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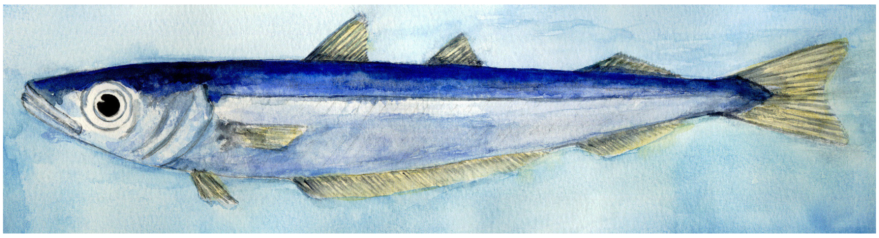

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY SPRING 2010

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Introduction

In spring 2010, five research vessels representing the Faroe Islands, Ireland, the Netherlands, Norway and Russia surveyed the blue whiting spawning grounds to the west of the UK and Ireland. 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 seventh coordinated international blue whiting spawning stock survey since 2004. 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*: Rybakov et al. 2010; *C. Explorer*: O'Donnell et al. 2010; *M. Heinason*: Jacobsen et al. 2010; *Tridens*: Couperus et al. 2010)

This report is based on correspondence undertaken after the International survey by all participants and during the post cruise meeting held in Bergen from May 3-4 with participation from Ireland and Norway.

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 2009) and continued by correspondence until the start of the survey. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Fridtjof Nansen	PINRO, Murmansk, Russia	5/4–17/4
Celtic Explorer	Marine Institute, Ireland	19/3–7/4
G.O. Sars	Institute of Marine Research, Bergen, Norway	21/3–03/4
Magnus Henson	Faroe Marine Research Institute, Faroe Islands	02/4–14/4
Tridens	Institute for Marine Resources & Ecosystem Studies (IMARES), the Netherlands	19/3–9/4

Cruise tracks 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). Regular communication between vessels was maintained during the survey (via email, InmarSat C and VHF radio) exchanging blue whiting distribution data, fleet activity and biological information.

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. All transducers were calibrated with a standard calibration sphere (Foote et al. 1987) prior to the survey. Acoustic settings by vessel are summarized in Table 2.

Acoustic Intercalibration

Inter-vessel acoustic calibrations are carried out when participant vessels are working within the same general area and time and weather conditions allow for an exercise to be carried out. The procedure follows the methods described by Simmonds & MacLennan 2007.

Biological sampling

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. The level of blue whiting sampling of by vessel is shown in Table 5.

Hydrographic sampling

Hydrographic sampling by way of vertical CTD cast was carried out by each participant vessel (Figure 2 and Table 1) up to a maximum depth of 1,100m 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 4.8) 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.

On G.O. Sars, 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. 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 trawl data were analysed with a SAS based routine called "BEAM" (Totland and Godø 2001) and used to calculate age and length stratified estimates of total biomass and abundance (numbers of individuals) within the survey area as a whole and within 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 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

No acoustic inter-calibrations were carried out during the 2010 survey due to time restrictions.

Distribution of blue whiting

During the 2010 survey a mismatch in temporal alignment from the pre-agreed survey plan (Appendix 3.) led to a 15 day time lag between participant vessels. This time lag was deemed too large to produce a single synoptic survey estimate and as a result survey data is presented here in a two survey format. The 'combined' survey is made up of data from Faroes, Netherlands, Norway and Ireland and is presented as a continuation of the current survey index. The 'Russian' survey data is presented as a stand alone single survey estimate. Both surveys covered core spawning areas along the shelf break and followed good temporal progression respectively.

Blue whiting were recorded in all areas surveyed. In total 9,015nmi (nautical miles) of survey transects were completed (combined survey 7,165nmi and Russian survey 1,850nmi) relating to an area coverage of 109,000nmi² (square nautical miles) and 40,000nmi² respectively (Figure 1, Tables 1 & 3).

Combined survey coverage was down by 18% overall, the largest single reduction occurred in the north Porcupine area (42% reduction) followed by Rockall (30% reduction) and Hebrides (11% reduction). The Faroes/Shetland area saw an increase in coverage of 30% as effort was extended further north in the search for blue whiting registrations. Reduced coverage in Rockall was a conscious decision as a result of the near zero blue whiting registrations encountered by the RV *Celtic Explorer* and RV *G.O. Sars*.

The gap in area coverage in the north Porcupine and south Hebrides areas can be attributed to poor weather encountered by the RV *Tridens* and the mismatch of timing of coverage by the co-survey vessel the RV *F. Nansen*. The concept of vessels co-surveying allocated areas within the same time period is to ensure no gaps in coverage occur. The area in question was likely to contain a high blue whiting abundance as indicated by the focus of international fishing effort during the time of surveying. None coverage of this area no doubt resulted in an underestimate of abundance in this core area by the combined survey (Figure 1 & 4).

The highest concentrations of blue whiting were recorded in the Hebrides core area which remains consistent with the results from previous surveys (Figure 8a, Table 3a). Overall the bulk of the stock was centred further south than during the same time in 2009 (Figure 4). Medium and high density registrations extended further into the Rockall Trough between 56-58 degrees of latitude than observed in 2009. To the north and south of this region blue whiting registrations of medium to high density were distributed almost entirely within a narrow band running close the shelf edge often extending no more than 10nmi west of the 250m contour (Figure 8c-d).

In the western and northern extremes of the survey area low density blue whiting registrations dominated. Aggregations observed in western Rockall during the 2009 survey and the associated commercial fishing activity were notably absent in 2010. Spawning blue whiting normally present in western Rockall appear to have been displaced eastwards into the Rockall Trough due which may be due to the influence of colder less saline water observed at depth in western Rockall by the RV *Celtic Explorer* (O'Donnell *et al.* 2010).

Stock size

Combined survey

The estimated total abundance of blue whiting for the 2010 international combined survey was 2.43 million tonnes, representing an abundance of 16.4x10^9 individuals (Figure 7, Tables 3a & 4a). Spawning stock was estimated at 2.4 million tonnes and 15.8x10^9 individuals. In comparison to 2009, there is a significant decrease (60%) in the observed stock biomass and a related decrease in stock numbers (65%).

		2004	2005	2006	2007	2008	2009	2010	Change from 2009 (%)
Biomass	Total	11.4	8	10.4	11.2	8	6.07	2.43	-60%
(mill. t)	Mature	10.9	7.6	10.3	11.1	7.9	6.03	2.4	-60%
Numbers	Total	137	90	108	104	68	46.7	16.4	-65%
(10^9)	Mature	128	83	105	102	67	45.8	15.8	-66%
Survey area (nm^2)		149,000	172,000	170,000	135,000	127,000	133,900	109,320	-18%

The Hebrides core area was found to contain 56% of the total biomass observed during the survey and is consistent with the results from previous surveys (50% in 2008, 62% in 2009 relative to total stock biomass for that year). The north Porcupine and Faroes/Shetland areas ranked second and third highest contributing 20% and 12% to the total respectively. The breakdown of combined survey biomass by sub area is shown below:

		Biomass (million tonnes)				
		2009		2010		
	Sub-area		% of total		% of total	Change (%)
I	S. Porcupine Bank	0.1	1	0.1	4	0%
II	N. Porcupine Bank	1.2	15	0.5	20	-58%
III	Hebrides	4.13	52	1.4	56	-66%
IV	Faroes/Shetland	0.74	9	0.3	12	-59%
V	Rockall	1.8	23	0.2	8	-89%

Russian survey

The estimated total abundance of blue whiting for the 2010 Russian survey was 3.79 million tonnes, representing an abundance of 27.2x10^9 individuals (Figure 5, Table 3b & 4b). Spawning stock was estimated at 3.65 million tonnes and 24.7x10^9 individuals.

Stock composition

Individuals of ages 1 to 13 years were observed during the survey. A comparison of age reading between nations was carried out and the results are presented in Appendix 2. Overall, good agreement in age readings was achieved across nations from the combined survey. The largest variation came from Russian age readings, where smaller individuals were markedly older than those for other nations. The 2009 year class (1-year old fish) was notably absent from Russian samples as compared to other nations which reported 1-year old fish from all sub areas (Table 4a-b).

The stock within the survey area is dominated by age classes 6, 7 and 5-years, of the 2004, 2003 and 2005 year classes respectively, contributing over 73% of spawning stock biomass (Table 4a, Figure 9 & 10).

The Hebrides area remains the most productive in the current survey time series and has consistently contributed over 50% to the total SSB (Figure 7). The age profiles of all sub areas are dominated by the three most prolific age classes within the stock (2003, 2002 and 2004). The Hebrides and Faroe/Shetland sub areas contained the oldest age classes observed, up to 13 years (1997 year class).

Juvenile blue whiting were represented in all sub areas in 2010. Maturity analysis of combined survey samples indicate that 10% of 1-year old and 96% of 2-year old fish were mature as compared to Russian estimates of where no 1-year old fish were observed and 1% of 2-year old fish were considered mature (Tables 4a-b).

From combined survey data the Porcupine sub areas were found to contain immature blue whiting as in previous years. The largest proportion of 1-yr old fish representing 2% (9,500t) of the total biomass and 8% (283 million individuals) of the total abundance was observed in the north Porcupine area. The Hebrides also contained immature representing 0.7% (9,200t) of total biomass and 3% (247 million) of total abundance.

Faroe/Shetland area had a significant contribution of 2-year old fish (2008 year class) representing 24% (59,400t) of the total biomass and 44% (870 million) of total abundance for this area. The positive signal of this pre-recruiting year class was not observed in any other sub area in the same proportion (Figure 10).

Overall immature blue whiting from the combined estimate represented 1% (23,400t) of the total biomass and 4% (615 million) of the total abundance recorded during the survey.

Hydrography

A combined total of 173 CTD casts were undertaken over the course of the survey. Horizontal plots of temperature and salinity at depths of 10m, 50m, 100 and 200m as derived from vertical CTD casts are displayed in Figures 11-14 respectively.

Concluding remarks

Main results

- The seventh international blue whiting spawning stock survey shows a significant decrease in stock biomass (-60%) and a related decrease in stock numbers (-65%) as compared to the previous year's survey.
- Total stock abundance is not considered fully reflected due to a gap in combined survey coverage between the 55-56ºN. This area was the focus of the bulk of international fishing effort during the survey and may therefore contain a significant yet undetermined contribution to the overall estimate in 2010.
- The stock in the survey area is dominated by 6, 7 and 5-years, of the 2004, 2003 and 2005 year classes respectively. Together these year classes account for 73% of spawning stock biomass.
- Mean length (29.8 cm) and weight (147.8 g) are the highest on record in the international survey time series indicating the continued reliance of the stock on larger older individuals.
- The contribution of immature fish to the total biomass remains small. However, a positive signal of 2-year old fish was observed in the Faroe/Shetland area and is an encouraging sign in a period of prolonged poor recruitment.
- Maturity analysis indicated that peak spawning in 2010 was later than in previous years due to the proportion of spent fish observed. In 2009 peak spawning was considered earlier as a much higher proportion of the stock surveyed was spent.
- The combined survey effort was carried out over 28 days as compared to 29 days in 2009. The 2010 survey commenced 3 days later than in 2009 so timing is considered comparable. It was planned during PGNAPES planning meeting in 2009 that the survey should be completed within a 21 day window.
- The F. Nansen began surveying 10 days later than in 2009 and 15 days after the Tridens began in the southern co-surveyed area. This large time lag continued northwards and as a result data from co-surveyed rectangles was non-admissible to the combined survey estimate.

