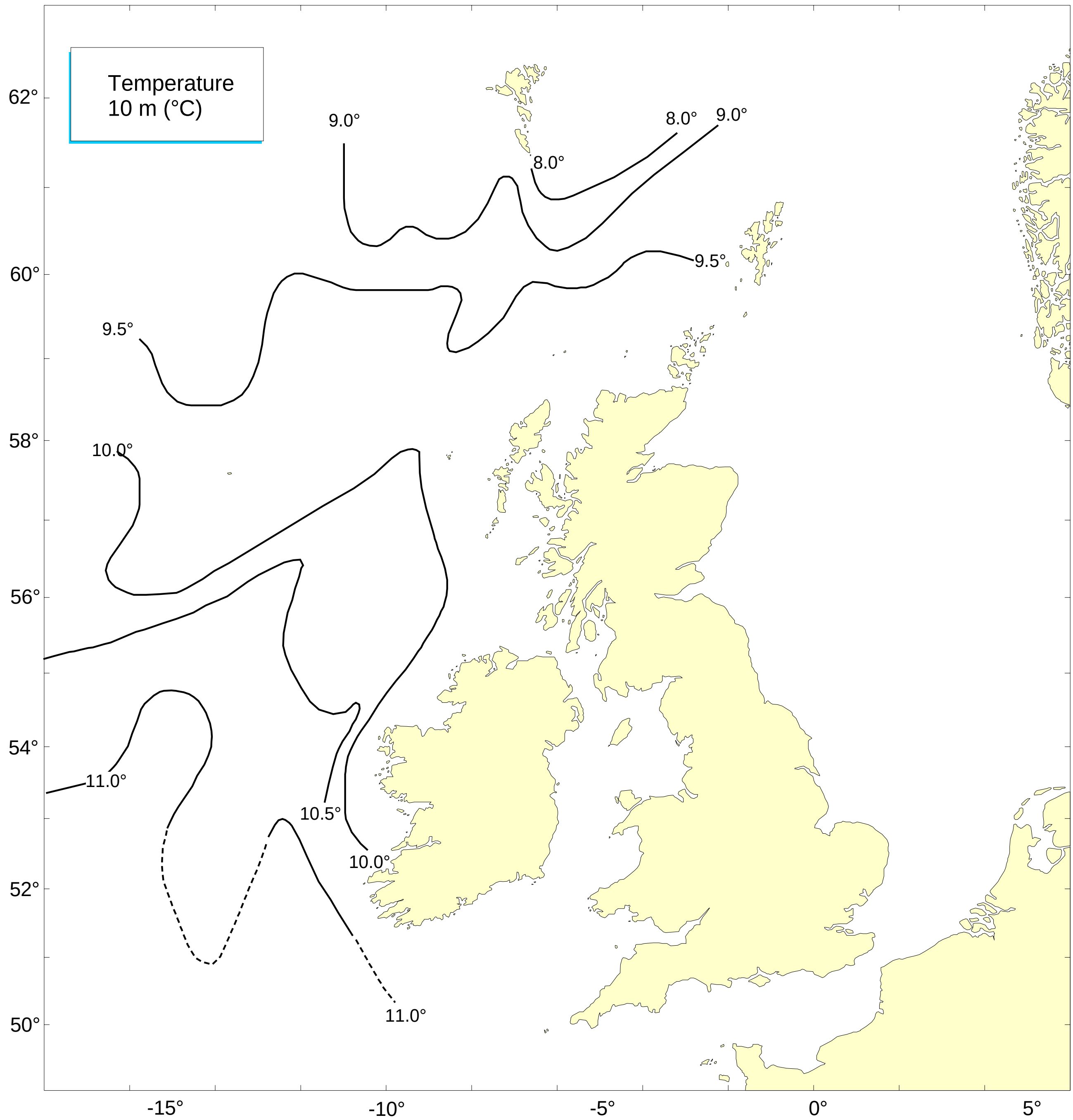


Figure 8. Horizontal temperature distribution, °C, at 10m depth

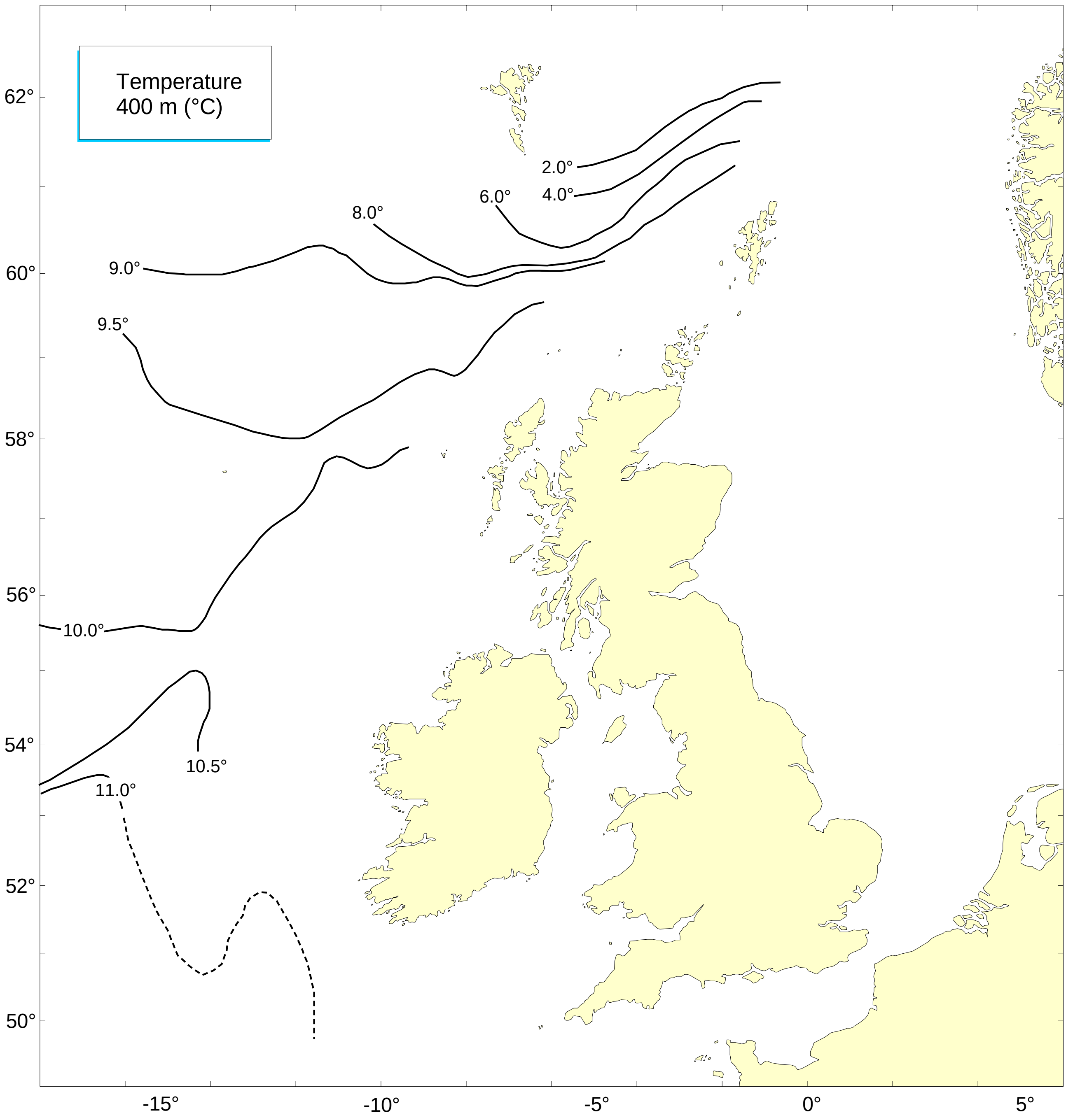


