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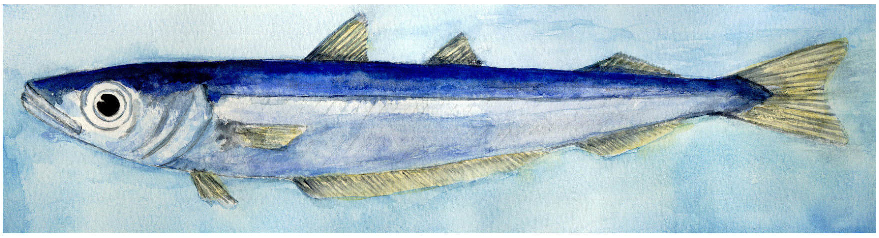

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY SPRING 2008

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Introduction

In spring 2008, five 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 fifth 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 (F. Nansen: Oganin et al. 2008; Celtic Explorer: O'Donnell et al. 2008; M. Heinason: Jacobsen et al. 2008; Tridens: Ybema et al. 2008).

This report is based on a workshop held after the international survey in Kaliningrad, 23–25/4/2008 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

Survey planning and Coordination

Coordination of the survey was initiated in the meeting of the Planning Group on Northeast Atlantic Pelagic Ecosystem Surveys (PGNAPES, ICES 2007) 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
Fridtjof Nansen	PINRO, Murmansk, Russia	24/3–14/4
Celtic Explorer	Marine Institute, Ireland	31/3–15/4
Gardar	Institute of Marine Research, Norway	29/3–06/4
Magnus Heinason	Faroese Fisheries Laboratory, Faroe Islands	05/4–16/4
Tridens	Institute for Marine Resources & Ecosystem Studies, the Netherlands	17/3–02/4

The cruise lines and trawl stations for each participant vessel are shown in Figure 1. Figure 2 shows combined CTD stations. Survey effort by each vessel is detailed in Table 1. All vessels worked in a northerly direction (Figure 3). Contacts were maintained between the vessels during the course of the survey, primarily through electronic mail but also through radio communication.

Sampling equipment

All vessels employed a single vessel midwater trawl for biological sampling, the salient properties of which are given in Table 5. Acoustic equipment for data collection and processing are also presented in Table 5.The survey and abundance estimate are based on acoustic data collected through scientific echo sounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote et al. 1987) prior to the survey for all vessels. The Celtic Explorer system was not calibrated due to unfavourable conditions at the selected site at the end of the survey. However, the system was last calibrated in October and will be again calibrated in July. Any irregularities arising will be communicated to the group. Salient acoustic settings are summarized in Table 2.

During the survey, 3 acoustic inter-vessel calibrations were carried out (Appendix 1-3) following the methods described by Simmonds & MacLennan 2007.

Biological sampling

All components of trawl catches were sorted and weighed; fish were identified to species (when possible) and other taxa to higher taxonomic levels. The level of blue whiting sampling of by each vessel is shown in Table 5.

Hydrographic sampling

Hydrographic sampling by way of vertical CTD casts was carried out by each participant vessel (Figure 2 and Table 1) up to a minimum depth of 1,000m in open water. Hydrographic equipment specifications are summarized in Table 5.

Acoustic data processing

Acoustic scrutiny was mostly based on trawl information and subjective categorisation. Post-processing software and procedures differed among the vessels. On Fridtjof Nansen, the FAMAS post processing software was used as the primary post-processing tool for acoustic data. Data were partitioned into the following categories, blue whiting, plankton, mesopelagic species and other species. The acoustic recordings were scrutinized once per day.

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using Sonar data's Echoview (V 4.2) post processing software for the previous days work. Data was partitioned into the following categories; plankton (<120 m depth layer), mesopelagic species, blue whiting and plankton & mesopelagic species. Partitioning of data into the above categories was carried out by an experienced scientist.

On Gardar, the acoustic recordings were scrutinized using the Large Scale Survey System (LSSS) once or twice per day. Blue whiting were separated from other recordings using catch information and characteristics of the recordings.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using Sonar data's Echoview (V 4.3) 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.

On Tridens, acoustic data were scrutinized every 24 hrs using Sonar data's Echoview (V 4.30) post processing software. Data were partitioned into only blue whiting using a new developed detection algorithm. Plankton will be partitioned in a later stage. All echograms had been scrutinized by two experienced scientists. To monitor transceiver output, a monitoring algorithm was created in Echoview. Both algorithms will contribute to a general Echoview template used in this survey.

Acoustic data analysis

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 1° latitude by 2° 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 200m.

To obtain an estimate of length distribution within each stratum, all length samples within that stratum were used. If the focal stratum was not sampled representatively, additional 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.

Results

Inter-calibration results

In total 3 inter-vessel calibrations were performed. Results from the inter-calibration between R/V Celtic Explorer and R/V Fridtjof Nansen (acoustic only) and the R/V Celtic Explorer and R/V Magnus Heinason are summarized in Appendices 1 & 2 respectively. The results of the inter-calibration between R/V Tridens and F/V Gardar are summarized in Appendix 3.

The acoustic inter-calibration between the R/V C. Explorer and the R/V F. Nansen was carried out in an area with no blue whiting. As a result the exercise was carried out on a low density mesopelagic layer over a single 15 nautical mile transect, with the F. Nansen acting as lead vessel. The results show similar agreement considering the conditions and acoustic logs intervals show good agreement. No comparative tow was carried out due to the absence of targets. A synchronised CTD cast was carried out with 0.4nmi spatial distance between vessels to a maximum depth of 1000m. Analysis of results indicate that profiles show the difference between recorded temperatures was close to zero and for salinity within the whole profile did not exceed 0.005 psu.

The acoustic inter-calibration between the R/V C. Explorer and the R/V M. Heinason was second exercise carried out (first was in 2007) in an area with high density registrations of blue whiting. The exercise was performed over a single 15 nautical mile transect, with the M. Heinason acting as lead vessel. Data analysis we focused on acoustic densities allocated to blue whiting. Acoustic recordings show variable agreement, with M. Heinason obtaining larger values during the first part of the track, but better agreement in the second half of the track. This may be accounted for to a degree by spatial heterogeneity of schools as vessels were 0.5nmi apart (Figure 2). Data from the comparative trawl exercise showed vessels had a similar overall catchability. Celtic Explorer (mean length: 27.7 cm, range 24-36cm) and Magnus Heinason (mean length: 28cm, range 23.5-36cm). For the same trawling period the C. Explorer recorded a higher catch (250Kg compared to 150Kg). In 2007, the Celtic Explorer showed a tendency to capture larger individuals during the same exercise.

Between the R/V Tridens and F/V Gardar an intercalibration was carried out following the standard procedure described by Simmonds & McLennan 2007. The target was an average dense blue whiting layer. Acoustic recordings showed good relative agreement but Gardar showed slightly higher values on average. Blue whiting caught by Tridens had a slightly different length frequency distribution (mean length of 27.6 cm +/- 2.19) compared to blue whiting caught by Gardar (mean length 28.9 cm +/- 2.24).

Distribution of blue whiting

Blue whiting were recorded all areas surveyed relating to a combined coverage of 127 thousand square nautical miles (Figures 4–6). The highest concentrations were recorded in the area between the Hebrides, Rockall and Faroe Banks and is consistent with the results from previous surveys. Schools with the greatest recorded density were observed by the Magnus Heinason to the north of the Rosemary Bank in the Hebrides sub area (Figure 7) but overall less variability in school density was detected this year compared to 2007.

In comparison to 2007, the biomass was comparatively distributed, with the exception of the southern sub areas (Porcupine Bank) where a significant reduction in distribution was observed. Over 50% of the total stock biomass was recorded in the Hebrides sub-area, as observed in 2006 and 2007. With the exception of the southern and western extremes of the survey area, the remaining strata were surveyed by more than one vessel, there is some inevitable variability in vessel-specific acoustic observations. This is illustrated by displaying vessel-specific estimates of mean acoustic density in each survey stratum (Figure 5). These are often in good agreement, but also significant discrepancies occur, which can be attributed to spatial and temporal heterogeneity in the abundance of blue whiting and temporal heterogeneity in coverage by the different vessels.

Stock size

The estimated total abundance of blue whiting for the 2008 international survey was 8 million tonnes, representing an abundance of $68x10^9$ individuals (Table 3). The spawning stock was estimated at 7.9 million tonnes and $67x10^9$ individuals. In comparison to the results in 2007, there is a significant decrease (30%) in the observed stock biomass and a related decrease in stock numbers whereas the survey area was not more than 6% lower than the previous year (see table below).

		2004	2005	2006	2007	2008	Change from 2007 (%)
Biomass (mill. t)	Total	11.4	8.0	10.4	11.2	8.0	–29
	Mature	10.9	7.6	10.3	11.1	7.9	–29
Numbers (10^9)	Total	137	90	108	104	68	–35
	Mature	128	83	105	102	67	–35
Survey area (nm^2)		149 000	172 000	170 000	135 000	127 000	–6

The reduction in survey area occurred mainly in the peripheral areas which have had low acoustic densities of blue whiting in previous years. However, coverage in the periphery remains an important component of the survey as a whole. The shift in survey effort allowed for a more focused allocation of individual vessel effort into core areas of known abundance.

Biomass observed for all sub areas was significantly reduced when compared to 2007. This reduction was most pronounced in the southern areas of the north and south Porcupine bank. The Hebrides sub area showed the lowest overall reduction across areas but still accounted for 22% decrease from 2007 observations.

	Sub-area	Biomass (million tonnes) 2007	% of total	2008	% of total	Change (%)
I	S. Porcupine Bank	0.75	7	0.1	1	-88
II	N. Porcupine Bank	1.8	16	1.2	15	-33
III	Hebrides	5.3	47	4.13	52	-22
IV	Faroes/Shetland	1.1	10	0.74	9	-33
V	Rockall	2.3	20	1.8	23	-21

Stock composition

Individuals of ages 1 to 14 years were observed during the survey. Stock in the survey area is dominated by age classes 5 and 4 years, of the 2003 and 2004 year classes respectively, contributing 51% of spawning stock biomass (Table 4, Figure 8).

Over 50% of the total spawning stock biomass was recorded in the Hebrides sub-area, as observed in 2006 and 2007. In general the age structure of stock in this area resembled that of the total survey area, with the exception of having a smaller proportion of older fish. (Figure 9).

Immature individuals were observed in all sub areas. Nonetheless, the total proportion of immature fish follows a similar pattern to that observed in 2007 and represents less than 1.5% of the total stock biomass. The proportion of juvenile fish was highest in the Hebrides sub-area. Compared to 2007, a higher proportion of immature individuals were observed in Faroes/Shetland sub area (Table 3). A significant proportion 2 year old fish were found to be immature as compared to previous years. Maturity analysis indicates almost 50% of 2 year old fish were immature in the Hebrides as compared only 20% in the Faroes/Shetland sub area, relating to 35% overall. The length at age of 2 year olds was smaller than in previous years indicating a reduced growth rate for this particular age class (Figure 9).

Hydrography

A combined total of 162 CTD casts were undertaken over the course of the survey. However, at this time the group was only able to produce vertical plots of temperature and salinity due to the absence of a physical oceanographer again at this year's post-cruise meeting. Horizontal plots of temperature and salinity at depths of 10m, 50m, 100 and 200m as derived from vertical CTD casts are displayed in Figures 10-13 respectively.

Concluding remarks

Main results

- The fifth international blue whiting spawning stock survey shows a significant decrease in stock biomass (29%) and a related decrease in stock numbers (34%) in comparison to the previous year's survey. The biomass estimate is comparable to the 2005 estimate. However, abundance in 2005 was bolstered by a series of strong year classes, namely the 2000 year class. In 2008, the same signals of pre-recruits are not visible from the 2008 survey.
- The stock in the survey area is dominated age classes 5 and 4 years, of the 2003 and 2004 year classes respectively, which together account for 51% of spawning stock biomass.
- Mean age (5.1 years), length (28.5 cm) and weight (117 g) are the highest on record in the international survey time series.
- The survey area was reduced by almost 6% from 2007. Most of the reduction came from peripheral areas with low density in 2007, namely in the western extremes. Nonetheless, estimates for the peripheral areas would have been expected to be of a similar magnitude had the same coverage been achieved.
- Most of the decrease in the stock estimate in 2008 comes from the southern sub-areas (the Porcupine Bank) this is in contrast to the situation observed in 2007, where an increase was noted from the 2006 estimate. Many factors could potentially cause this difference. The most likely are: (1) a true reduction in abundance in these areas and (2) between-year variation in how well the survey cruise tracks "hit" fish concentrations (i.e. how well the survey captures the true spatial distribution).
- Increased proportion of immature 2 year olds (2006 year class) was observed from maturity analysis of 2008 data.
- The spawning stock biomass appears to be maintained largely by growth of individuals in the spawning stock and to a lesser extent recruitment to the spawning stock.