Interpretation of the results

- Both surveys (Combined and Russian) provide a snapshot of relative abundance within the survey area at the time of surveying. It is not possible to overlay estimates due to the significant time lag. Had all vessels covered areas as agreed within the allocated time frame it would be possible to produce a single survey estimate with a high degree of precision.
- The 2010 estimate of abundance for the combined survey can be considered robust for those areas covered. Over 76% of the total biomass was observed in sub areas surveyed by more than one vessel. However, the gap in coverage has no doubt resulted in an under estimate of the stock.
- The Russian survey appears to have successfully contained the stock within the survey area as a consequence of the more eastward orientation in 2010 and may be a more representative estimate of the stock as a whole.
- Survey timing is fixed annually to coincide with peak spawning of the stock. In 2010 as in 2009 the time of peak spawning varied. However, in both years the stock was contained within the survey area due to the extensive survey area and so estimates of abundance are credible.

Recommendations

- Agreements made by *all* survey participants during the planning phase (WGNAPES) need to be adhered to by *all* participants during the survey to ensure synoptic coverage.
- The results of the blue whiting otiliths exchange program should be made available prior to the WGNAPES meeting in August for discussion at the meeting.

Achievements

- Good at sea communications between participant vessels for the combined survey was achieved and allowed the survey to be adapted to ensure coverage of area of distribution.
- Delivery of survey data in the PGNAPES format to Leon Smith was achieved in a timely fashion.

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Table 1. Survey effort by vessel. March-April 2010.

Vessel	Effective survey period	Length of cruise track (nm)	Trawl stations	CTD stations	Aged fish	Length-measured fish
Fridtjof Nansen	5/4–17/4	1,850	19	55	1078	3,897
Celtic Explorer	20/3–3/4	2,260	13	42	450	1,350
G.O. Sars	21/3–3/4	2,140	12	28	176	600
Magnus Heinason	02/4–14/4	1,490	9	28	463	1,039
Tridens	23/3–4/4	1,275	9	21	450	1,171
Total		9,015	62	174	2,617	8,057

Table 2. Acoustic instruments and settings for the primary frequency. March-April 2010.

	Fridtjof Nansen	Celtic Explorer	G.O. Sars	Magnus Heinason	Tridens
Echo sounder	Simrad EK60	Simrad EK 60	Simrad ER 60	Simrad EK 500	Simrad EK 60
Frequency (kHz)	**38, 120**	**38**, 18, 120, 200	**38**, 18, 70, 120, 200,	**38**	**38**
Primary transducer	ES38B	ES 38B	ES 38B - SK	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Drop keel	Hull	Towed body
Transducer depth (m)	4.5	8.7	8.5	3	7
Upper integration limit (m)	10	15	15	7	12
Absorption coeff. (dB/km)	10	10	9.8	10	9.8
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	2.43	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	-20.8	-20.9	-20.5
Sv Transducer gain (dB)				27.15	25.09
Ts Transducer gain (dB)	25.72	25.71	26.62	27.1	
s_A correction (dB)	-0.63	-0.63	-0.63		-0.63
3 dB beam width (dg)					
alongship:	6.99	6.97	7.09	7	7.09
athw. ship:	7.04	7.01	7.07	6.9	7.02
Maximum range (m)	750	750	750	750	750
Post processing software	FAMAS	Sonardata Echoview	LSSS	Sonardata Echoview	Sonardata Echoview

Table 3. Assessment factors of blue whiting. (Top: Combined survey (Netherlands, Norway, Faroes and Ireland) and bottom: Russian survey). March-April 2010.

a). Combined survey

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	9,404	0.87	0.88	98.6	0.12	0.13	99.6	141.4	30.3	13.3
II	N. Porcupine Bank	13,741	3.65	3.68	99.1	0.47	0.47	99.7	127.2	29.9	34.1
III	Hebrides	29,744	8.61	8.64	99.7	1.38	1.38	99.9	159.5	30.4	46.3
IV	Faroes/Shetland	19,389	1.96	1.99	98.2	0.24	0.25	99.1	123.7	26.2	12.7
V	Rockall	37,042	1.25	1.25	99.9	0.21	0.21	100.0	170.2	30.4	5.7
Tot.		109,320	16.33	16.4	99.6	2.43	2.43	99.8	147.8	29.8	22.2

b). Russian survey

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	-	-	-	-	-	-	-	-	-	-
II	N. Porcupine Bank	12,208	2.37	2.65	89	0.34	0.36	94	136	29.2	30.6
III	Hebrides	23,844	21.16	23.14	91	3.14	3.24	97	140	29.3	139.6
IV	Faroes/Shetland	4,151	1.18	1.42	83	0.17	0.19	89	132	29.5	51.6
V	Rockall	-	-	-	-	-	-	-	-	-	-
Total		40,203	24.71	27.21	91	3.65	3.79	96	139	29.3	97.3

Table 4a. Combined survey stock estimate of blue whiting, March-April 2010.

Length	Age in years (year class)										Numbers	Biomass	Mean weight	Prop. mature*
	1	2	3	4	5	6	7	8	9	10+				
(cm)	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	(*10-$^{6)}$	(10^6 kg)	(g)	(%)
13.0 – 14.0	1	0	0	0	0	0	0	0	0	0	1	0	15	0
14.0 – 15.0	0	0	0	0	0	0	0	0	0	0	0	0	.	.
15.0 – 16.0	10	0	0	0	0	0	0	0	0	0	10	0.2	19.6	0
16.0 – 17.0	22	0	0	0	0	0	0	0	0	0	22	1	24	0
17.0 – 18.0	56	5	0	0	0	0	0	0	0	0	61	2	27	0
18.0 – 19.0	204	0	0	0	0	0	0	0	0	0	204	6	31	0
19.0 – 20.0	184	31	4	0	0	0	0	0	0	0	219	8	37	0
20.0 – 21.0	89	115	24	0	0	0	0	0	0	0	228	11	47	0
21.0 – 22.0	44	216	28	0	0	0	0	0	0	0	288	16	57	50
22.0 – 23.0	16	297	92	0	0	0	0	0	0	0	405	27	67	75
23.0 – 24.0	5	284	47	0	0	0	0	0	0	0	336	24	73	100
24.0 – 25.0	0	121	15	0	0	0	0	0	0	0	136	11	82	100
25.0 – 26.0	0	81	123	7	0	0	0	0	0	0	211	17	82	100
26.0 – 27.0	0	17	101	35	28	0	0	0	0	0	181	18	98	100
27.0 – 28.0	0	0	110	190	73	61	25	0	0	0	459	55	120	100
28.0 – 29.0	0	13	60	117	229	425	195	43	5	0	1087	145	134	100
29.0 – 30.0	0	0	57	310	580	732	773	191	0	30	2673	378	141	100
30.0 – 31.0	0	0	0	71	539	1401	952	313	67	16	3359	516	154	100
31.0 – 32.0	0	0	0	35	531	1018	731	434	10	10	2769	458	165	100
32.0 – 33.0	0	0	0	0	319	662	450	566	36	0	2033	359	176	100
33.0 – 34.0	0	0	0	0	152	439	157	233	80	0	1061	204	192	100
34.0 – 35.0	0	0	0	0	18	29	69	78	49	13	256	57	223	100
35.0 – 36.0	0	0	0	0	26	54	48	14	41	0	183	45	245	100
36.0 – 37.0	0	0	0	0	0	0	155	0	0	0	155	40	260	100
37.0 – 38.0	0	0	0	0	0	0	35	0	21	7	63	17	279	100
38.0 – 39.0	0	0	0	0	0	18	5	0	3	1	27	9	311	100
39.0 – 40.0	0	0	0	0	0	0	0	0	0	0	0	0	.	.
40.0 – 41.0	0	0	0	0	0	0	14	0	0	0	14	5	340	100
41.0 – 42.0	0	0	0	0	0	0	0	0	0	0	0	0	.	.
42.0 – 43.0	0	0	0	0	0	0	0	0	0	0	0	0	.	.
43.0 – 44.0	0	0	0	0	0	0	0	0	0	0		0	.	.
44.0 – 45.0	0	0	0	0	0	0	0	0	0	3	3	2	596	100
TSN (10^6)	631	1180	661	765	2495	4839	3609	1872	312	80	16444	2430.4		
TSB (10^6 kg)	22.3	80.8	59.6	102.6	374.2	759.1	616.8	333.2	65.5	16.4	2430.5			
Mean length (cm)	19.2	22.8	25.6	28.9	30.7	31	31.3	31.8	33.3	36.8	29.8			
Mean weight (g)	35.4	68.5	90.3	134.2	149.9	156.8	170.9	177.9	210.2	195	147.8			
% mature*	10	96	100	100	100	100	100	100	100	100				
% of SSB	10	96	100	100	100	100	100	100	100	100				

* Percentage of mature individuals per age or length class

Table 4b. Russian survey stock estimate of blue whiting, March-April 2010.

Length	Age in years (year class)										Numbers	TSB Biomass	Mean weight	Prop mature
	1	2	3	4	5	6	7	8	9	10+				
(cm)	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	(*10-6)	(10^6 kg)	(g)	(%)
13.0 - 14.0	0	10	2	0	0	0	0	0	0	0	11.9	0.2	14.5	0
14.0 - 15.0	0	116	12	0	0	0	0	0	0	0	128.3	1.9	14.5	0
15.0 -16.0	0	178	34	0	6	0	0	0	0	0	217.9	3.8	17.7	0
16.0 - 17.0	0	208	14	9	0	0	0	0	0	0	230.2	4.6	20.0	0
17.0 - 18.0	0	288	21	0	0	0	0	0	0	0	309.2	7.5	24.1	0
18.0 - 19.0	0	408	92	0	0	0	0	0	0	0	499.3	15.7	31.4	0
19.0 - 20.0	0	74	225	0	6	0	0	0	0	0	304.7	11.6	37.9	0
20.0 - 21.0	0	19	138	92	0	0	0	0	0	0	249.3	11.1	44.7	0
21.0 - 22.0	0	38	122	0	0	0	0	0	0	0	159.5	8.0	49.9	12
22.0 -23.0	0	7	67	30	0	0	0	0	0	0	104.9	5.9	56.7	15
23.0 -24.0	0	28	75	25	8	4	0	0	0	0	139.1	9.2	65.8	66
24.0 - 25.0	0	13	111	203	27	14	0	0	0	0	367.5	27.0	73.4	71
25.0 - 26.0	0	6	177	291	39	39	0	0	0	0	551.9	46.6	84.4	93
26.0 - 27.0	0	0	94	199	86	0	16	0	0	0	395.0	36.7	92.8	100
27.0 - 28.0	0	0	114	106	131	44	38	50	12	0	495.8	53.2	107.3	100
28.0 - 29.0	0	0	131	382	779	695	217	109	0	0	2313.6	277.1	119.8	98
29.0 - 30.0	0	9	159	388	859	1384	792	210	0	0	3800.6	491.3	129.3	99
30.0 - 31.0	0	0	81	547	1176	2226	1689	584	307	36	6645.3	934.5	140.6	100
31.0 - 32.0	0	0	28	144	579	1089	1053	465	28	27	3413.9	515.5	151.0	99
32.0 - 33.0	0	0	8	200	403	925	873	357	93	0	2860.1	485.4	169.7	100
33.0 - 34.0	0	0	0	76	299	698	889	167	61	0	2188.5	399.6	182.6	100
34.0 - 35.0	0	0	0	2	83	190	261	157	38	0	730.8	146.3	200.1	100
35.0 - 36.0	0	0	0	0	62	23	56	79	87	0	305.9	68.1	222.5	100
36.0 - 37.0	0	0	0	22	20	47	89	0	0	0	177.9	45.0	252.6	100
37.0 - 38.0	0	0	0	64	0	57	64	42	86	35	348.2	96.9	278.2	100
38.0 - 39.0	0	0	0	0	10	10	19	20	0	10	68.4	20.4	298.3	100
39.0 - 40.0	0	0	0	0	19	0	8	58	0	0	85.2	29.1	342.0	100
40.0 - 41.0	0	0	0	0	0	39	48	8	0	0	95.2	33.4	350.8	100
41.0 - 42.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	-	-
42.0 - 43.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	-	-
43.0 - 44.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	-	-
44.0 - 45.0	0	0	0	0	0	0	8	0	0	0	8.3	3.5	424.0	100
TSN (10^6)	0	1401.9	1704.3	2780.7	4591.6	7484.0	6119.0	2304.9	712.2	107.8	27206.4	3788.8		
TSB (10^6 kg)	0	38.8	130.1	345.2	660.2	1122.2	965.9	377.9	127.2	21.3	3788.8			
Mean L (cm)	-	17.2	23.6	28.2	29.9	30.5	31.2	31.4	32.2	65.0	29.33			
Mean W (g)	-	27.7	76.3	124.1	143.8	149.9	157.8	164.0	178.6	364.9	139.3			
% Mature	-	1	52	96	97	100	100	100	100	100				
% of SSB	-	1	52	96	97	100	100	100	100	100				

Table 5. Country and vessel specific details, March-April 2010.

