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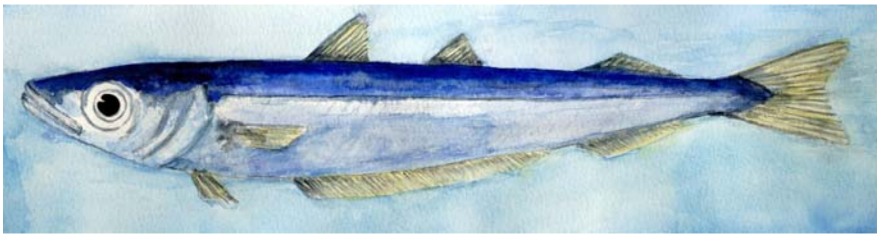

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY SPRING 2005

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Introduction

In spring 2005, six research vessels representing the Faroe Islands, Ireland, the Netherlands, Norway and Russia surveyed the spawning grounds of blue whiting west of the British Isles. International co-operation allows for wider and more synoptic coverage of the stock and more rational utilisation of resources than uncoordinated national surveys. The survey was the second coordinated international blue whiting spawning stock survey since mid-1990s. The primary purpose of the survey was to obtain estimates of blue whiting stock abundance in the main spawning grounds using acoustic methods as well as to collect hydrographic information. Results of all the surveys are also presented in national reports (Atlantniro: Shnar et al. 2005; Celtic Explorer: O'Donnell et al. 2005; F. Nansen: Oganin et al. 2005; G. O. Sars: Heino et al. 2005; M. Heinason: Jacobsen et al. 2005; Tridens: Ybema et al. 2005).

This report is based on a workshop held after the international survey in Bergen, 20–22/4/2005, where the data were analysed and the report written. Parts of the document were worked out through correspondence during and after the workshop.

Material and methods

Coordination of the survey was initiated in the meeting of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES, formerly Planning Group on Surveys on Pelagic Fish in the Norwegian Sea) in August 2004 (ICES 2004a), and continued by correspondence until the start of the survey. The participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Atlantniro	AtlantNIRO, Kaliningrad, Russia	15/3–8/4
Celtic Explorer	Marine Institute, Ireland	28/3–11/4
Fridtjof Nansen	PINRO, Murmansk, Russia	18/3–14/4
G. O. Sars	Institute of Marine Research, Bergen, Norway	17/3–13/4
Magnus Heinason	Faroese Fisheries Laboratory, the Faroes	1/4–12/4
Tridens	Netherlands Fisheries Research Institute, the Netherlands	10/3–21/3

The cruise lines are shown in Figure 1. Figures 2 and 3 show respectively trawl and CTD stations. Survey effort by each vessel is detailed in Table 1. All vessels worked their survey in a northerly direction (Figure 4). Frequent contacts were maintained between the vessels during the course of the survey, primarily through electronic mail.

Bad weather hampered the survey during the periods from about 17/3 to 18/3 and from about 6/4 to 12/4.

The survey was based on scientific echo sounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote et al. 1987) prior to [Atlantniro, Celtic Explorer, F. Nansen, M. Heinason, Tridens, G. O. Sars (2 weeks earlier)] and/or after (Celtic Explorer, G. O. Sars, Tridens) the survey. Salient acoustic settings are summarized on page 3.

Post-processing software and procedures differed among the vessels. On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using Sonar data's Echoview (V 3.25) post processing software for the previous days work. Data was partitioned into the following categories plankton (<200 m depth layer), mesopelagic species, blue whiting and bottom fish (including argentines, mackerel and horse mackerel). Partitioning of data into the above categories was largely subjective and was viewed by 3 scientists. Adjustments for drop-outs were applied where necessary.

On F. Nansen, the BI60 software was used as the primary post-processing tool for acoustic data. Data were partitioned into the following categories: blue whiting, plankton (<250 m depth layer), mesopelagic species and other species (including, plankton <250 depth layer and bottom fishes). Adjustments for drop-outs were applied where necessary using the "PRIDE" program developed by PINRO.

Table. Acoustic instruments and settings for the primary frequency (boldface).

	Atlantniro	Celtic Explorer	Fridtjof Nansen	G. O. Sars	Magnus Heinason	Tridens
Echo sounder	Simrad EK 500	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 500	Simrad EK 60
Frequency (kHz)	**38**	**38**, 18, 120, 200	**38**, 120	**38**, 18, 70, 120, 200	**38**	**38**
Primary transducer	ES 38B	ES 38B - Serial	ES 38B	ES 38B - SK	ES38B	ES 38B
Transducer installation	Hull (steel blister)	Drop keel	Hull	Drop keel	Hull	Towed body
Transducer depth (m)	5	8.7	5	8	3	7
Upper integration limit (m)	10	15	10	15	7	12
Absorption coeff. (dB/km)	10	9.6	10.1	9.785	10	9.6
Pulse length (ms)	1	1.024	1.024	1	Medium	1.024
Band width (kHz)	3.8	2.425	2.425	2.425	Wide	2.43
Transmitter power (W)	2000	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.6	-20.6	-20.9	-20.8	-20.6	-20.6
Sv Transducer gain (dB)	27.75				25.32	
Ts Transducer gain (dB)	27.88	25.22	25.55	25.71	25.33	26.5
s_A correction (dB)		-0.53	-0.67	-0.66		-0.58
3 dB beam width (dg)						
alongship:	6.9	7.5	6.99	6.98	7.03	7.10
athw. ship:	6.8	7.5	6.75	6.97	6.93	7.10
Maximum range (m)	750	750	750	750	750	600
Post processing software	Sonardata Echoview	Sonardata Echoview	BI60	BEI	Sonardata Echoview	Sonardata Echoview

On G. O. Sars, the acoustic recordings were scrutinized using the Bergen Echo Integrator (BEI, Foote et al. 1991) once or twice per day. Blue whiting were separated from other recordings using catch information, characteristics of the recordings, and frequency response between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms. Adjustments for drop-outs were unnecessary although noise of unknown origin plagued data when swell was against the cruise track.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using Sonar data's Echoview (V 3.25) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), mesopelagic species, blue whiting and krill. Partitioning of data into the above categories was based on trawl samples. No correction for drop outs were made, and this caused some problems during the latter part of the survey, i.e. the northernmost cruise tracks in the Faroese area.

On Tridens, acoustic data were backed up every 24 hrs and scrutinised later in the laboratory using Sonar data's Echoview (V 3.25) post processing software. Data was partitioned into the following categories plankton (all layers), mesopelagic species, blue whiting and bottom fish (including argentines, mackerel and horse mackerel). Partitioning of data into the above categories was largely subjective and was viewed by 1 scientist.

All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Atlantniro	Celtic Explorer	F. Nansen	G. O. Sars	Magnus Heinason	Tridens
Circumference (m)	716	768	716	486	640	1120
Vertical opening (m)	50	48	50	25-30	38-48	30-70
Mesh size in codend (mm)	16	50	16	22	40	±20
Typical towing speed (kn)	3.3-4.0	3.5-4.0	3.3-3.9	3.0-4.0	3.0-4.0	3.5-4.0

On G. O. Sars, some additional samples were taken with a larger version of normal pelagic trawl that had 586 m circumference and vertical opening of about 35 m (6 samples), and one sample was taken with a large blue whiting trawl with 1200 m circumference and 55 m vertical opening. On Magnus Heinason, some samples of krill and mesopelagic fish were taken with a small meshed trawl (7 mm meshes in the cod-end).

Catch from the trawl hauls was sorted and weighed; fish were identified to species (when possible) and other taxa to higher taxonomic levels. Normally a sub-sample of 50 (Celtic Explorer, G. O. Sars, Tridens) or 50-100 (F. Nansen, M. Heinason) blue whiting were sexed, aged, and measured for length and weight, and their maturity status were estimated using established methods. An additional sample of 50 fish (M. Heinason, G. O. Sars, occasionally 150), 100 (Celtic Explorer), 250 (Tridens, only length) or 300-400 (F. Nansen) was measured for length and weight. On Atlantniro 50 fish were measured for length, weight and sex and an additional 250 were measured for length.

The acoustic data as well as the data from trawl hauls were analysed with a SAS based routine called “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 representatively covered 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.

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 representing 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. No weighting of individual trawl samples was used because of differences in trawls and numbers of fish sampled and measurements. 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 separately for each sub-area. 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.

The hydrographical situation in the surveyed area was mapped by G. O. Sars, Fridtjof Nansen and Celtic Explorer (Figure 3, Table 1). Three sections with higher horizontal resolution were occupied: two east-west sections at the western shelf edge of the Porcupine Bank at latitude 53° 30'N and 53° 00'N and a section from the Faroes to Shetland (the Nolsø-Flugga section). G. O. Sars and Celtic Explorer are equipped with SBE911 CTDs and Fridtjof Nansen with a FSI CTD. In addition, on G. O. Sars surface (~4m) temperature, salinity and fluorescence were continuously registered along the complete track of the cruise using a ship-mounted thermosalinograph (SBE21).

Results

Inter-calibration results

Results from the inter-calibrations are summarized in the Appendices 1-4. Acoustic inter-calibrations showed that the performance of Magnus Heinason was similar to G. O. Sars (which was used as the reference vessel). Bad weather prevented the planned inter-calibration between F. Nansen and G. O. Sars, while inter-calibration between F. Nansen and Atlantniro was conducted under good conditions and suggested little difference in performance. Celtic Explorer tended to record lower values than G. O. Sars, but the most plausible explanation for this is—given the similarity of the acoustic equipment and sphere calibrations before and after the survey—the strong small-scale spatial heterogeneity observed in the inter-calibration area.

Results from Tridens suggested much lower recordings than G. O. Sars (by a factor of about six), probably caused by a bad cable connection found after the survey. A scrutiny of single target echoes, blue whiting acoustic densities and comparisons with other vessels suggests that the problem started only after the port call of Tridens to Galway. It was decided to exclude acoustic data after that time, but use the earlier data as they stand. Acoustic data from all other vessels were used as they stand, subject to exclusion of some data from very shallow waters where no blue whiting were observed.

Catchability varies greatly among the vessels due to the large variety of gear employed (see the text table on page 3). In particular, G. O. Sars is typically using a trawl that has much smaller vertical opening than the trawls on other vessels. This tended to yield catches that were rather low (often <100 kg). Tows during the inter-calibration exercises nevertheless suggested rather small differences in size selectivity [differences in mean length relative to G. O. Sars: +0.8 cm (Celtic Explorer), +0.3 cm (Tridens), –0.5 cm (M. Heinason)].

Based on the inter-calibration trawl hauls, age readings on G. O. Sars and Celtic Explorer appear to be rather similar. There is a significant difference in aging between Tridens and G. O. Sars with mean age at length being about one year higher on the former vessel as compared to the latter. No inter-calibration hauls were available to compare aging between F. Nansen and G. O. Sars, but comparing all survey hauls suggests a significant difference (blue whiting of ages 1–5 years tend to be larger on G. O. Sars compared to F. Nansen, while the opposite is true for older fish). At the time of running the stock estimate age data from Atlantniro and M. Heinason were not available. Age readings from G. O. Sars and Celtic Explorer only were used in the final stock estimate whereas length distributions from all vessels were utilized. As no calibrated age readings from the southern Porcupine Bank sub-area were available, age-length key from the northern Porcupine Bank was used for both sub-areas.

Distribution of blue whiting

Blue whiting were recorded in most of the survey area that covered almost 172 thousand square nautical miles (Figure 5, 6). The highest concentrations were recorded in the area between the Hebrides, Rockall and Bill Bailey/Faroes Banks. In comparison to 2004, the bulk of the biomass was observed further offshore in relation to the Hebrides shelf brake.

As most strata were surveyed by more than one vessel, there is some inevitable variability in vessel-specific acoustic observations. This is illustrated by displaying among-vessel coefficients of variability (Figure 6), based on data weighted by survey effort by vessel. These are often higher than 50%, showing that the degree of spatial and temporal heterogeneity in abundance of blue whiting is often large.

The highest recordings were observed at depths of 450-600 m, sometimes extending to around 300 m depth (or even shallower) on the slope areas. 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/Shetland sub-area. Blue whiting southwards of the Porcupine Bank were only observed on the slope areas, clearly associated with the bottom at depths of 400-500 meters.

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 and out of the spawning area. For example, fishing activity began well before the survey in the international waters and near the Porcupine Bank.

Stock size

The estimated total abundance of blue whiting for the 2005 international survey was 8.0 million tonnes, representing an abundance of 90.3×10^9 individuals (Table 2). The spawning stock was estimated at 7.6 million tonnes and 83.1×10^9 individuals. The geographical distribution of total stock biomass by stratum is shown in Figure 7.

In comparison to the results in 2004, the decrease in stock numbers and biomass are substantial, despite an increase in the area covered:

		2004	2005	Change (%)
Biomass (mill. t)	Total	11.4	8.0	–30
	Mature	10.9	7.6	–30
Numbers (10^9)	Total	137	90	–34
	Mature	128	83	–35
Survey area (nm^2)		149 000	172 000	+15

There was heterogeneity in the temporal trend between the sub-areas, however. There was no change in the southern Porcupine Bank, whereas biomass increased in the Rockall sub-area:

Sub-area		Biomass (million tonnes) 2004		2005		Change (%)
			% of total		% of total	
I	S. Porcupine Bank	0.21	2	0.21	3	0
II	N. Porcupine Bank	1.1	10	0.47	6	–56
III	Hebrides	5.8	52	4.3	54	–26
IV	Faroes/Shetland	2.7	24	1.4	18	–47
V	Rockall	1.3	12	1.6	20	+21

In order to allow comparisons with earlier results, a separate estimate was calculated for the international zone. This gave a biomass estimate of 1.08 million tonnes, which is substantially less than the estimate calculated on basis of Russian data in 2003, 2.9 million tonnes. This difference can, at least to a certain extent, be probably explained by the later coverage of the area in 2005 in comparison to 2003. In 2004, the coverage was less than in 2003 and in 2005 as only one Russian vessel participated the survey; the estimate in 2004 was correspondingly low at 0.6 million tonnes.

Stock composition

Stock in the survey area is dominated by age classes 5 and 4 years (year classes 2000 and 2001), which make together about 60% of spawning stock biomass (Table 3, Figure 8). The same year classes were dominating in 2004. Blue whiting of ages 3 and 6 years make most of the remaining spawning stock biomass (31 %).

More than half of the spawning stock biomass was recorded in the Hebrides sub-area. Blue whiting of ages 5 and 4 years, in that order, were most common (Figure 9). In other areas, younger blue whiting were relatively more abundant. This pattern is consistent with the observations in 2004.

The majority of fish older than one year in age were mature. The proportion of mature fish was the highest in the Hebrides and northern Porcupine Bank sub-areas (Table 2). The highest proportion of juvenile fish was observed in the Faroes/Shetland sub-area. In contrast, the proportion of juvenile blue whiting in 2004 was the highest in the southern Porcupine Bank sub-area, although also the Faroes/Shetland sub-area hosted a large proportion of juveniles.

Hydrography

The horizontal distribution of temperature and salinity at 10, 200, 400 and 600 meters depths are shown in Figures 10–17. The maps are based on CTD data collected on board G. O. Sars, Fridtjof Nansen and Tridens (Figure 3). The cooperation has given a good 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 differences 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 16) 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 19, Faroe-Shetland section). This gives rise to the strongest horizontal gradients in the area too, particularly in deep water.

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 52°N to 60°N at 10m, 200m, 400m and 600m depths (Figures 10-13). Due to a northward flowing shelf edge current, the warmest and most saline water is found in a narrow band along the shelf edge. The thickness of the mixed layer was 600-800m deep along the continental slope and between the Rockall Bank and the Faroe Banks. In the Rockall Channel the thickness of the mixed layer is more variable. On some station the thickness was only 250-300m whereas on the stations with the deepest mixed layer it was 800–900m deep.

In the last couple of years and this year the temperatures in the southern part of the area were above 11°C.Both last year and 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. The temperature is lower this year than last year.

At the Porcupine section (Figure 18) 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 intrusion of low salinity water on the western most station with salinities about 0.2 lower than the neighbouring station. The strong influence of water of Mediterranean origin seen last year was not observed this year, resulting in lower salinities.

On the Faroe-Shetland section (Figure 19) there is a characteristic wedge shaped core of Atlantic water on the eastern slope and Atlantic water in the upper hundred meters across the whole channel. Below the Atlantic water, cold and low salinity (S<34.90) intermediate water of Norwegian Sea origin extending up to about 500m. The 0°C isotherm is found at 600m depth at the western side, 500m central in the channel and it slopes downward to nearly 700m at the eastern side. This is about the same depth as last year, but shallower than in 2003. The temperature and salinity (S<34.4) in the core of the Atlantic water are lower than last year, and this a continuation of a cooling and freshening seen last year compared to the record warm and saline water in 2003.

Based on the hydrographic observations obtained during the blue whiting surveys, the mean temperature and salinity from 50 to 600m of all the stations in deep water (bottom depth>600m) in 2° latitude times 2° longitude boxes have been calculated for each survey. The box with limits 52° to 54°N and 16° to 14°W had few gaps, and the time series of mean temperature and salinity for this box is shown in Figure 20. 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 (~10.5°C). In 2004 was the warmest on record (~10.8°C), but this year (~10.4°C) is colder than the three preceding years. This is above the long-term average, but about average for the last 10 years.

Concluding remarks

- The second international blue whiting spawning stock survey, in comparison to the survey in 2004, shows a clear reduction in stock numbers and biomass (~30–35%), despite an increase in the area surveyed (+15%).
- The stock continues to be dominated by age classes 2000 and 2001 (in that order) that make 60% of SSB.
- The effort by six participating vessels gave a very broad spatial coverage. In addition, through overlapping coverage in core areas, information on the spatial and temporal dynamics of blue whiting is gained, giving a better idea of accuracy of the results. In addition, biological sampling was extensive. Thereby more confidence on the results is obtained.
- Abundance estimates from acoustic surveys should generally be interpreted as relative indices rather than absolute measures. In particular, acoustic abundance estimates critically depend on the applied target strength. The target strength currently used for blue whiting is based on cod and considered to be too low, possibly as much as by 40% (see Godø et al. 2002, Heino et al. 2003, 2005). This would imply an overestimation of stock biomass by a similar factor. This bias is, however, roughly constant from year to year, and does not affect conclusions about relative change in abundance of stock.
- The overall timing of survey appears to be rather suitable with respect to weather and covering the traditional core distribution area of blue whiting. The possibility of covering western (west of Rockall) and southern (off Porcupine Bank) areas earlier in the season, at the time of the peak fishery in those areas, should be considered.
- Data exchange during the survey continues to be a problem. It is essential that all data are available well in advance of the meeting where they will be used. With all vessels, rate of the data delivery and/or the format of the data delivered to G. O. Sars left room for improvements. The conversion program from PGNAPES to the format required by BEAM (stock estimation program used at IMR) is still a beta version suffering from bugs and misspecifications. In addition, G. O. Sars is not yet able to automatically deliver its own data to other vessels in the PGNAPES format.
- Differences exist not only in the vessels themselves and their acoustic instrumentation and trawl gear, but also in survey procedures such as numbers of fish measured, parameters measured (and their scale and resolution) and survey design. Combining the data would be facilitated if a greater agreement on the procedures could be achieved.
- Because blue whiting often occur patchily, good trawl sample coverage can only be achieved if all vessels could fish at any time of the day.
- Age readings between the vessels still require calibration. On some vessels, otolith reading takes place only after the survey. We recommend compiling an updated estimate once calibrated age readings become available (age reading workshop will take place in June 2005), before the PGNAPES and WGNPBW meetings in August 2005.
- We recommend sharing expertise (e.g., in scrutinizing echograms) through exchange of scientific personnel.
- In order to facilitate planning of the survey in 2006, we recommend each participant to compile a list of most important problems encountered in running the survey. In addition, some problems have been identified when joining the data. Planning Group for North-east Atlantic Pelagic Ecosystem Surveys (PGNAPES) should agree upon how the problems are to be solved, including clear deadlines for key problems.

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Table 1. Survey effort by vessel.