Figure 9. Horizontal temperature distribution, °C, at 400m depth

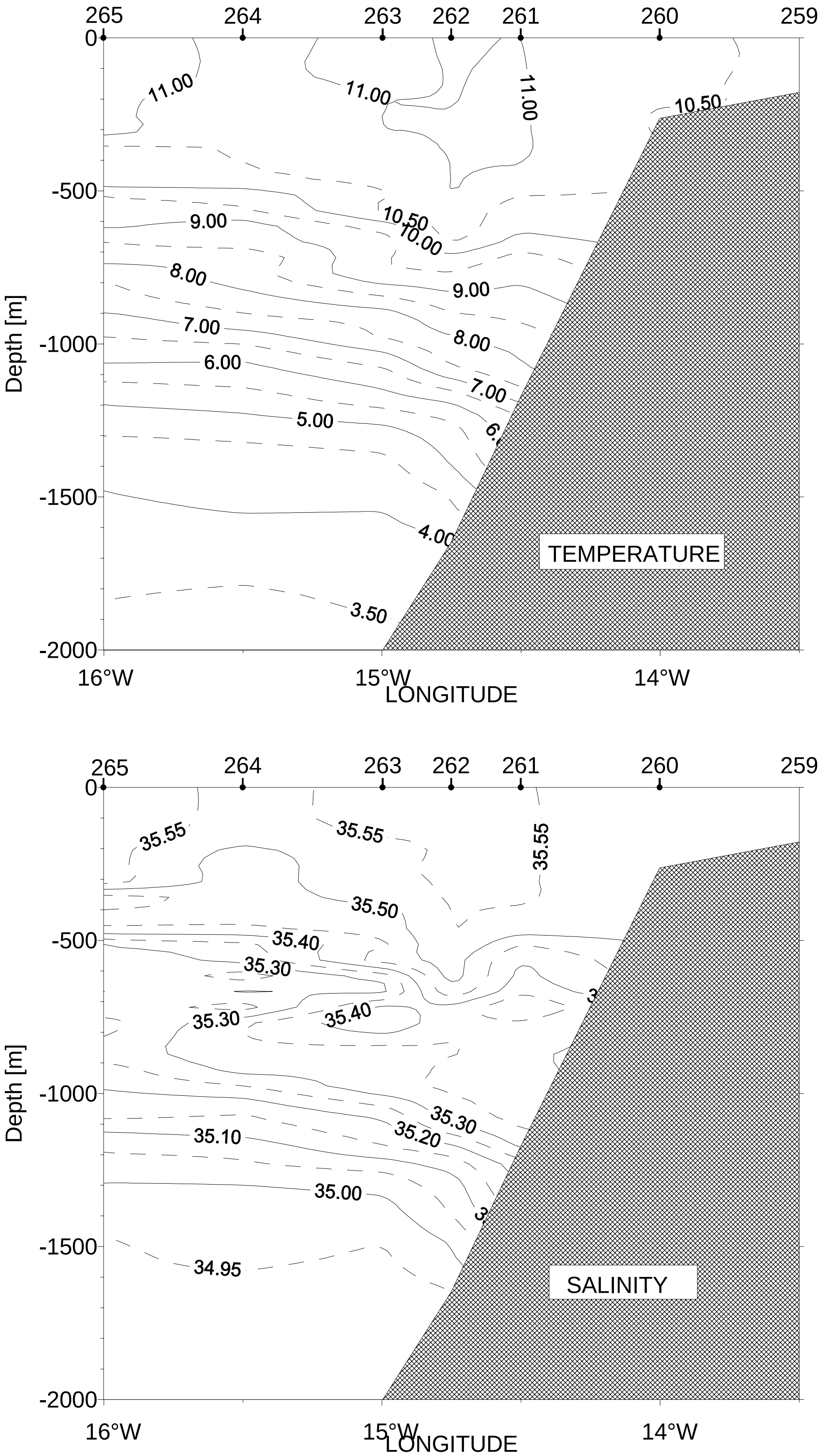


Figure 10 Vertical distribution of temperature (°C) and salinity in a section at the shelf edge at the Porcupine Bank at 53° 30'N. Station numbers at the top of the panels