	Fridtjof Nansen	Celtic Explorer	G.O. Sars	Magnus Heinason	Tridens
Trawl dimensions					
Circumference (m)	716	768	600	640	1120
Vertical opening (m)	50	50	30	40	30-70
Mesh size in codend (mm)	16	20	16	40	±20
Typical towing speed (kn)	3.2-4.2	3.5-4.0	3.0-3.5	3.0-4.0	3.5-4.0
Biological sampling					
Length Only	3897				±200
Lenth/Weight		100	70	200	
Length/Weight/Sex/Maturity	1078	50	30	100	50
Hydrographic sampling					
CTD Unit	SBE19plus	SBE911	SBE911	SBE911	SBE911
Standard sampling depth (m)	1000	1000	1000	1000	1000

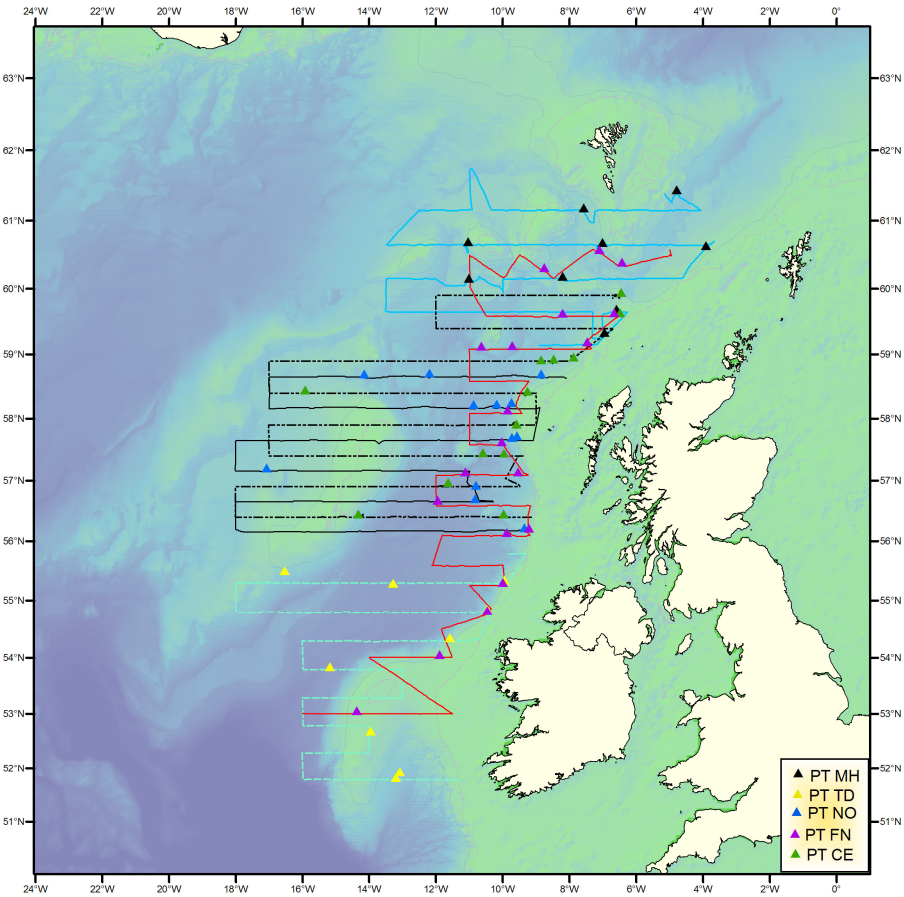


Figure 1. All survey vessel cruise tracks and trawl stations. PT: Indicates pelagic trawl station. CE: Celtic Explorer; MH: Magnus Heinason; TD: Tridens; FN: Fridtjof Nansen: NO: G.O. Sars. March-April 2010.

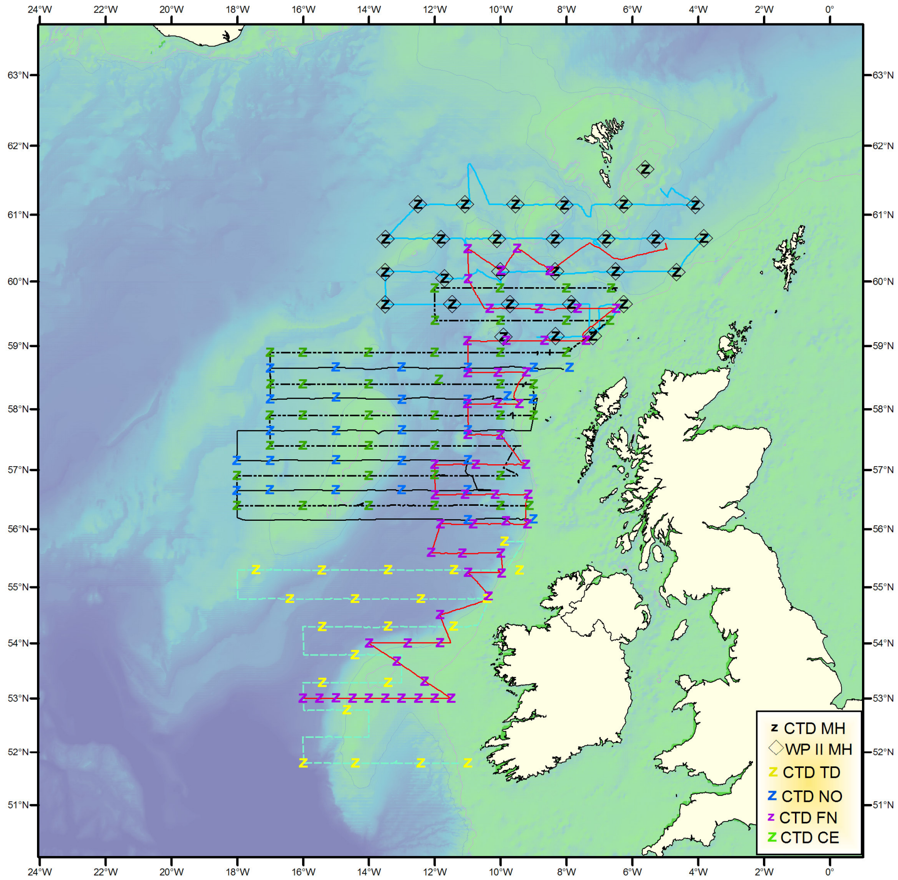


Figure 2. CTD stations overlaid onto vessel cruise tracks for all surveys. WP II: Indicates plankton trawl. CE: Celtic Explorer; MH: Magnus Heinason; TD: Tridens; FN: Fridtjof Nansen: NO: G.O. Sars. March-April 2010.

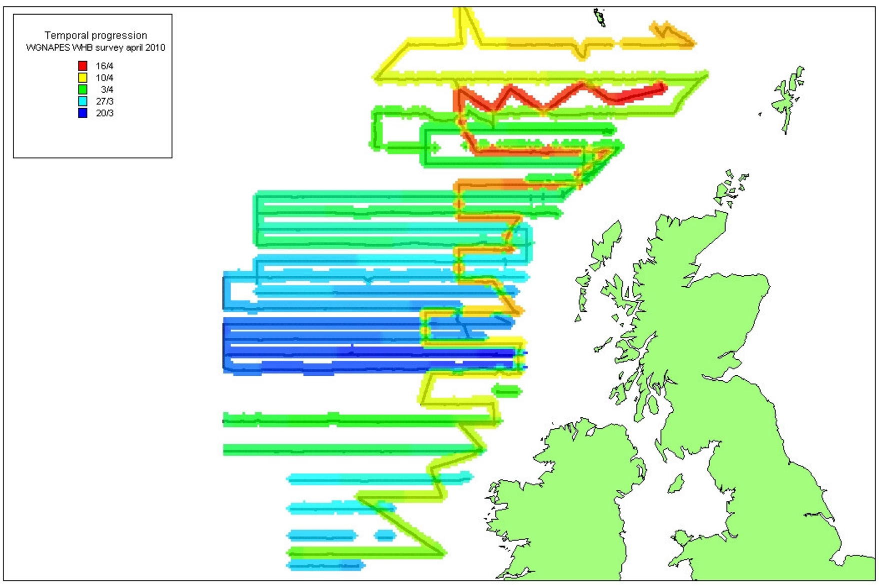


Figure 3. Temporal progression for all surveys, 20 March–16 April 2010.