Vessel	Effective survey period (dd/mm)	Length of cruise track (nm) *	Trawl stations	CTD stations	Aged fish	Length-measured fish
Atlantniro	15/3–8/4	1970	30	0 **	0 **	5789
Celtic Explorer	28/3–11/4	2169	16	15	709	1409
Fridtjof Nansen	18/3–14/4	2694	25	117	2343	15854
G. O. Sars	17/3–13/4	3117	25	91	1271	3919
Magnus Heinason	1/4–12/4	1295	8	4	0 **	1600
Tridens	10/3–21/3	1140	7	21	300	1364

* With acoustic observations used in the stock estimate.
** Available at the time of calculating the stock estimate.

Table 2. Assessment factors of blue whiting, spring 2005.

Sub-area		Numbers (milliards)			Biomass (million tonnes)			Mean weight	Mean length	Density
	$n.mile^2$	Mature	Total	%mature	Mature	Total	%mature	g	cm	$t/n.mile^2$
I S. Porcupine Bank	22568	2.48	2.70	91.8	0.20	0.21	96.1	77.0	24.3	9
II N. Porcupine Bank	28352	5.79	5.89	98.3	0.46	0.47	99.2	79.2	26.1	16
III Hebrides	35658	44.6	45.2	98.7	4.28	4.29	99.7	95.0	27.1	120
IV Faroes/Shetland	31468	11.8	15.8	74.5	1.14	1.43	79.2	90.5	26.2	45
V Rockall	53804	18.5	20.7	89.2	1.55	1.61	96.3	77.4	25.1	30
Tot.	171850	83.1	90.3	92.0	7.64	8.01	95.4	88.6	26.3	47

Table 3. Stock estimate of blue whiting, spring 2005.

Length (cm)	Age in years (year class) 1 2004	2 2003	3 2002	4 2001	5 2000	6 1999	7 1998	8 1997	9 1996	10 1995	11 1994	Numbers (10^6)	Biomass (10^6 kg)	Mean weight (g)	Prop. mature* (%)
13.0 – 14.0	2	0	0	0	0	0	0	0	0	0	0	2	0	13.1	8
14.0 – 15.0	46	0	0	0	0	0	0	0	0	0	0	46	0.6	14.1	7
15.0 – 16.0	451	34	0	0	0	0	0	0	0	0	0	485	9	17.8	11
16.0 – 17.0	985	28	0	0	0	0	0	0	0	0	0	1013	21	21.1	13
17.0 – 18.0	861	90	0	0	0	0	0	0	0	0	0	952	24	25.4	17
18.0 – 19.0	756	91	0	0	0	0	0	0	0	0	0	847	26	30.7	21
19.0 – 20.0	272	541	0	0	0	0	0	0	0	0	0	813	30	37.4	54
20.0 – 21.0	119	1125	25	0	0	10	0	0	0	0	0	1279	52	40.4	79
21.0 – 22.0	36	703	395	0	0	0	0	0	0	0	0	1134	54	47.2	85
22.0 – 23.0	33	419	1342	148	0	0	0	0	0	0	0	1941	111	57.2	85
23.0 – 24.0	0	823	3034	620	199	0	0	0	0	0	0	4676	294	62.9	86
24.0 – 25.0	49	262	4526	3507	1891	0	0	0	0	0	0	10236	711	69.5	91
25.0 – 26.0	0	204	5243	6608	3628	472	0	0	0	0	0	16155	1246	77.1	95
26.0 – 27.0	20	0	2645	6827	6516	579	16	0	0	0	0	16603	1404	84.6	97
27.0 – 28.0	0	0	1240	4270	5719	759	71	5	0	0	0	12063	1140	94.5	98
28.0 – 29.0	0	0	235	2348	3352	1282	254	85	0	0	0	7555	805	107	99
29.0 – 30.0	0	0	74	908	3285	1095	249	24	0	0	0	5635	663	118	99
30.0 – 31.0	0	0	9	238	1177	1484	68	129	37	0	0	3143	419	133	100
31.0 – 32.0	0	0	8	19	833	1480	311	18	5	0	0	2673	397	148	100
32.0 – 33.0	0	0	0	86	11	601	302	62	47	0	0	1108	183	165	100
33.0 – 34.0	0	0	0	0	11	347	295	146	0	0	0	799	146	183	100
34.0 – 35.0	0	0	0	0	0	142	295	81	79	2	4	602	121	201	100
35.0 – 36.0	0	0	0	0	7	9	61	8	43	0	0	128	27	209	100
36.0 – 37.0	0	0	0	0	31	37	47	140	0	0	0	254	63	247	100
37.0 – 38.0	0	0	0	0	0	0	44	3	14	0	0	62	15	241	100
38.0 – 39.0	0	0	0	0	0	0	0	13	14	0	0	28	8	282	100
39.0 – 40.0	0	0	0	0	0	1	3	10	43	0	0	58	18	311	100
40.0 – 41.0	0	0	0	0	0	0	0	5	39	0	0	45	17	382	100
41.0 – 42.0	0	0	0	0	0	0	0	0	2	0	0	2	0.5	343	100
TSN (10^6)	3631	4320	18774	25579	26660	8298	2016	728	323	2	4	90336			
TSB (10^6 kg)	99	217	1377	2194	2546	1046	320	128	76	0.5	0.7	8005			
Mean length (cm)	17.6	21.6	25.0	26.4	27.4	29.8	31.9	33.0	35.6	34.9	34.5	26.3			
Mean weight (g)	27.3	50.2	73.3	85.8	95.5	126	159	176	236	212	183	88.6			
Condition (g/dm^3)	5.0	5.0	4.7	4.7	4.6	4.8	4.9	4.9	5.2	5.0	4.5	4.9			
% mature*	13	79	93	93	100	100	100	100	100	100	100	92			
% of SSB	0	2	17	27	33	14	4	2	1	0	0				

* Percentage of mature individuals per age or length class

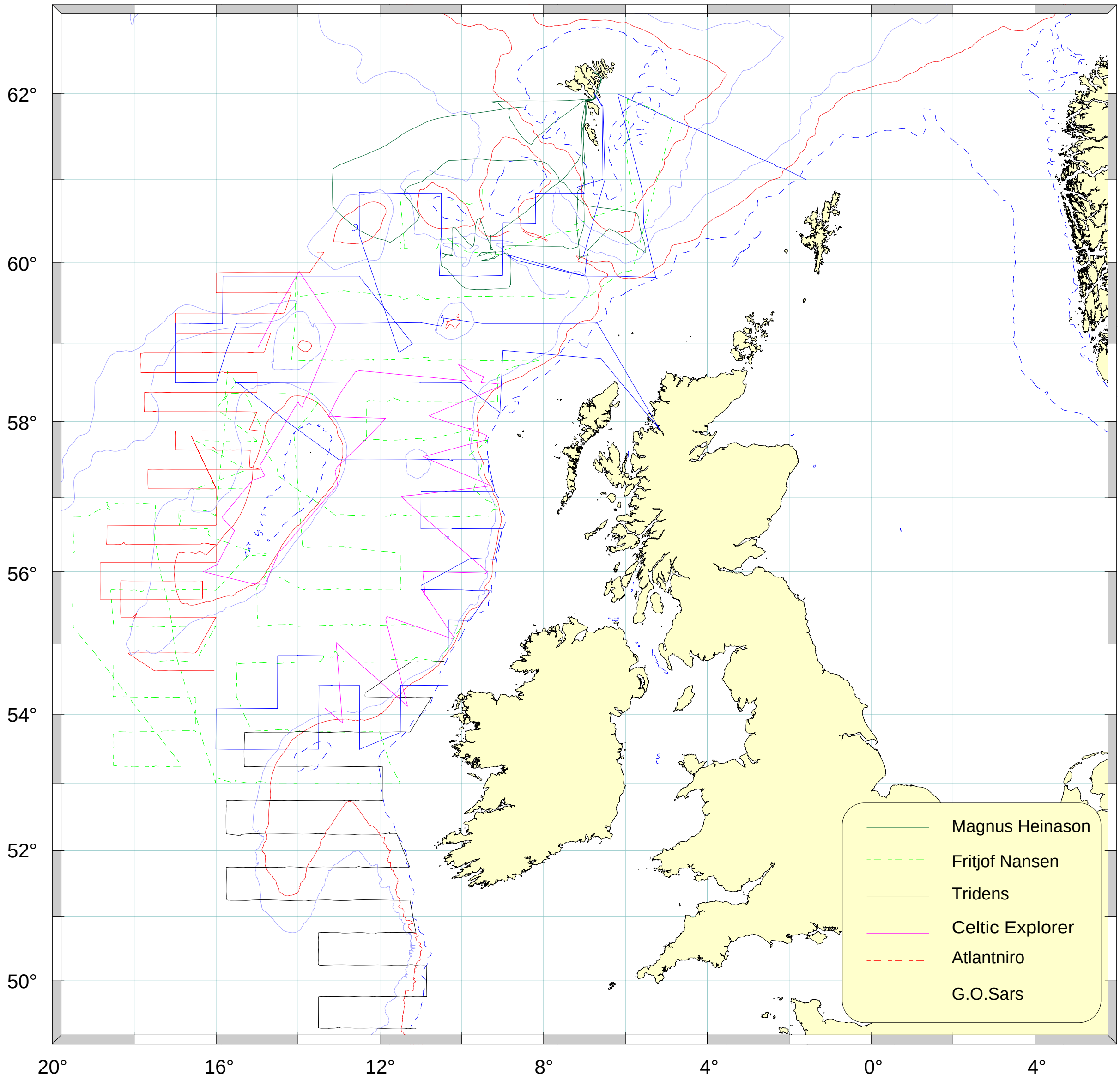


Figure 1. Cruise tracks during the International Blue Whiting Spawning Stock Survey in spring 2005. The figure shows all survey activity; in Figure 4, only the cruise tracks from which acoustic data were used in the stock estimate are shown.

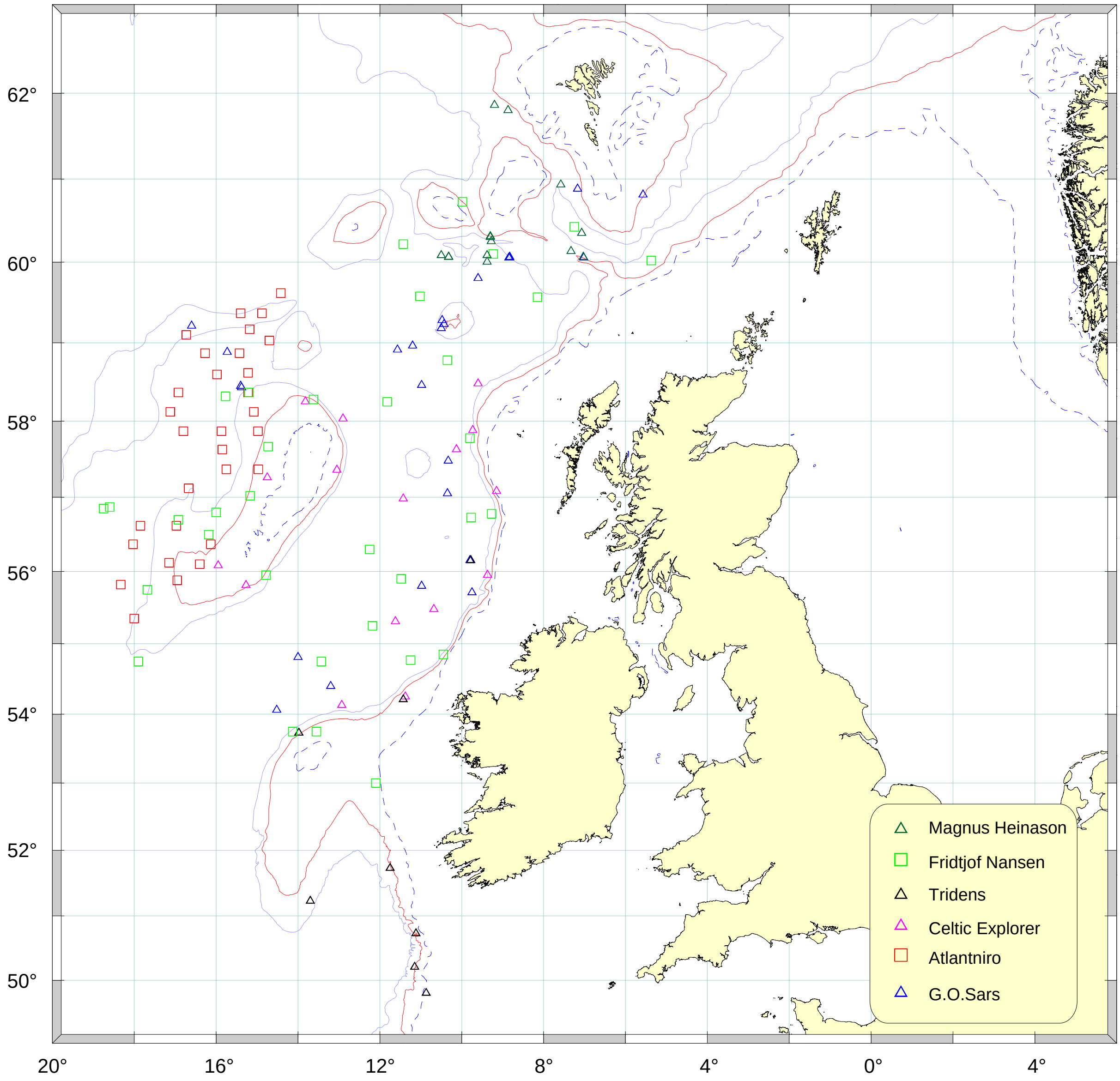


Figure 2. Trawl stations for R/V G. O. Sars, R/V Fridtjof Nansen, Celtic Explorer, R/V Atlantniro, R/V Magnus Heinason and R/V Tridens, in March-April 2005.

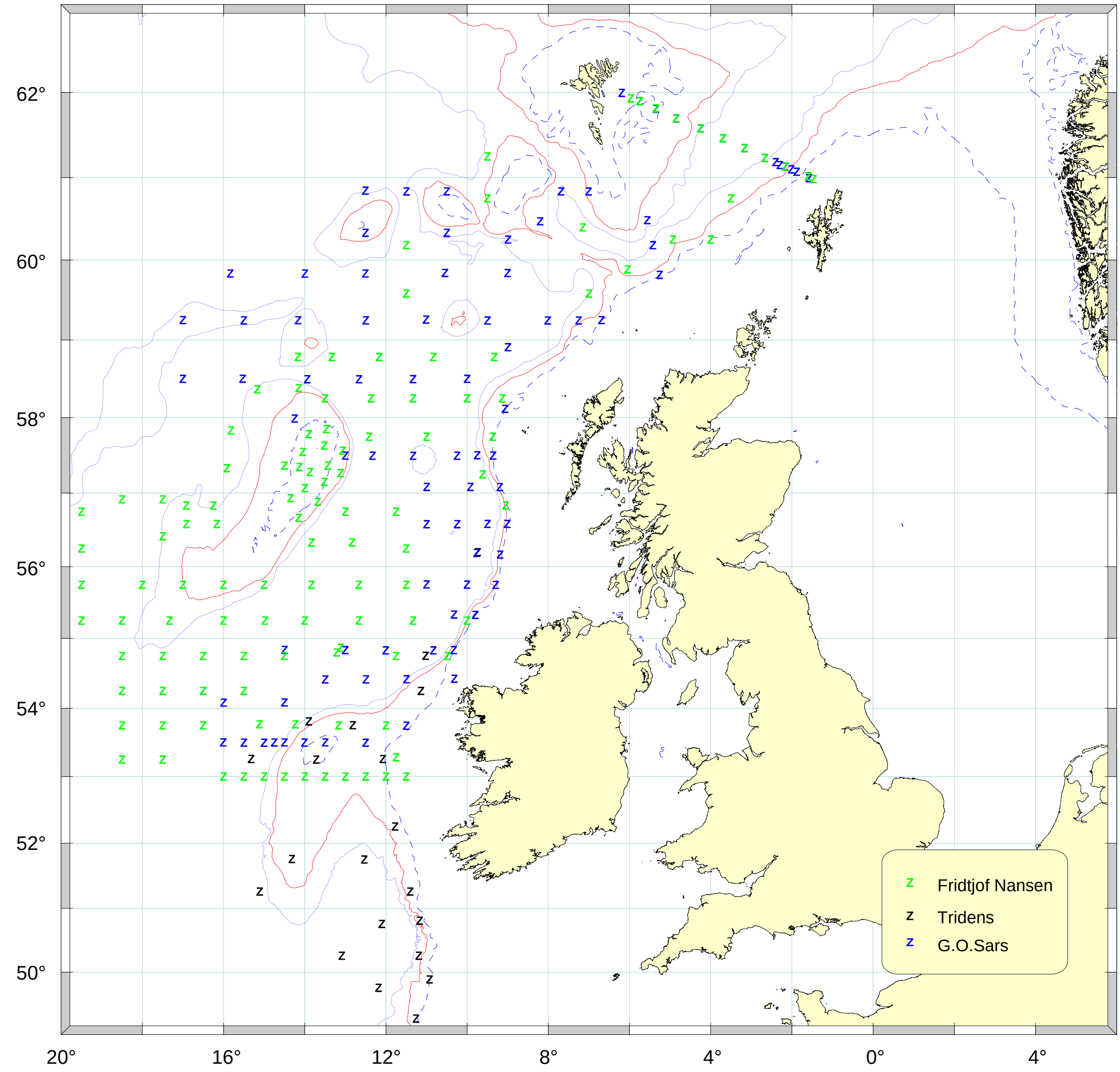


Figure 3. CTD stations for R/V G. O. Sars, R/V Fridtjof Nansen and R/V Tridens in March-April 2005.

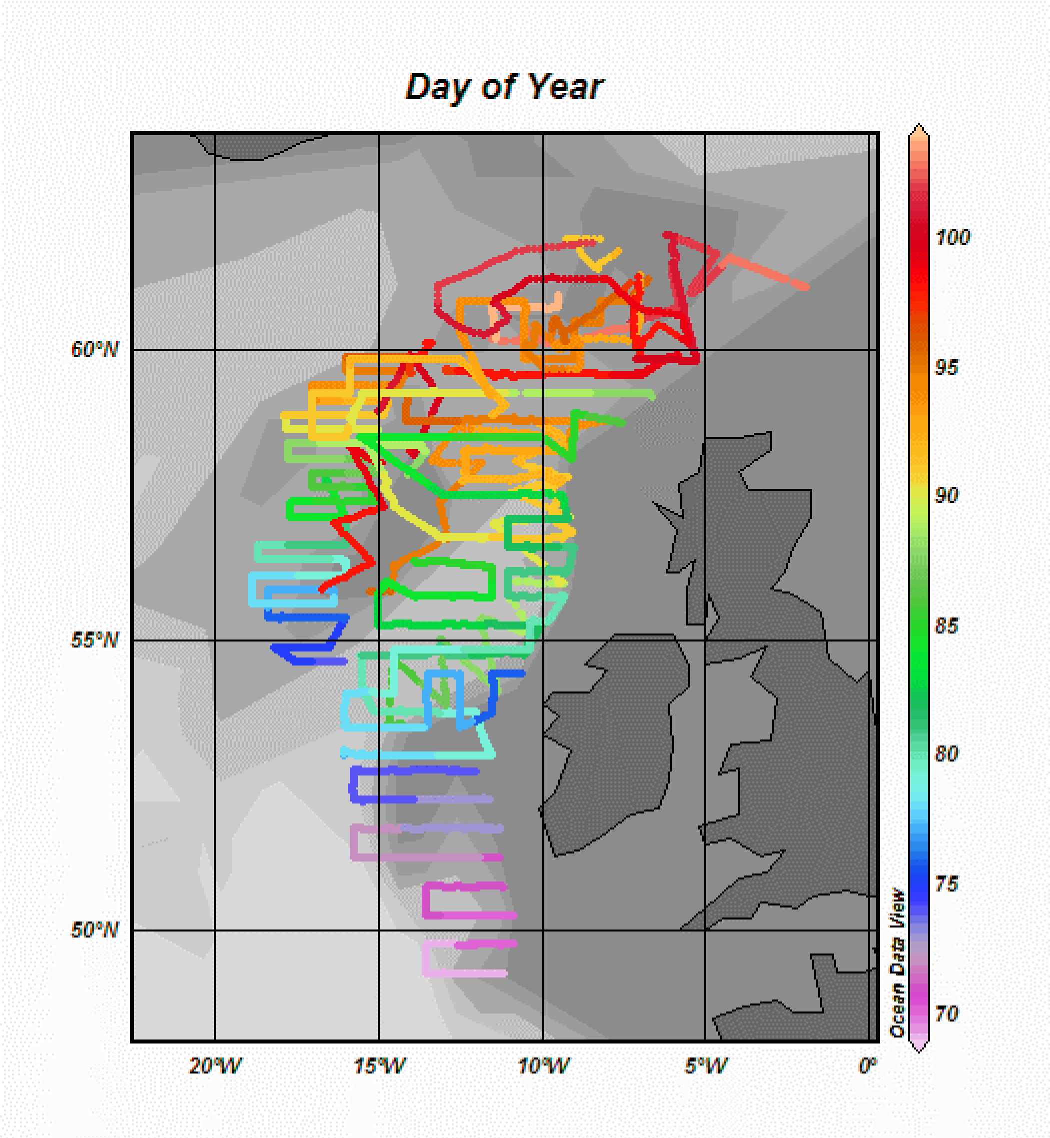


Figure 4. Temporal progression of the survey, 10 March–14 April 2005. Only cruise tracks from which acoustic data were used in the stock estimate are shown.