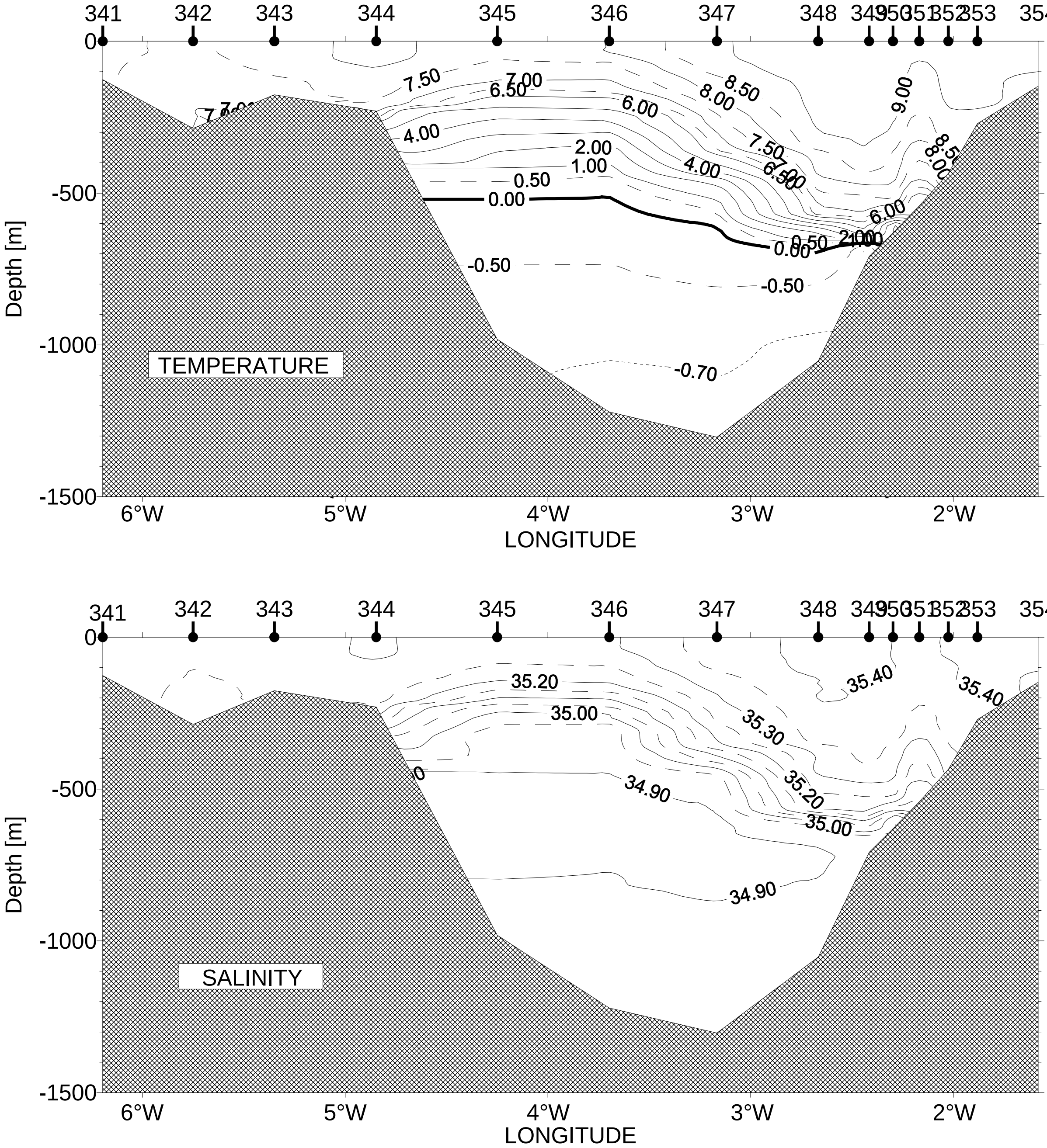


Figure 11. Vertical distribution of temperature (°C) and salinity in a section from the Faroes to Shetland (Nolsø-Flugga). Station numbers at the top of the panels.

