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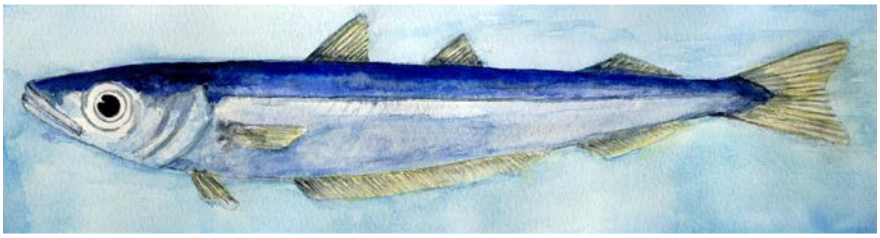

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2012

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Material and methods

Survey planning and Coordination

Coordination of the survey was initiated in the meeting of the Working Group on Northeast Atlantic Pelagic Ecosystem Surveys (WGNAPES, ICES 2011) and continued by correspondence until the start of the survey. During the survey, updates on vessel positions and trawl activities were collated by the survey coordinator and distributed to the participants twice a day. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Fridtjof Nansen	**PINRO, Murmansk, Russia**	**24/3 – 6/4**
Celtic Explorer	**Marine Institute, Ireland**	**24/3 – 5/4**
Brennholm	**Institute of Marine Research, Bergen, Norway**	**28/3 – 8/4**
Magnus Heinason	**Faroe Marine Research Institute, Faroe Islands**	**31/3–8/4**
Tridens	**Institute for Marine Resources & Ecosystem Studies (IMARES), the Netherlands**	**26/3–5/4**

The survey design used and described in ICES (2011) allowed for a flexible setup of transects and good coverage of the spawning aggregations. Due to favourable weather conditions throughout the survey period and full vessel availability, the survey resulted in a high quality coverage of the stock. Transects of all vessels were consistent in spatial coverage and timing, delivering full coverage of the respective distribution areas within 2 weeks.

Cruise tracks and trawl stations for each participant vessel are shown in Figure 1. Figure 2 shows combined CTD stations. All vessels, apart from Magnus Heinason worked in a northerly direction (Figure 3). Regular communication between vessels was maintained during the survey (via email and internet weblog) exchanging blue whiting distribution data, echograms, fleet activity and biological information.

Sampling equipment

All vessels employed a 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. This year, an inter-calibration was carried out involving the Celtic Explorer and Tridens. Results of this exercise are described in Appendix 3.

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 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 1000 m in open water. Hydrographic equipment specifications are summarized in Table 5.

Acoustic data processing

Acoustic scrutiny was mostly based on categorisation by experienced experts aided by trawl composition information. Post-processing software and procedures differed among the vessels:

On Fridtjof Nansen, the FAMAS 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 Myriax's EchoView (V 4.8) post-processing software for the previous day's work. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On Brennholm, the acoustic recordings were scrutinized using the Large Scale Survey System (LSSS) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using Sonar data's Echoview (V 5.1) 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 backed up continuously and scrutinized every 24-48 hrs using the Large Scale Survey System LSSS (V 1.5.1) post processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

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 200 m.

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). Following the decisions made at the “Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES)” (ICES 2012), the target strength (TS)-to-fish length (L) relationship (Pedersen et al. 2011) used is:

$$TS = 20 \log_{10} (L) - 65.2$$

For conversion from acoustic density (s_A, $m^2/n.m.^2$) to fish density (ρ) the following relationship was used:

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

where $\langle\sigma\rangle = 3.795 \cdot 10^{-6} L^{2.00}$ 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 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

One inter-calibration exercise was carried out between the *RV Celtic Explorer* and the *RV Tridens* on the 5th April in the northern survey area along the shelf edge. The results of this exercise are presented in Appendix 3.

Distribution of blue whiting

Unlike in the previous year's survey, the Rockall subarea was covered in 2012. However, observed densities of blue whiting in that area were low. Blue whiting were recorded in all areas surveyed. In total 8,629 n.m. (nautical miles) of survey transects were completed. The total area of all the sub-survey areas covered was 88,746 n.m.² (Figure 1, Tables 1 & 3).

Compared to the combined survey in 2011, the survey coverage was up by 29% overall. The majority of this increase was attributed to coverage of the Rockall area and an increase in the Faeroese area. The S. Porcupine area saw an increase in coverage by 28% and the Hebrides area were covered in the same extent as the year before.

The highest concentrations of blue whiting were recorded in the Hebrides core area which remains consistent with the results from previous surveys (Figure 7, Table 3a). Overall the bulk of the stock was centred in the core area as in 2011 (Figures 4 & 5). Medium and high density registrations were concentrated along the shelf slope. Medium to high density were distributed almost entirely within a narrow band running close the shelf edge.