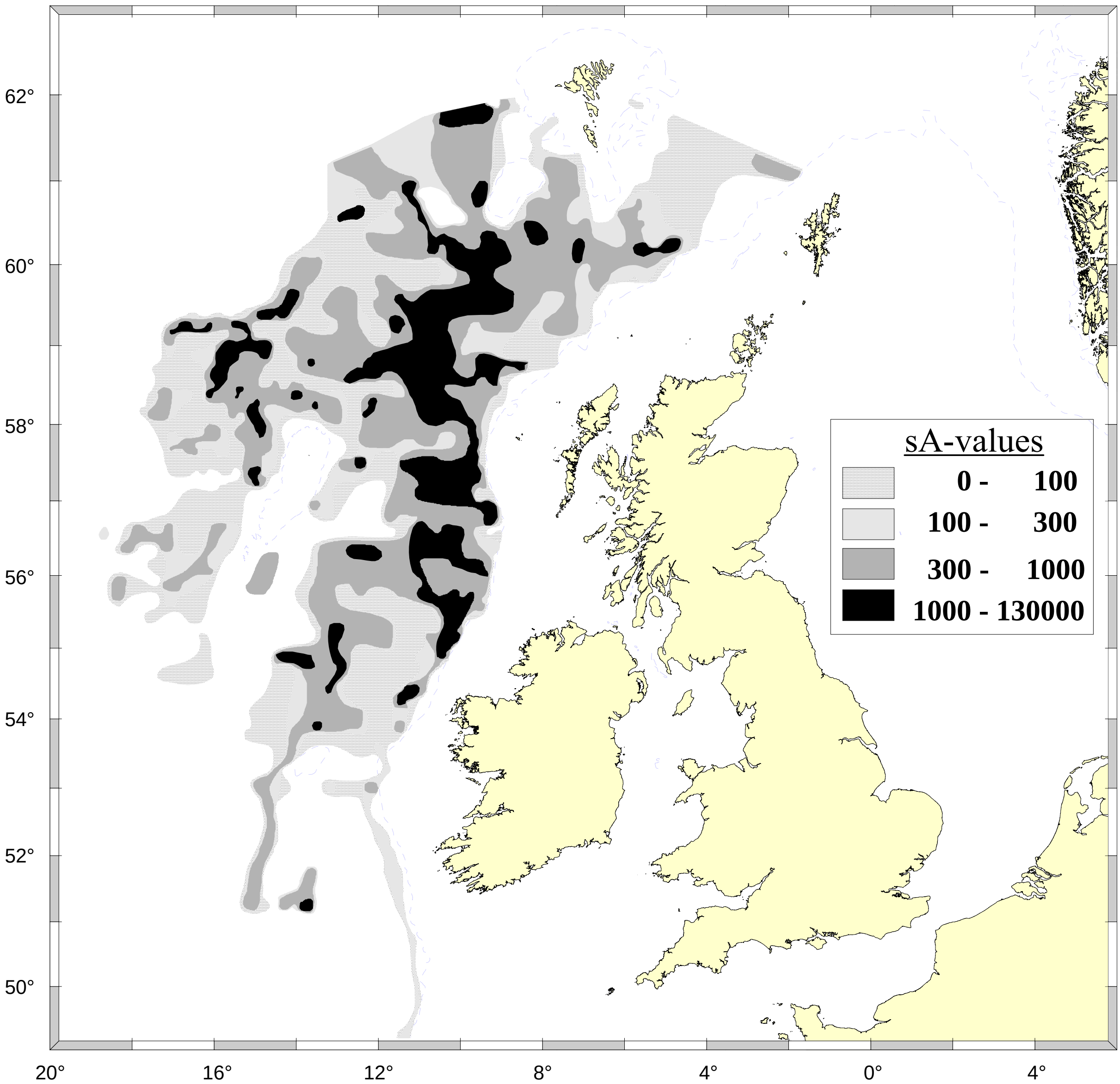


Figure 5. Schematic map of blue whiting acoustic density (s_A, m^2/nm^2) in spring 2005.

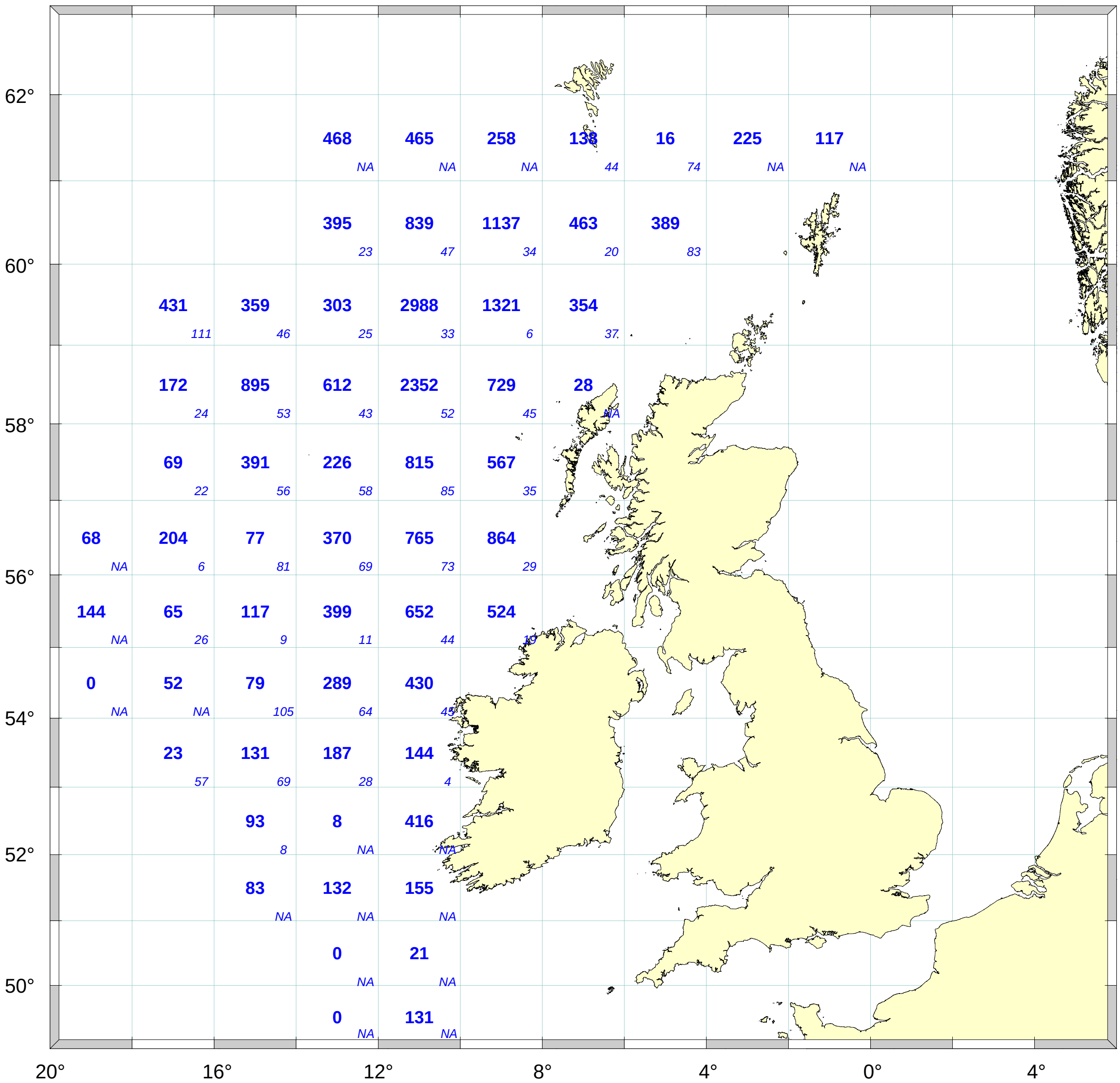


Figure 6. Mean acoustic density (s_A, m^2/nm^2) per stratum. The value printed in the lower right corner is among-vessel coefficient of variability (CV, %).

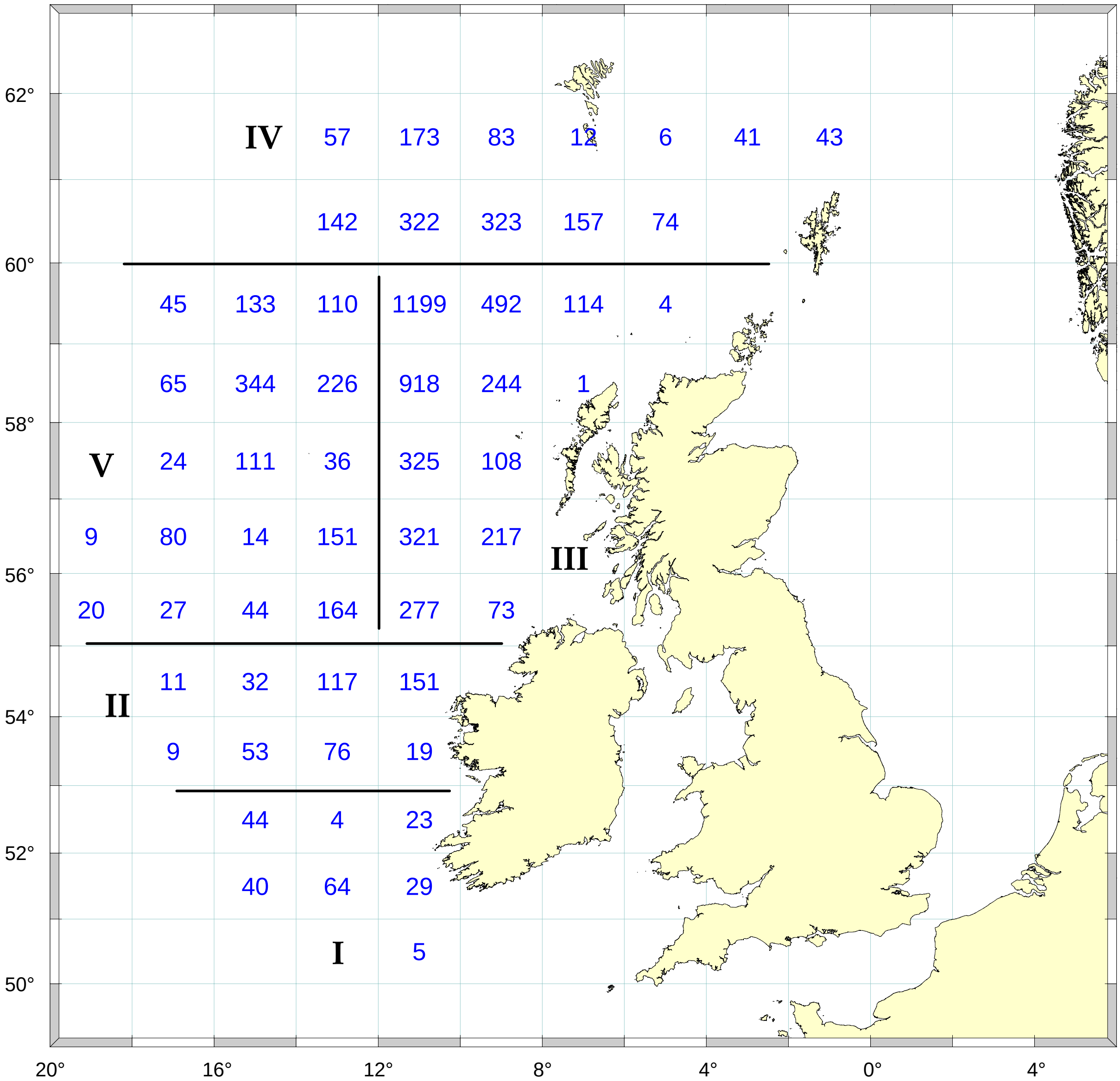


Figure 7. Blue whiting biomass in 1000 tonnes, spring 2005. Marking of sub-areas I-V used in the assessment.

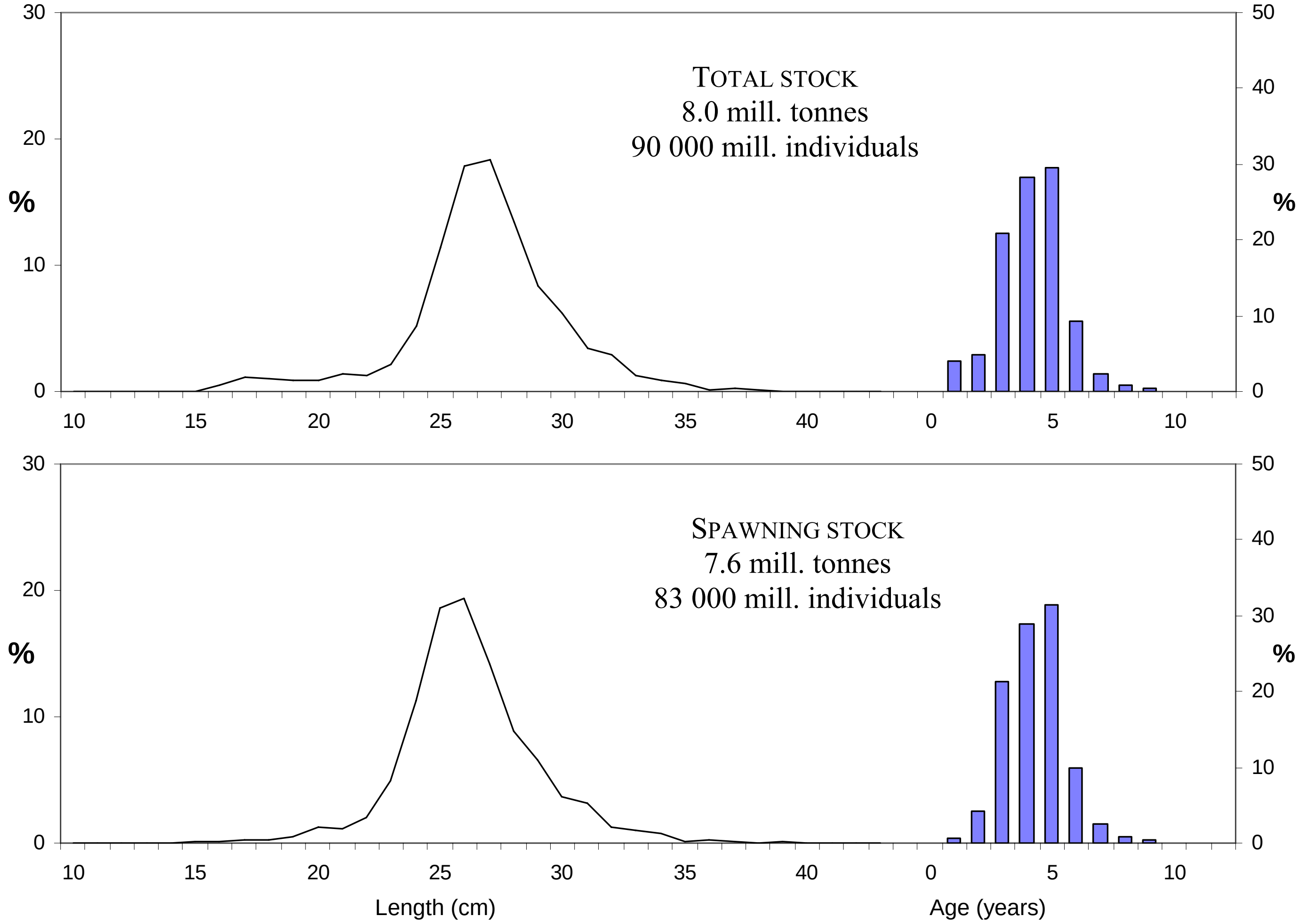


Figure 8. Length and age distribution in the total and spawning stock of blue whiting in the area to the west of the British Isles, spring 2005.

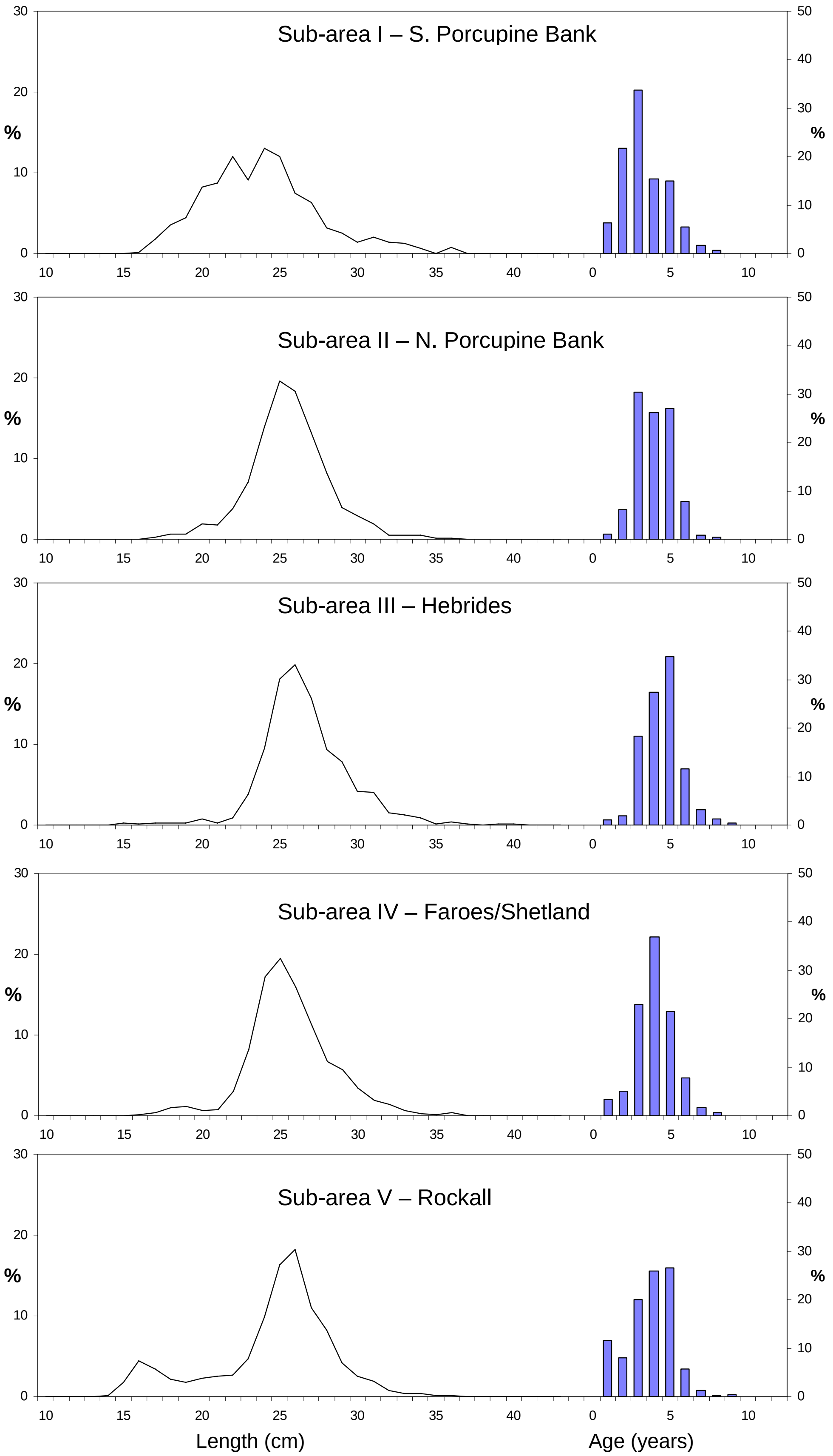


Figure 9. Length and age distribution of blue whiting by sub-areas (I–V), spring 2005.