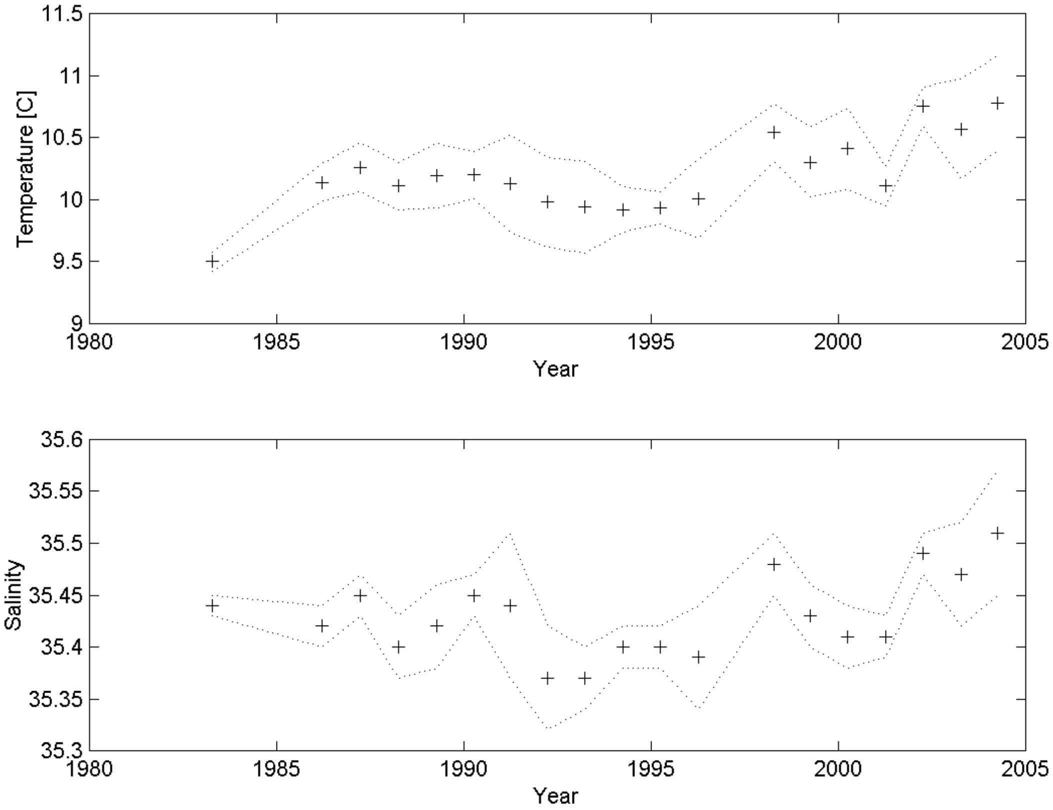


Figure 12. Yearly mean temperature and salinity from 50-600 m (crosses) of all stations in a box with bottom depth >600 m, west of the Porcupine bank bounded by 52° to 54°N and 16 to 14°W. Dotted lines are drawn at plus-minus one standard deviation of all observations in each box, each year.

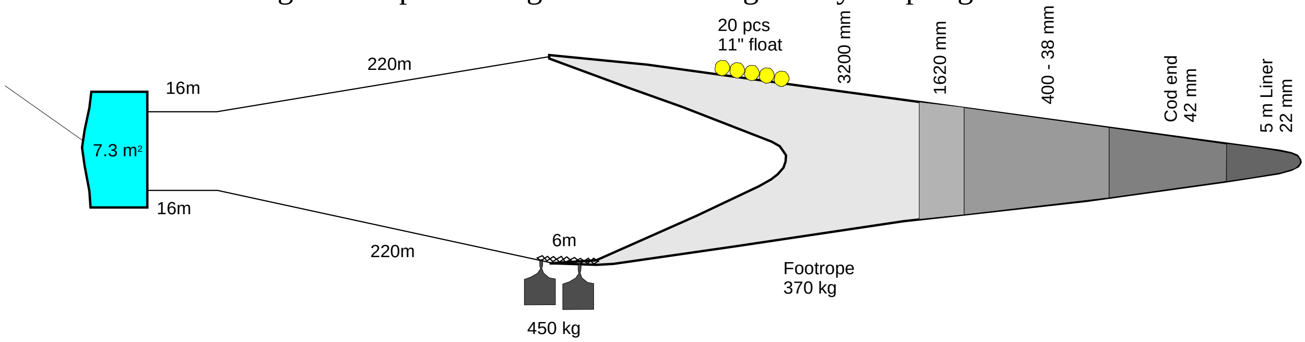
Appendix 1. Acoustic equipment and setting of the instruments

Acoustic equipment and setting of the instruments on the R/V "Johan Hjort", 19 March - 18 April 2004.