Stock size

The estimated total abundance of blue whiting for the 2012 international survey was 2.22 million tonnes, representing an abundance of 18.2×10^9 individuals (Figure 6, Tables 3 & 4). Spawning stock was estimated at 2.12 million tonnes and 16.5×10^9 individuals. In comparison to the 2011 survey estimate, there is a significant increase (+38%) in the observed stock biomass and a related increase in stock numbers (+50%).

		2004	2005	2006	2007	2008	2009	2010	2011	2012	Change from 2011 (%)
Biomass	Total	3.6	2.6	3.4	3.6	2.6	2	1.3	1.6	2.2	38%
(mill. t)	Mature	3.6	2.4	3.3	3.6	2.6	2	1.3	1.5	2.2	47%
Numbers	Total	41.9	29	34.7	33.5	22.1	15.2	9.3	12.1	18.2	50%
(10^9)	Mature	39.2	26.7	33.8	32.9	21.7	15.0	8.9	9.7	16.5	70%
Survey area (nm^2)		149,000	172,000	170,000	135,000	127,000	133,900	109,320	68,851	88,746	29%

The Hebrides core area was found to contain 71% of the total biomass observed during the survey and is consistent but slightly lower with the result of last years surveys (76% in 2011 relative to total stock biomass for that year). The Faroes/Shetland and north Porcupine areas ranked second and third highest contributing 16% and 11% to the total respectively. The breakdown of survey biomass by sub area is shown below:

	Sub-area	Biomass (million tonnes) 2011	% of total	2012	% of total	Change (%)
I	S. Porcupine Bank	0.01	1	0.01	1	0%
II	N. Porcupine Bank	0.08	5	0.25	11	213%
III	Hebrides	1.20	76	1.58	71	32%
IV	Faroes/Shetland	0.28	18	0.37	16	32%
V	Rockall	-	-	0.01	0	NA

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. Results show good agreement across participants for all age classes with a broad range of lengths for the youngest and oldest fish in the range.

The stock biomass within the survey area is dominated by age classes 3, 7, 8 and 6 of the 2009, 2005, 2004 and 2006 year classes respectively (Table 4), contributing over 65% of spawning stock biomass.

The Hebrides area remains the most productive in the current survey time series and has consistently contributed over 50% to the total SSB (Figure 6). The age profiles of the other sub-areas were additionally represented by younger age classes (3, 2 and 1-year old). The Faroe/Shetland and Porcupine sub-areas were strongly dominated by 1-3 year old fish.

Young blue whiting were represented to various extents in all sub areas in 2012 (Figure 9). Maturity analysis of survey samples indicate that 25% of 1-year old, 59% of 2-year old and 97% of 3-year old fish were mature as compared to the 2011 estimates, where 8% of 1-year old fish, 22% of 2-year old fish and 84% of 3-year old fish were considered mature (Tables 4).

From the survey data, the Faroese/Shetland sub-area was found to contain significant proportion of young blue whiting (1-3 years). This together represents 75% (275,000t) of the total biomass and 86% (3199 million individuals) of the total abundance in this area.

Overall, immature blue whiting from the estimate represented less than 3% (65,000t) of the total biomass and less than 10% (1732 million) of the total abundance recorded during the survey.

Hydrography

A combined total of 150 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 10-13 respectively.

Concluding remarks

Main results

- The 9th International Blue Whiting Spawning stock Survey 2012 shows an increase when compared to the 2011 estimate. The updated survey time series shows a recovery from the declining trend observed since 2007.
- Favourable weather conditions, full vessel availability and a survey design with increased focus on the majority of spawning aggregations resulted in a successful coverage of the whole survey area. The survey design would have allowed for flexible adaptation of transect coverage in case of vessel loss or delay, however given the aforementioned reasons, such action was not necessary, resulting in a high quality coverage of the survey area in space and time.
- The survey was carried out over 14 days this year, which is the same as in the previous year. This is well within the 21 day time window recommended to cover the spawning stock.
- Estimated uncertainty around the mean acoustic density is the lowest observed in the time series so far. It is about half as large as those observed in previous years with the exception of 2007 when a much higher uncertainty was recorded.
- The stock biomass within the survey area is dominated by age classes 3, 7, 8 and 6 of the 2009, 2005, 2004 and 2006 year classes respectively, contributing over 65% of spawning stock biomass
- Mean length (28.1 cm) and weight (123.5 g) are lower than the previous years. This can be attributed to the progression of the 3 dominate year classes and increasing contribution of young fish to the total stock biomass.
- A positive signal of 2 and 3-year old fish continues to be observed across all areas and the latter is now considered fully recruited to the spawning stock.