Interpretation of the results

- 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, Pedersen et al. 2006). 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.
- Distribution of blue whiting in the spawning area is highly dynamic. The temporal concentration of survey effort into a 4 week window was completed as planned to reduce the effects of double counting to a minimum. Temporal progression was consistent by participating vessels within core areas.
- Variability in the stock estimate from southern areas between 2007 and 2008 would suggest a possible mismatch in timing of peak spawning or spatial coverage due to highly localised aggregations. Temporal coverage in southern areas has remained constant throughout the time series.

Recommendations

- Coordinated survey timing- was greatly improved this year as compared to previous years with the entire survey program being undertaken within 4 weeks, as compared to 6 weeks in 2007. All members agreed that the temporal progression of the 2007 survey was too long and so positive action was taken to amend this situation. It is recommended this concentrated survey effort will be continued into 2009
- Since temporal and spatial distribution of blue whiting in the Porcupine area is highly variable, survey design needs to be more adaptive utilising information from the commercial fleet to fine tune the effort allocation in this area prior to the survey.
- Preliminary survey tracks will be formulated at the PGNAPES 2008 meeting for surveys carried out in 2009. It is a requirement that all participants in the 2009 survey program adhere to this pre-agreed allocation of survey effort
- Dedicated sub group should be maintained within PGNAPES meeting to address issues arising from the survey program in 2008
- Again for the second time we have had no dedicated hydrographer present at the post cruise meeting to review the oceanographic data. This is an untenable situation that needs to be addressed at PGNAPES 2008 and before the 2009 survey program
- Continue and maintain established at sea communications with data summaries, fleet activity and survey findings during the survey. Discussion is to take place in the PGNAPES meeting on a standard information exchange format.
- A photographic species ID guide for all surveys will be circulated in draft form for review will be circulated at the PGNAPES 2008.
- Echoview Template. Leon Smith has updated Template (V9) with common species codes. Sytse Ybema has also been working on a template that includes a school detection algorithm and transmission detection window. For the 2009 survey it is recommended the templates are combined
- Intercalibration methods to be reviewed and the manual updated to include R-scripts and compatible data formats
- A member from each participant country should be present at the post cruise meeting to present the survey data and ensure the timely production of the combined cruise report
- Discussions are to take place in the PGNAPES sub meeting on how to use the Oracle database to streamline data extraction into "Beam" for the combined estimate
- Discussions are to take place in the PGNAPES meeting on how to use hydrographical data within this group.
- Discussions are to take place in the PGNAPES meeting mismatch between planned and executed survey tracks.
- Location of 2009 post cruise meeting will be in Galway, dates to be confirmed.

Achievements

- Good coverage of core distribution and outlying areas
- Much improved temporal progression of combined survey effort
- Improved coordination of survey effort both temporally and spatially
- All vessels undertook acoustic inter-vessel calibrations.
- Timely delivery of data in the PGNAPES format

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Table 1. Survey effort by vessel. March-April 2008.

Vessel	Effective survey period	Length of cruise track (nm) *	Trawl stations	CTD stations	Aged fish	Length-measured fish
Fridtjof Nansen	24/3–14/4	2461	18	62	1393	4801
Celtic Explorer	31/3–15/4	2480	15	28	750	2500
Gardar	29/3–06/4	1503	8	26	234	762
Magnus Heinason	04/4–16/4	1316	8	30	309	1031
Tridens	19/3–02/4	1413	19	15	950	951

* Used in the stock estimate. Steaming in, e.g., shallow areas excluded.

Table 2: Acoustic instruments and settings for the primary frequency. March-April 2008.

	Fridtjof Nansen	Celtic Explorer*	Gardar	Magnus Heinason	Tridens
Echo sounder	Simrad ES60	Simrad EK 60	Simrad EK 60	Simrad EK 500	Simrad EK 60
Frequency (kHz)	**38**, 120	**38**, 18, 120, 200	**38**	**38**	**38**
Primary transducer	ES38B	ES 38B	ES 38B	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Hull	Hull	Towed body
Transducer depth (m)	4.5	8.7	9	3	7
Upper integration limit (m)	10	15	15	7	12
Absorption coeff. (dB/km)	10.1	9.9	9.8	10	9.7
Pulse length (ms)	1.024	1.024	1.024	Medium	1.024
Band width (kHz)	2.425	2.425	2.425	Wide	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.73	-20.6	-20.6	-20.9	-20.6
Sv Transducer gain (dB)				27.22	25.11
Ts Transducer gain (dB)	25.57	25.55	26.5	27.35	
s_A correction (dB)	-0.61	-0.65	-0.65		-0.67
3 dB beam width (dg)					
alongship:	6.99	6.39	7.10	7.02	6.99
athw. ship:	6.99	6.67	7.10	6.86	6.96
Maximum range (m)	750	1000	900	750	750
Post processing software	FAMAS	Sonardata Echoview	LSSS	Sonardata Echoview	Sonardata Echoview

* Indicates calibration results from October 2007.

Table 3. Assessment factors of blue whiting. March-April 2008.

Sub-area		Numbers (10^9)			Biomass (10^6 tonnes)			Mean weight	Mean length	Density
	n.mile^2	Mature	Total	%mature	Mature	Total	%mature	g	cm	ton/n.mile^2
I S. Porcupine Bank	9986	0.75	0.77	97	0.1	0.1	97	120	28.7	9
II N. Porcupine Bank	22128	10.3	10.3	100	1.2	1.2	100	116	28.7	54
III Hebrides	33237	36	36.6	99	4.1	4.1	100	113	28.3	124
IV Faroes/Shetland	14426	5.2	5.85	89	0.7	0.74	96	126	27.6	51
V Rockall	47043	14.4	14.4	100	1.8	1.8	100	125	29.2	38
Tot.	126821	66.7	67.9	98.1	7.9	8.0	99	117	28.5	63

Table 4. Stock estimate of blue whiting, March-April 2008.

	Age in years (year class)										Numbers	Biomass	Mean	Prop.
Length	1	2	3	4	5	6	7	8	9	10+			weight	mature*
(cm)	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	(10^6)	(10^6 kg)	(g)	(%)
16.0 – 17.0	2	0	0	0	0	0	0	0	0	0	2	0	21	0
17.0 – 18.0	38	0	0	0	0	0	0	0	0	0	38	1.1	29.4	0
18.0 – 19.0	126	61	0	0	0	0	0	0	0	0	187	6.3	33.9	28
19.0 – 20.0	265	246	0	0	0	0	0	0	0	0	511	18.4	36	10
20.0 – 21.0	246	189	0	0	0	0	0	0	0	0	435	18.4	42.4	33
21.0 – 22.0	216	341	10	0	0	0	3	0	0	0	570	27.4	48.2	55
22.0 – 23.0	21	156	186	0	0	0	0	0	0	0	362	22.1	60.9	72
23.0 – 24.0	42	243	43	106	0	0	0	0	0	0	434	29.4	67.7	97
24.0 – 25.0	0	260	401	365	10	53	0	0	0	0	1088	81.5	74.9	96
25.0 – 26.0	0	176	1047	1796	428	86	0	0	0	0	3531	297.3	84.2	100
26.0 – 27.0	0	0	1448	5414	1893	267	103	0	0	0	9125	834.1	91.4	100
27.0 – 28.0	0	0	918	5205	5167	1972	376	70	0	0	13709	1387	101.2	100
28.0 – 29.0	0	0	282	3640	5670	2654	794	291	19	0	13350	1484.5	111.2	100
29.0 – 30.0	0	0	94	776	4224	2822	1183	394	14	37	9545	1173.8	123	100
30.0 – 31.0	0	0	14	244	1589	1565	1353	377	72	220	5434	753.3	138.6	100
31.0 – 32.0	0	0	0	137	735	989	885	380	87	157	3370	523.1	155.3	100
32.0 – 33.0	0	0	0	0	243	638	521	665	46	66	2179	377.7	173.3	100
33.0 – 34.0	0	0	0	74	185	358	364	378	92	110	1561	295.8	189.5	100
34.0 – 35.0	0	0	0	57	0	156	278	289	89	3	872	184.5	211.5	100
35.0 – 36.0	0	0	0	0	0	17	318	87	128	127	677	155.9	230.2	100
36.0 – 37.0	0	0	0	0	0	57	96	71	82	47	353	89.6	254.2	100
37.0 – 38.0	0	0	0	0	0	25	35	15	37	79	191	48.3	252.9	100
38.0 – 39.0	0	0	0	0	0	37	49	55	6	15	162	54.1	333	100
39.0 – 40.0	0	0	0	0	0	14	27	21	65	7	134	44.4	331.5	100
40.0 – 41.0	0	0	0	0	0	0	8	0	54	2	65	24.6	381.6	100
41.0 – 42.0	0	0	0	0	0	0	25	0	0	38	63	24.8	395.5	100
TSN (10^6)	956	1672	4443	17814	20144	11710	6418	3093	791	908	67948			
TSB (10^6 kg)	40.1	98.1	409.4	1785.6	2273	1501.1	975.8	521.1	177.8	175.6	7957.5			
Mean length (cm)	20.2	22.3	26.3	27.3	28.6	29.6	31	31.9	34.7	33.4	28.5			
Mean weight (g)	41.9	58.7	92.2	100.2	112.8	128.2	152	168.4	225.1	192.9	117.1			
Condition (g/dm^3)	5.1	5.3	5.1	4.9	4.8	4.9	5.1	5.2	5.4	5.2	5.1			
% mature*	23	64	100	100	100	100	100	100	100	100	98.1			
% of SSB	0	1	5	23	29	19	12	7	2	2				

* Percentage of mature individuals per age or length class

Table 5. Country and vessel specific details, March-April 2008.

	Fridtjof Nansen	Celtic Explorer	Gardar*	Magnus Heinason	Tridens
Trawl dimensions					
Circumference (m)	716	768	2400	640	1120
Vertical opening (m)	50	50	140	40	30-70
Mesh size in codend (mm)	16	20	40	40	±20
Typical towing speed (kn)	2.7-3.3	3.5-4.0	3.5-4.0	3.0-4.0	3.5-4.0
Biological sampling					
Length Only					200
Lenth/Weight	200	100	70	100	
Length/Weight/Sex/Maturit	100	50	30	100	50
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE911	SBE911
Standard sampling depth	1000	1000	1000	1000	1000

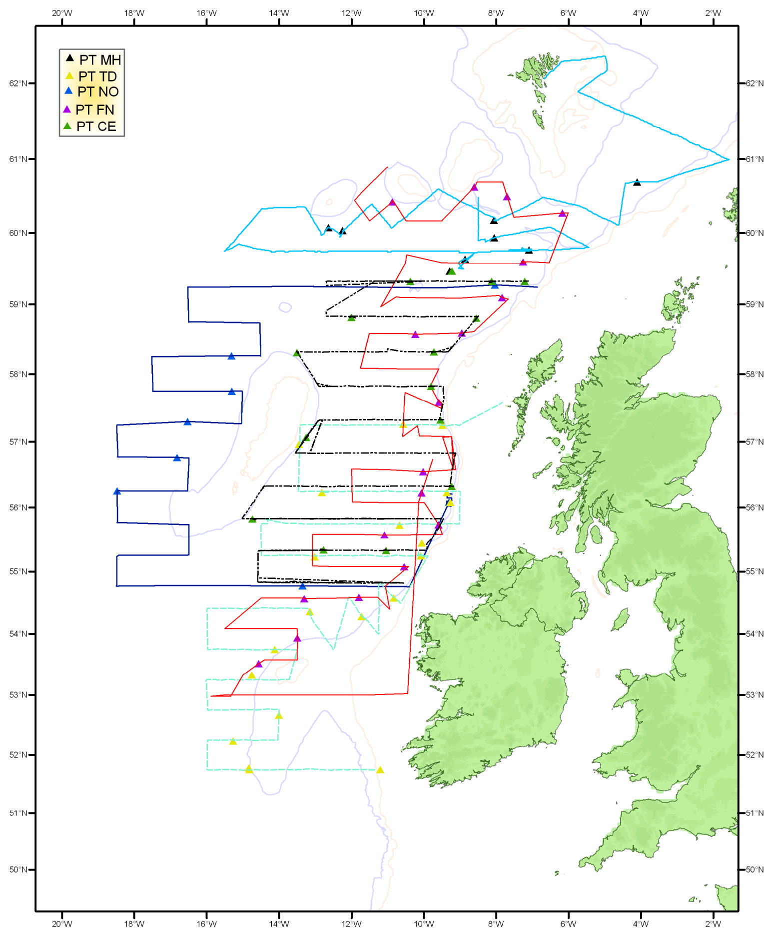

Figure 1. Combined vessel cruise tracks and trawl stations. CE: Celtic Explorer; MH: Magnus Heinason; TD: Tridens; FN: Fridtjof Nansen: NO: Gardar. March-April 2008.