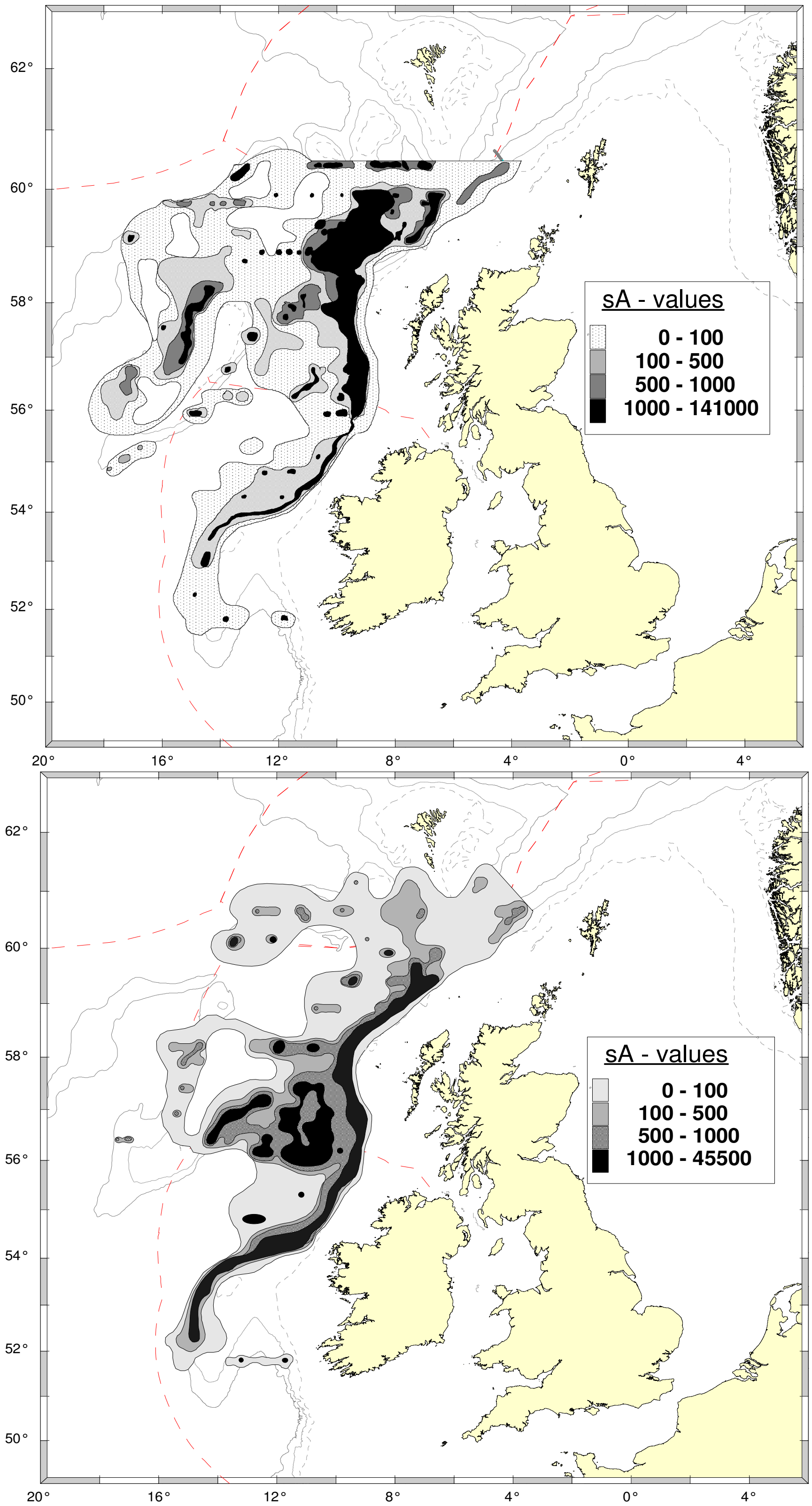


Figure 4. Schematic maps of Combined survey blue whiting acoustic density (s_A, m^2/nm^2) in March-April 2009 (upper panel) and 2010 (lower panel).

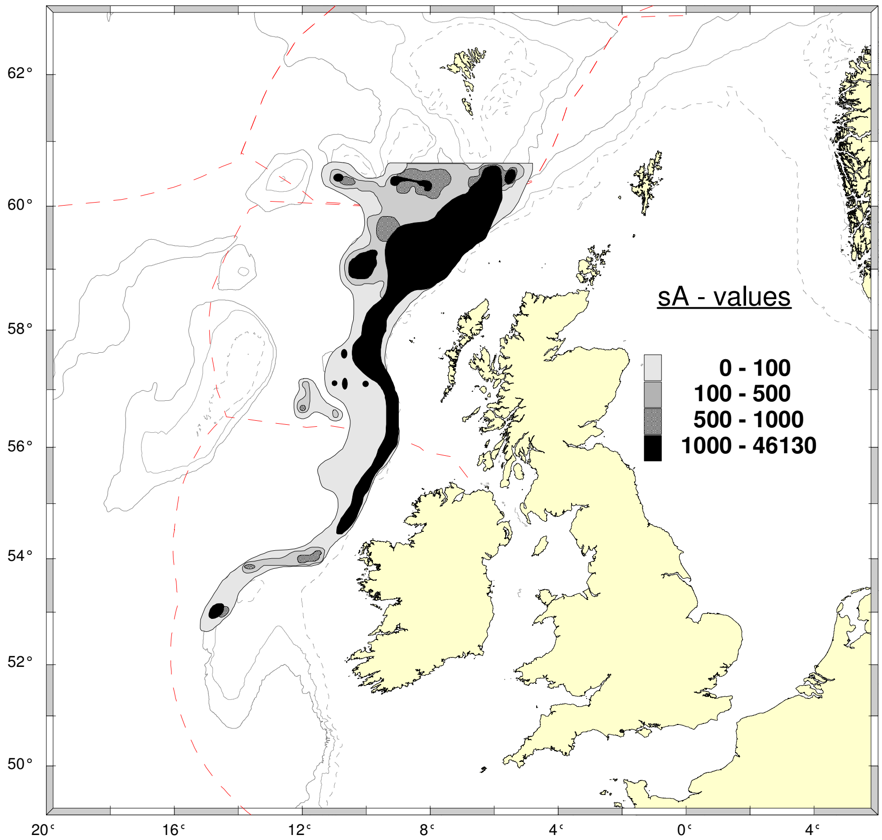


Figure 5. Schematic map of Russian survey blue whiting acoustic density (s_A, m^2/nm^2) in 2010 .

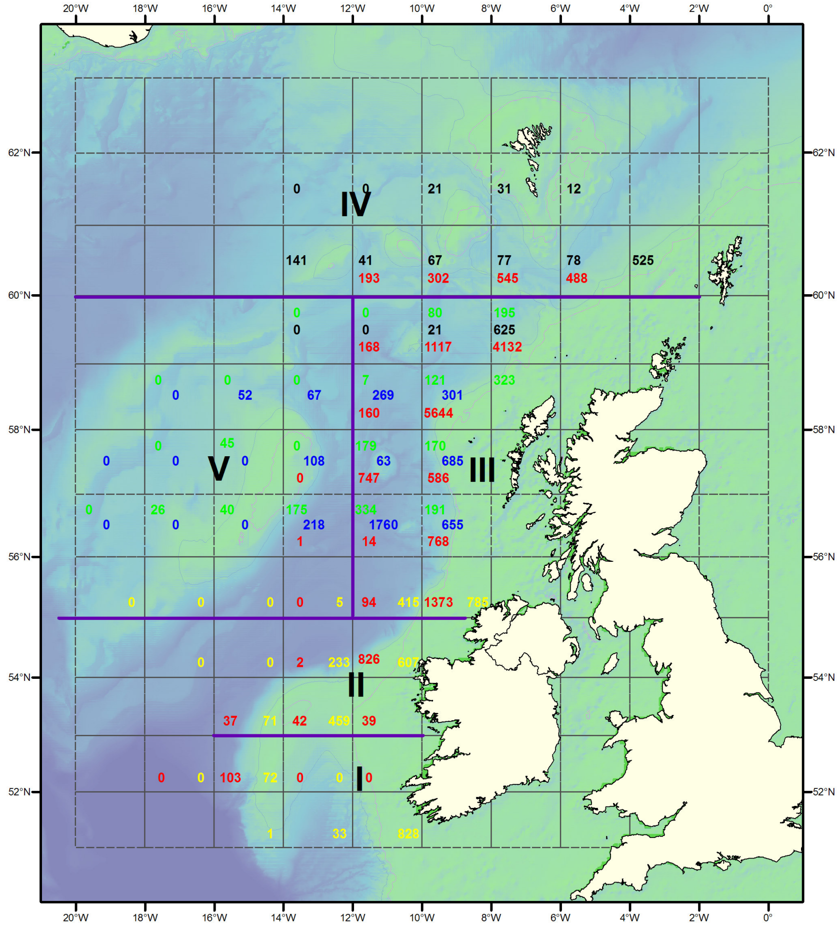


Figure 6. Mean blue whiting acoustic density (s_A, m^2/nm^2) by individual vessel: Celtic Explorer: green, Magnus Heinason: grey, Netherlands: yellow, Fridtjof Nansen: red, G.O. Sars: blue. March-April 2010. Note: A time lag of 15 days was recorded between the RU survey and the coordinated survey.

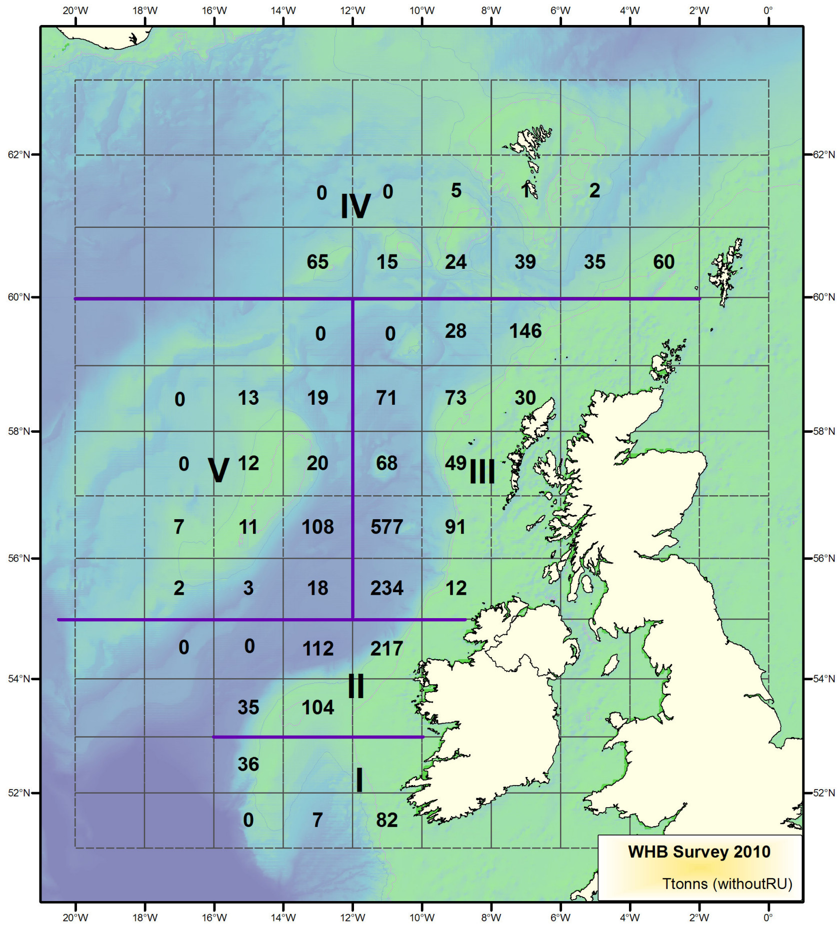
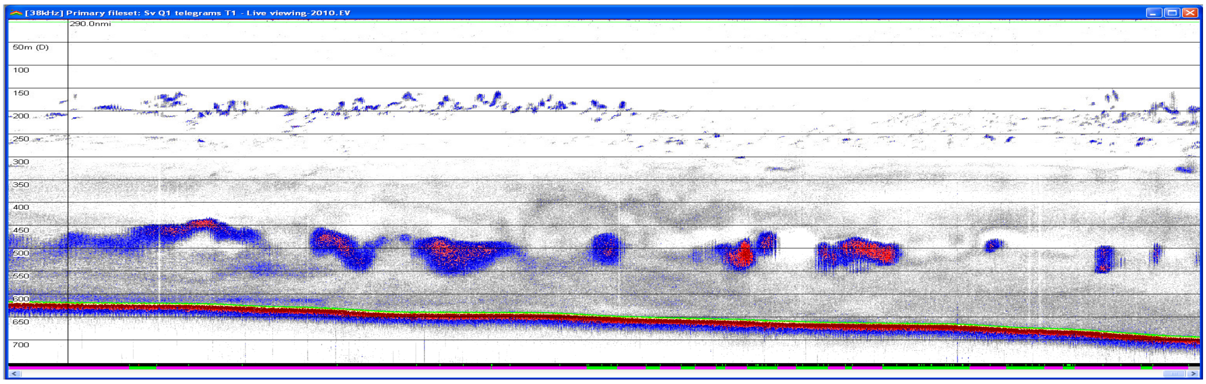
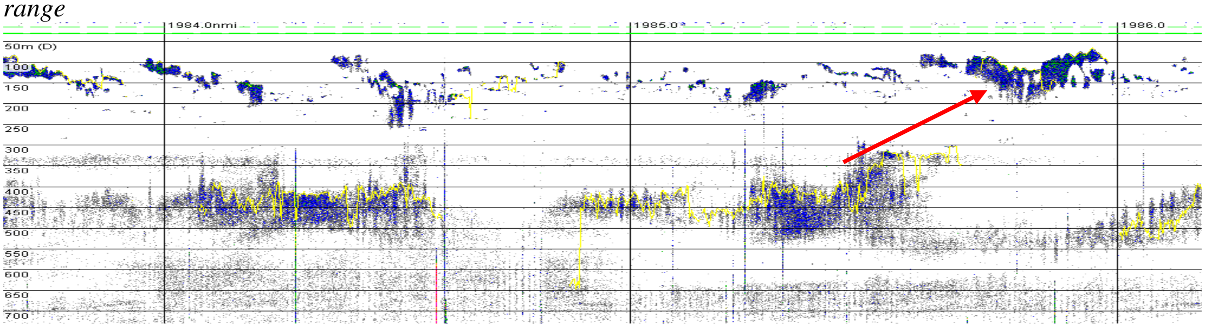