Interpretation of the results

- Compared to the main spawning area, densities of blue whiting aggregations observed in the Rockall area were low. Coverage will be continued as in previous surveys since this area is still considered important.
- The chosen survey design covered the area within 2 weeks with good temporal progression and degree of spatial coverage. Together with the 2011 survey, it was the shortest period required to complete coverage of the survey area.
- The 2012 estimate of abundance for the survey can be considered robust for those areas covered. Over 99% of the total biomass was observed in sub-areas surveyed by more than one vessel.
- Survey timing is fixed annually to coincide with peak spawning of the stock. In 2012 as in the three previous years, the time of peak spawning varied. However, in all these years the stock was contained within the survey area due to the extensive survey area and so estimates of abundance are credible.

Recommendations

- Participants are encouraged to share experience in otolith age reading and personnel on surveys. It is recommended that an age reading workshop is scheduled to improve consistency across survey participants (WGIPS).
- The same maturity scale needs to be used by all participants. To increase experience and consistency in maturity classification, a maturity workshop should run concurrently with the age reading workshop.
- The 2013 survey will be carried out as detailed in Appendix 4.

- It is the responsibility of individual survey participants to ensure that all data is screened prior to submission to the PGNAPES data base following the details outlined in the survey manual.

Achievements

- The whole survey area was covered within 14 days. In previous years (except 2011) the minimum time for achieved coverage was 28 days.
- Delivery of survey data in the PGNAPES format to Leon Smith was achieved in a timely fashion.
- Calibrated acoustic data was collected from 2 Dutch freezer trawlers actively involved in the fishery. The availability of these data may aid survey planning in the future and give additional information about blue whiting distribution on the spawning grounds.

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Table 1. Survey effort by vessel. March-April 2012.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling	Aged fish	Length-measured fish
Fridtjof Nansen	24/3 - 6/4	1,939	17	58	'	748	2,866
Celtic Explorer	24/3 - 5/4	1,808	15	19	'	680	2,049
Brennholm	28/3 - 8/4	1,925	15	28	27	421	1,600
Magnus Heinason	31/3 - 8/4	1,230	9	21	20	495	1,132
Tridens	26/3 - 5/4	1,727	13	24	'	850	950
Total		8,629	69	150	47	3,194	8,597

Table 2. Acoustic instruments and settings for the primary frequency. March-April 2012.

	Fridtjof Nansen	Celtic Explorer	Brennholm	Magnus Heinason	Tridens
Echo sounder	Simrad EK60	Simrad EK 60	Simrad EK 60	Simrad EK60	Simrad EK 60
Frequency (kHz)	**38, 120**	**38**, 18, 120, 200	**38**, 18, 200, 333	**38**	**38**, 120
Primary transducer	ES38B	ES 38B	ES38B	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Drop keel	Hull	Towed body
Transducer depth (m)	4.5	8.7	8	3	7
Upper integration limit (m)	10	15	10	7	15
Absorption coeff. (dB/km)	10	9.7	-	10.1	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	-	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	-	21.9	21.9
2-way beam angle (dB)	-20.79	-20.6	-	-20.9	-20.5
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.53	25.89	-	24.85	26.17
s_A correction (dB)	-0.58	-0.62	-	-0.59	-0.58
3 dB beam width (dg)					
alongship:	6.96	6.91	-	7.24	6.67
athw. ship:	6.95	6.92	-	7.12	7.04
Maximum range (m)	750	750	750	750	750
Post processing software	FAMAS	Sonardata Echoview	LSSS	Sonardata Echoview	LSSS

Table 3. Assessment factors of blue whiting for IBWSS March-April 2012.

Sub-area		Area	Numbers (10^9)			Biomass (10^6 tonnes)			Mean weight	Mean length	Density
		nmi^2	Mature	Total	%mature	Mature	Total	%mature	g	cm	ton/n.mile^2
I	S. Porcupine Bank	5,483	0.11	0.13	85	0.012	0.013	92	98.5	26.3	2.4
II	N. Porcupine Bank	20,242	2.22	2.63	84	0.239	0.254	94	96.6	26.1	12.5
III	Hebrides	35,894	10.96	11.66	94	1.554	1.576	99	135	29.4	43.9
IV	Faroes/Shetland	19,467	3.10	3.71	84	0.338	0.365	93	98.3	24.7	18.7
V	Rockall	7,660	0.08	0.08	100	0.011	0.011	100	138.3	30.0	1.4
Tot.		88,746	16.47	18.21	90	2.154	2.219	97	121.8	28	25.0

Table 4. Survey stock estimate of blue whiting, March-April 2012.