Echo sounder:	Simrad EK - 500
Frequency:	38 kHz
Transducer:	ES38B - SK
Absorption coeff.:	10 dB/km
Pulse length:	Medium (1ms)
Band width:	Wide (3.8 kHz)
Transmitter power:	2000 W
Angle sensitivity:	21.9 dB
2-way beam angle:	-21.0 dB
Sv Transducer gain:	27.53 dB
Ts Transducer gain:	27.73 dB
3 dB Beamwidth	
alongship:	7.0 dg
athw. ship:	6.7 dg
Range:	750 m

Appendix 2. Configuration of the large pelagic trawl

The figure below gives details of the configuration of the large pelagic trawl (Åkratrål) used to collect most of the biological samples during the blue whiting survey in spring 2004.



Appendix 3. Taxa encountered during the blue whiting survey in spring 2004.

Family	Species	Norwegian name	Abundance P	Abundance B
Chimaeridae (Havmusfam.)	*Chimaera monstrosa* Linnaeus, 1758	Havmus		R+
Scyliorhinidae (Rødhaifam.)	*Galeus melastomus* Rafinesque, 1810	Hågjel		R+
Dalatiidae	*Etmopterus spinax* (Linnaeus, 1758)	Svarthå		R+
Rajidae (Skatefam.)	*Raja circularis* Couch, 1838	Sandskate		r
Derichthyidae	*Derichthys serpentinus* Gill, 1884		X	
	Nessorhamphus ingolfianus (Schmidt, 1912)		r	
Nemichthyidae (Sneppeålfam.)	*Nemichthys scolopaceus* Richardson, 1848	Sneppeål	r	
Clupeidae (Sildefam.)	*Clupea harengus* Linneaus, 1758	Sild	r	
Opisthoproctidae	*Opisthoproctus soleatus* Vaillant, 1888		r	
Alepocephalidae (Glatthodefiskfam.)	*Xenodermichthys copei* (Gill, 1884)	Kortsnutet glatthodefisk	R+	
Platytroctidae	*Normichthys operosus* Parr, 1951		r	
	Sagamichthys schnakenbecki (Krefft, 1953)		r	
	Searsia koefoedi Parr, 1937		r	
Argentinidae (Vassildfam.)	*Argentina silus* (Ascanius, 1775)	Vassild		R+
Microstomatidae	*Nansenia groenlandica* (Reinhardt, 1840)	Sølvsmelt	R+	
	Nansenia oblita (Facciolá, 1887)		r	
Gonostomatidae (Laksesyldfam.)	*Bonapartia pedaliota* Goode & Bean, 1896)		r	
	Cyclothone braueri Jespersen & Taaning, 1926		r+	
	Gonostoma elongatum Guenther, 1878		r	
Sternoptychidae (Perlemorsfiskfam.)	*Argyropelecus hemigymnus* Cocco, 1829	Flekket perlemorsfisk	R+	
	Argyropelecus olfersi (Cuvier, 1829)	Stor perlemorsfisk	R+	
	Maurolicus muelleri (Gmelin, 1789)	Laksesild	R+	
Stomiidae (Dragekjeftfam.)	*Stomias boa ferox* Reinhardt, 1843	Boafisk/Storkjeft	R	
	Chauliodus sloani Bloch & Schneider, 1801	Segltannfisk	R	
	Chirostomias pliopterus Regan & Trewavas, 1930		r	
	Melanostomias bartonbeani Parr, 1927		r	
Notosudidae	*Scopelosaurus lepidus* (Krefft & Maul, 1955)		r	
Paralepidae (Laksetobisfam.)	*Arctozenus rissoi* (Bonaparte, 1840)	Liten laksetobis	R+	
	Macroparalepis affinis Ege, 1933		r	
Scopelarchidae	*Benthalbella infans* Zugmayer, 1911		X	
Evermannellidae	*Evermannella balbo* (Risso, 1820)		r	
Myctophidae (Lysprikkfiskfam.)	*Benthosema glaciale (*Reinhardt, 1837)	Nordlig lysprikkfisk	R+	
	Bolinichthys supralateralis (Parr, 1928)		X	
	Diaphus holti Taaning, 1918		r+	