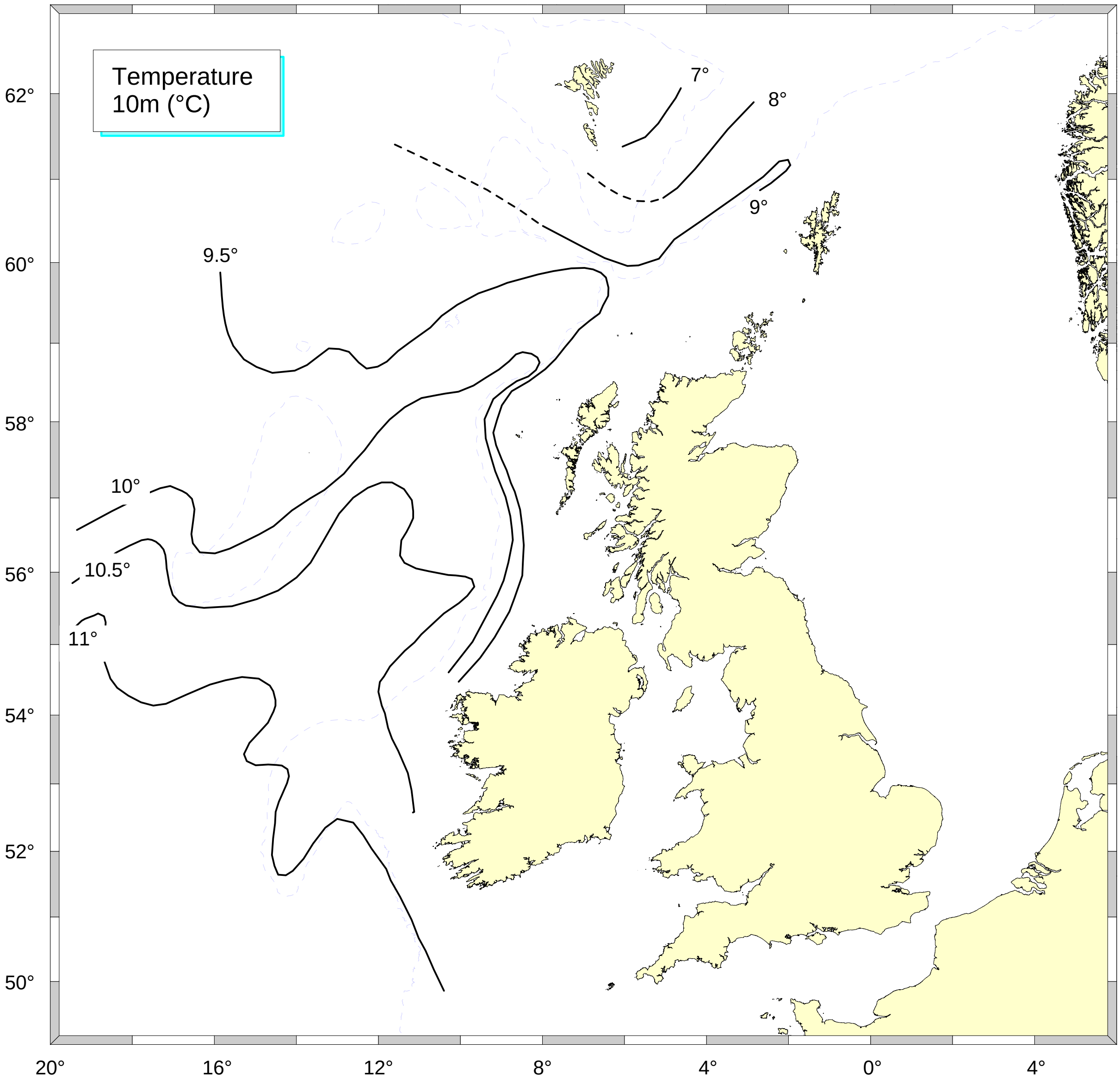


Figure 10. Horizontal temperature distribution, °C, in March-April 2005 at 10m depth.

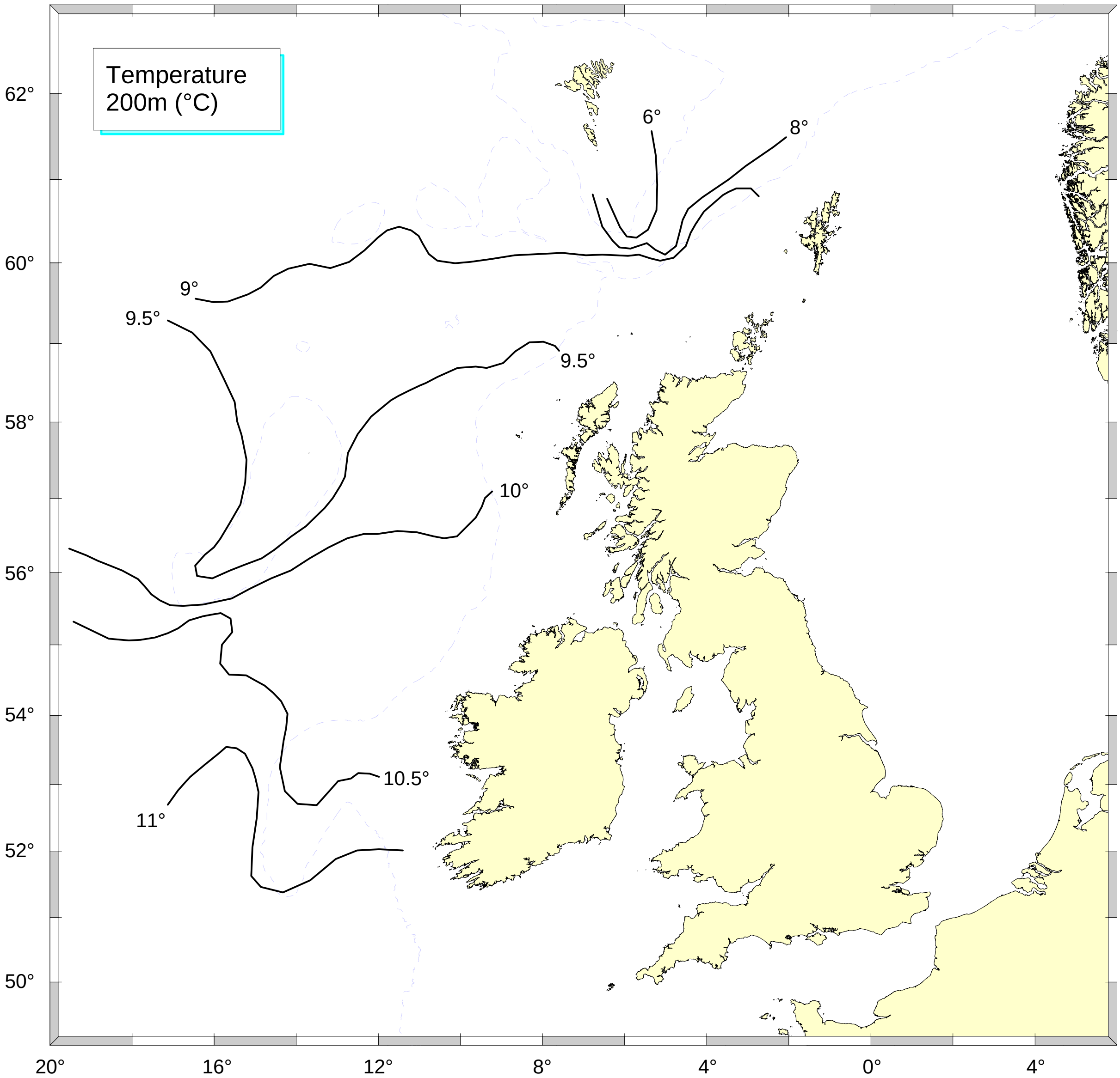


Figure 11. Horizontal temperature distribution, °C, in March-April 2005 at 200m depth.

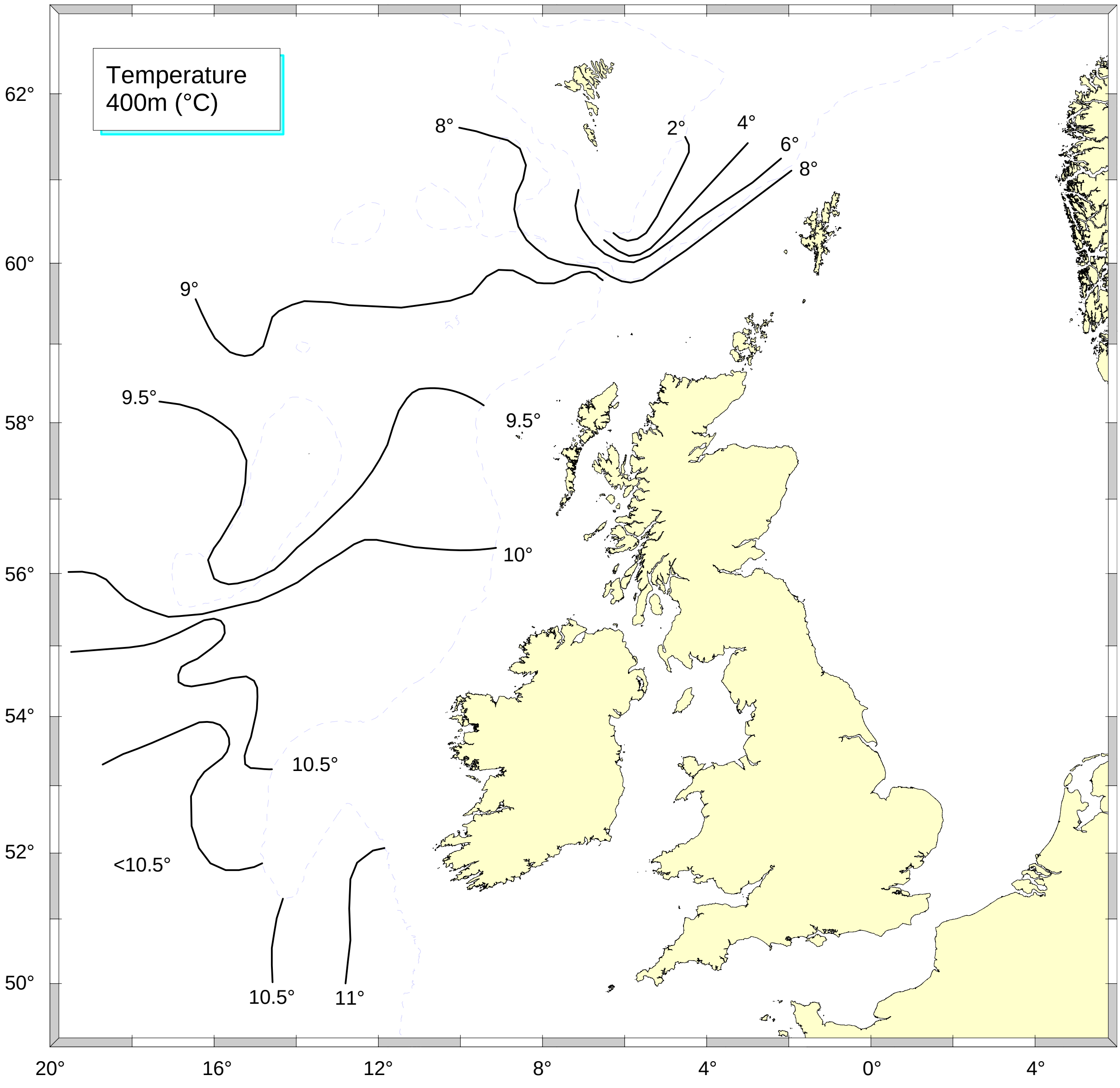


Figure 12. Horizontal temperature distribution, °C, in March-April 2005 at 400m depth.

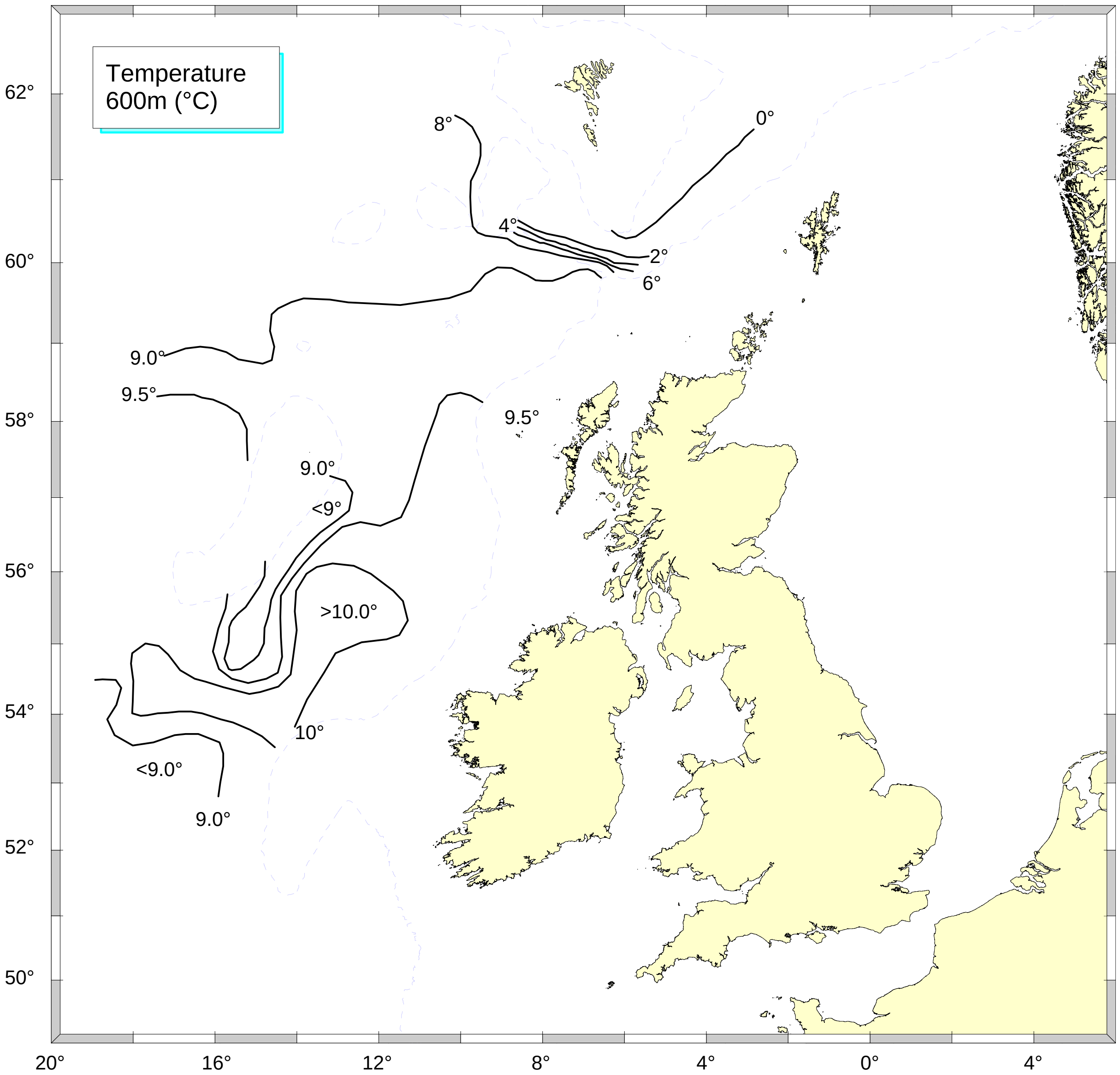


Figure 13. Horizontal temperature distribution, °C, in March-April 2005 at 600m depth.

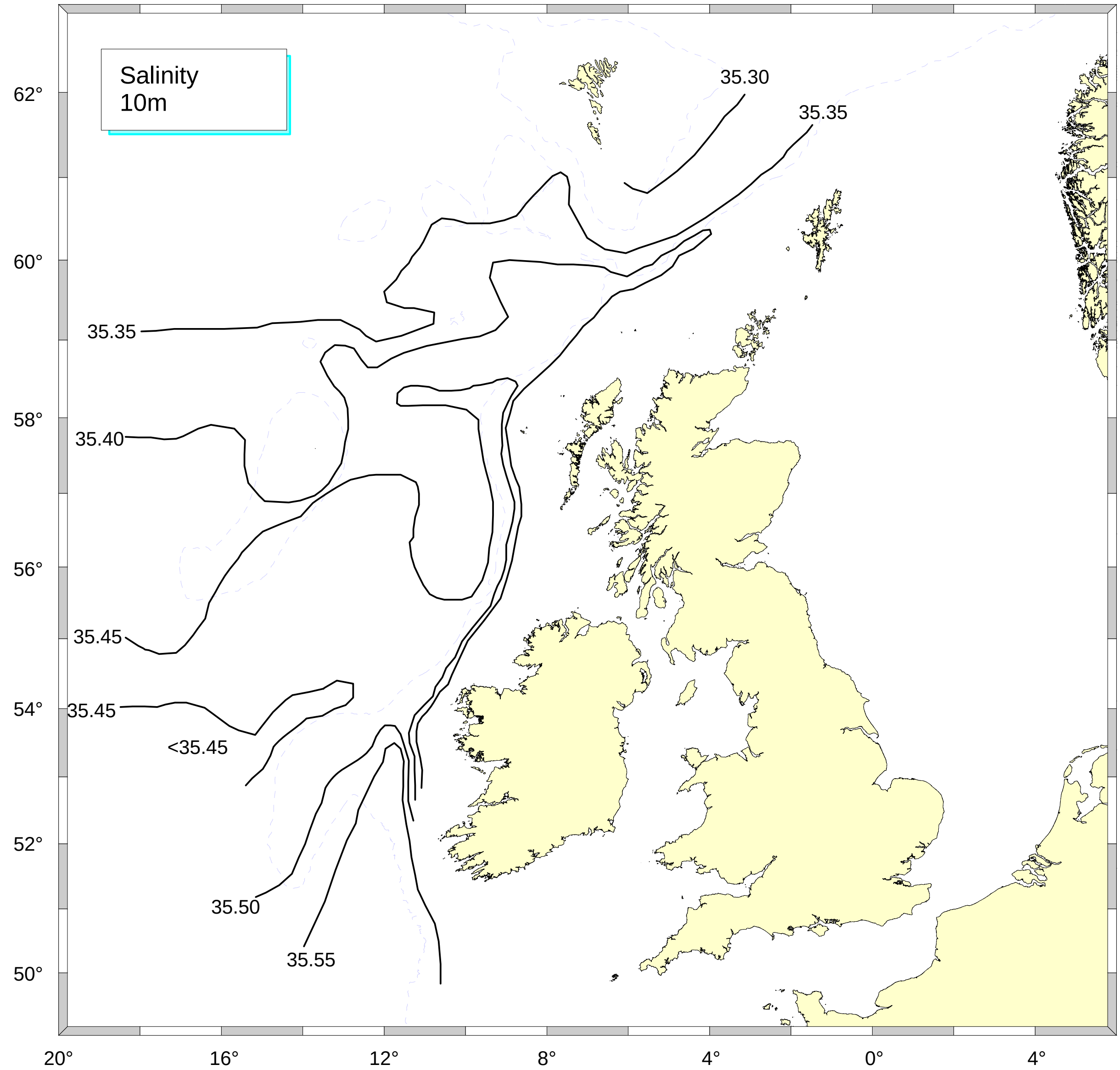


Figure 14. Horizontal salinity distribution, °C, in March-April 2005 at 10m depth.