Length	Age in years (year class)										Numbers	Biomass	Mean	Prop.
Length	1	2	3	4	5	6	7	8	9	10+			weight	mature*
(cm)	2011	2010	2009	2008	2007	2006	2005	2004	2003		(*10-$^{6)}$	(10^6 kg)	(g)	(%)
11.0 – 12.0											0			
12.0 – 13.0											0			
13.0 – 14.0	9	0	0	0	0	0	0	0	0	0	9	0.1	12	0
14.0 – 15.0	6	5	0	0	0	0	0	0	0	0	11	0.2	15	0
15.0 – 16.0	65	19	5	0	0	0	0	0	0	0	89	2	22	4
16.0 – 17.0	90	88	27	0	0	0	0	0	0	0	205	4.9	24	12
17.0 – 18.0	226	141	21	0	0	0	0	0	0	0	388	11.1	29	17
18.0 – 19.0	298	121	54	0	0	0	0	0	0	0	473	16.1	34	9
19.0 – 20.0	182	197	23	0	0	0	0	0	0	0	402	15.9	40	22
20.0 – 21.0	150	129	13	7	0	0	0	0	0	0	299	14	47	37
21.0 – 22.0	73	90	31	4	0	0	0	0	0	0	198	11.1	56	67
22.0 – 23.0	46	116	65	0	0	0	0	0	0	0	227	14.9	66	92
23.0 – 24.0	26	263	398	29	3	0	0	0	0	0	719	55.3	77	94
24.0 – 25.0	7	254	1186	67	3	0	0	0	0	0	1517	124.2	82	98
25.0 – 26.0	0	205	1867	39	0	0	0	6	0	0	2117	187.2	88	99
26.0 – 27.0	0	106	1459	97	6	0	0	0	0	0	1668	158.7	95	100
27.0 – 28.0	0	75	943	178	15	7	7	0	0	0	1225	128.8	105	100
28.0 – 29.0	0	17	482	227	44	20	0	8	0	0	798	92.4	116	100
29.0 – 30.0	0	6	72	223	60	74	131	54	23	22	665	90.6	136	100
30.0 – 31.0	0	0	23	78	162	261	225	102	90	91	1032	152.6	148	100
31.0 – 32.0	0	0	3	35	109	319	449	305	242	135	1597	251.9	158	100
32.0 – 33.0	0	0	6	23	99	301	481	275	209	164	1558	266.7	172	100
33.0 – 34.0	0	0	0	6	18	214	333	296	230	182	1279	237	185	100
34.0 – 35.0	0	0	0	0	16	90	255	142	131	173	807	162.7	201	100
35.0 – 36.0	0	0	0	0	0	22	112	163	96	104	497	109.2	220	100
36.0 – 37.0	0	0	0	0	9	20	76	50	24	71	250	60.2	240	100
37.0 – 38.0	0	0	0	0	0	9	8	16	24	42	99	25.5	257	100
38.0 – 39.0	0	0	0	0	0	6	0	24	7	7	44	12.6	287	100
39.0 – 40.0	0	0	0	0	0	0	0	3	0	22	25	7.9	323	100
40.0 – 41.0	0	0	0	0	0	0	0	0	2	5	7	2.3	342	100
41.0 – 42.0	0	0	0	0	0	0	0	0	0	4	4	1.6	376	100
42.0 – 43.0	0	0	0	0	0	0	0	0	0	0	0	0	.	100
43.0 – 44.0	0	0	0	0	0	0	0	0	0	3	3	1.5	434	100
44.0 – 45.0														
TSN (10^6)	1178	1832	6678	1013	544	1343	2077	1444	1078	1025	18212	2219		
TSB (10^6 kg)	45.9	121.4	606.9	117.9	82.1	226.7	364.1	262.3	194.5	197.1	2219			
Mean length (cm)	18.8	22.2	25.8	28.1	30.9	32.1	32.6	33	33	34				
Mean weight (g)	39	66.3	90.9	116.4	150.9	168.4	175.5	181.7	180.4	210				
Condition (g/dm^3)														
% mature*	25	59	97	99	100	100	100	100	100	100				

* Percentage of mature individuals per age or length class

Table 5. Country and vessel specific details, March-April 2012.

	Fridtjof Nansen	Celtic Explorer	Brennholm	Magnus Heinason	Tridens
Trawl dimensions					
Circumference (m)	716	768	2300	640	1120
Vertical opening (m)	50	50	110	40	30-70
Mesh size in codend (mm)	16	20	40	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
Plankton sampling	0	5	27	16	0
Sampling net	-	Gulf Sampler	WP2 plankton net	WP2 plankton net	-
Standard sampling depth (m)	-	200	400	200	-
Hydrographic sampling					
CTD Unit	SBE19plus	SBE911	SAIV	SBE911	SBE911
Standard sampling depth (m)	1000	1000	1000	1000	1000