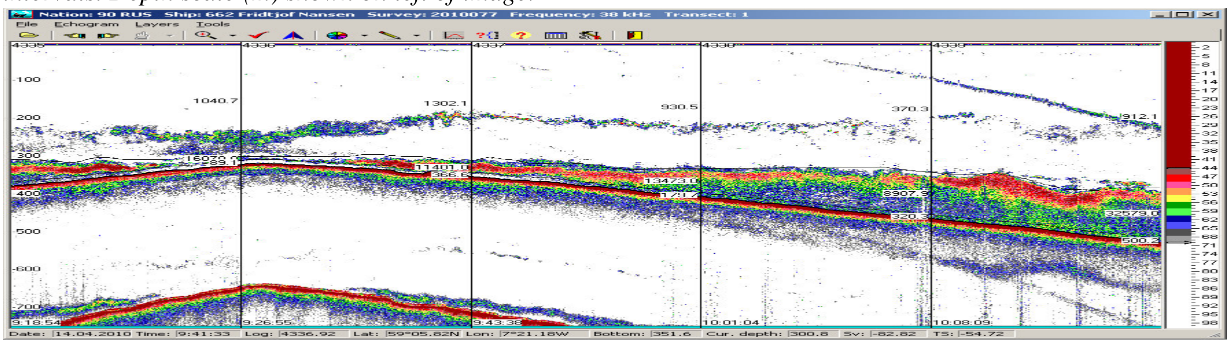
Figure 7. Blue whiting biomass for the Combined survey by sub-area as used in the assessment. March-April 2010.



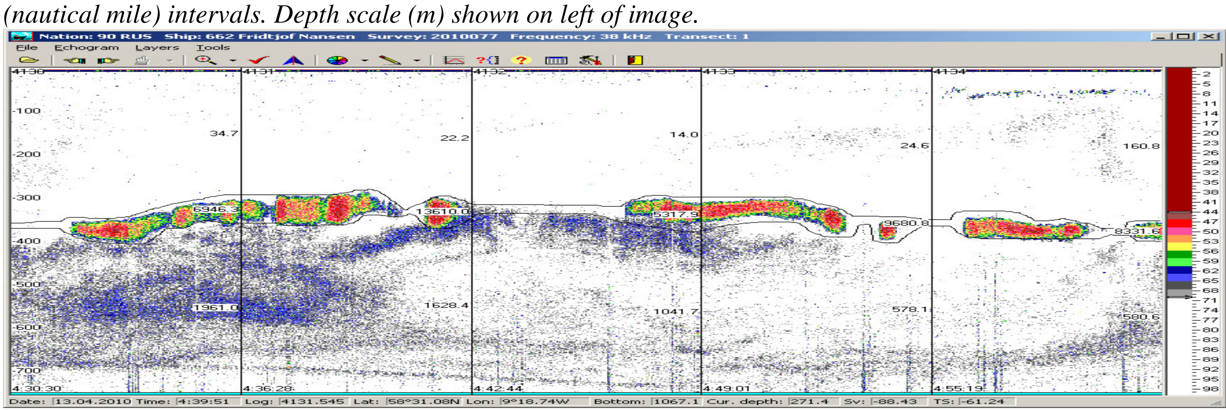
a). High density schools of blue whiting recorded by the RV Magnus Heinason. NASC value 11,868. Located on *shelf slopes to the west of the Hebrides (Sub area III). Depth scale (m) shown on left of image. Sonar colour range*



b). *Example of low to medium density surface schools (70-100m) frequently encountered to the north of 58ºN by the RV Celtic Explorer. Trawl targeted surface schools (red arrow) yielded one single 8.6Kg monkfish (Lophius piscatorius) bottom depth 1,500m Sub area III. Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*



c). *High density schools of blue whiting recorded by the RV Fridtjof Nansen in the Hebrides sub area along the shelf break. Recorded on FAMAS post processing software Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.*



d) High density schools of blue whiting recorded by the RV Fridtjof Nansen in the Hebrides sub area along the shelf break. Recorded on FAMAS post processing software. Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale (m) shown on left of image.

Figure 8. Blue whiting and echograms of interest encountered during the combined International blue whiting March-April 2010.

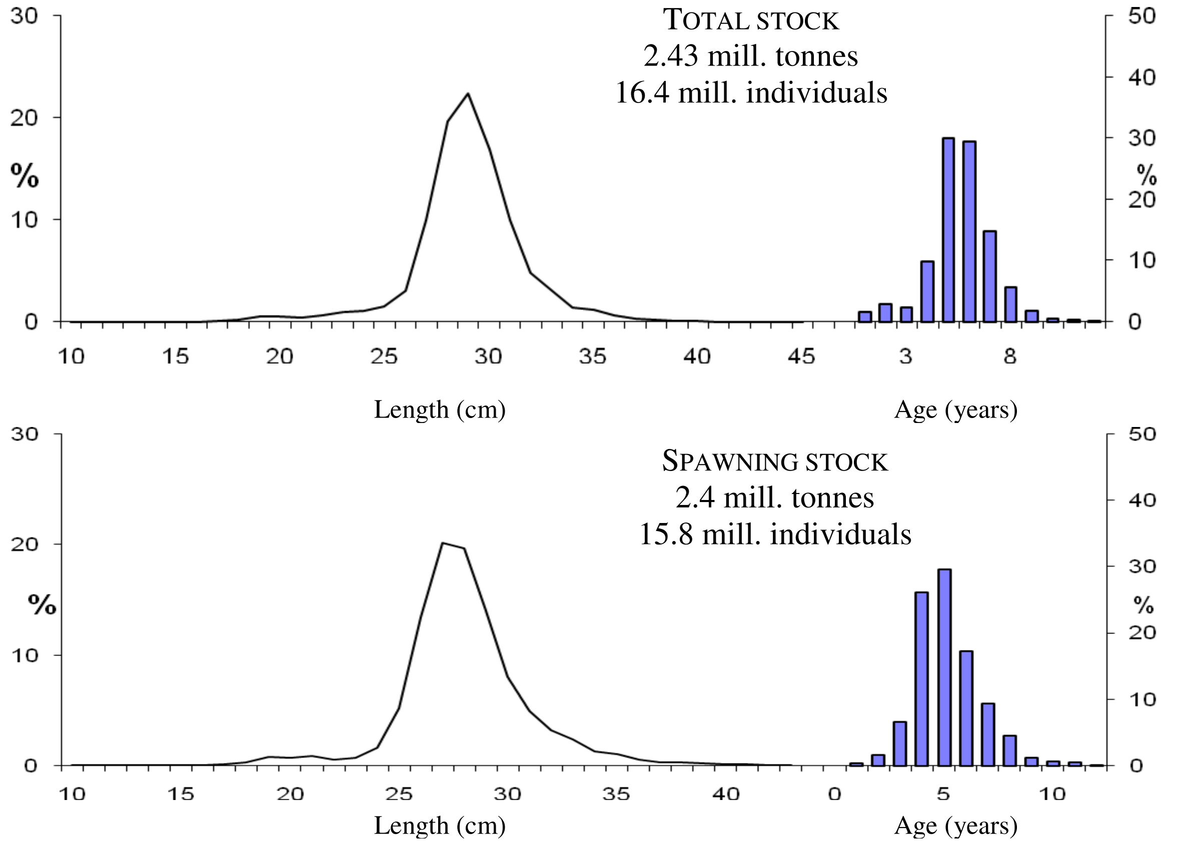


Figure 9. Length and age distribution for the Combined survey data as total and spawning stock biomass of blue whiting in western waters. March-April 2010.

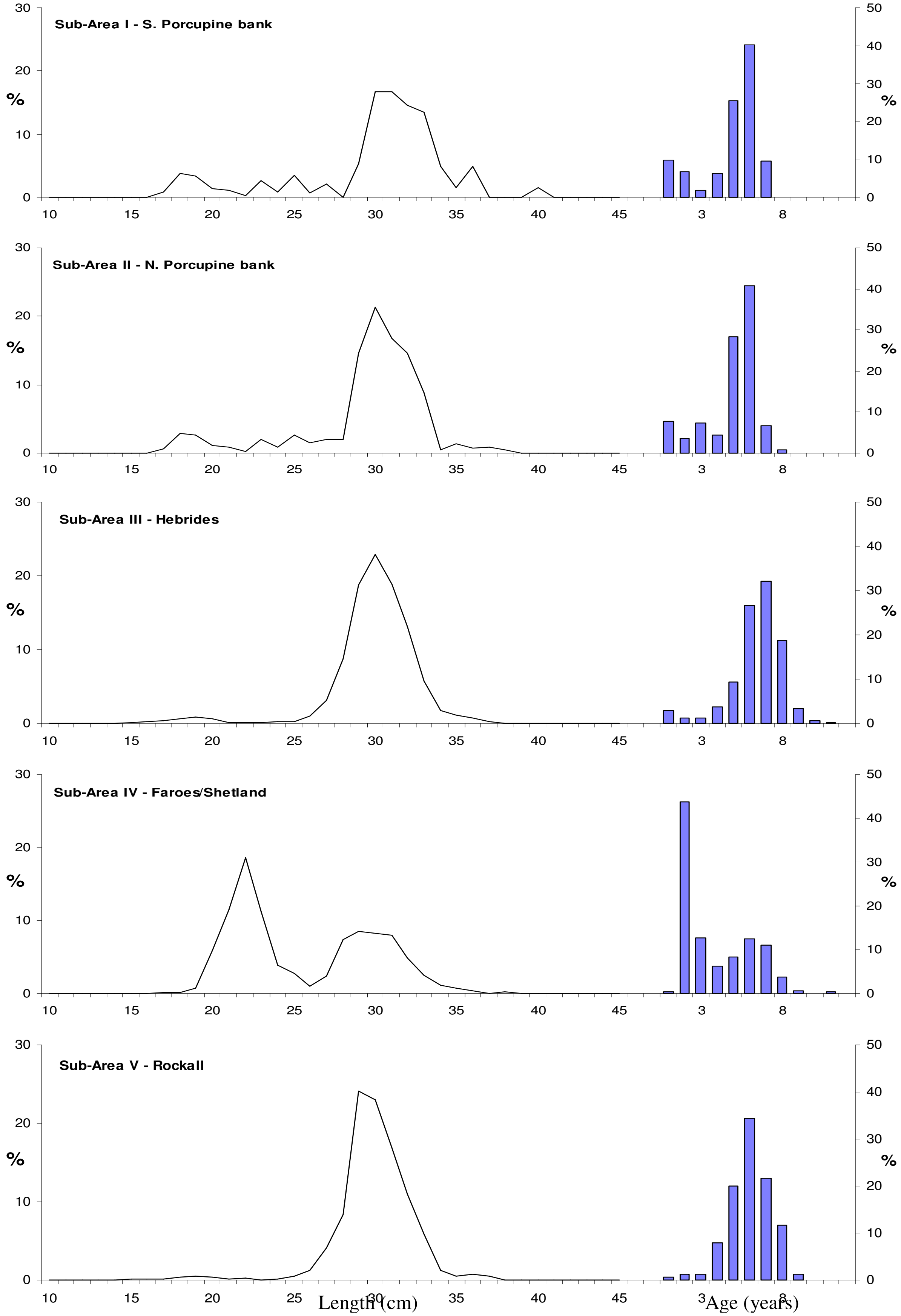


Figure 10. Length and age distribution (numbers) for Combined survey data for blue whiting by sub-area (I–V). March-April 2010.