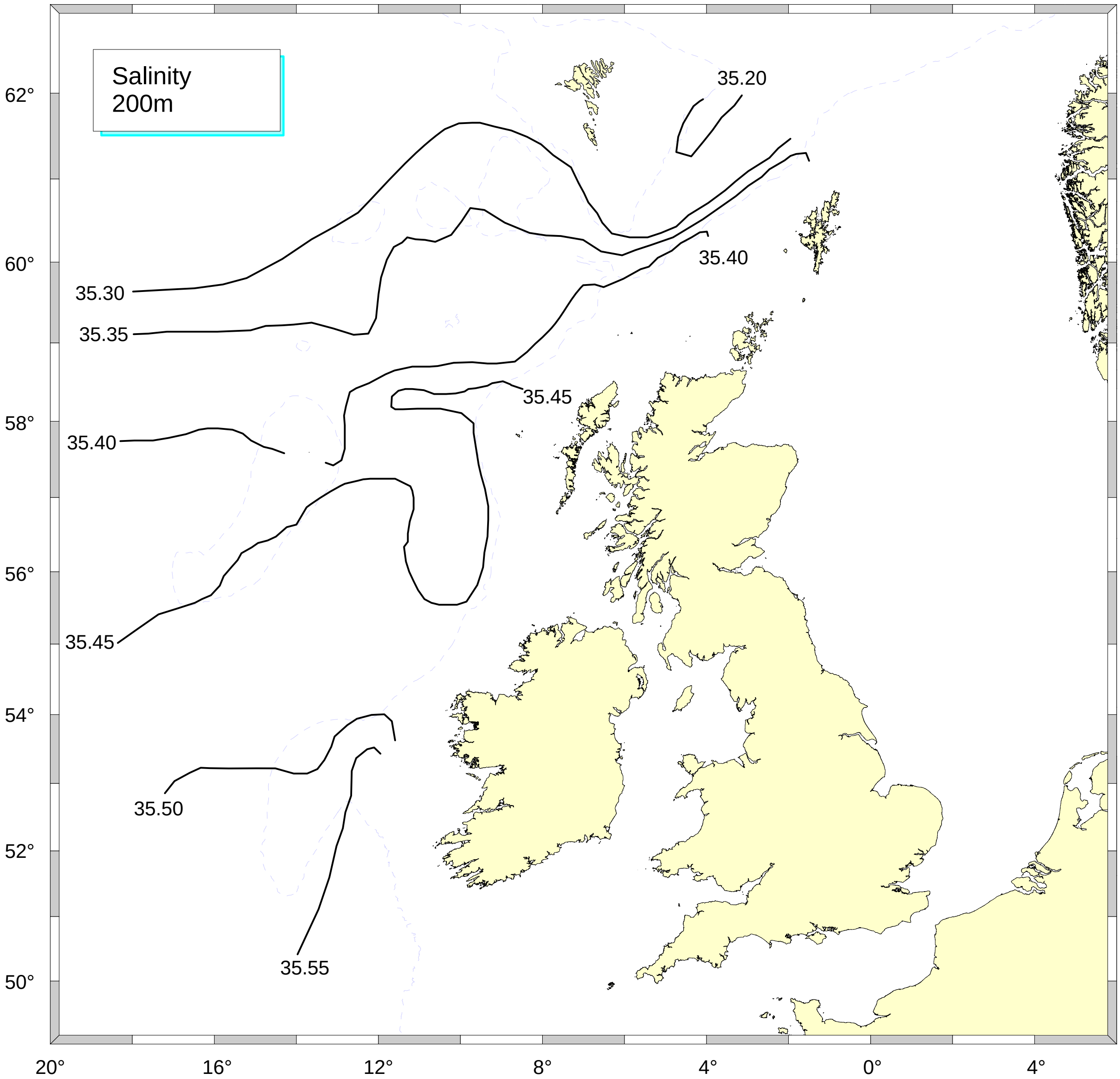


Figure 15. Horizontal salinity distribution, °C, in March-April 2005 at 200m depth.

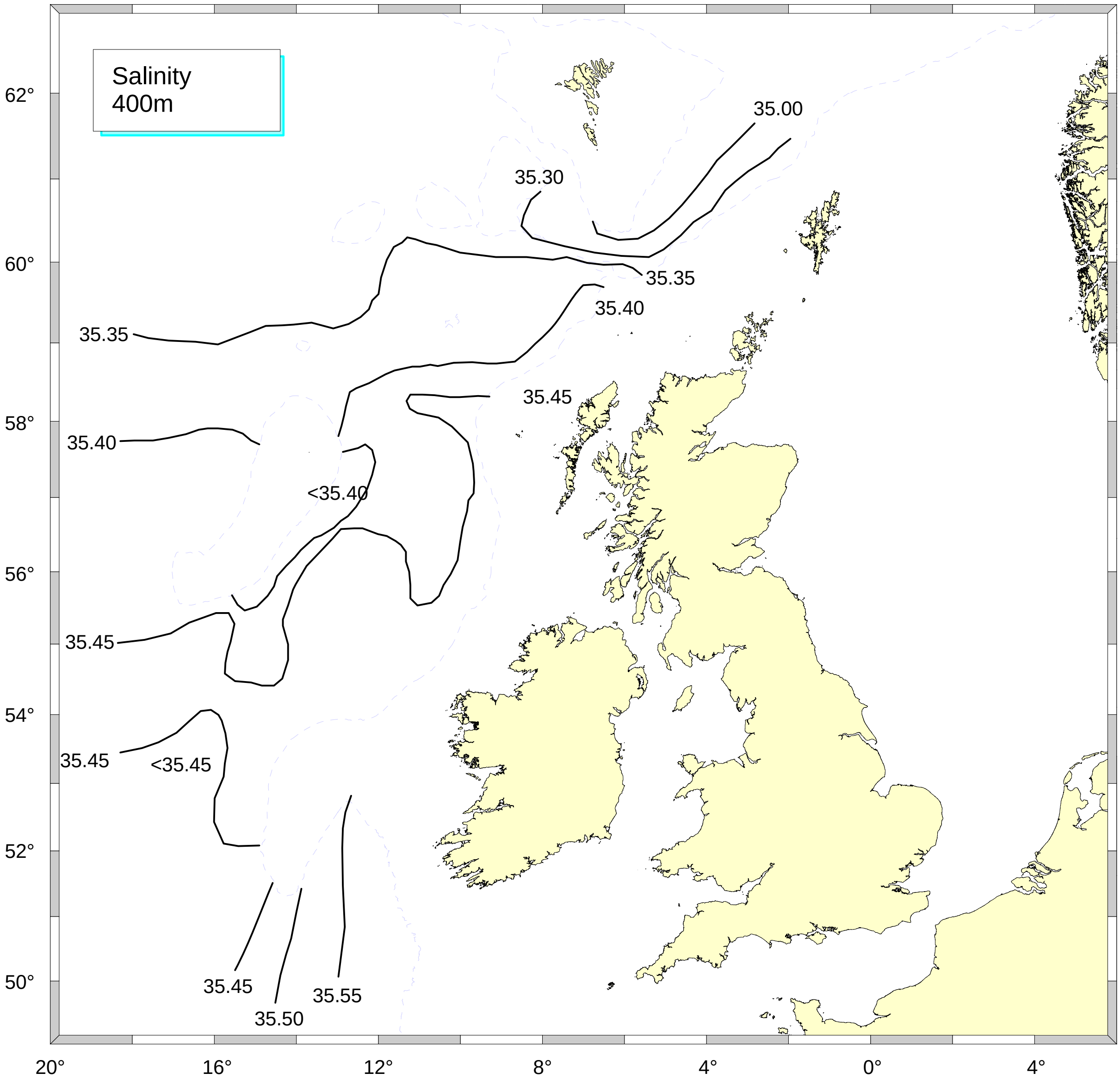


Figure 16. Horizontal salinity distribution, °C, in March-April 2005 at 400m depth.

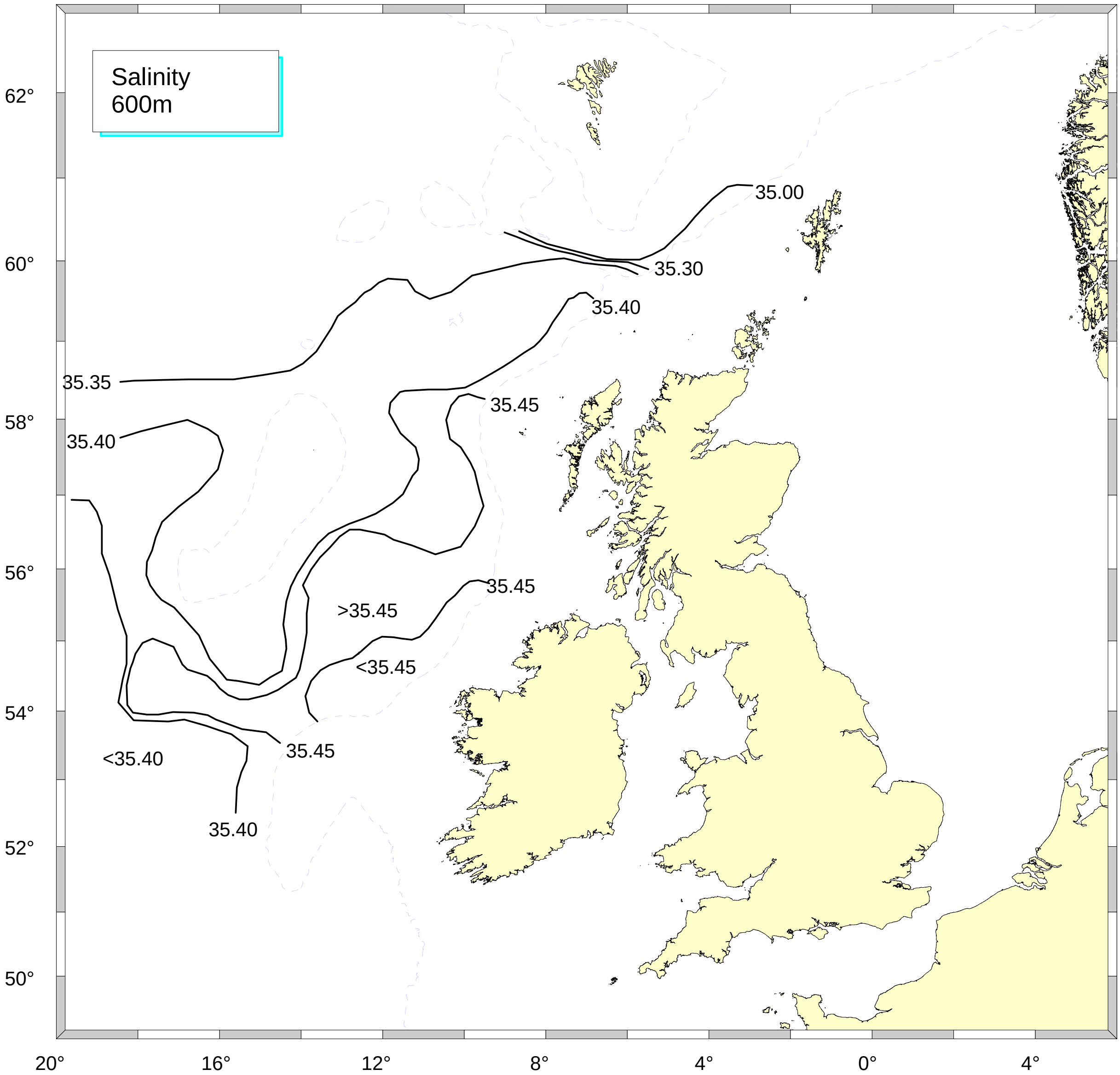


Figure 17. Horizontal salinity distribution, °C, in March-April 2005 at 600m depth.

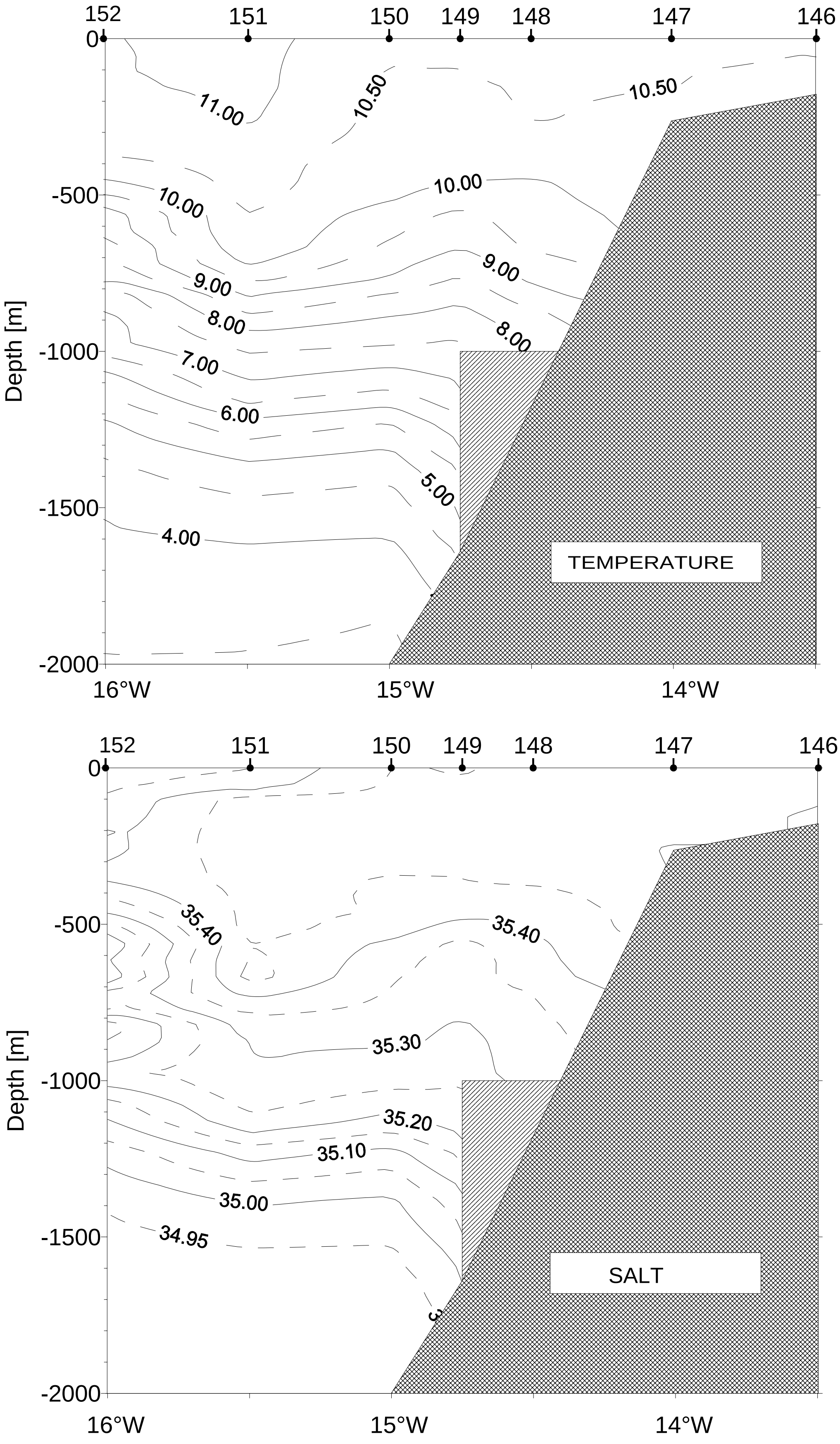


Figure 18. Vertical distribution of temperature (°C) and salinity in a section at the shelf edge at the Porcupine Bank at 53° 30'N. Station numbers at the top of the panels.

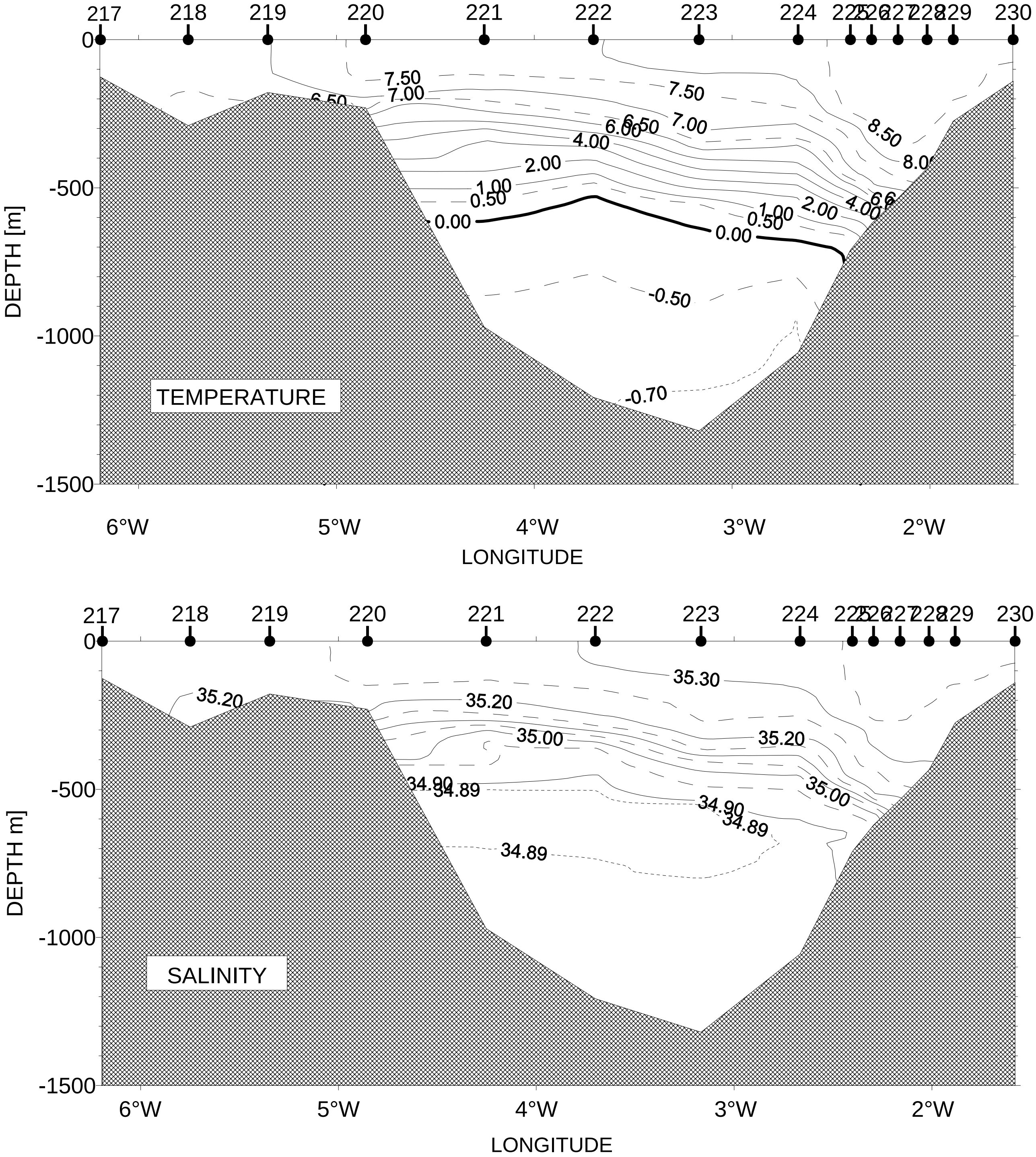


Figure 19. Vertical distribution of temperature (°C) and salinity in a section from the Faroes to Shetland (Nolsø-Flugga). Station numbers at the top of the panels.