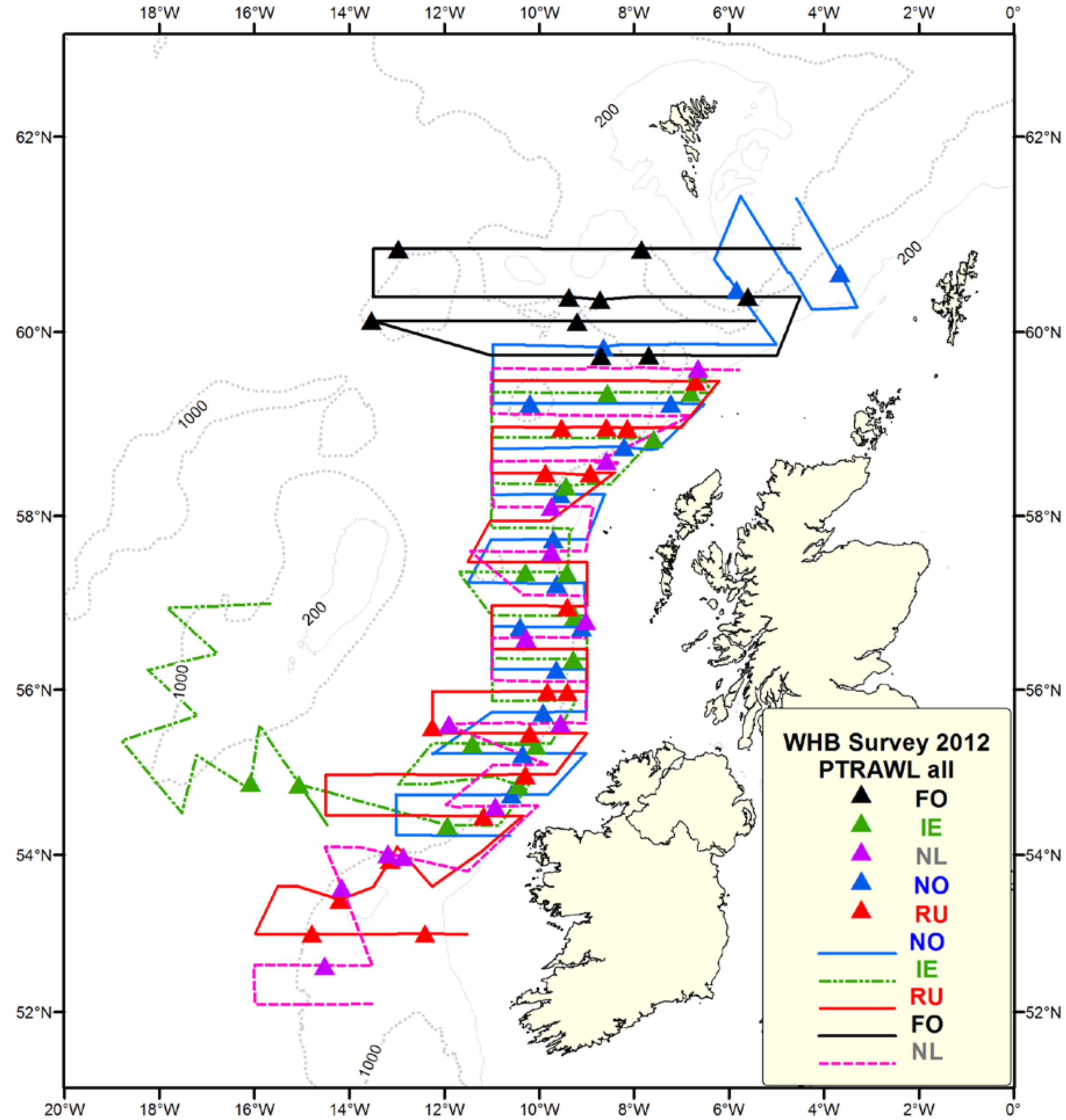


Figure 1. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning stock Survey (IBWSS) from March-April 2012. PT: Indicates pelagic trawl station. IE: Ireland (Celtic Explorer); FO: Faroese (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fridtjof Nansen): NO: Norway (Brennholm).