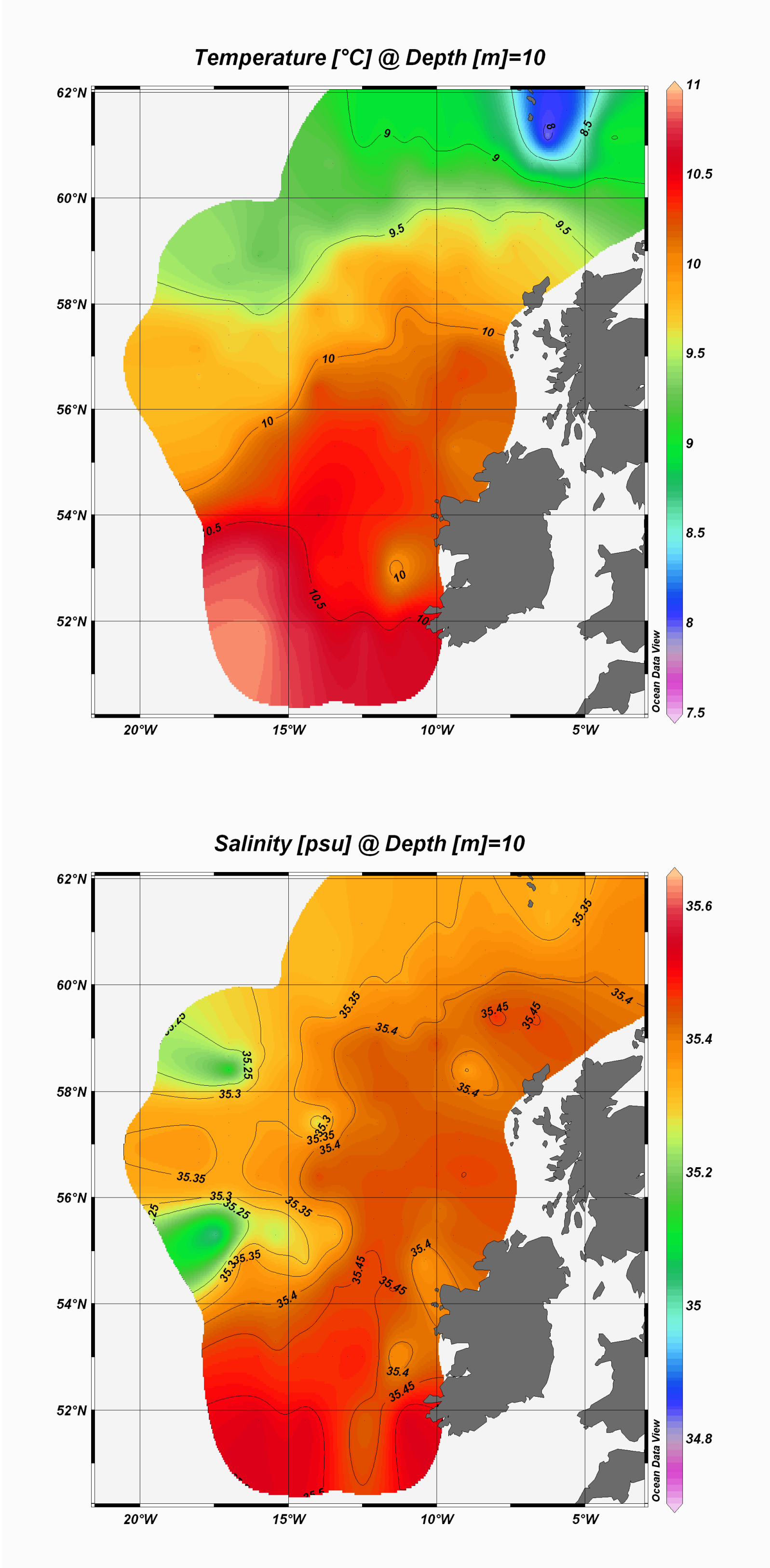


Figure 11. Horizontal temperature (top panel) and salinity (bottom panel) at 10m subsurface as derived from vertical CTD casts. March-April 2010.

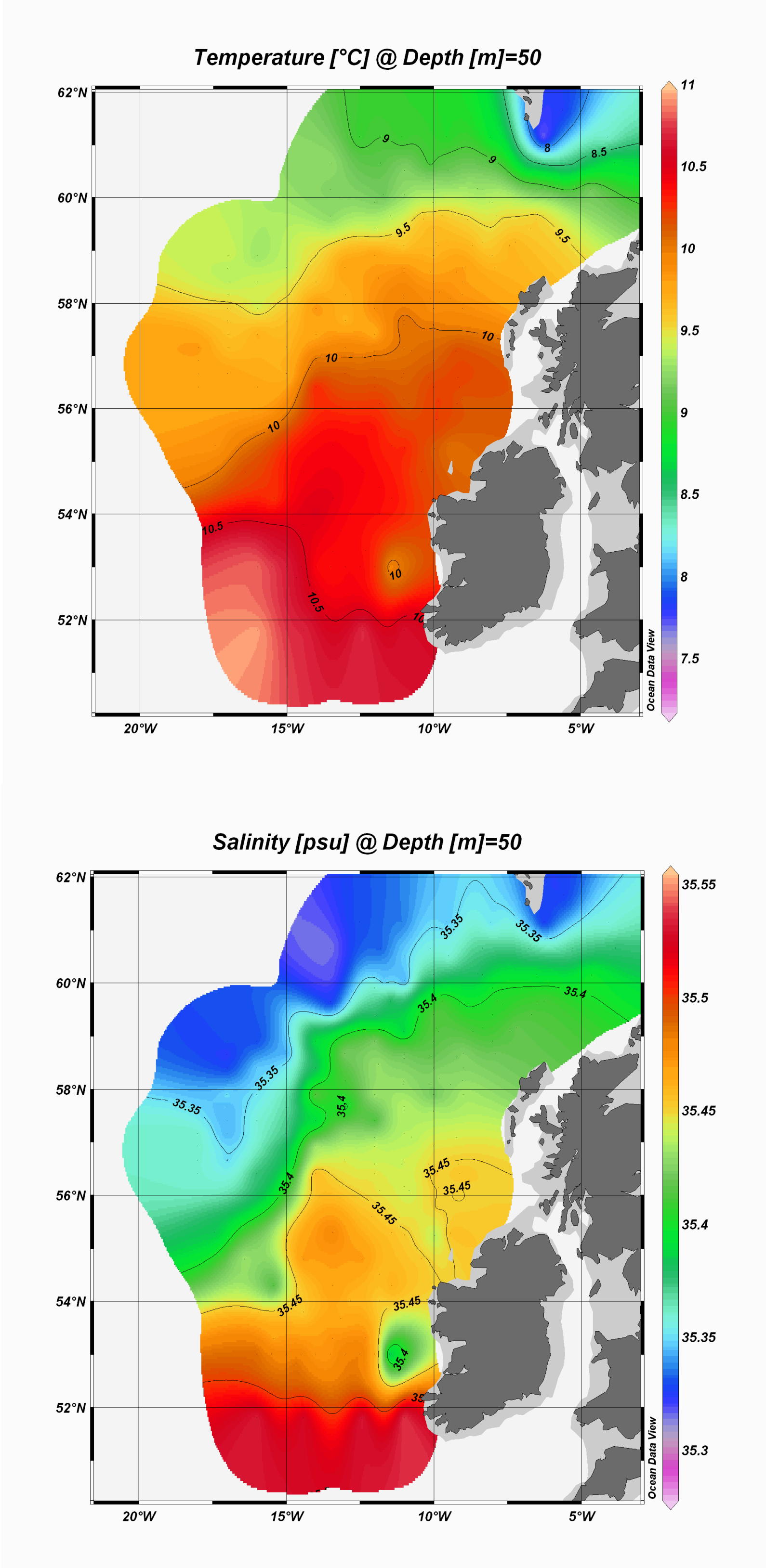
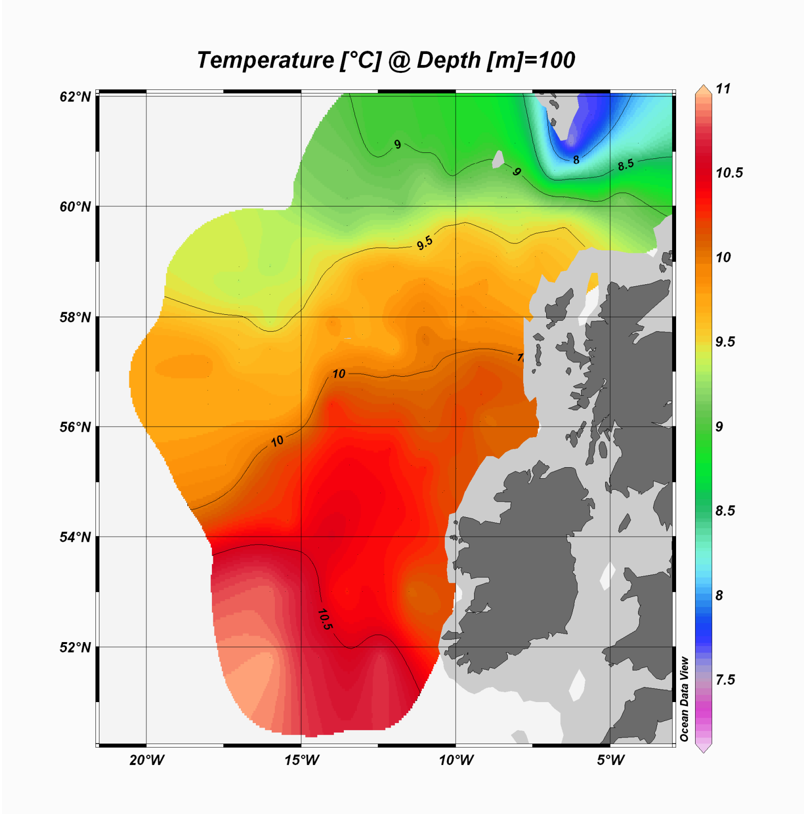


Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 50m as derived from vertical CTD casts. March-April 2010.