	Diaphus metopoclampus (Cocco, 1829)		r	
	Diaphus rafinesquii (Cocco, 1838)		r	
	Electrona risso (Cocco, 1829)		R	
	Lampadena speculigera Goode & Bean, 1896		r	
	Lampanyctus crocodilus (Risso, 1810)	Kjempelysprikkfisk	R+	
	Lampanyctus intricarius Taaning, 1928		r	
	Lampanyctus macdonaldi (Goode & Bean, 1896)	Brun lysprikkfisk	r	
	Lobianchia gemellarii (Cocco, 1838)		R	
	Myctophum punctatum Rafinesque, 1810	Liten lysprikkfisk	R+	
	Nannobrachium atrum (Taaning, 1928)		r	
	Notolychnus valdiviae (Brauer, 1904)		X	
	Notoscopelus kroyeri (Malm, 1861)	Stor lysprikkfisk	R+	
	Protomyctophum arcticum (Luetken, 1892)	Nordatlantisk lysprikkfisk	r	
	Symbolophorus veranyi (Moreau, 1888)		r	
Trachipteridae (Sølvkveitefam.)	*Trachipterus arcticus* (Bruennich, 1788)	Sølvkveite	X	
Melamphaidae	*Scopelogadus beanii* (Guenther, 1887)		r+	
Macrouridae (Skolestfam.)	*Caelorinchus caelorhincus* (Risso, 1810)	Spiritist		R+
	Coryphaenoides rupestris Gunnerus, 1765	Skolest		X
	Malacocephalus laevis (Lowe, 1838)	Småskjellet skolest		X
Gadidea (Torskefam.)	*Gadiculus argenteus thori* Schmidt, 1914	Sølvtorsk	r	R+
	Melanogrammus aeglefinus (Linnaeus, 1758)	Huse (kolje)		r
	Merlangius merlangus (Linnaeus, 1758)	Hvitting	X	
	Micromesistius poutassou (Risso, 1827)	Kolmule	R+	R+
	Pollachius virens (Linnaeus, 1758)	Sei	r	R
Lotidae	*Brosme brosme* (Ascanius, 1772)	Brosme		R
	Molva dypterygia (Pennant, 1784)	Blålange		X
	Molva molva (Linnaeus, 1758)	Lange		R
Phycidae	*Phycis blennoides* (Bruennich, 1768)	Skjellbrosme		R
Berycidae (Beryxfam.)	*Beryx decadactylus* Cuvier, 1829	Beryx		X
Syngnathidae (Nålefiskfam.)	*Entelurus aequoreus* (Linnaeus, 1758)	Stor havnål	R+	r
Sebastidae (Uerfam.)	*Helicolenus dactylopterus* (Delaroche, 1809)	Blåkjeft		R+
Triglidae (Knurrfam.)	*Chelidonichthys lucernus* (Linnaeus, 1758)	Rødknurr	r	
Percichthyidae	*Howella sherborni* (Norman, 1930)		r	
Anarhichadidae (Steinbitfam.)	*Anarhichas minor* Olafsen, 1772	Flekksteinbit		X
Centrolophidae (Svartfiskfam.)	*Centrolophus niger* (Gmelin, 1789)	Svartfisk	X	
Scophthalmidae (Varfam.)	*Lepidorhombus boscii* (Risso, 1810)	Fireflekket var		R+
	Lepidorhombus whiffiagonis (Walbaum, 1792)	Glassvar		R+
Pleuronectidae (Flyndrefam.)	*Glyptocephalus cynoglossus* (Linnaeus, 1758)	Smørflyndre		R+
	Hippoglossoides platessoides (Fabricius, 1780)	Gapeflyndre		R

Larvae	Leptocephali	X

Abbreviations:

P…..Pelagic trawl
B…..Bottom trawl

R…..common species (found in more than 1/3 of pelagic or bottom trawls)
r…...rare species (found in less than 1/3 of pelagic or bottom trawls)
+.….abundant species (found - at least occasionally - in high numbers (more than 20 per trawl)
X…..single specimen