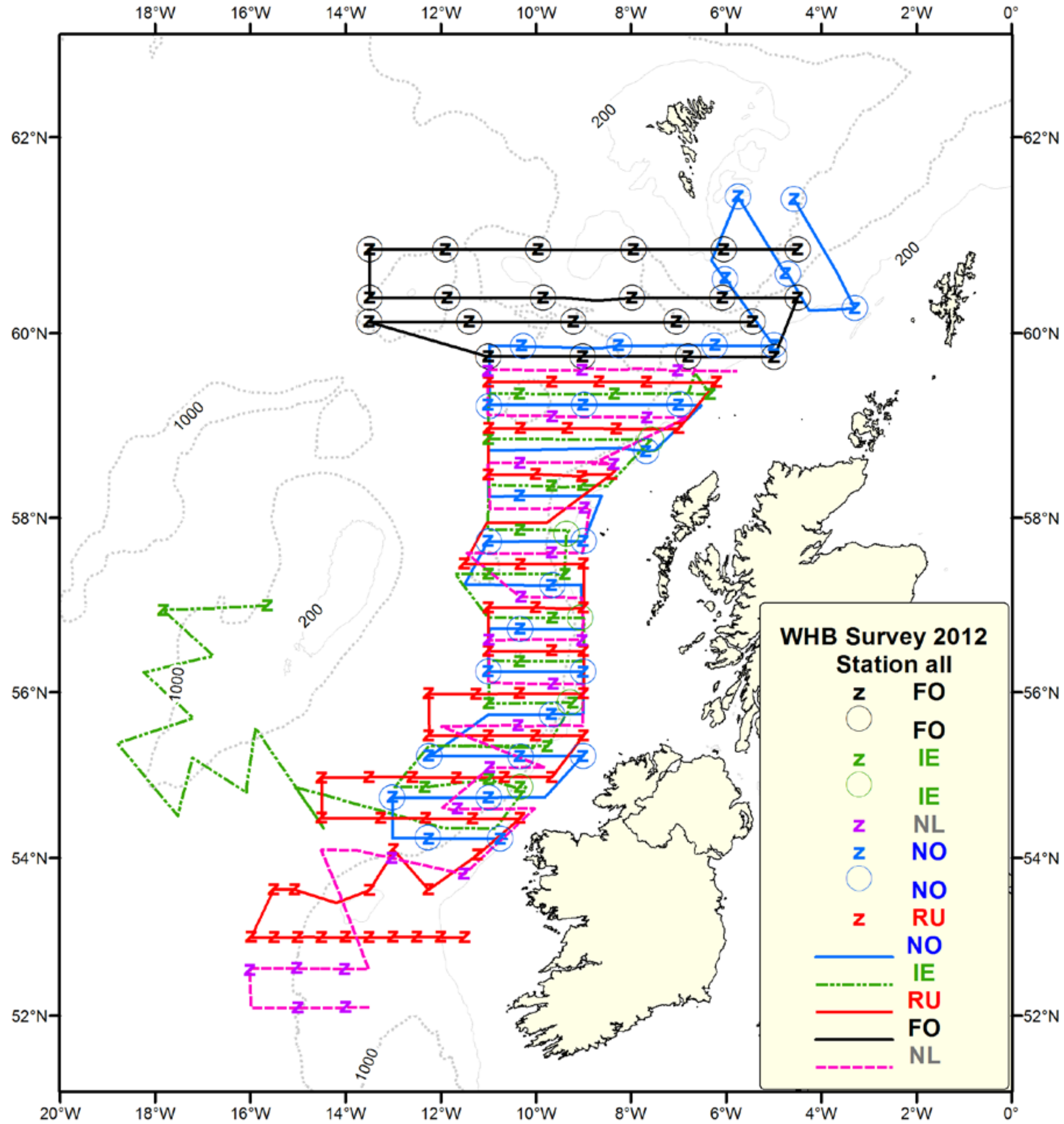


Figure 2. CTD stations overlaid onto vessel cruise tracks for the combined survey. WP II: plankton trawl. green: Celtic Explorer; black: Magnus Heinason; purple: Tridens; red: Fridtjof Nansen: blue: Brennholm. March-April 2012.