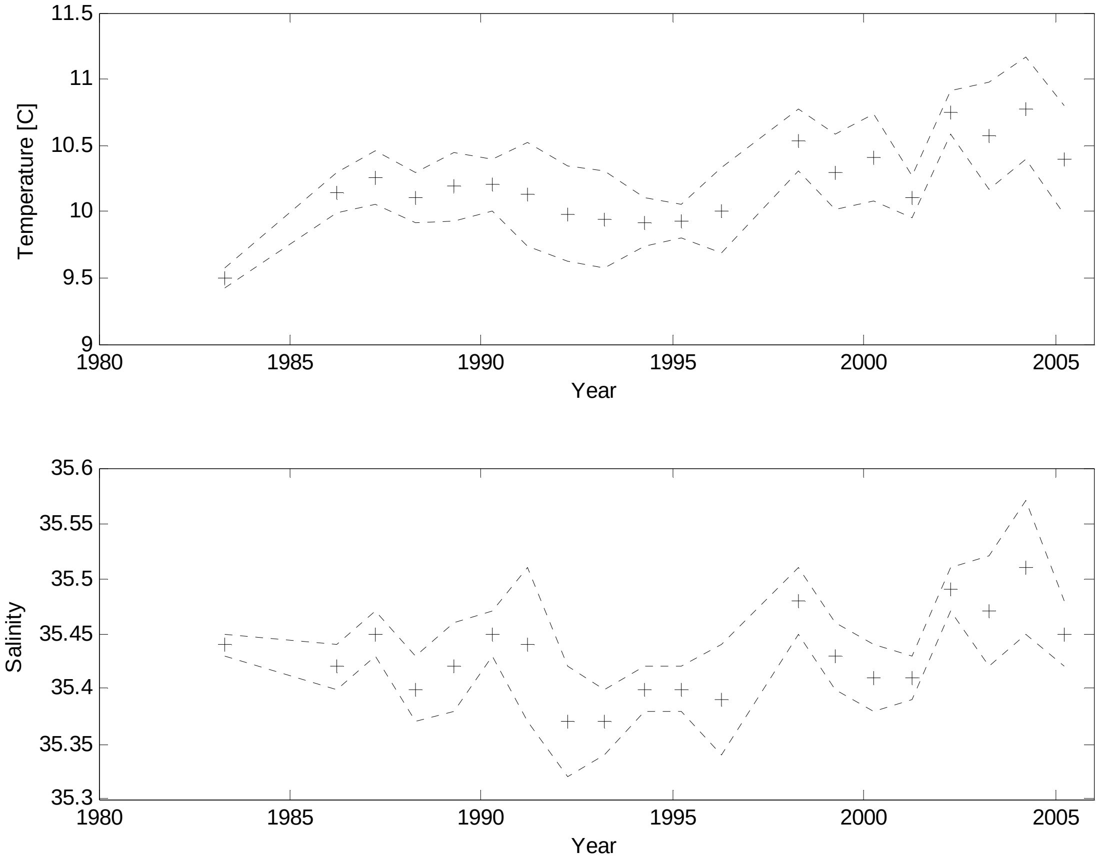


Figure 20. Yearly mean temperature and salinity from 50-600m (crosses) of all stations in a box with bottom depth>600m, west of the Porcupine bank bounded by 52° to 54°N and 16° to 14°W. Dotted lines are drawn at plus-minus one standard deviation of all observations in each box, each year.

Appendix 1. Inter-calibration between R/V Tridens and R/V G. O. Sars

Acoustic inter-calibration between R/V G. O. Sars and R/V Tridens was conducted on 22 March 2005 north of the Porcupine Bank at N 56^{o} 10’ and W 10^{o} 00’. The weather was initially favourable with fresh breeze from southeast, gradually increasing to strong breeze, eventually to southern near gale. The main acoustic feature in the area was a well-defined and almost continuous layer of blue whiting in depths around 400-600 metres.

In the beginning of the inter-calibration the logs were synchronized. The inter-calibration was the run over 44 nautical miles between 07:15-12:35 GMT. For the first 5 nm, both vessels were cruising northward at parallel courses, with G. O. Sars on the port side of Tridens at a distance of 0.1-0.2 nm. The vessels then turned 90 ^{o} and continued towards east. Bottom depth was in the excess of 1000 m and false bottom echoes were minimal nuisance.

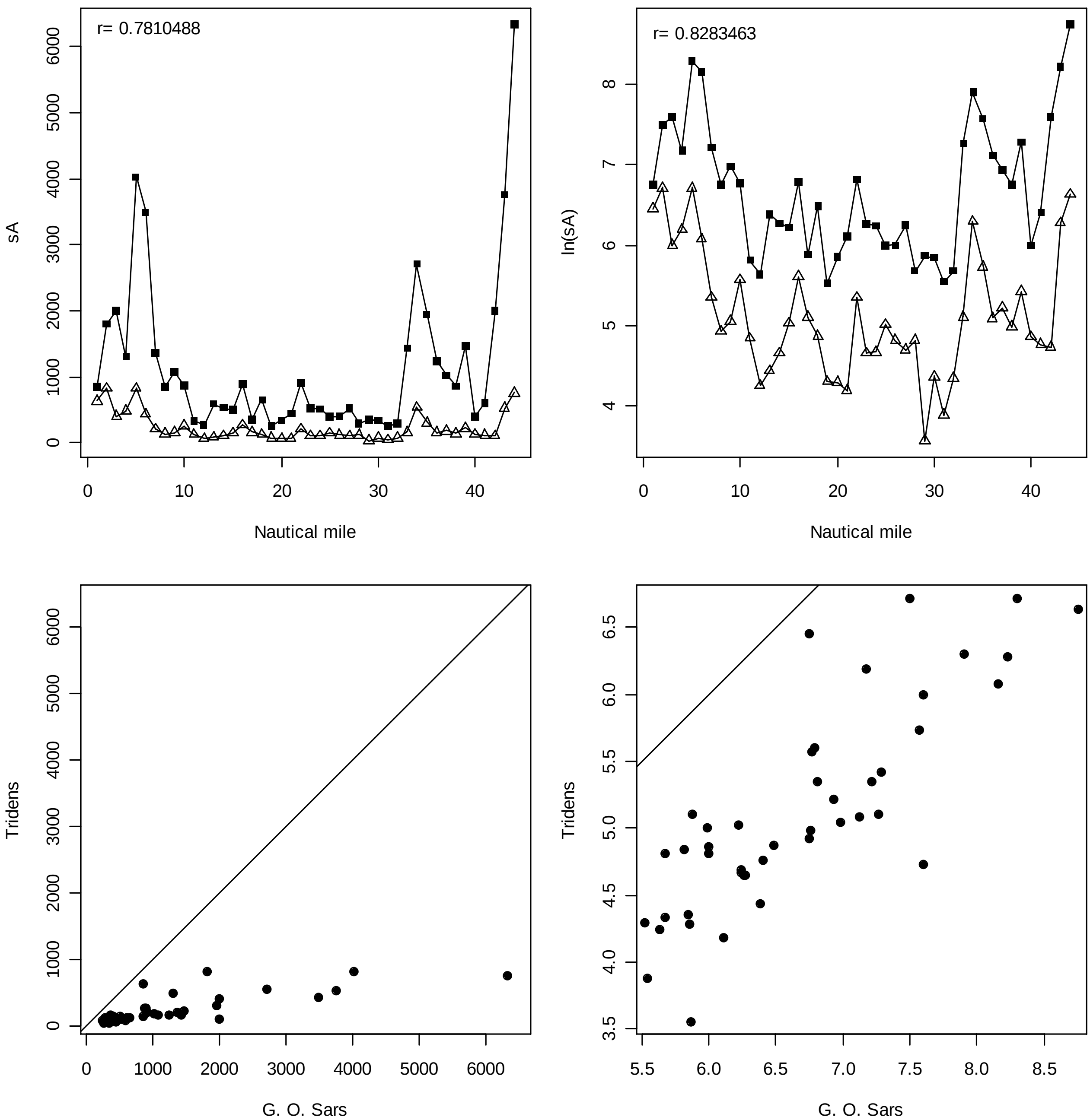


Figure 1. Comparison of blue whiting acoustic densities recorded by Tridens (triangles) and G. O. Sars (squares). The lower panels give same data as scatterplots.

Table 1. Regression models for the full data (n=44). Two regression models are estimated for both data, one with and without intercept (i.e. regression through the origin). The null hypothesis for t-tests on slope is that the slope is not different from one. Acoustic densities from G. O. Sars are taken as the independent variable and those from Tridens as the dependent variable.

Data	Parameter	Estimate	Std. Error	t value	Pr(>|t|)	R^2 (%)
All	Intercept	76.0	27.9	2.72	0.009	61.0
	Slope	0.134	0.017	52.4	<0.001	
All	Slope	0.165	0.013	65.3	<0.001	79.5
All, log scale	Intercept	-0.032	0.543	-0.06	0.953	68.6
	Slope	0.772	0.081	2.82	0.007	
All, log scale	Slope	0.768	0.010	23.9	<0.001	99.3

In the data analysis we focused on acoustic densities (s_A, m^2/nm^2) allocated to blue whiting. On both vessels the routine procedures were followed for scrutinizing the data. Figure 1 shows that there is a tendency for Tridens to record much lower acoustic densities than G. O. Sars. After the inter-calibration, a bad cable connection was found with Tridens and it was therefore concluded that this had probably caused the lower values. A closer look at the raw data files also raised the possibility of a non-continuous error. A pattern of appearance of single target positions in the transverse section of the beam was evidently present from 19 to 21 March.

After the acoustic inter-calibration, pelagic trawls of the two vessels were compared. Both vessels towed to the same direction at a distance of about half nautical mile apart. Tridens towed at depth of 450 m for 30 minutes and caught 3000 kg of blue whiting. G. O. Sars towed for 20 minutes at depths of 450-500 metres and caught 150 kg of blue whiting (first cod-end towed for 10 min: 70 kg; second cod-end towed for 10 min: 80 kg). As seen in Fig. 2, blue whiting in the pooled catch of G. O. Sars were slightly smaller in length (mean ±sd: 26.5 ±2.1 cm) than the blue whiting in the catch of Tridens (26.8±2.4cm). The difference was statistically insignificant (p=0.115). The same is true if the catch by G. O. Sars is split to sub-samples (first cod-end: 26.6±2.1 cm; second cod-end: 26.4±2.1 cm). Thus, despite the large difference in catch weight, the two trawls appear to display only a minor difference in size selectivity.

Mean age for the sample taken by G. O. Sars is 4.6 ±1.0 years (mean ±sd), whereas that for Tridens is 3.6 ±1.1 years, a highly significant difference (p<0.001) — despite the smaller length of fish aged on G. O. Sars, 26.5 ±2.6 cm, compared with 27.1 ±2.1 cm on Tridens. Linear model AGE~VESSEL+LENGTH shows a large vessel factor (-1.2 years) that is statistically significant (p<0.001). The age readings between the vessels are thus not consistent.

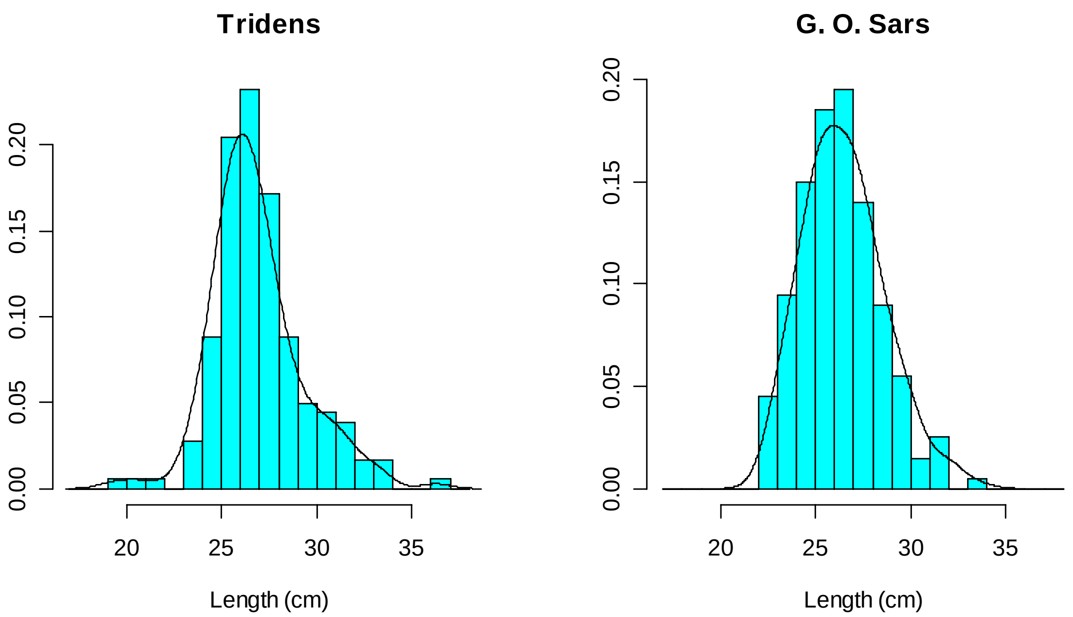


Figure 2. Length distributions from the trawls hauls by Tridens and G. O. Sars. Smoothing is obtained by normal kernel density estimates. G. O. Sars: n=200; Tridens: n=181

Appendix 2. Inter-calibration between R/V Celtic Explorer and R/V G. O. Sars

Acoustic inter-calibration between R/V G. O. Sars and R/V Celtic Explorer was conducted on 2-3 April southwest of the Rosemary Bank at N 59° 00' and W 11° 10'. The weather was rather favourable with fresh-strong breeze from southwest. The main acoustic feature in the area was a well-defined, almost continuous layer of blue whiting that varied greatly in density. The blue whiting layers was in depths between 400 and 600 metres.

In the beginning of the inter-calibration the logs were synchronized. The inter-calibration was the run over 29 nautical miles between 20:56-00:57 GMT. For the first 15 nm, both vessels were cruising southwest at parallel courses, with G. O. Sars leading and Celtic Explorer on starboard side at position ~135° at a distance of 0.5-0.6 nm. The vessels then turned 180° and continued back with Celtic Explorer leading. During the southwest course swell caused dropouts and noise in the recordings. Bottom depth was in the excess of 1000 m and false bottom echoes were of little nuisance.

In the data analysis we focused on acoustic densities (s_A, m^2/nm^2) allocated to blue whiting. On both vessels the routine procedures were followed for scrutinizing the data. Figure 1 shows acoustic densities recorded by the two vessels and allocated to blue whiting. These display some obvious discrepancies both in the beginning of the inter-calibration as well as in the very end. Regression model suggest that intercept is not significantly different from zero. Regression forced through the origin has a slope that is significantly smaller than one and rather moderate coefficient of determination (R2). However, visual inspection of both Figure 1 and the actual echograms suggests that the recordings in the beginning and the end of this exercise are not comparable because of spatial heterogeneity in blue whiting density even at small spatial scales. Another set of regressions was therefore run for the subset of data where the most discrepant recordings were omitted (nautical miles 1-5 and 29). Also in this case the data support regression through the origin. The slope is still significantly smaller than one, but the coefficient of determination is much higher. Thus, in this case the pattern suggested is that Celtic Explorer tended to record lower acoustic densities than G. O. Sars. However, as neither vessel consistently recorded the same registrations over the course of the exercise this remains uncertain. Overall, the results may be more of an artefact of the small-scale heterogeneity observed rather than an actual quantifiable difference in vessel performance.

The interpretation of the results must be made with caution. The difference between G. O. Sars and Celtic Explorer is obvious only at high densities, omission of which would leave a cluster of data points not showing any systematic difference (cf. Figure 1). The difference observed for high densities could still be accounted for spatial heterogeneity in density of blue whiting in the area (there is 24-fold difference between miles 3 and 4 for G. O. Sars and 18-fold difference between miles 5 and 6 for Celtic Explorer). The other possibilities are differences in (1) the performance of acoustic equipment, and (2) post-processing of the data. The former possibility seems unlikely, as both vessels are equipped with EK 60 echosounders with drop-keel mounted transducers. While the latter possibility cannot be excluded, it also appears unlikely because scrutinizing well-defined blue whiting aggregations observed during the exercise is easy and no difference was observed at low densities. While the conclusions from this inter-calibration are thus left open, calling for some caution in combining the data. For the purpose of generating a joint estimate the data from the Celtic Explorer can be used without correction.

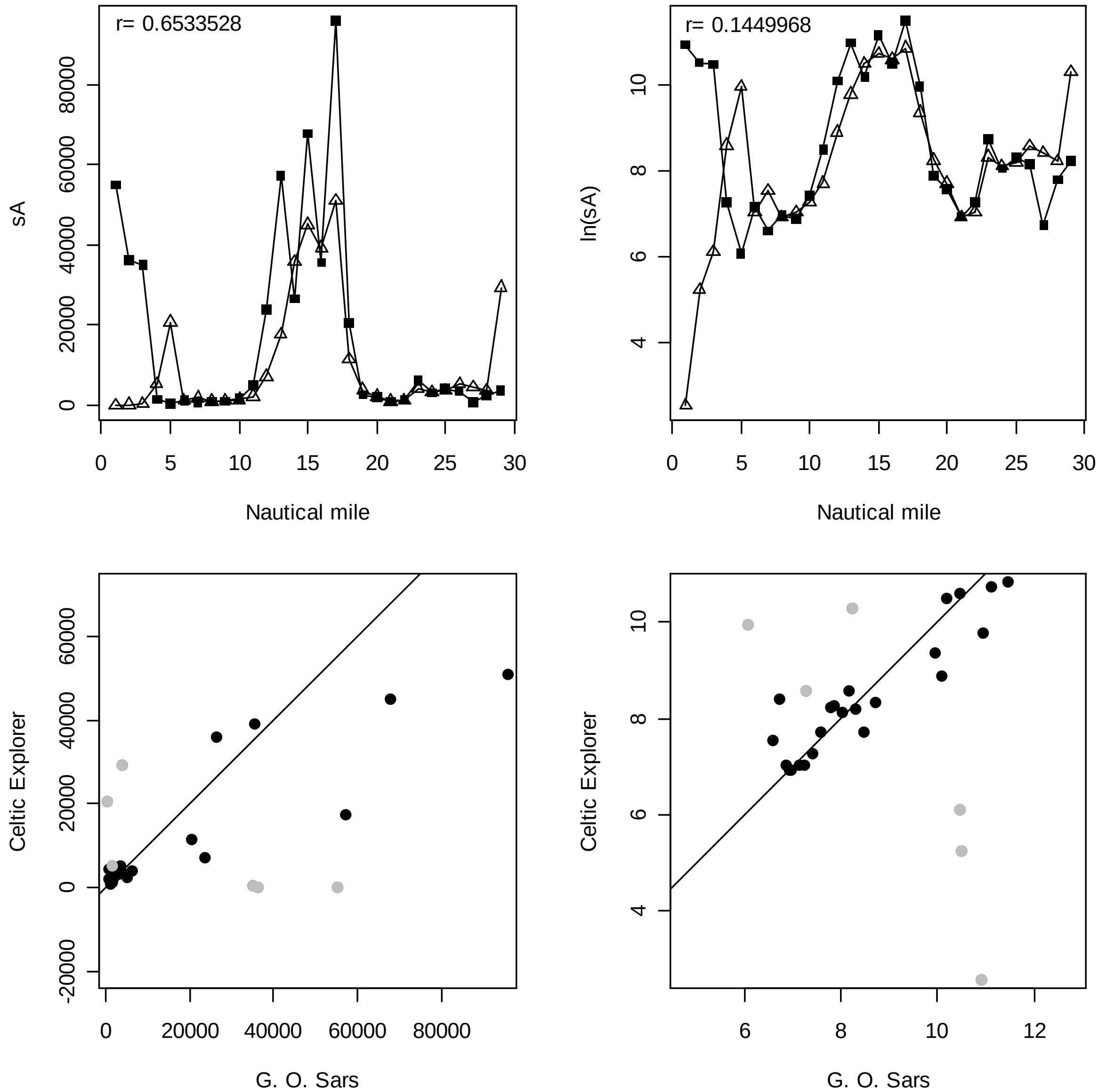


Figure 1. Comparison of blue whiting acoustic densities recorded by Celtic Explorer (triangles) and G. O. Sars (squares). The lower panels give same data as scatterplots. Grey dots correspond to miles 1-5 and 29 that were excluded from some regressions in Table 1. The diagonals are drawn as continuous lines.