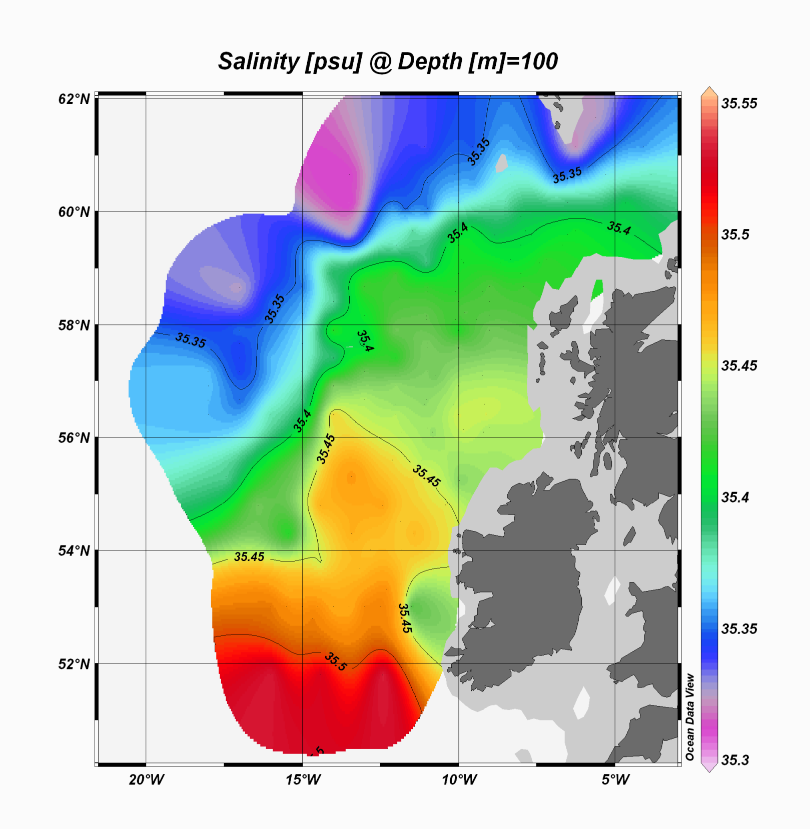


Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 100m as derived from vertical CTD casts. March-April 2010.

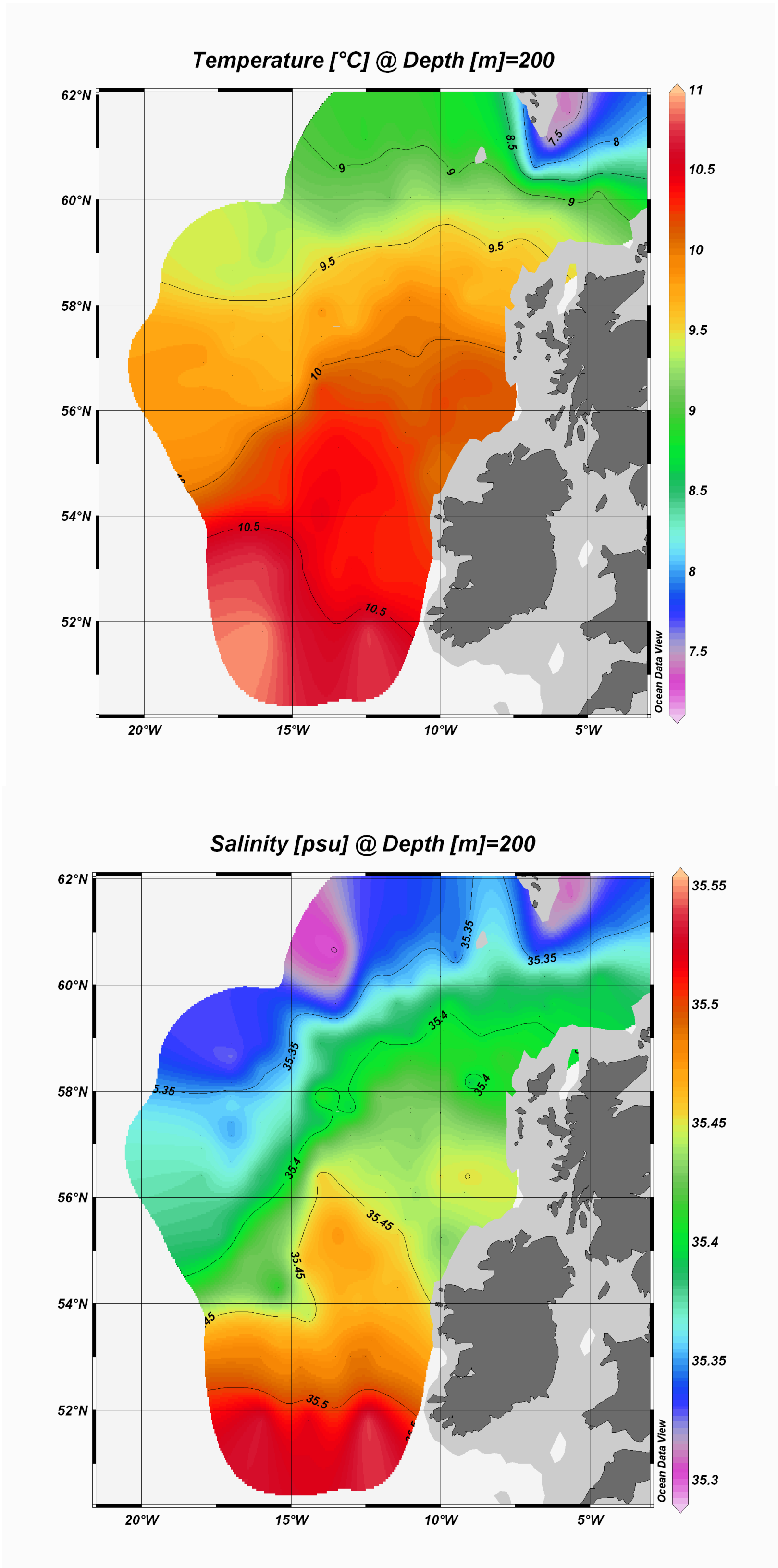


Figure 14. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2010.

Appendix 1. Uncertainty in the acoustic observations and its implications on the stock estimate

Ciaran O'Donnell

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 in previous years (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 1 nmi ESDU (elementary sampling distance units). 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 1 nmi). 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 here 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 2010 survey as well six earlier international surveys. Mean acoustic density over the survey area is 174.2 m^2/nm^2 (as compared to 378 m^2/nm^2 in 2009) with 95% confidence interval being 145…206 m^2/nm^2. Relative to the mean, the approximate 95% confidence limits are –16%...+18%, and 50% confidence limits are –6.4%...+5.7%. This level of acoustic uncertainty is similar as observed in previous years with the exception of 2007. Overall mean acoustic density has shown a consistent decrease annually since 2007 and in 2010 is at the lowest in the time series.

Figure 2 summarizes the results and puts them in the biomass context. The results clearly show that the observed consistent decline in biomass from 2008 to 2010 is more uncertainty than could be accounted for from spatial heterogeneity alone and is regarded as statistically significant. However, due to the gap in area coverage in an area likely to contain blue whiting the overall estimate and the acoustic values used to generate these confidence intervals could be revised upwards. That said the overall trend indicates a continued decrease year-on-year in biomass for this stock.

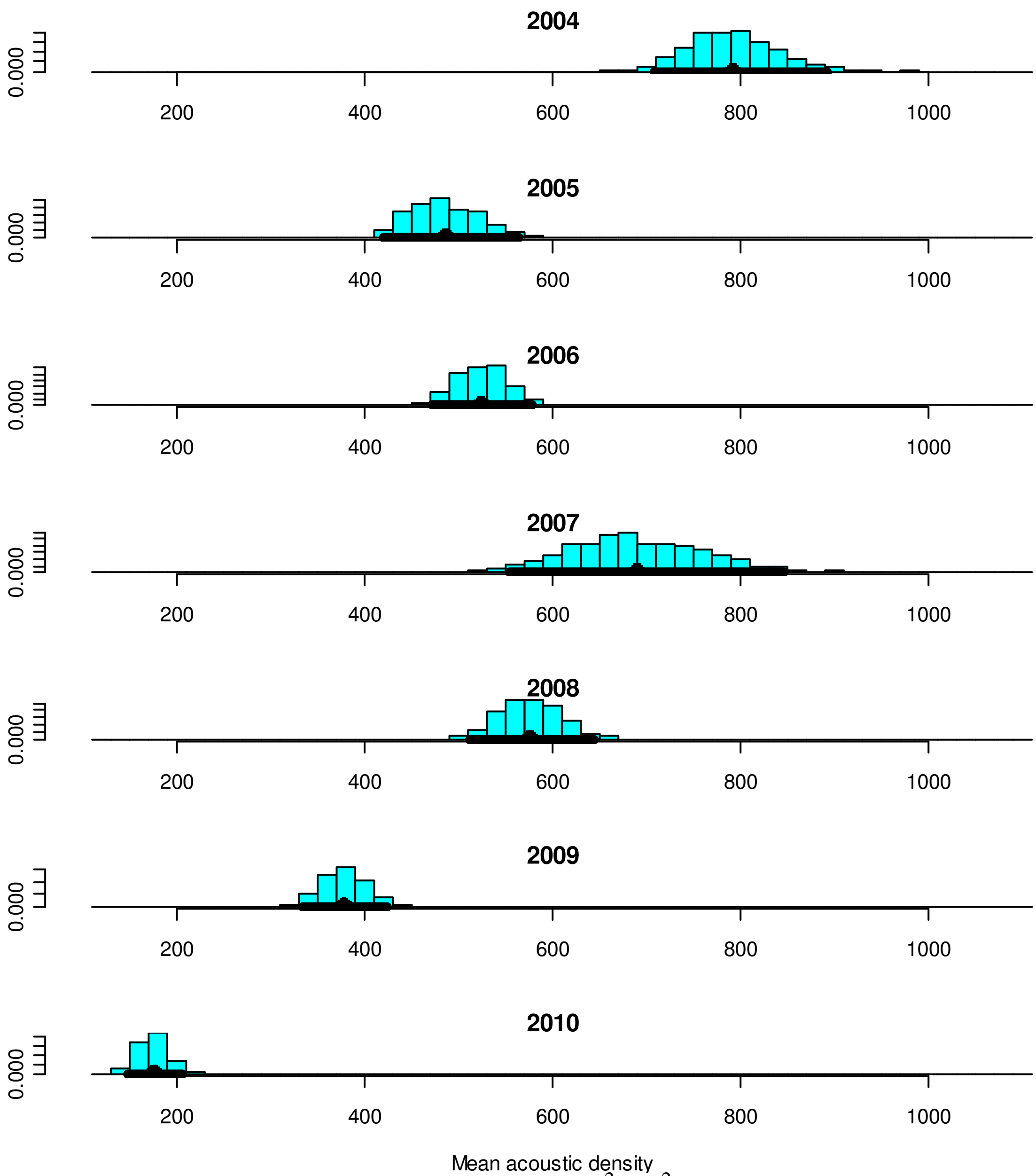


Figure 1. Distribution of mean acoustic density (in m^2/nm^2) by year based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