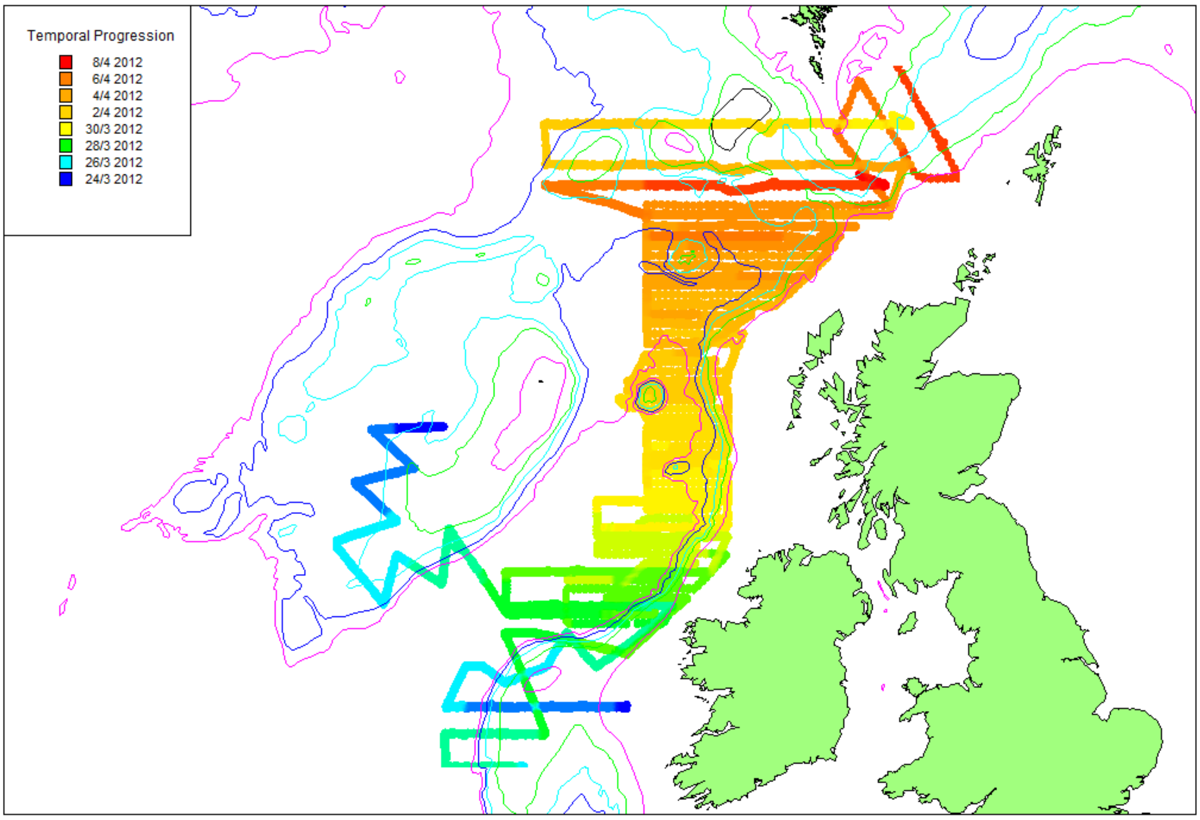


Figure 3. Temporal progression for the International Blue Whiting Spawning stock Survey (IBWSS), 24 March – 8 April 2012.