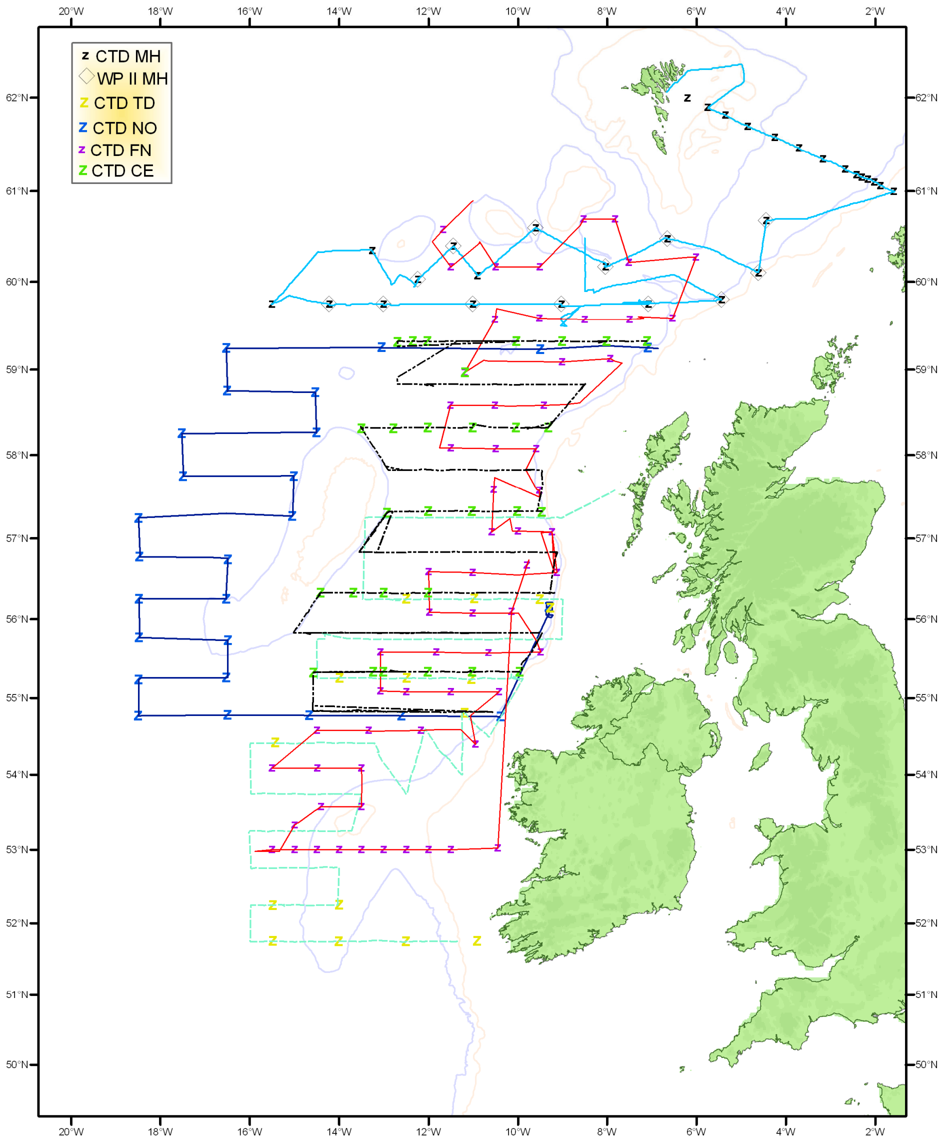

Figure 2. Combined CTD stations overlaid onto vessel cruise tracks. CE: Celtic Explorer; MH: Magnus Heinason; TD: Tridens; FN: Fridtjof Nansen: NO: Gardar. March-April 2008.

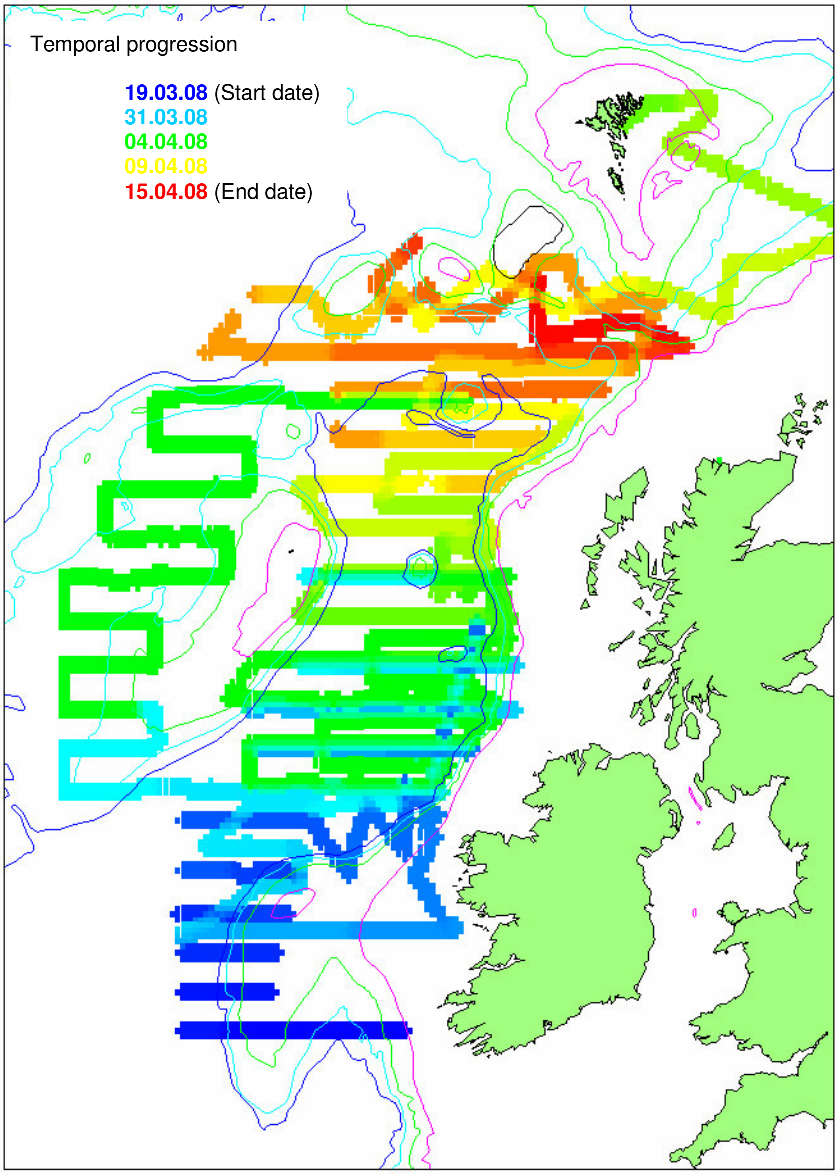

Figure 3. Temporal progression of the combined survey, 19 March–15 April 2008.

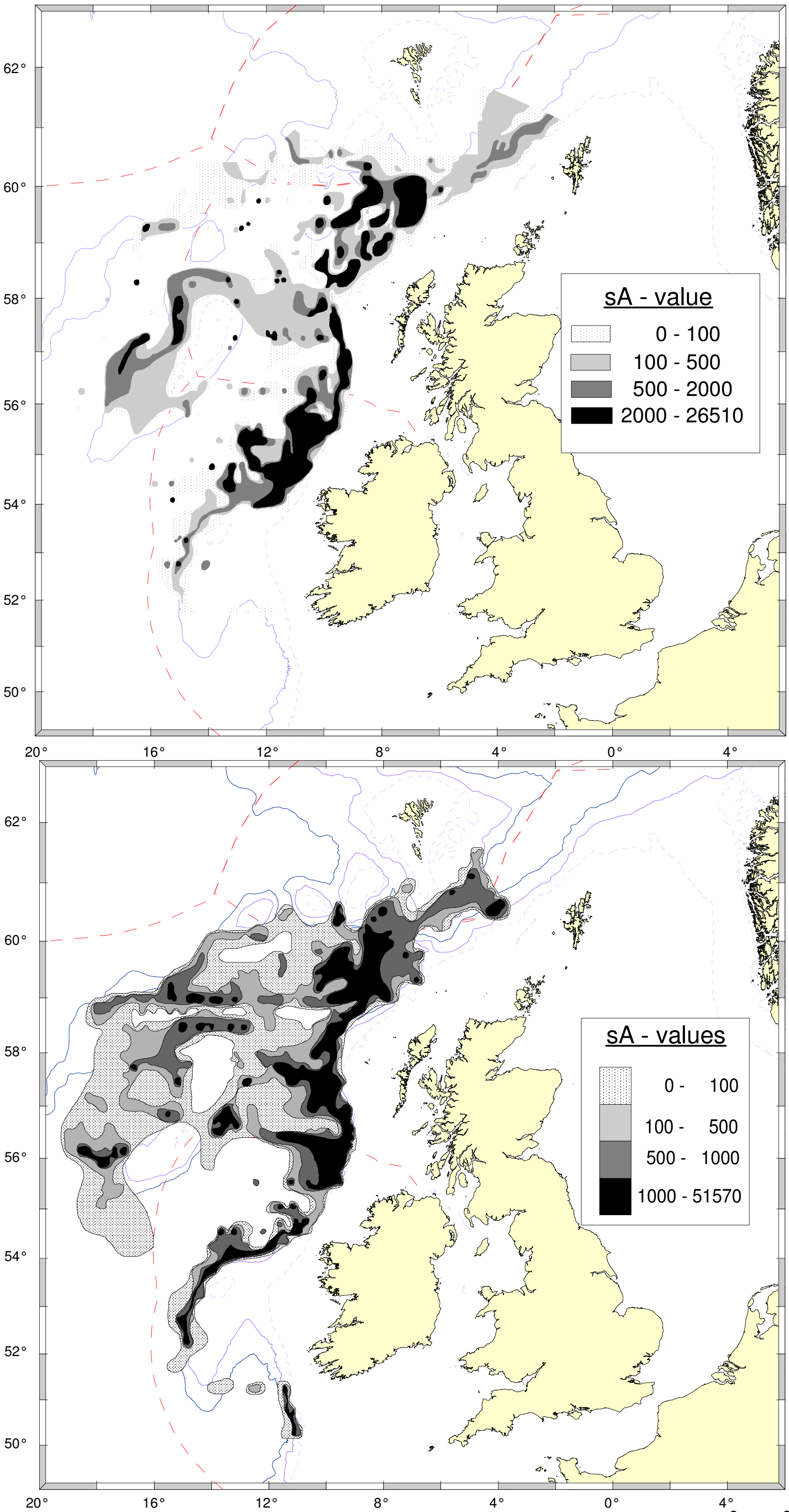

Figure 4. Schematics maps of combined blue whiting acoustic density (s_A, m^2/nm^2) in March-April 2007 (lower panel) and 2008 (upper panel).