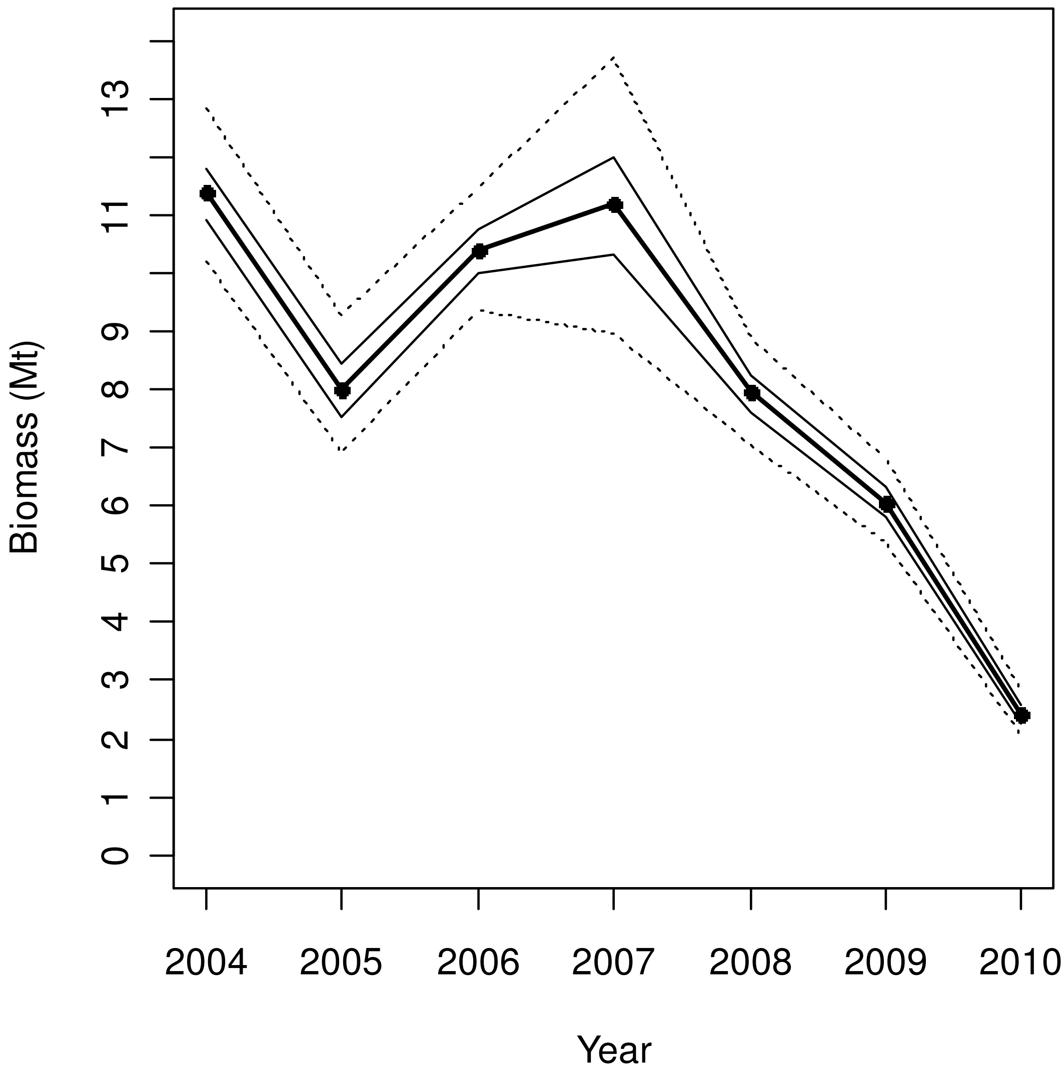


Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations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

Appendix 2. Review of age determination of blue whiting by national participants.

Åge Høines and Øyvind Tangen

A review on the consistency of age readings was carried out using the data collected during the 2010 survey. Results show mixed agreement across participants for most age classes. The most striking difference is the Russian age readings compared to the others, with older ages for the smallest fish and opposite for the bigger fish. The Russian age readings also show higher variation in length across the age estimates.

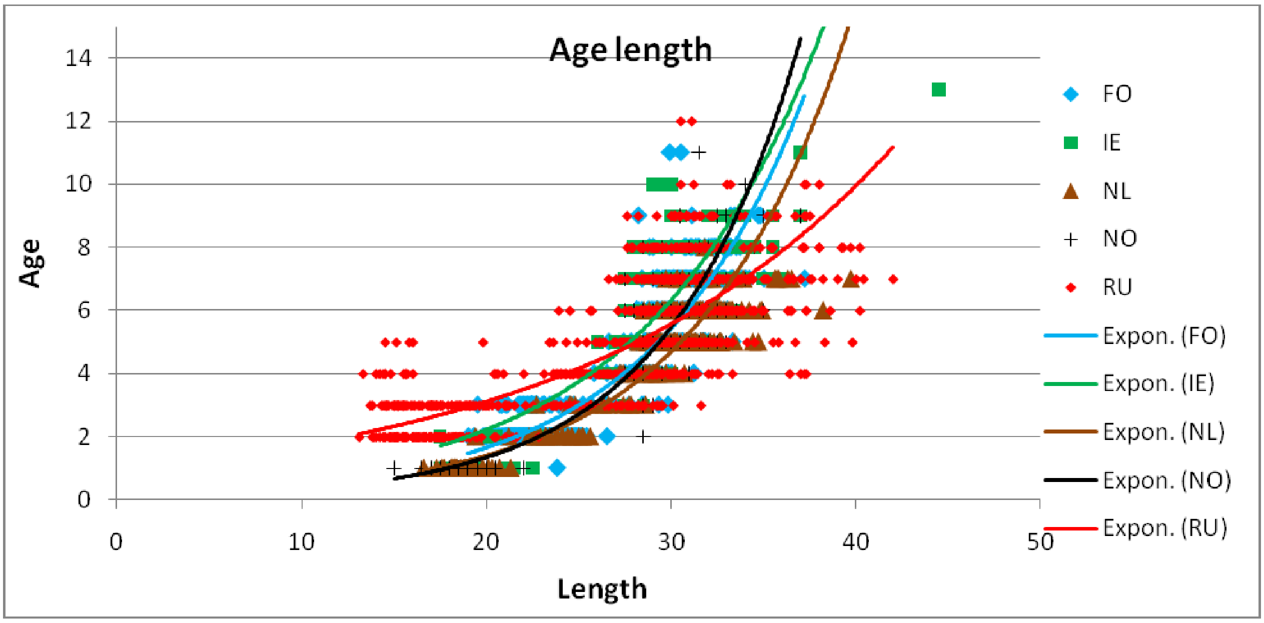


Figure 1. Profile of national age estimates as determined from otolith reading of trawl samples carried out over all individual blue whiting surveys in 2010 (FO; Faroes, IE; Ireland, NL: Netherlands, NO; Norway and RU; Russia).

Appendix 3. Agreed survey coverage and effort allocation as taken from the PGNAPES report 2009 for the 2010 blue whiting survey program.

Ciaran O'Donnell

It is planned that five parties; Faroe Islands, the Netherlands (EU-coordinated), Ireland (EU-coordinated) Norway and Russia, will contribute to the survey of blue whiting stock survey in March-April 2010.

Survey timing and design were discussed in some detail. It was decided to that the survey should be reduced temporally from 4 to 3 weeks in a bid to reduce the effects of double counting of northward migrating schools. Careful consideration was given to the start and end time of this 3 week window so as to not adversely affect the integrity of the time series while still providing synoptic coverage. The group agreed that the stock was well contained within the existing geographical bounds and that the allocation of effort was well balanced. The group also agreed that survey design, in terms of transect structure, is effective and should be maintained in 2010. To ensure transect coverage was not replicated the start points of each participant will be randomised in 2010.

Area allocation for each survey participant is listed below and Figure 1 shows the position of target areas described in the text.

Ship	Nation	Vessel time (days)	Active survey time (days)	Preliminary survey dates	Primary target area [secondary]
Celtic Explorer	EU (Ireland)	21	18	17/3–7/4	1 [2c]
G.O. Sars	Norway	18	14	21/3–4/4	1 [2a,b]
Magnus Heinason	The Faroes	14	11	25/3–7/4	2c [1]
Tridens	EU (Netherlands)	21	14	17/3–7/4	2a [1,3a]
Vilnus or F. Nansen	Russia	30	21	17/3-7/4	2a [1,2c]

Preliminary cruise tracks for the 2010 survey are presented in Figure 2.

As survey coordinator in 2010 Ireland has been tasked with communicating cruise tracks and survey coverage to the group. Detailed cruise lines for each ship will be agreed and circulated to the group as soon as final vessel availability and dates has been decided. As the survey is planned with inter-vessel cooperation in mind it is hoped that participants will stick to the planned transect positioning to ensure that survey effort is evenly allocated within the survey area as observed during the planning stages.

The survey will be carried according to survey procedures described in the "Manual for Acoustic Surveys on Norwegian Spring Spawning Herring in the Norwegian Sea and Acoustic Surveys on Blue whiting in the Eastern Atlantic" (PGNAPES report 2008).

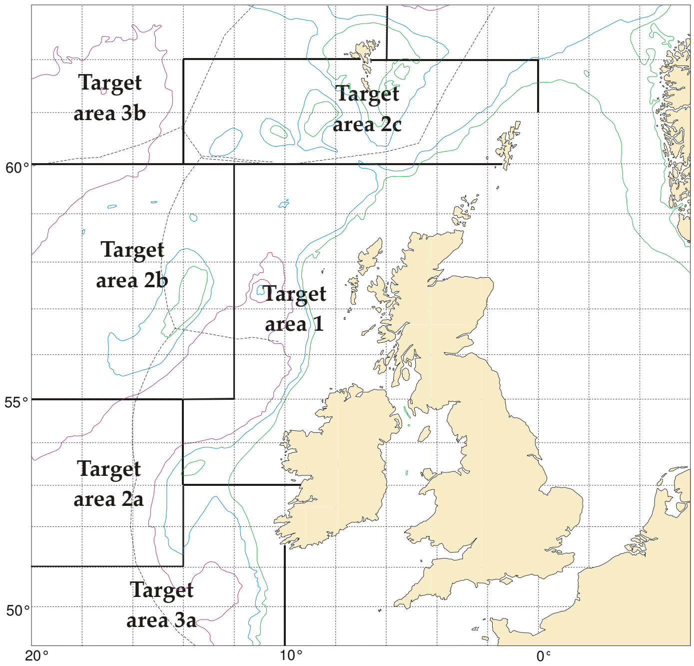


Figure1. Target areas for the International blue whiting spawning stock surveys.

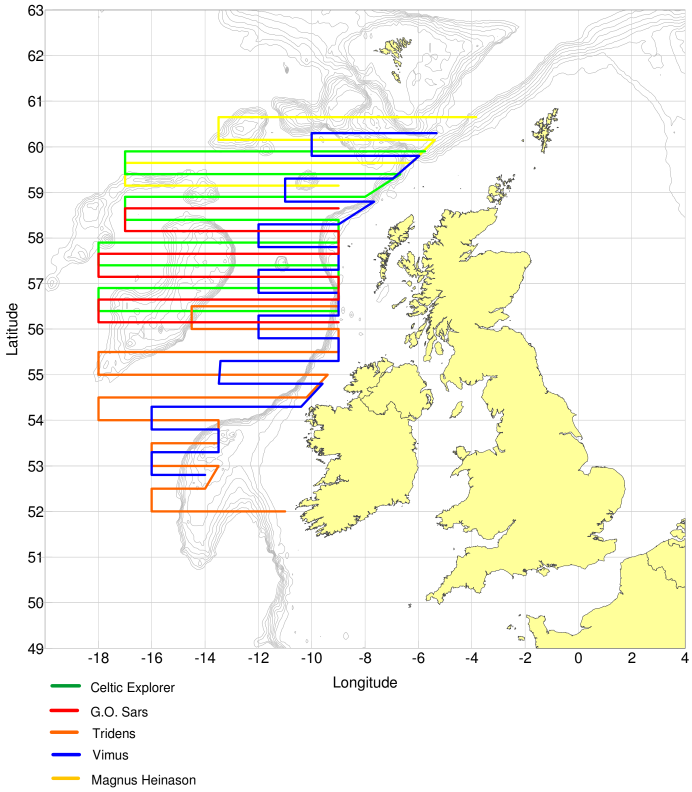


Figure 2. Preliminary survey tracks for the 2010 International blue whiting spawning stock.