Table 1. Regression models for the full data (n=29) and for the subset where the most deviating nautical miles are removed (n=23). Two regression models are estimated for both data, one with and without intercept (i.e. regression through the origin). The null hypothesis for t-tests on slope is that the slope is not different from one. Acoustic densities from G. O. Sars are taken as the independent variable and those from Celtic Explorer as the dependent variable.

Data	Parameter	Estimate	Std. Error	t value	Pr(>|t|)	R^2 (%)
All	Intercept	3794	2606	1.46	0.160	42.7
	Slope	0.392	0.087	6.96	<0.001	
All	Slope	0.465	0.073	7.34	<0.001	59.2
All\{1-5,29}	Intercept	2117	1769	1.20	0.245	80.6
	Slope	0.548	0.060	7.56	<0.001	
All\{1-5,29}	Slope	0.587	0.051	8.12	<0.001	85.8

After the acoustic inter-calibration, pelagic trawls of the two vessels were compared. Both vessels towed to the same direction at a distance of about half nautical mile apart. Celtic Explorer towed at depth of 480-520 m for 5 minutes and caught 3250 kg of blue whiting. G. O. Sars towed for 35 minutes at depths of 440-530 metres and caught 7 kg of blue whiting (first cod-end towed for 16 min: 2.3 kg; second cod-end towed for 19 min: 4.5 kg). In addition to the difference in the size of gear that favoured Celtic Explorer, acoustic observations suggested that Celtic Explorer trawled in an area of higher density of blue whiting than G. O. Sars did.

As seen in Fig. 3, blue whiting in the pooled catch of G. O. Sars were somewhat smaller (mean ±sd length: 27.1±2.2 cm) to the blue whiting in the catch of Celtic Explorer (27.9±2.7cm). The difference was statistically significant (p=0.013). The result is unaltered if the catch by G. O. Sars is split to sub-samples (first cod-end: 26.9±2.2 cm; second cod-end: 27.2±2.3 cm). Larger difference observed now (0.8 cm in favour of Celtic Explorer) as compared to similar comparison in 2004 (0.1 cm in favour of Celtic Explorer) may be related to heterogeneity of blue whiting in the area. The second cod-end of G. O. Sars represents a denser registration, probably more akin to the one fished on by Celtic Explorer, and is also more similar in size. However, given the difference in the size of the gear, it is expected that Celtic Explorer will catch larger fish than G. O. Sars.

Mean age for the sample taken by G. O. Sars is 4.4±0.9 years (mean±sd), whereas that for Celtic Explorer is 5.3±1.6 years, a highly significant difference (p=0.002). To some extent this reflects smaller length of fish aged on G. O. Sars, 26.5±3.0 cm, compared with 28.5±2.1 cm on Celtic Explorer. However, linear model AGE~VESSEL+LENGTH shows a non-negligible vessel factor (0.5 years) that is statistically significant (p=0.007 for all data and p=0.004 when only overlapping length range is considered). The age readings between the vessels are thus less consistent than they were in 2004.

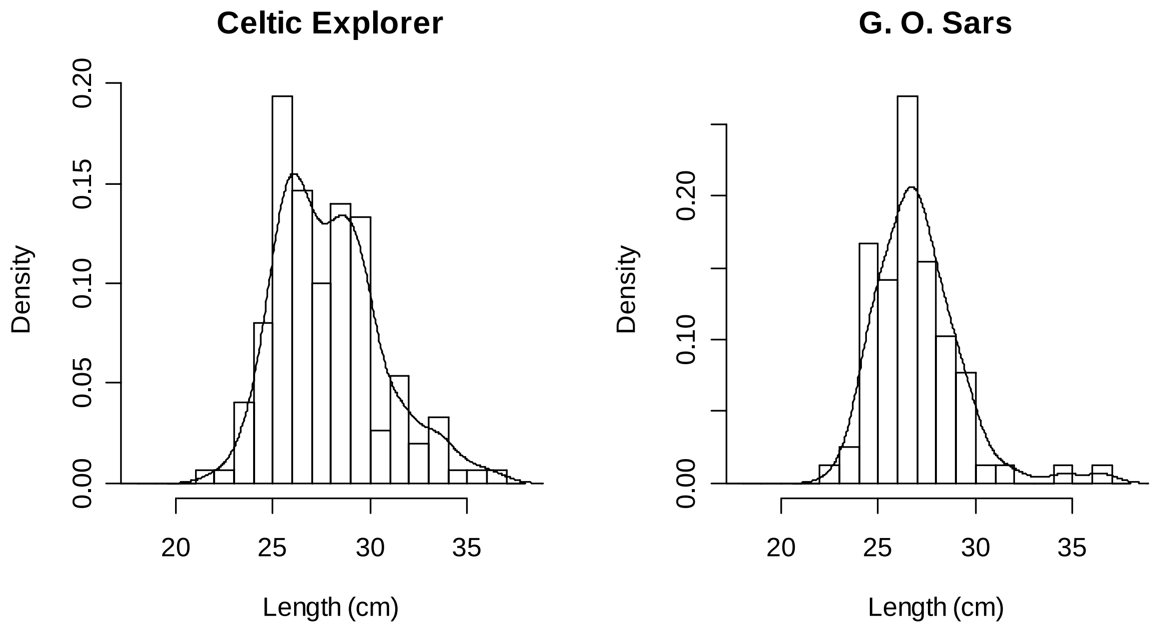


Figure 3. Length distributions from the trawls hauls by Celtic Explorer and G. O. Sars. Smoothing is obtained by normal kernel density estimates. G. O. Sars: n=78; Celtic Explorer: n=150.

Appendix 2. Inter-calibration between R/V Magnus Heinason and R/V G. O. Sars

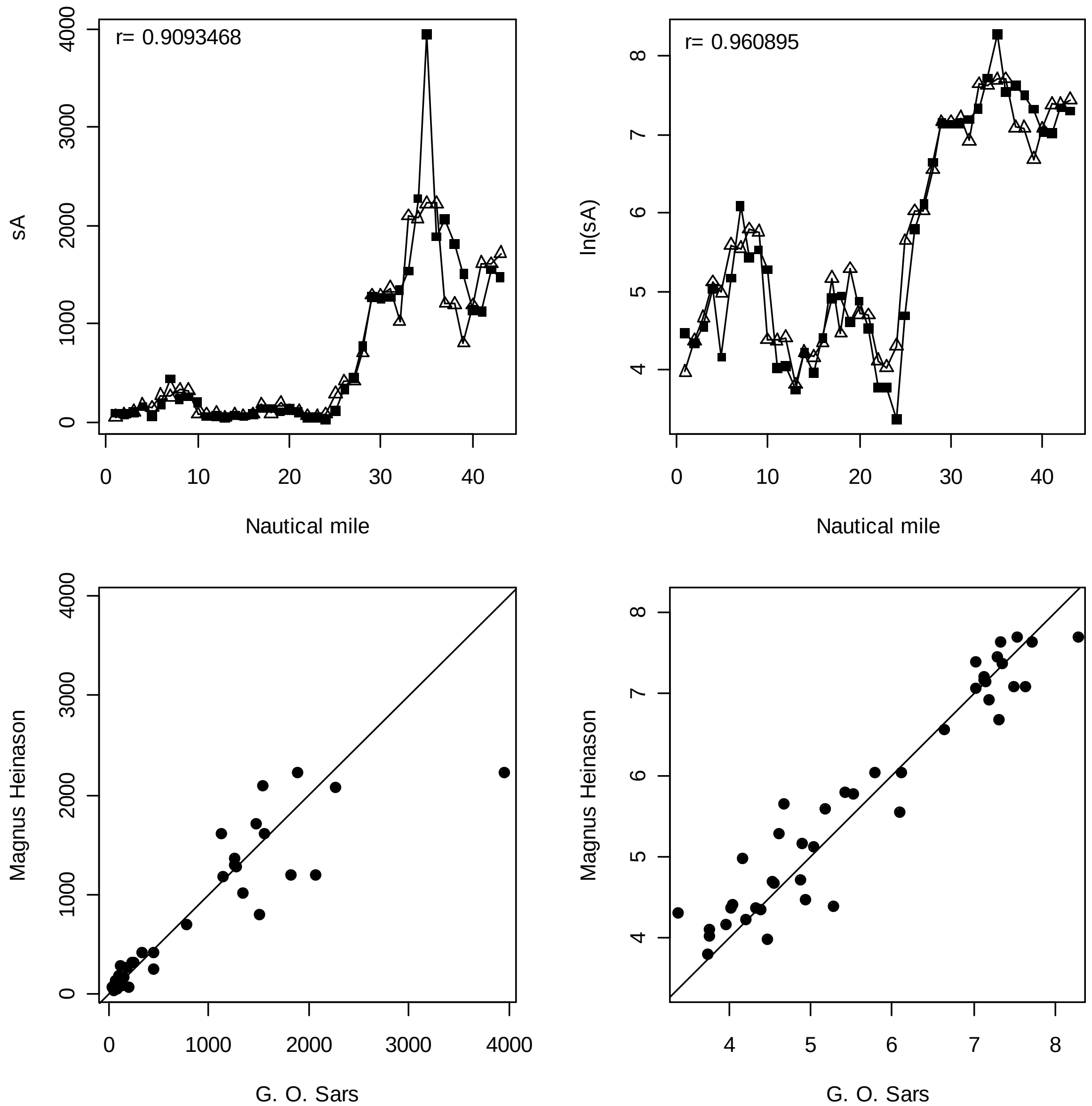
Acoustic inter-calibration between R/V G. O. Sars and R/V Magnus Heinason was conducted on 8 April south of the Faroes at N 60° 30’ and W 7° 05’. The weather was not particularly favourable—near gale to gale from northwest—but as the inter-calibration was run from north to south, the acoustic recordings were of decent quality. The main acoustic features in the area were (1) a weak layer of blue whiting in depths between 350 and 450 metres that gradually got stronger closer to the Wyville-Thompson Ridge, (2) a layer of presumed macro-zooplankton immediate below and partly mixed with the blue whiting layer, and (3) mesopelagics, probably predominantly pearlside, in depths between 150 and 250 metres.

The inter-calibration was the run over 43 nautical miles between 09:16-13:51 GMT. Vessels were cruising southwest at parallel courses, with Magnus Heinason leading and G. O. Sars on port side at position ~160° at a distance of about 0.5 nm.

In the data analysis we focused on acoustic densities (s_A, m^2/nm^2) allocated to blue whiting. On both vessels the routine procedures were followed for scrutinizing the data. Figure 1 shows acoustic densities recorded by the two vessels and allocated to blue whiting. These are in good quantitative agreement, with only one nautical mile showing a larger discrepancy. Regression model suggests that intercept is not significantly different from zero. Regression forced through the origin has a slope that is significantly smaller than one and rather high coefficient of determination (R^2). Eliminating the outlier (nautical mile 35), the slope no longer is statistically significantly different from one. These results suggest that combining the acoustic data from these two vessels is unproblematic.

Table 1. Regression models for the full data (n=43) and for the subset where an outlier is removed (n=42). Intercept is estimated in the first regression, whereas regression through the origin is assumed in the latter one. The null hypothesis for t-tests on slope is that the slope is not different from one. Acoustic densities from G. O. Sars are taken as the independent variable and those from Magnus Heinason as the dependent variable.

Data	Parameter	Estimate	Std. Error	t value	Pr(>|t|)	R^2 (%)
All	Intercept	119.0	59.4	2.01	0.052	82.7
	Slope	0.758	0.054	4.47	<0.001	
All	Slope	0.827	0.043	3.99	<0.001	89.7
All\{35}	Intercept	48.8	51.5	0.95	0.349	86.9
	Slope	0.906	0.066	1.70	0.097	
All\{35}	Slope	0.941	0.041	1.43	0.159	92.7



Fiure 1. Comparison of blue whiting acoustic densities recorded by Magnus Heinason (triangles) and G. O. Sars (squares). The lower panels give same data as scatterplots. The diagonals are drawn as continuous lines.

After the acoustic inter-calibration, pelagic trawls of the two vessels were compared. Both vessels towed to the same direction at a distance of about half nautical mile apart. Magnus Heinason towed at depth of 400 m for 60 minutes and caught 700 kg of blue whiting. G. O. Sars towed for 61 minutes at depths of 380-420 metres and caught 155 kg of blue whiting (first cod-end towed for 21 min: 70 kg; second cod-end towed for 20 min: 50 kg; third cod-end towed for 20 min: 35 kg).

As seen in Fig. 3, blue whiting in the pooled catch of G. O. Sars were somewhat larger (mean±sd length: 26.8±2.7 cm) compared to the blue whiting in the catch of Magnus Heinason (26.3±2.1cm). The difference was statistically significant ($p=0.015$). When the catch by G. O. Sars is analysed by subsamples, only the fish in the first were significantly larger (27.1±2.4 cm) than the fish caught by Magnus Heinason ($p=0.004$), whereas the difference was qualitatively similar but smaller and insignificant for the second cod-end and third cod-end (respectively 26.6±3.0 cm and 26.7±2.7 cm, corresponding to $p=0.387$ and $p=0.136$). This suggests a small difference in selectivity, which might be related to slightly higher towing speed (~0.5 knot) by G. O. Sars.

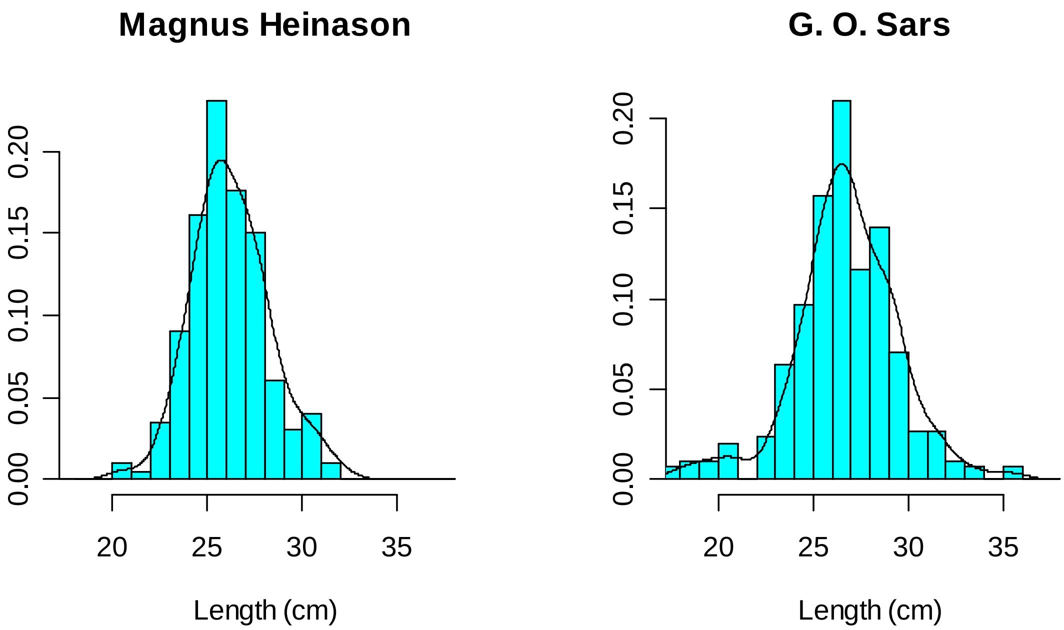


Figure 3. Length distributions from the trawls hauls by Magnus Heinason and G. O. Sars. Smoothing is obtained by normal kernel density estimates. G. O. Sars: n=300; Magnus Heinason: n=199.

Appendix 4. Inter-calibration between R/V Atlantniro and R/V Fridtjof Nansen

The acoustic inter-calibration between “Atlantniro” and “F. Nansen” was conducted on 03 April 2005 on the northern slopes of the Rockall Bank (N58° 22’ and W15° 00’) under very good weather conditions. The “F. Nansen” used the EK60 echosounder and the “Atlantniro” used EK500 echosounder. Standard instrument settings were kept during inter-calibration process (same as during the main survey).

The inter-calibration was run over 50 nautical miles. The ships following side-by-side at distance 0.3 nm and speed was 8.0 knots. The turn has been executed on a back course after first 25 nm and the logs were synchronized. During inter-calibration the depths were mainly between 750 and 1000 m.

The recording during the inter-calibration consisted of scatters of plankton in surface layer, mesopelagic fish (Myctophidae) in depths 100-200 m and blue whiting in depths around 500-550 m (Figure 1). The data were analysed using simple statistical comparisons and regression analysis by depth layers of 100 m. Only depths upper 600 m was analysed. In addition, the data were scrutinized, and the acoustic densities allocated to blue whiting were compared.

Figure 2 shows acoustic densities recorded by the two vessels for the depth layers corresponding to the main selected layers. These display similar overall patterns but considerable differences between individual observations in raw data (in spite of the fact that both ships are absolutely identical – with hull-mounted transducers).

We have decided that regression models fitted on both natural and logarithmic scales show reasonable fits (moderately high R^2) with positive intercepts and slope parameters less than one (Table 1); the deviations from one-to-one relationship are mostly statistically significant. The general pattern suggested by these regressions is that Atlantniro tends to record lower acoustic densities than “Fridtjof Nansen”. But in the scrutinized data this relationship may be reversed.

In our opinion the regressions presented here give a good basis for combining the results of the two vessels.

Figure 1. BI60 echogram obtained onboard r/v “F. Nansen” during the inter-calibration between r/v “F. Nansen” and r/v “Atlantniro”

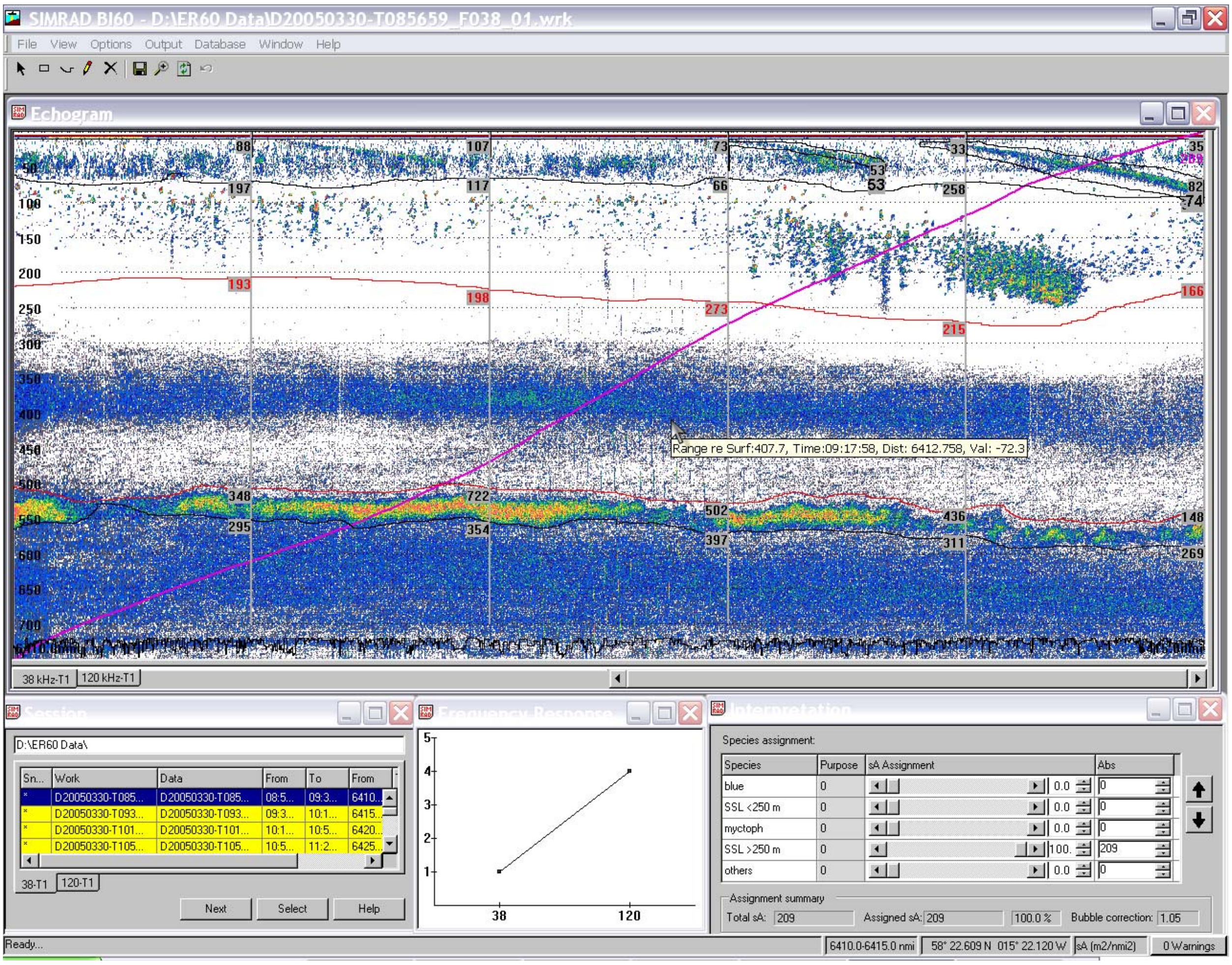


Figure 2. Time series of sA-values from r/v “Atlantniro” and r/v “F. Nansen”. Correlation coefficients between the time series are inserted.