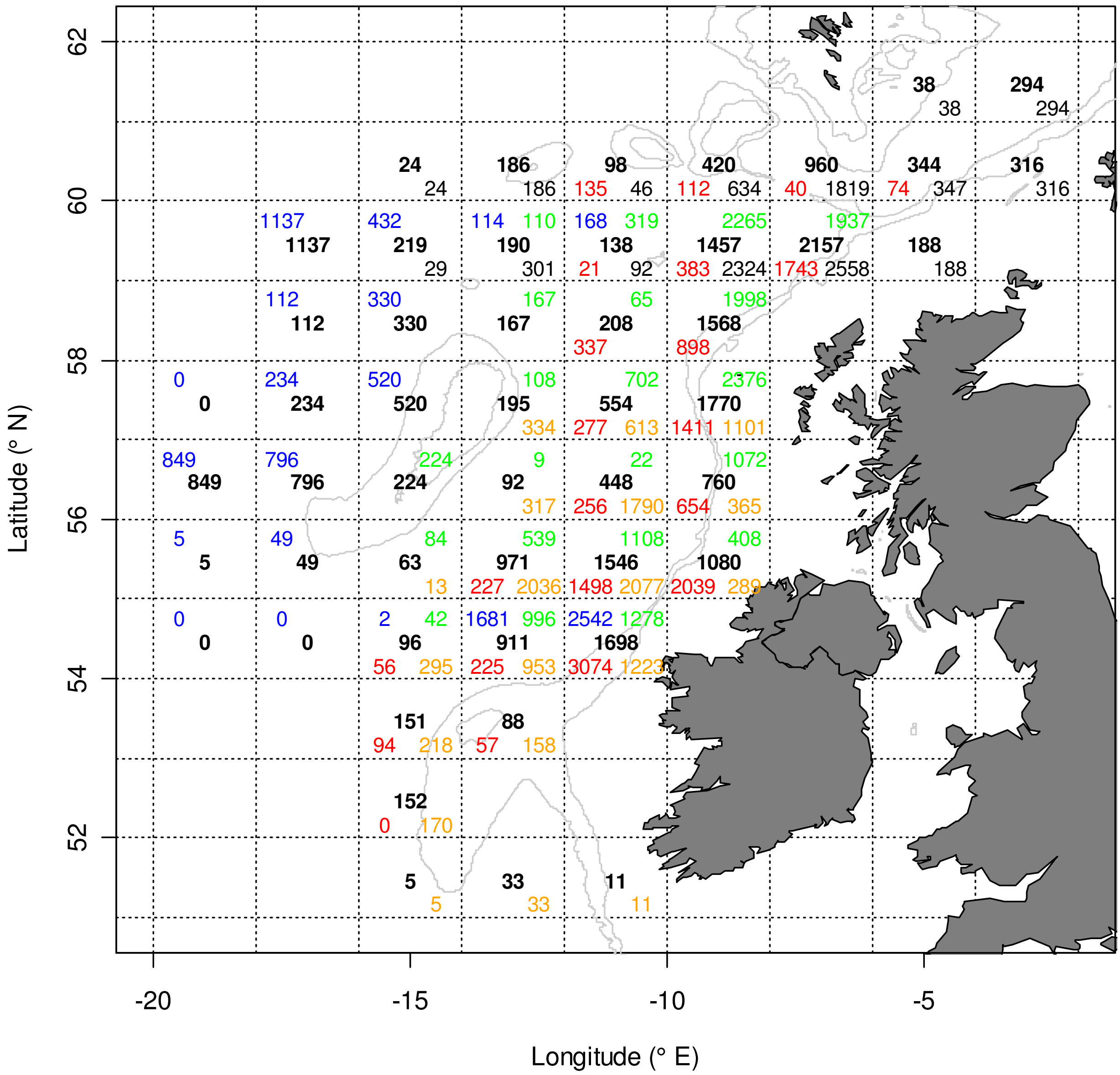

Figure 5. Mean blue whiting acoustic density (s_A, m^2/nm^2) for all vessels combined and for each individual vessel: Celtic Explorer: green, Magnus Heinason: grey, Netherlands: orange, Fridtjof Nansen: red, Gardar: blue. Combined totals are displayed in the middle of the square in bold black.March-April 2008.

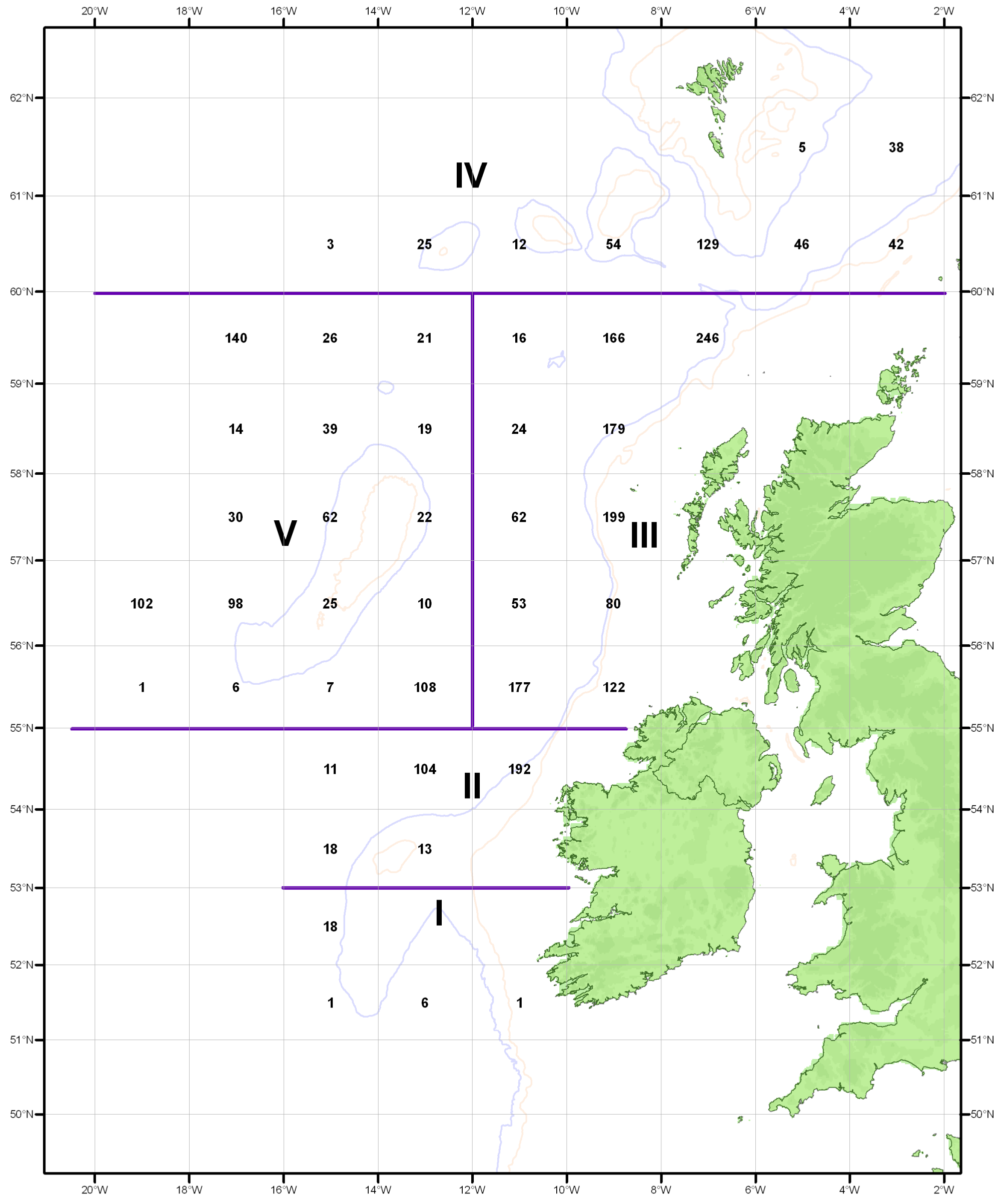

Figure 6. Blue whiting biomass in 1000 tonnes by sub-area as used in the assessment. March-April 2008.

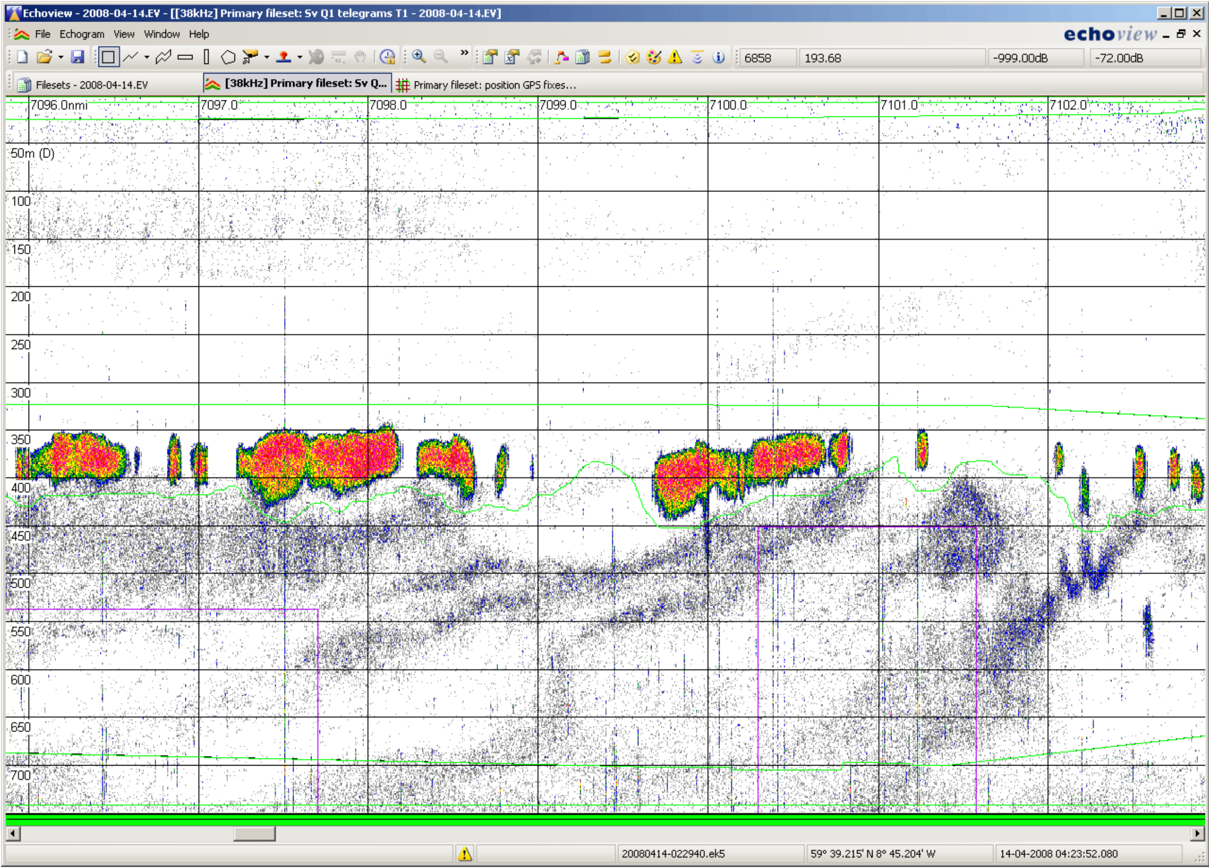

Figure 7. Typical high density school observed by the R/V Magnus Heinason to the north of the Rosemary Bank in the Hebrides sub area. March-April 2008.

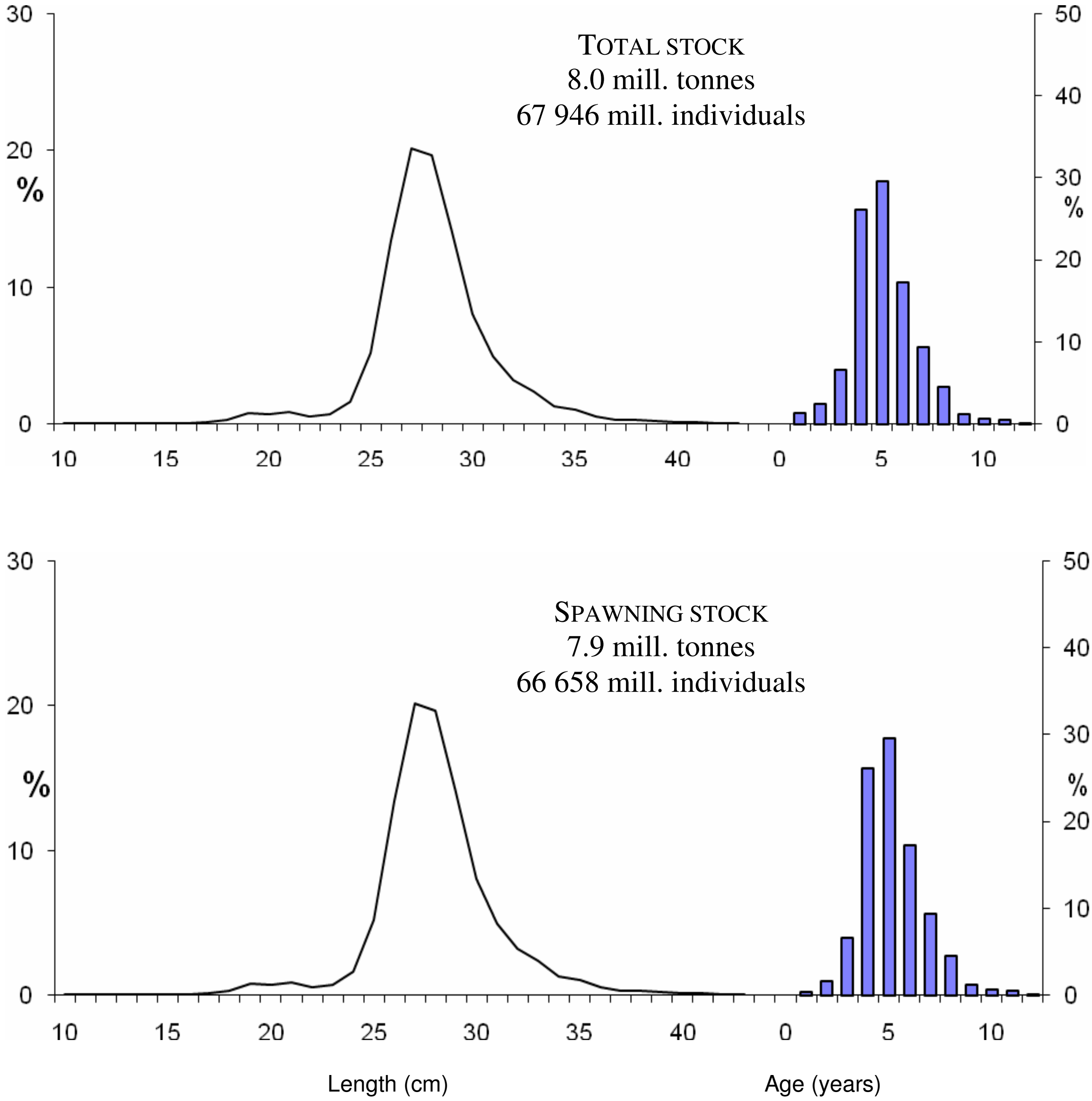

Figure 8. Length and age distribution in the total and spawning stock of blue whiting in the area to the west of the British Isles. March-April 2008.

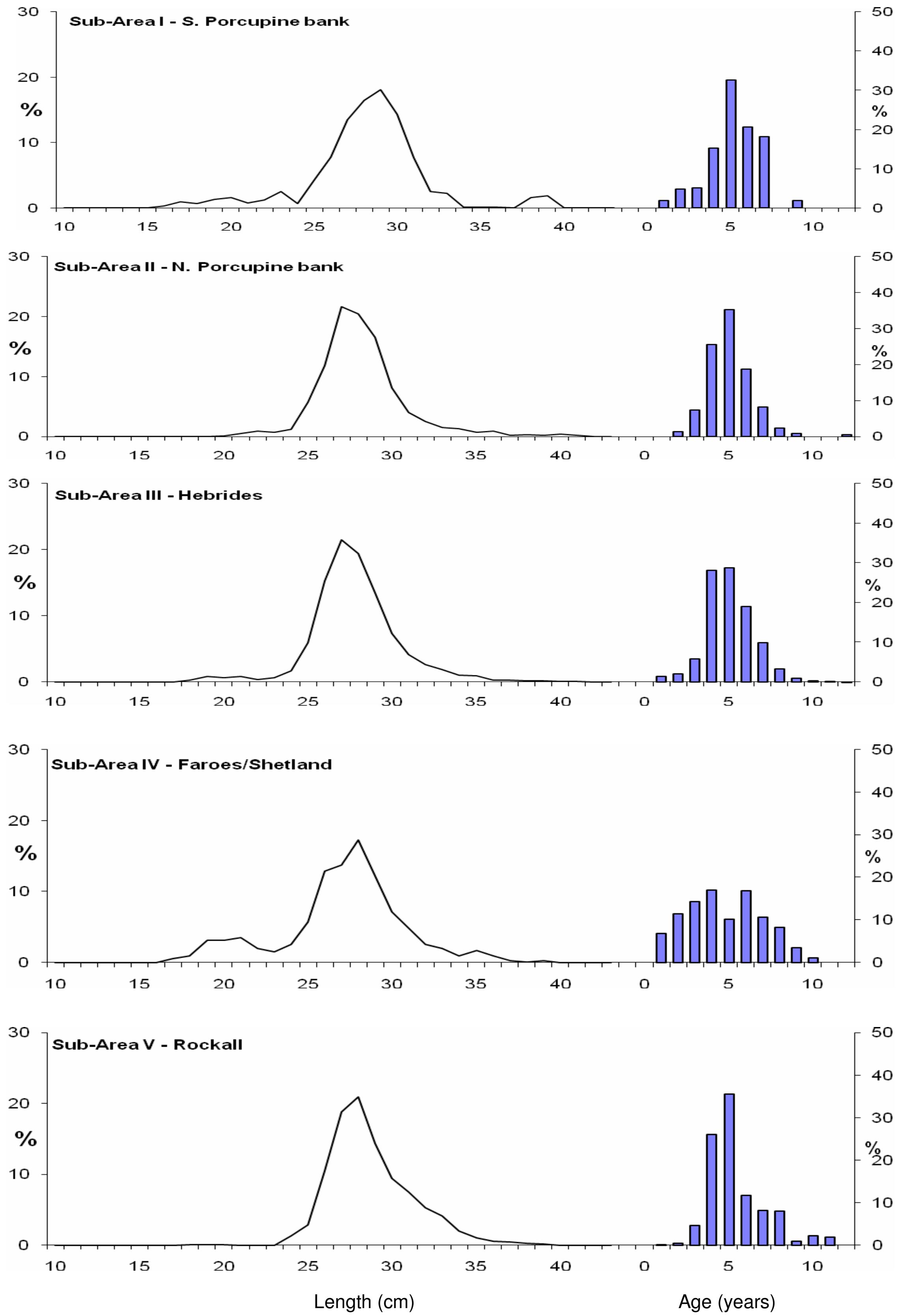

Figure 9. Length and age distribution (numbers) of blue whiting by sub-areas (I–V). March-April 2008.

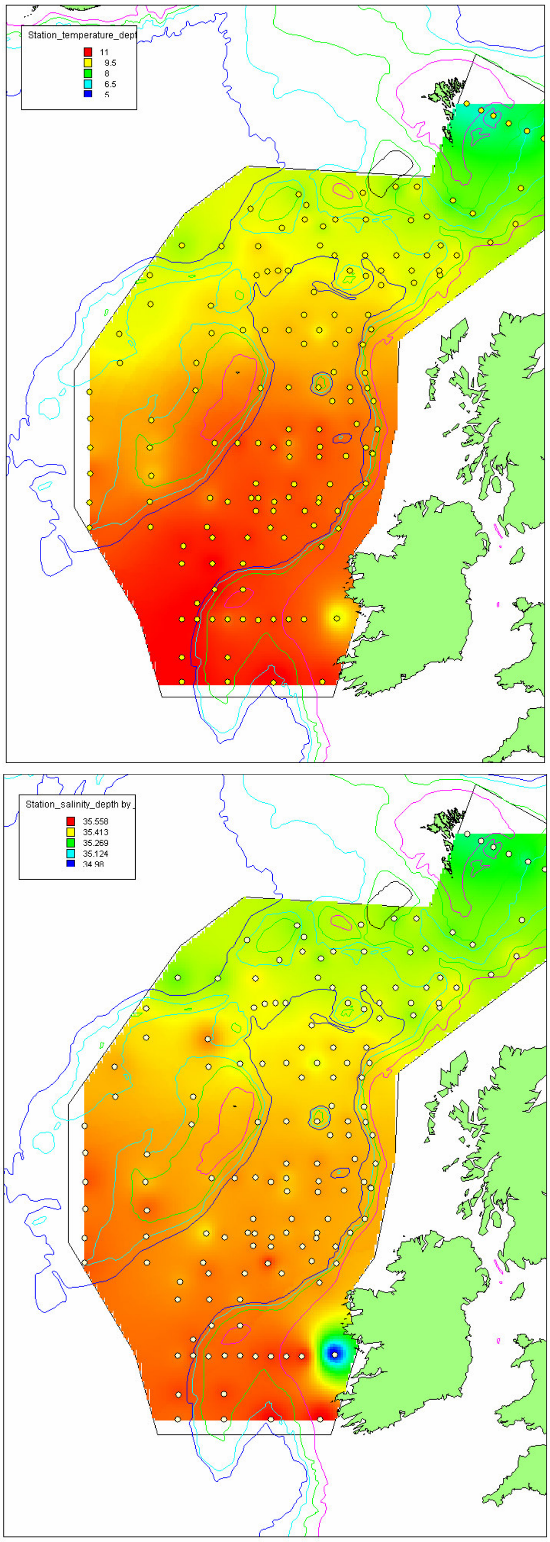

Figure 10. Horizontal temperature (top panel) and salinity (bottom panel) at 10m subsurface as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2008.

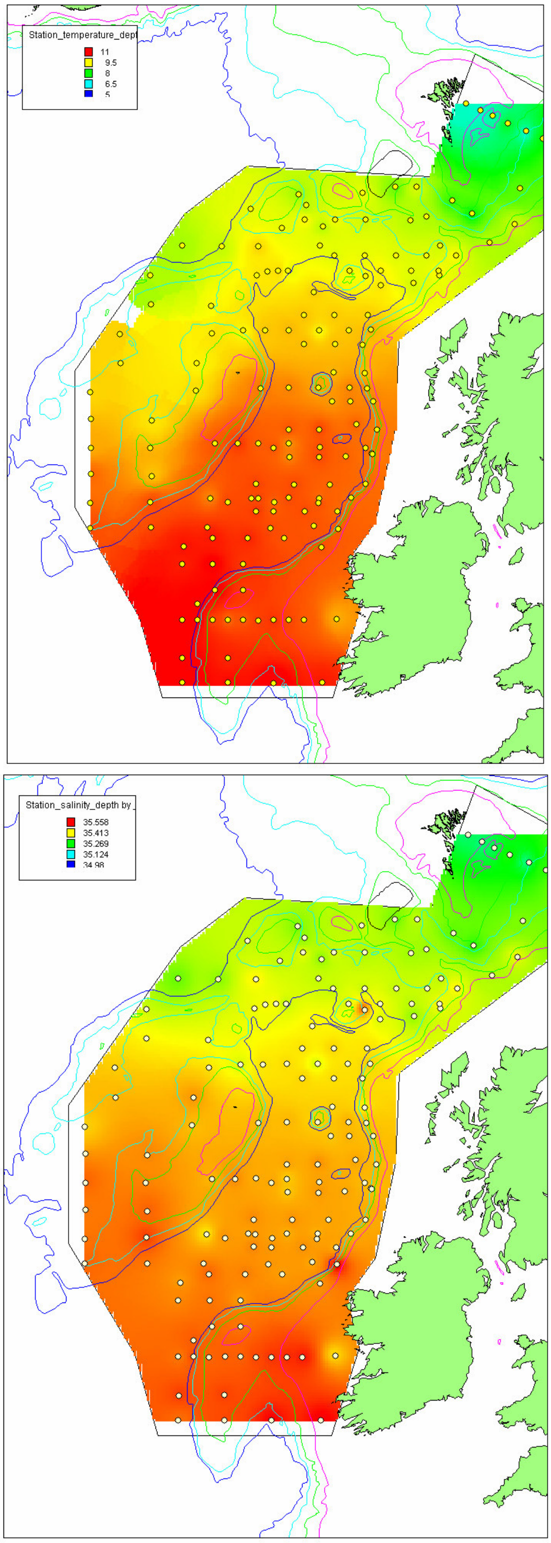

Figure 11. Horizontal temperature (top panel) and salinity (bottom panel) at 50m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2008.