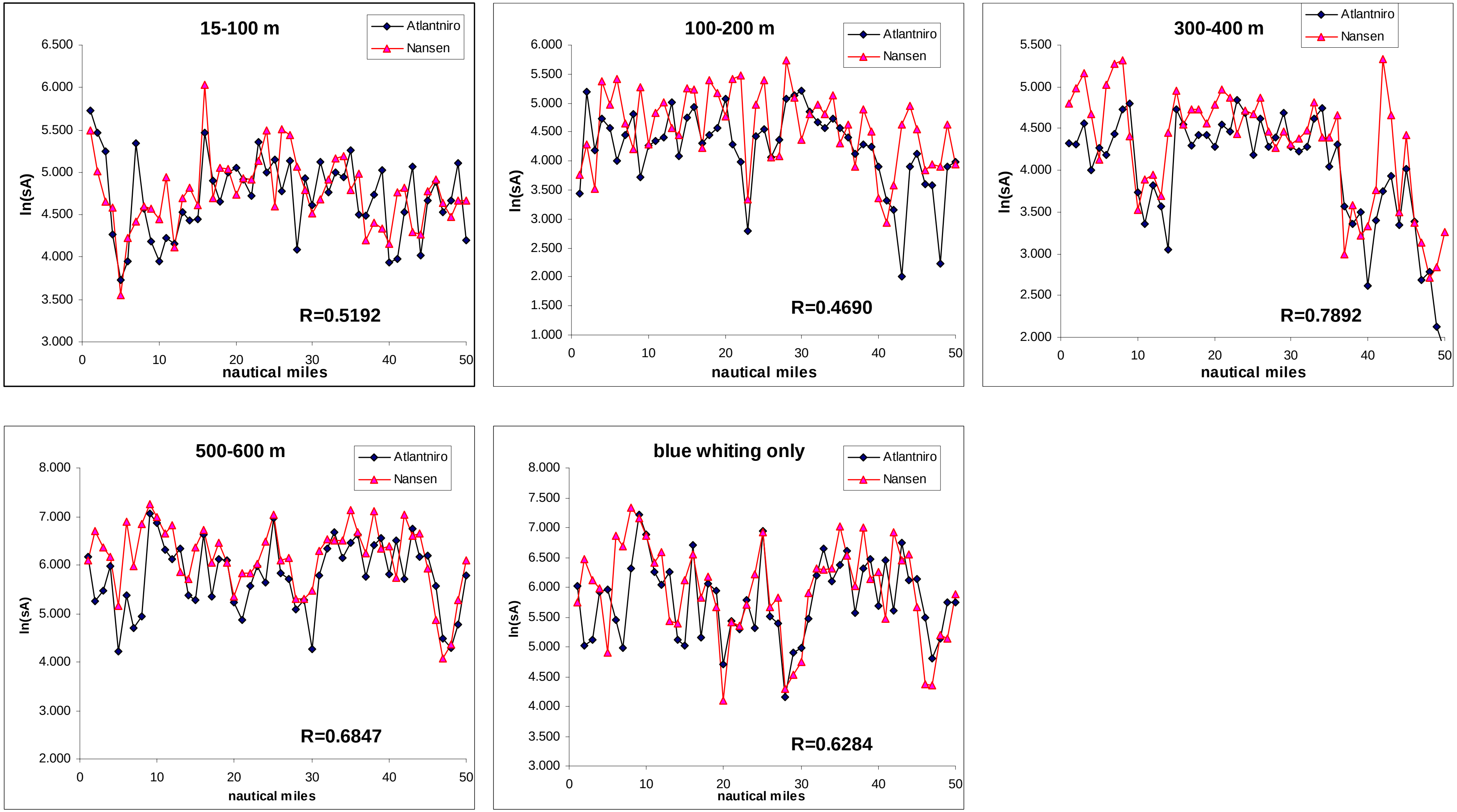


Figure 3. Scatter plots of sA-values from r/v “Atlantniro” and r/v “Fridtjof Nansen”

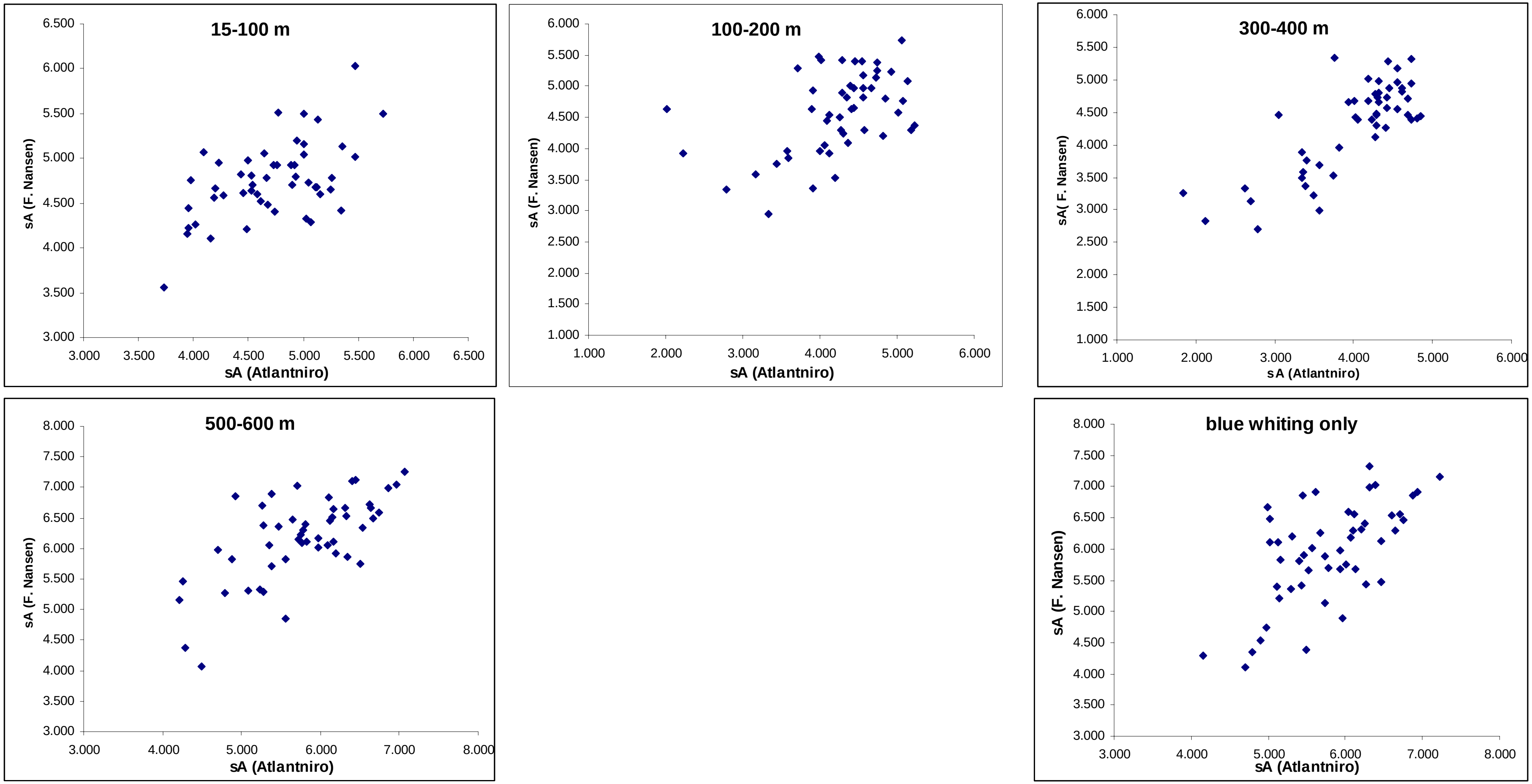


Table 1. Comparison of acoustic estimates between r/v "Atlantniro" and r/v "Fridtjof Nansen". All calculations are based on sA-values that have been transformed to logarithmic scale (base *e*). Logarithms of zeros have been replaced with a small number (-1, corresponding to sA=0.1).
(Values from "Atlantniro" are taken as the independent variable and those from "Fridtjof Nansen" as the dependent variable).

	15-100		100-200		200-300		300-400		400-500		500-600		600-700		15-500			
	Ch 1		Ch 2		Ch 3		Ch 4		Ch 5		Ch 6		Ch 7				bw only	
nm	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen	Atlantniro	Nansen
1	5.724	5.493	3.442	3.761	0.711	1.099	4.318	4.804	4.159	3.989	6.163	6.103	5.339	5.170	6.858	6.812	6.010	5.747
2	5.466	5.017	5.188	4.290	1.477	0.000	4.313	4.977	3.977	3.892	5.264	6.711	5.424	5.438	6.602	7.122	5.027	6.477
3	5.250	4.654	4.192	3.526	1.232	1.386	4.560	5.170	4.356	4.454	5.465	6.363	5.827	5.631	6.502	6.889	5.121	6.113
4	4.269	4.585	4.738	5.380	4.247	2.773	4.006	4.673	4.157	4.585	5.976	6.168	5.157	5.489	6.549	6.905	5.930	5.973
5	3.731	3.555	4.565	4.977	-0.563	5.429	4.273	4.127	4.106	4.489	4.213	5.153	6.146	5.412	5.822	6.223	5.968	4.895
6	3.950	4.220	4.012	5.416	2.048	1.946	4.185	5.017	3.995	4.220	5.378	6.896	5.025	5.485	6.095	7.313	5.449	6.859
7	5.342	4.419	4.438	4.654	1.719	3.258	4.440	5.278	3.899	4.431	4.704	5.976	5.078	6.412	6.288	6.759	4.989	6.678
8	4.577	4.605	4.819	4.205	2.999	2.303	4.724	5.313	3.661	4.754	4.930	6.855	6.237	6.682	6.236	7.269	6.310	7.329
9	4.188	4.564	3.719	5.283	2.514	3.258	4.805	4.407	4.114	4.718	7.069	7.253	5.724	5.075	7.290	7.549	7.217	7.149
10	3.957	4.443	4.273	4.290	3.783	4.883	3.742	3.526	4.162	4.762	6.863	6.980	5.183	5.620	7.079	7.233	6.875	6.864
11	4.231	4.949	4.341	4.828	5.572	5.635	3.352	3.892	4.213	4.745	6.313	6.657	5.167	5.489	6.676	7.097	6.255	6.406
12	4.153	4.111	4.399	5.004	0.767	0.693	3.814	3.951	4.378	4.663	6.109	6.828	5.125	5.638	6.579	7.163	6.041	6.588
13	4.534	4.700	5.010	4.575	0.765	4.290	3.567	3.689	4.272	5.030	6.348	5.861	5.151	5.749	6.826	6.621	6.261	5.437
14	4.433	4.820	4.088	4.454	3.956	1.386	3.053	4.454	4.422	4.779	5.381	5.714	5.271	5.613	6.143	6.576	5.119	5.388
15	4.453	4.615	4.747	5.257	1.075	2.639	4.733	4.949	4.559	4.771	5.273	6.370	5.337	5.521	6.406	7.035	5.014	6.115
16	5.467	6.028	4.931	5.226	1.850	2.773	4.554	4.543	4.004	4.949	6.627	6.721	5.625	5.416	7.155	7.418	6.706	6.552
17	4.904	4.700	4.297	4.234	1.414	0.000	4.301	4.727	4.355	4.369	5.352	6.057	5.177	5.088	6.347	6.682	5.162	5.826
18	4.649	5.050	4.455	5.403	-0.440	0.693	4.424	4.736	3.911	4.043	6.124	6.447	4.839	5.247	6.660	7.073	6.065	6.180
19	5.003	5.037	4.567	5.176	0.532	1.099	4.419	4.564	3.282	4.127	6.085	6.059	5.252	5.771	6.677	6.821	5.934	5.669
20	5.048	4.736	5.078	4.771	0.397	2.944	4.276	4.779	3.531	4.673	5.228	5.338	5.447	5.687	6.411	6.501	4.709	4.098
21	4.921	4.927	4.281	5.425	2.346	1.099	4.549	4.963	4.053	4.477	4.877	5.826	5.462	5.743	6.200	6.841	5.434	5.421
22	4.727	4.920	3.979	5.468	0.503	1.386	4.458	4.868	3.210	3.807	5.566	5.826	5.455	5.677	6.290	6.789	5.295	5.355
23	5.351	5.136	2.785	3.332	0.881	0.693	4.847	4.443	3.762	4.605	5.967	6.023	5.452	5.659	6.669	6.680	5.783	5.704
24	5.003	5.497	4.437	4.963	2.419	0.693	4.687	4.718	3.938	4.290	5.649	6.479	5.382	5.638	6.518	7.109	5.310	6.208
25	5.156	4.605	4.540	5.394	4.188	4.043	4.179	4.673	4.226	4.787	6.968	7.038	5.063	4.745	7.289	7.430	6.934	6.918
26	4.774	5.509	4.055	4.060	1.321	0.000	4.620	4.875	3.348	4.564	5.830	6.107	5.509	5.541	6.472	6.889	5.519	5.667
27	5.136	5.438	4.363	4.094	-0.202	1.099	4.287	4.466	3.655	4.522	5.716	6.140	5.537	5.606	6.498	6.838	5.397	5.816
28	4.088	5.063	5.066	5.746	-0.221	0.000	4.400	4.263	3.407	3.850	5.091	5.308	5.450	5.583	6.199	6.673	4.161	4.297
29	4.928	4.796	5.141	5.088	3.835	2.833	4.692	4.466	4.112	4.234	5.283	5.293	5.331	5.509	6.516	6.458	4.892	4.536
30	4.611	4.522	5.221	4.369	4.238	1.792	4.282	4.304	4.334	4.543	4.263	5.460	5.220	5.568	6.226	6.353	4.977	4.741
31	5.126	4.682	4.850	4.804	1.327	4.304	4.227	4.382	3.968	4.205	5.788	6.293	5.346	5.714	6.612	6.822	5.464	5.895
32	4.762	4.920	4.664	4.970	2.813	0.693	4.289	4.477	3.913	4.369	6.331	6.537	5.328	5.371	6.811	7.037	6.204	6.313
33	5.003	5.159	4.566	4.820	1.325	2.708	4.617	4.820	3.495	3.664	6.675	6.501	4.946	5.075	7.066	7.027	6.648	6.290
34	4.939	5.193	4.722	5.130	1.236	0.000	4.737	4.394	3.895	4.745	6.156	6.503	5.072	5.273	6.788	7.100	6.095	6.304
35	5.259	4.787	4.571	4.304	-0.426	0.000	4.050	4.394	4.737	4.913	6.450	7.124	5.121	5.338	6.997	7.410	6.382	7.024
36	4.498	4.984	4.411	4.625	-1.827	1.099	4.311	4.654	4.733	5.043	6.634	6.673	5.124	5.606	7.022	7.169	6.605	6.532
37	4.484	4.205	4.123	3.912	-0.759	3.932	3.565	2.996	4.773	4.844	5.754	6.230	5.399	5.541	6.429	6.649	5.574	6.022
38	4.741	4.407	4.288	4.890	3.576	-1.000	3.364	3.584	4.738	4.710	6.409	7.102	5.264	5.447	6.844	7.363	6.319	6.998
39	5.023	4.331	4.256	4.500	-3.296	5.820	3.493	3.219	4.358	4.654	6.542	6.347	5.103	5.375	6.935	6.765	6.467	6.132
40	3.940	4.159	3.912	3.367	6.104	4.868	2.620	3.332	4.402	4.905	5.806	6.389	5.278	5.447	6.271	6.746	5.678	6.253
41	3.974	4.762	3.326	2.944	4.358	2.996	3.397	3.761	4.769	4.828	6.501	5.740	5.123	4.942	6.796	6.422	6.458	5.464
42	4.529	4.812	3.159	3.584	1.888	1.609	3.757	5.333	4.877	5.030	5.708	7.026	4.757	5.081	6.383	7.405	5.613	6.922
43	5.067	4.290	2.016	4.625	1.266	1.386	3.939	4.663	4.779	4.078	6.741	6.594	5.200	5.063	7.076	6.976	6.753	6.455
44	4.019	4.263	3.903	4.942	3.066	4.290	3.339	3.497	4.209	4.263	6.168	6.642	4.858	4.905	6.519	6.987	6.118	6.551
45	4.668	4.779	4.118	4.543	1.950	-1.000	4.019	4.419	3.274	3.829	6.199	5.919	4.765	5.037	6.610	6.571	6.136	5.672
46	4.892	4.920	3.592	3.850	2.095	-1.000	3.389	3.367	3.695	4.220	5.561	4.860	4.817	4.949	6.214	6.016	5.497	4.377
47	4.524	4.644	3.572	3.951	-5.205	-1.000	2.691	3.135	3.989	3.871	4.492	4.078	4.889	5.293	5.655	5.656	4.799	4.352
48	4.674	4.477	2.234	3.912	-3.438	-1.000	2.781	2.708	3.981	4.025	4.283	4.369	5.283	5.635	5.555	5.663	5.139	5.201
49	5.107	4.673	3.896	4.625	-2.137	-1.000	2.127	2.833	4.065	3.912	4.783	5.268	5.641	5.106	5.993	6.153	5.738	5.132
50	4.203	4.663	3.993	3.951	-2.727	-1.000	1.836	3.258	3.961	3.689	5.773	6.087	4.874	4.771	6.217	6.498	5.737	5.881
	int.	2.498	int.	2.711	int.	1.377	int.	1.248	int.	2.352	int.	2.395	int.	2.419	int.	1.746	int.	1.572
	slope	0.478	slope	0.444	slope	0.308	slope	0.763	slope	0.513	slope	0.654	slope	0.574	slope	0.779	slope	0.755
	r	0.519	r	0.469	r	0.364	r	0.789	r	0.568	r	0.685	r	0.502	r	0.708	r	0.628
	n	49	n	49	n	49	n	49	n	49	n	49	n	49	n	49	n	49
	p	0.000	p	0.001	p	0.010	p	0.000	p	0.000	p	0.000	p	0.000	p	0.000	p	0.000
min.	3.731	3.555	2.016	2.944	-5.205	-1.000	1.836	2.708	3.210	3.664	4.213	4.078	4.757	4.745	5.555	5.656	4.161	4.098
max.	5.724	6.028	5.221	5.746	6.104	5.820	4.847	5.333	4.877	5.043	7.069	7.253	6.237	6.682	7.290	7.549	7.217	7.329
average	4.709	4.736	4.227	4.601	1.331	1.828	3.988	4.272	4.083	4.459	5.777	6.156	5.272	5.443	6.537	6.825	5.786	5.928
st.dev.	0.471	0.419	0.684	0.651	2.307	1.972	0.706	0.688	0.424	0.383	0.727	0.702	0.310	0.361	0.388	0.431	0.666	0.813
abs.dev.		0.027		0.374		0.497		0.284		0.376		0.379		0.171		0.288		0.142
rel.dev.		0.6%		9%		37%		7.1%		9.2%		6.6%		3.3%		4.4%		2.5%