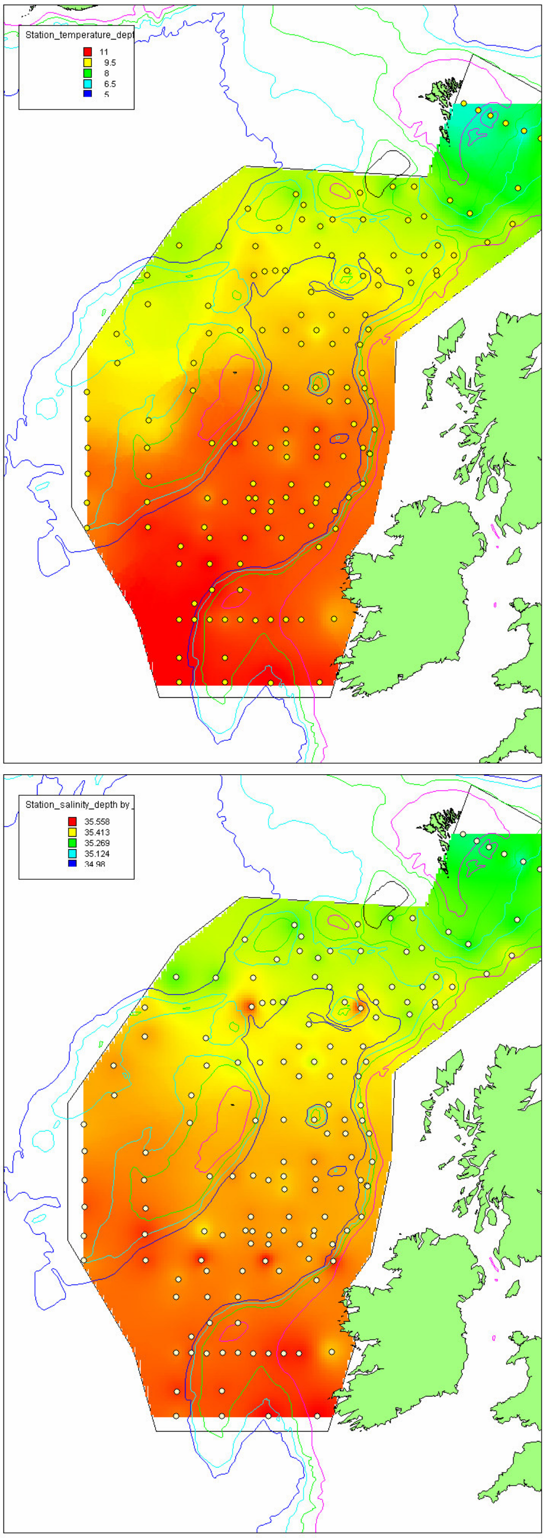

Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 100m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2008.

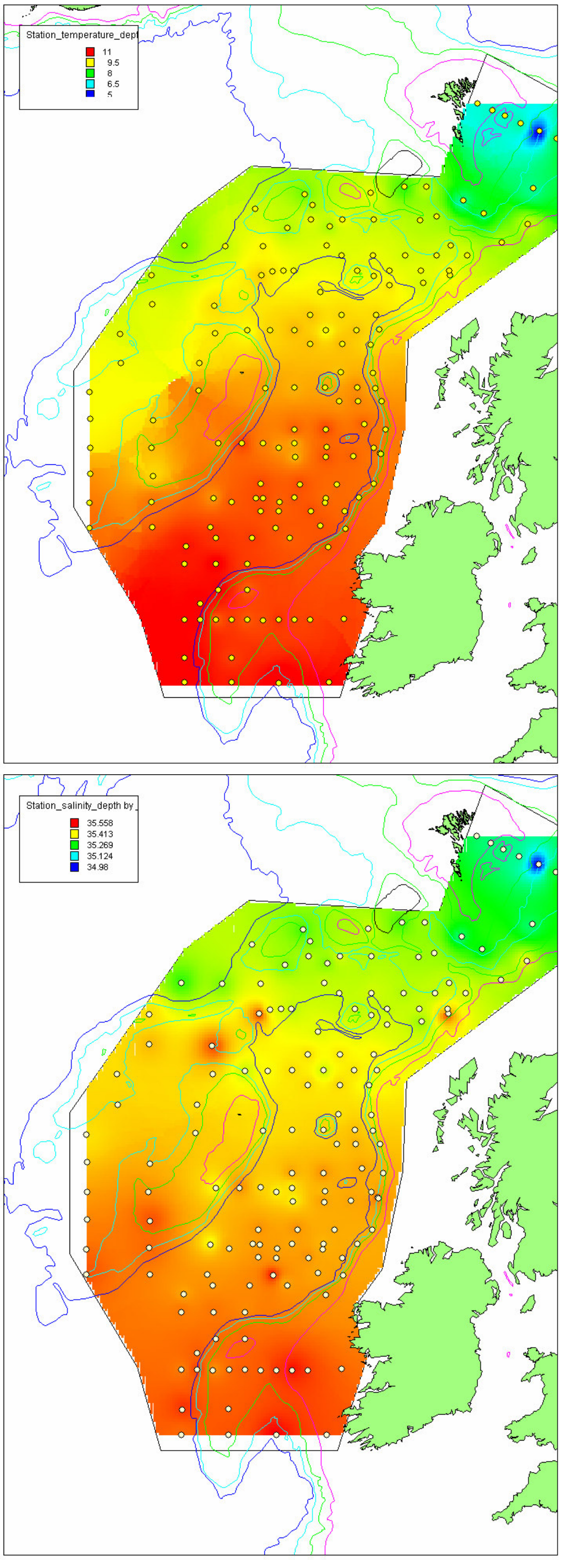

Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2008.

Appendix 1. Inter-calibration between R/V Celtic Explorer and R/V Fridtjof Nansen

Acoustic inter-calibration between R/V Celtic Explorer and R/V Fridtjof Nansen was conducted on April 10 to the southwest of the Rosemary Bank. The weather conditions were moderate with winds recorded at 5-20kts from the E and moderate swell of 2.5m from the N. The main acoustic features in the area were lacking with no visible signs of blue whiting schools in the area. As a result it was decided to compare the backscatter from a mesopelagic layer present at approximately 150m.

The exercise was carried out over a single 15nmi transect with the F. Nansen acting as lead vessel cruising at 7kts and beginning at 15:35 at position 59°07'N & 010°45W. The Explorer followed at 0.4nmi and 0.5 degrees to port of the F. Nansen. Transect orientation was aligned to run with the prevailing wind direction to reduce the effects of data drop outs on the hull mounted transducer onboard the F. Nansen. The requested ER 60 settings from the F. Nansen were adopted by the Explorer (ping rate 1.2; bottom detection minimum 750, max 790m).

In the data analysis the entire channel data (surface to 750m) for each 1nmi ESDU was analysed as no obvious schools were visible. Figure 1 shows acoustic densities recorded by the two vessels and for each ESDU. Acoustic recordings show a degree of agreement with the exception of the second mile interval. From 4 to 15nmi the recorded data is similar considering the low density of the layer surveyed. Overall, it appears that the C. Explorer is recording slightly higher densities than observed by the F. Nansen. However, this may be attributed by the spatial heterogeneity of the low density mesopleagic layer. .

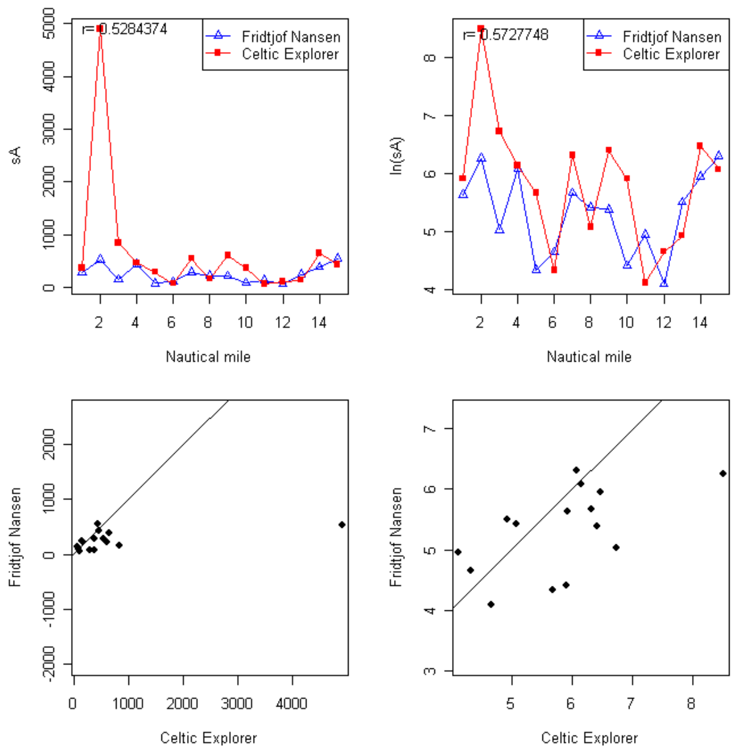

Figure 1. Comparison of blue whiting acoustic densities recorded by Fridtjof Nansen (open triangles) and Celtic Explorer (squares). The lower panels show the data as scatterplots. The diagonals are drawn as continuous lines.

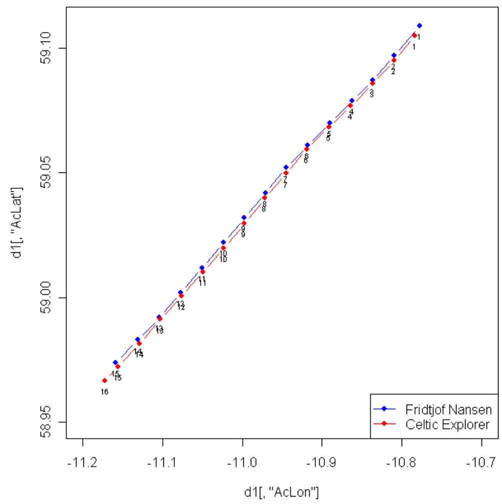

Figure 2. Intercalibration track followed by the Fridtjof Nansen (blue squares) and Celtic Explorer (red squares).

At log intervals of 12-14nmi vessels appear to be most aligned and this is reflected in the acoustic observations recorded. Considering the availability of targets during the exercise the exercise was indeed useful and sufficed to say that intercalibration exercises on low density acoustic registrations of mesopelagic layer are not ideal.

Appendix 2. Inter-calibration between R/V Celtic Explorer and R/V Magnus Heinason

Acoustic inter-calibration between R/V Celtic Explorer and R/V Magnus Heinason was conducted on April 13 at 23:40 to the northeast of the Rosemary Bank at position 59 28.07N & 008 50.84W and took a westward direction over a 15nmi single transect with the M. Heinason acting as the lead vessel cruising at 8.5 knots for 15 nm to position 59 28.04N & 009 20.11W. Weather conditions were moderate with winds of 25 knots from the N and a northerly swell of 3-3.5 m.

The main acoustic features in the area were (1) up to 200 metres thick layer of blue whiting in depths between 400 and 600 metres that was strongest towards the end of the transect, (2) a layer of presumed macro-zooplankton from depth 300 metres downward, partly mixed with the blue whiting layer, and (3) plankton and mesopelagic fish, in the uppermost 200 metres.

The inter-calibration was the run over 25 nautical miles between 02:48-05:47 GMT. Vessels were cruising SSE at parallel courses, with the distance between the tracks being about 0.5 nm.

Data analysis 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 allocated to blue whiting. The recordings show variable agreement. Recordings by the Celtic Explorer appear more consistent and less variable than those recorded by the M. Heinason for most of the recorded transect. Two distinct areas of interest are visible. Firstly, at 5-9 nm medium density schools are recorded progressing to an area of lower density. The second, from 10-14 nm shows a similar pattern of acoustic density. The recording of the M. Heinason show much greater mile by mile variability with sharp contrasts in recorded values between successive miles. This may be accounted for to a degree by spatial heterogeneity of schools as vessels were 0.5 nm apart (Figure 2).

At the end of the acoustic inter-calibration a comparative trawl exercise was undertaken. Both vessels turned and towed in parallel over the area that acoustic integration was carried out at a distance of about 0.3 nm apart. Celtic Explorer actively towed for 20 minutes at depths of 410–460 m and caught 250 kg of blue whiting. Magnus Henson towed in the same depth for the same time and caught 150 kg of blue whiting.

The blue whiting in the catch of Celtic Explorer were larger in mean length (mean length: 27.7 cm, range 24-36 cm) compared to the blue whiting in the catch of Magnus Heinason (mean length: 28cm, range 23.5-36cm) as shown in Figure 3. The results indicate that both the Celtic Explorer and the Magnus Heinason equally captured similar blue whiting size classes with no bias towards smaller or larger individuals. In 2007, the Celtic Explorer showed a tendency to capture slightly larger individuals during the same exercise. However, this may be some way attributed to the spatial heterogeneity of schools encountered.

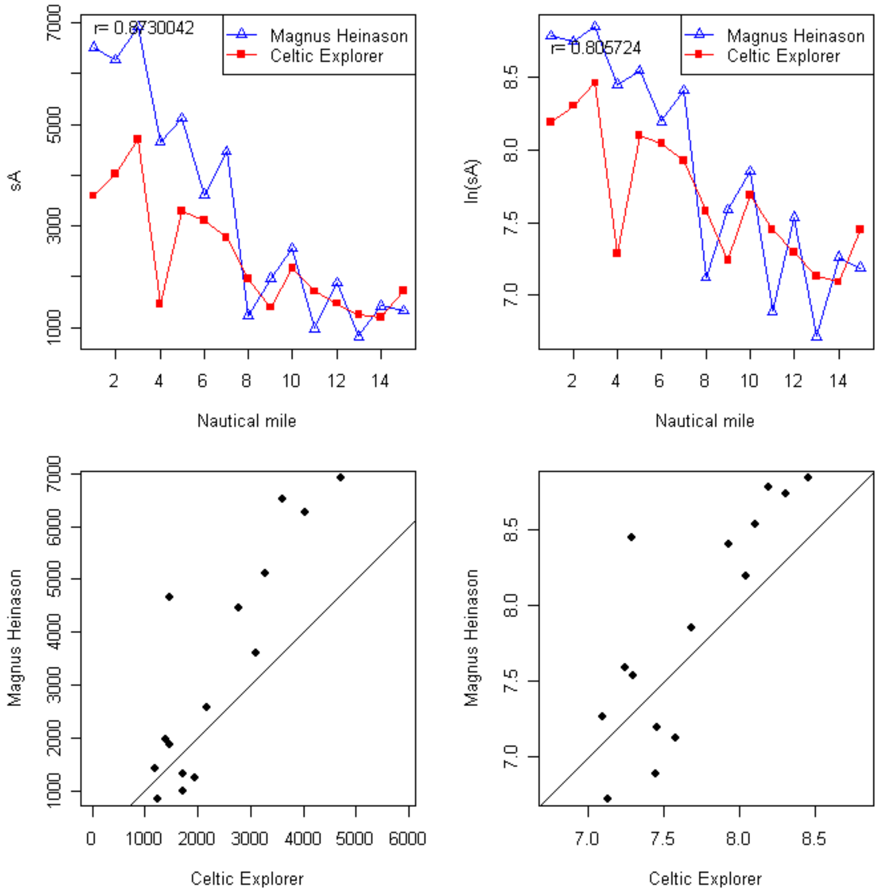

Figure 1. Comparison of blue whiting acoustic densities recorded by Magnus Heinason (open triangles) and Celtic Explorer (squares). The lower panels give same data as scatterplots. The diagonals are drawn as continuous lines.

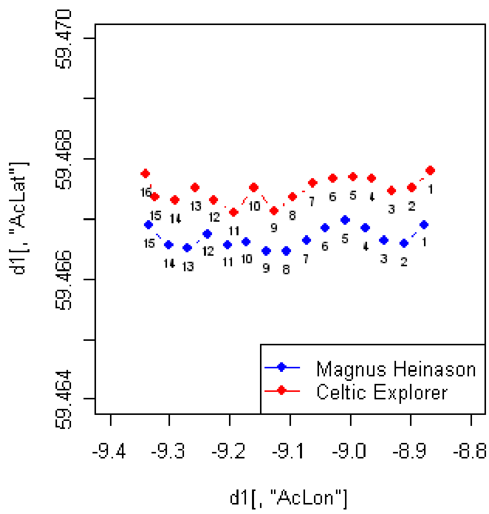

Figure 2. Intercalibration track followed by the Magnus Heinason (blue diamonds) and Celtic Explorer (red diamonds).

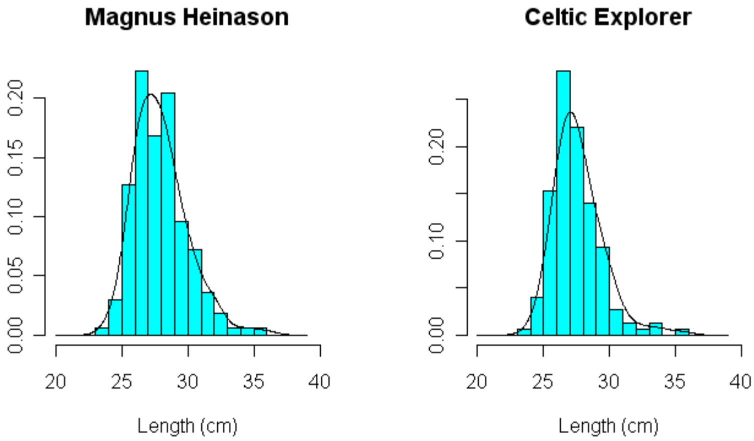

Figure 3. Length distributions from the trawls hauls by Magnus Heinason and Celtic Explorer. Smoothing is obtained by normal kernel density estimates.

Appendix 3. Inter-calibration between R/V Tridens and F/V Gardar (Norwegian charter vessel)

An acoustic inter-calibration between R/V Tridens and F/V Gardar was conducted on March 29 from about 07.26 to 11.05hrs UTC. The weather was moderate (4m swells from W). The main acoustic features in the area were a layer of blue whiting up to 50m thick, in depths between 400 and 600m and a layer presumed to be plankton and mesopelagic fish in the uppermost 200m. Both layers followed a North/South contour. Inter-vessel calibration was done according to the standard given in Simmonds & McLennan 2007 (Figure 1) where both vessel get the opportunity to take the lead in order to exclude any vessel avoidance differences. The inter-calibration was run over 30 nautical miles between 07:26 -11:05hrs UTC (Figure 1). Vessels cruised at 10 knots on parallel courses, with the distance between the tracks being approximately 0.5 nm.

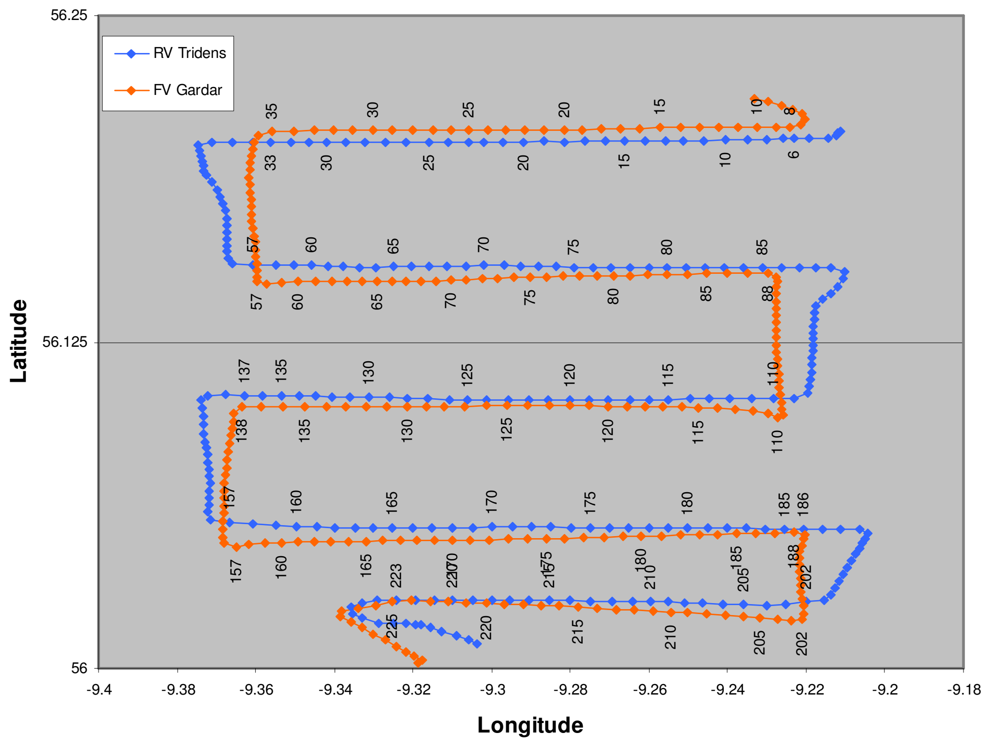

Figure 1. Cruise tracks of R/V Tridens and F/V Gardar. Numbers are in minutes from start of intercalibration, showing the temporal difference in tracks.

Acoustic comparison

In the data analysis we focused on acoustic densities (a_A, m2/nm2) allocated to blue whiting. On both vessels routine procedures were followed for scrutinizing the data. Figure 2 shows acoustic densities recorded by the two vessels, allocated to blue whiting and adjusted for positional differences.

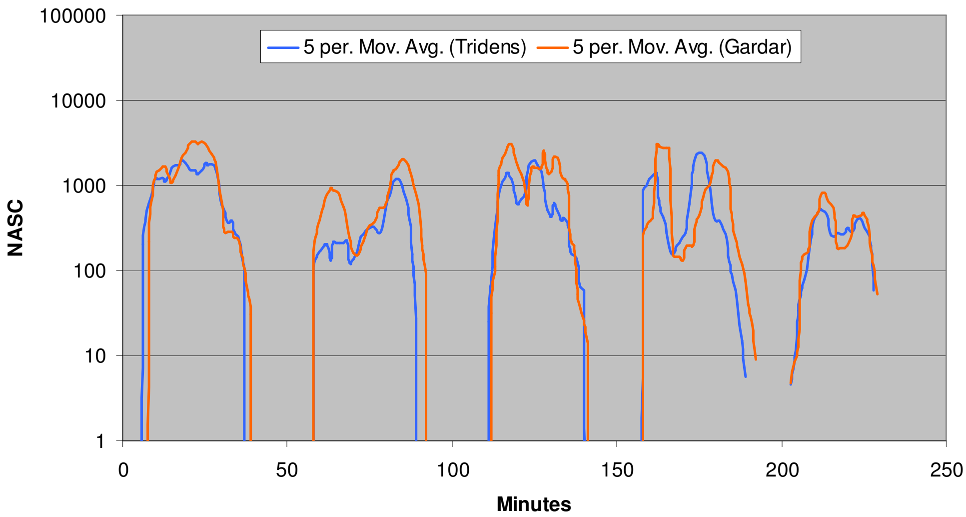

Figure 2. NASC values exported in I minute intervals and plotted as a 5 minute moving average plotted on a logarithmic scale.

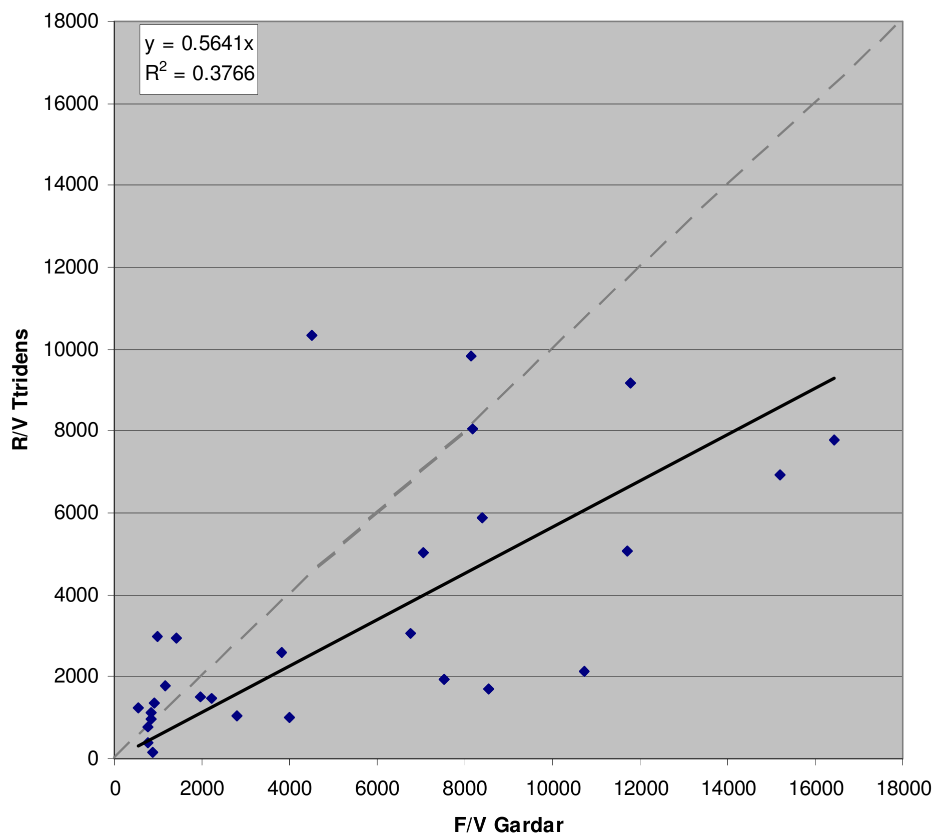

Figure 3. Comparison of 5 minute NASC values between R/V Tridens and F/V Gardar

Trawl comparison
After the acoustic inter-calibration, both vessels performed a pelagic trawl of the blue whiting layer, for later comparison. The vessels towed in the same direction at a distance of about 1 nm apart.

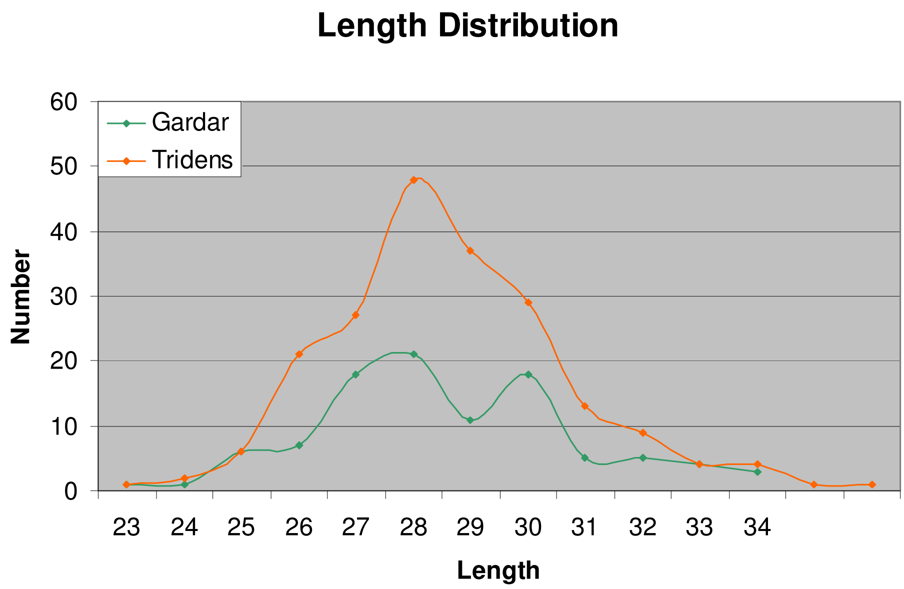

Figure 4. Blue whiting caught by RV Tridens had a mean length of 27.645 cms with a Std Dev. of +/- 2.199 n=203. compared to blue whiting caught by FV Gardar with a mean length of 28.875 cms and a Std Dev. of +/- 2.242 n=100.

CTD comparison
After the trawl comparison, CTD downcasts were performed on both vessels down to a depth of 1000m.

Appendix 4. Uncertainty in the acoustic observations and impacts on the stock estimate

Mikko Heino

The exercise to estimate uncertainty in acoustic blue whiting observations and the consequences of this uncertainty to stock estimates is repeated using the same procedure as last year (Appendix 3 in Heino et al. 2007).

For the purpose of calculating stocks estimates, acoustic data (acoustics density (s_A) representing blue whiting, in m^2/nm^2) from each vessel are expressed as average values over 5 nm stretches of survey track. Acoustic density for each survey stratum is calculated as an average across all observations within a stratum, weighted by the length of survey track behind each observation (some observations represent more or less than 5 nm). Normally, these values are then converted to stratum-specific biomass estimates based on information on mean length of fish in the stratum and the assumed acoustic target strength; the total biomass estimate is the sum of stratum-specific estimates. Here it is not attempted to repeat the whole estimation procedure, but instead uncertainty in global mean acoustic density estimate is characterized. Since mean size of blue whiting does not vary very much in the survey area, uncertainty in mean acoustic density should give a good, albeit conservative, estimate of uncertainty in total stock biomass.

Bootstrapping is used to characterize uncertainty in the mean acoustic density. Bootstrapping is done by stratum, treating observations from all vessels equally and using lengths of survey track behind each observation as weights when calculating mean density. With 1000 such bootstrap replicates for each stratum, 1000 bootstrap estimates of mean acoustic density, weighted by the stratum areas are calculated. Bootstrapped mean acoustic density is the mean of these 1000 bootstrap estimates, and confidence limits can be obtained as quantiles of that distribution.

Figure 1 shows the results of this exercise with the data from the 2008 survey as well four earlier international surveys. Mean acoustic density over the survey area is 576 m^2/nm^2, with 95% confidence interval being 511…644 m^2/nm^2. Relative to the mean, the approximate 95% confidence limits are –11%...+12%, and 50% confidence limits are –4.1%...+3.8%. This is similar level of acoustic uncertainty as observed in 2004–2006, and much less as observed in 2007. This is caused by a few very high density observations in 2007, with three highest values accounting for more than 20% of total cumulative acoustic density. In other years there are no observations that are as influential.

Figure 2 summarizes the results and puts them in the biomass context. The results clearly show that the observed decline in biomass between 2006–2007 and 2008 is more than could be expected from uncertainty arising from spatial heterogeneity. In other words, within the considered domain of uncertainty, the decline is statistically significant.

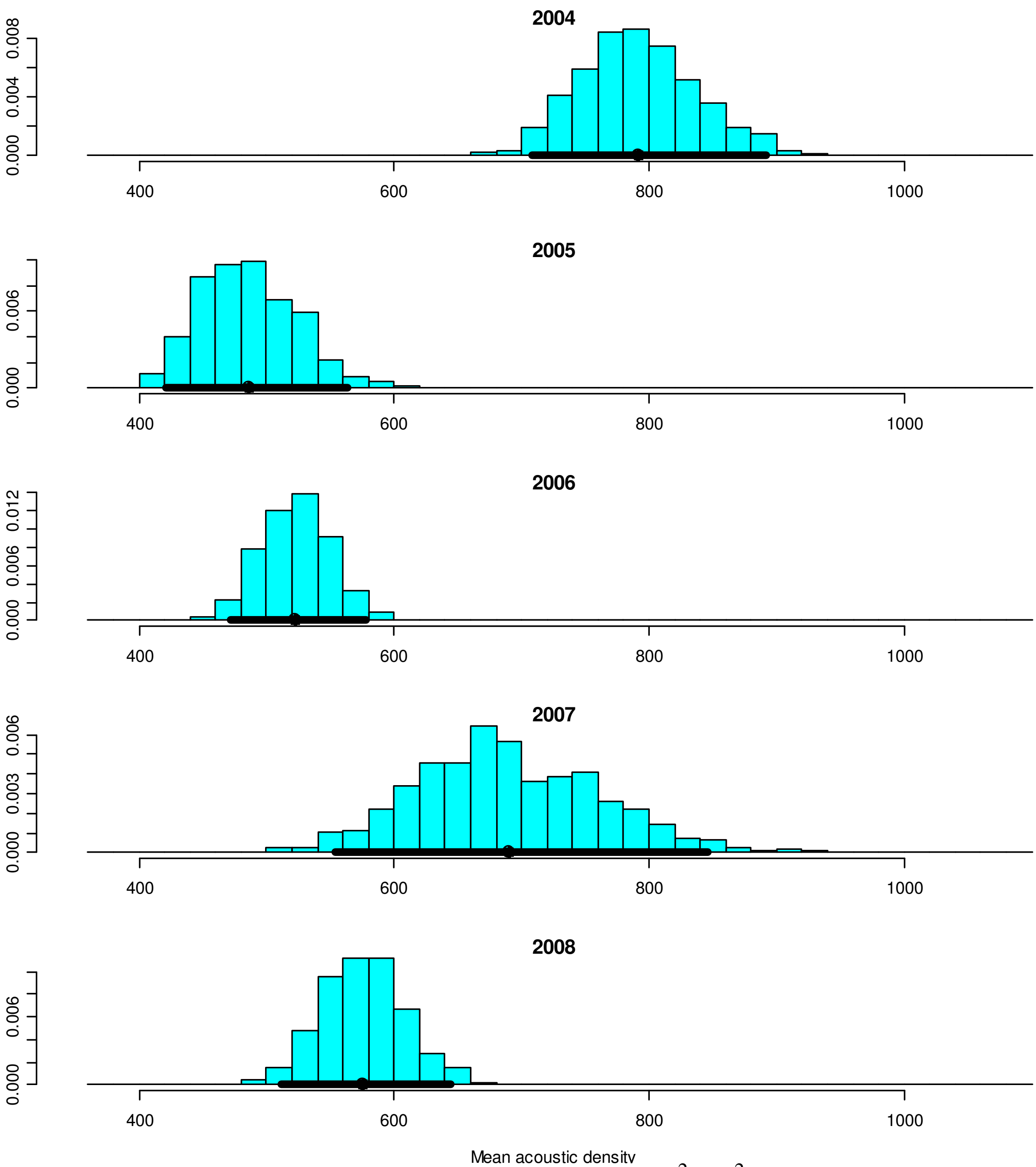

Figure 1. Distribution of mean acoustic density (in m^2/nm^2) based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

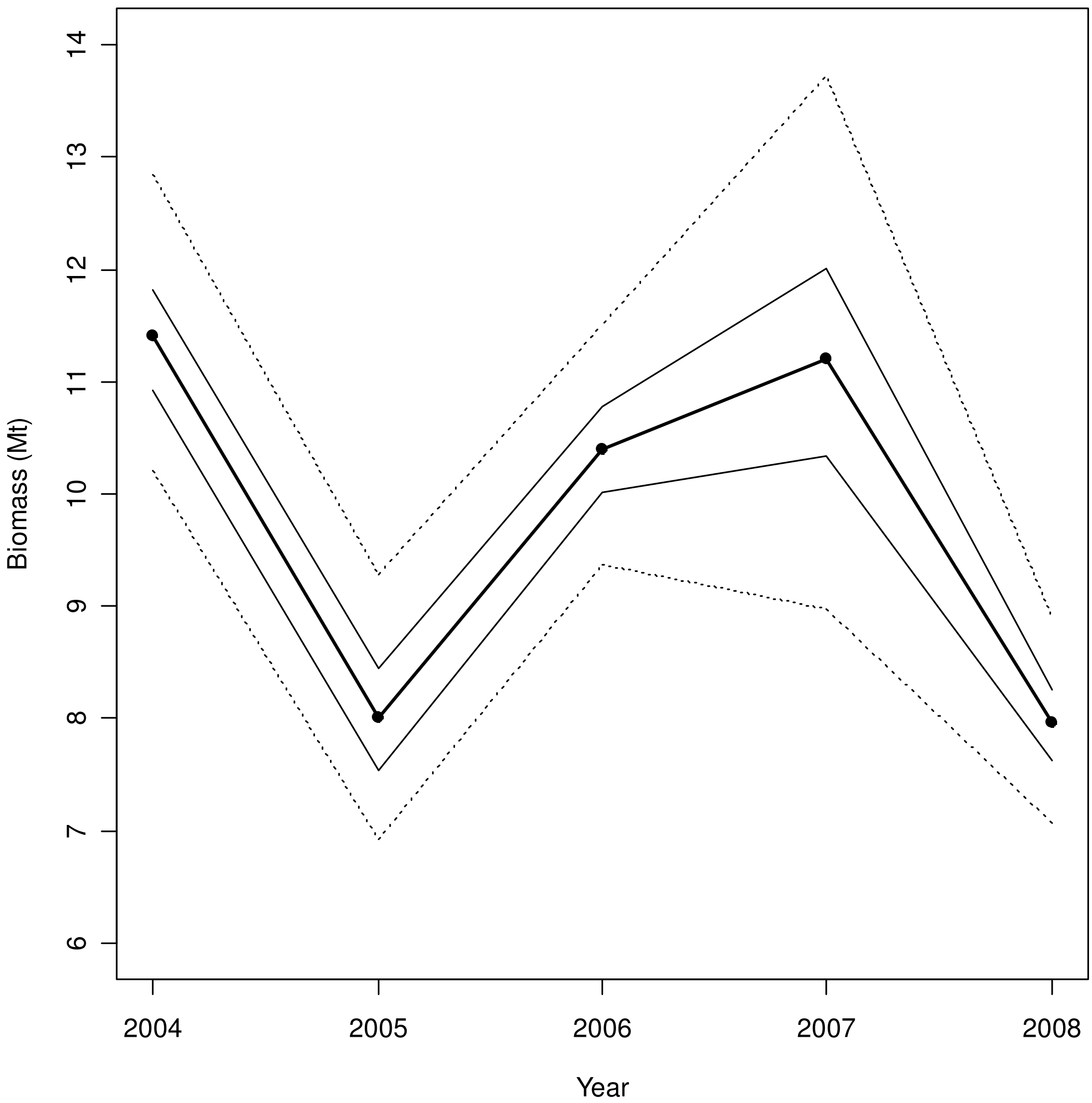

Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations from the mean values. These confidence limits only account for spatio-temporal variability in acoustic observations.