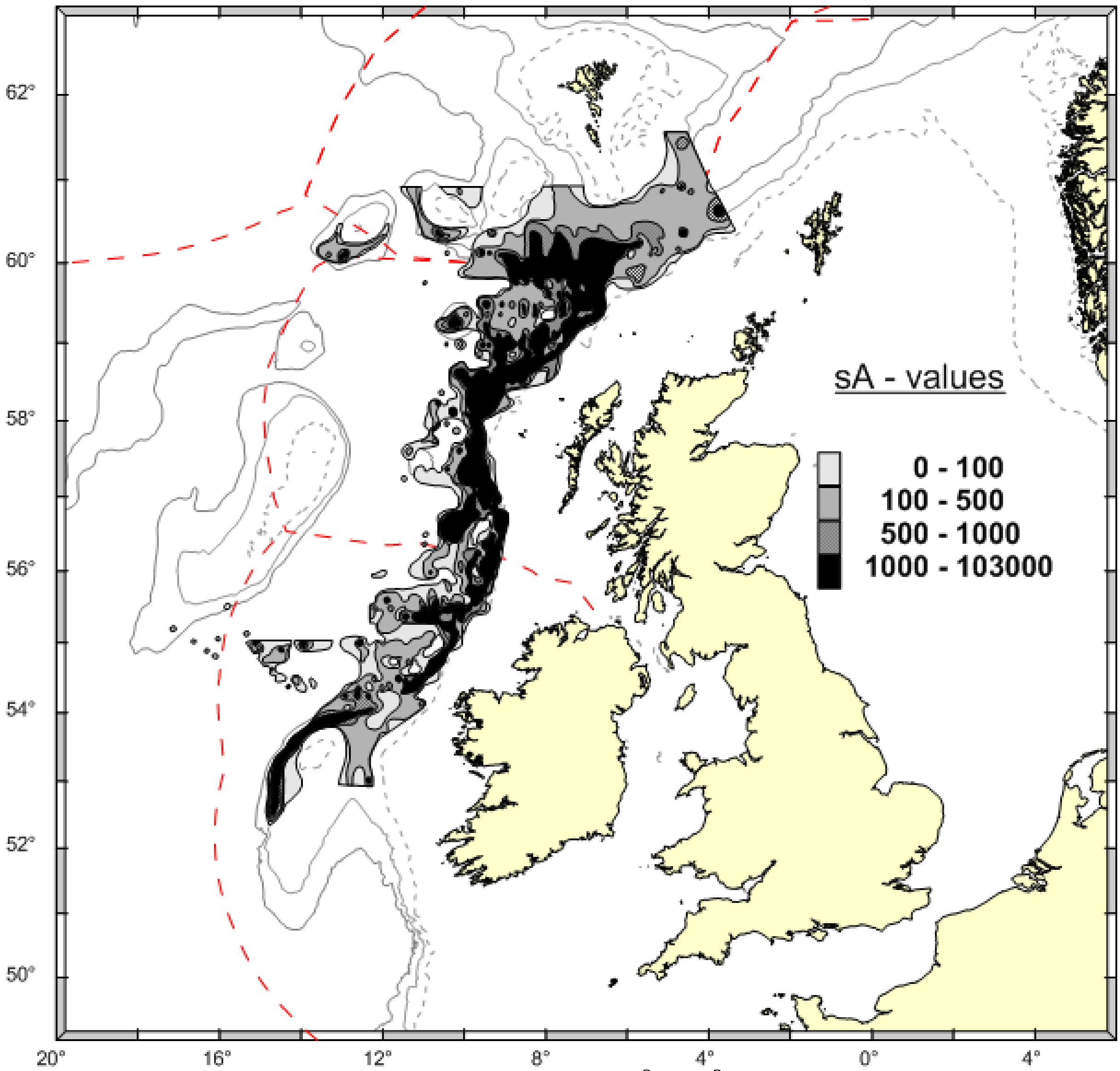


Figure 4. Map of blue whiting acoustic density (s_A, $m^2/n.m.^2$) , 24 March – 8 April 2012.

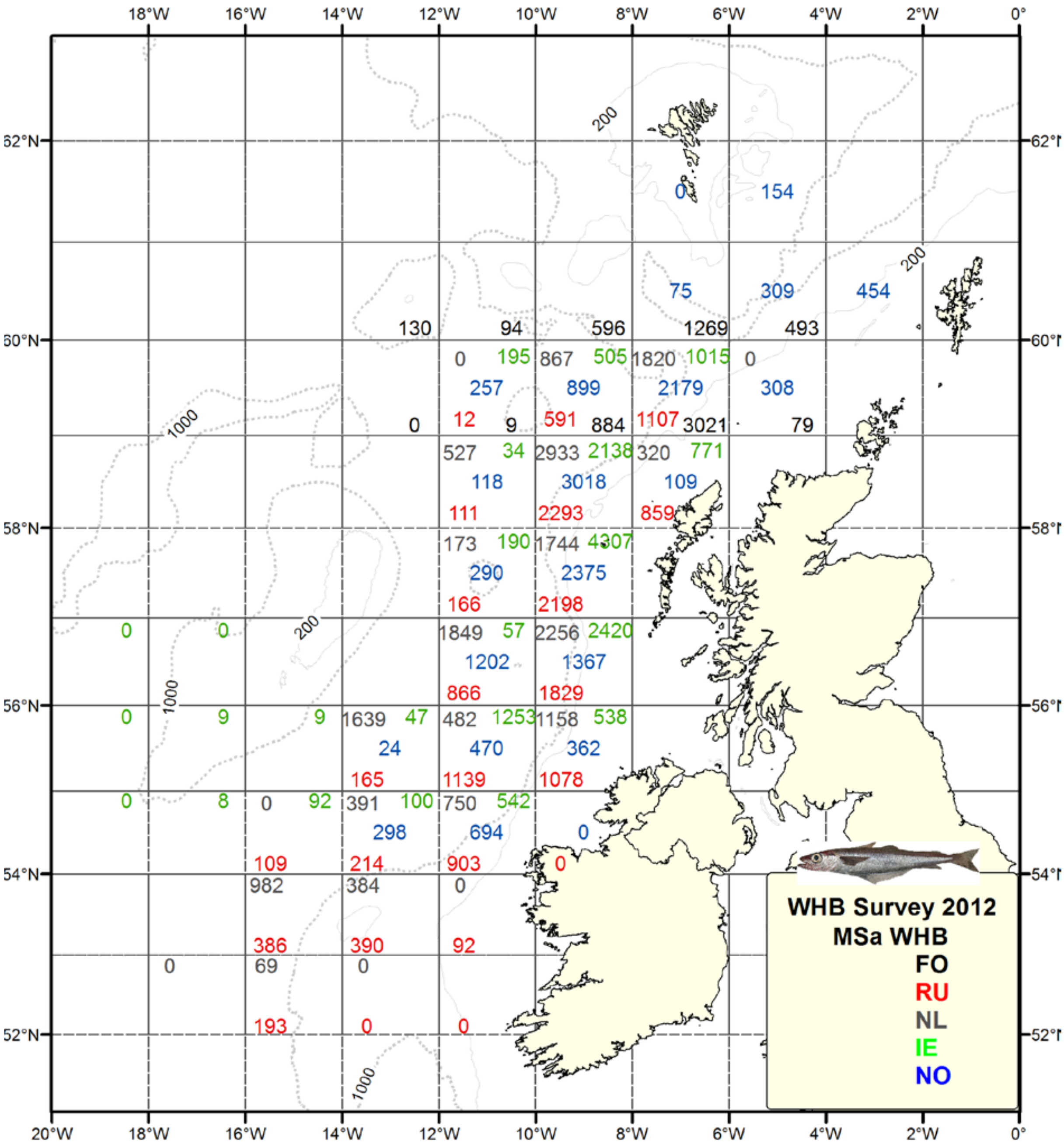


Figure 5. Mean blue whiting acoustic density (s_A, m^2/n.m.^{2}) for IBWSS 2012 by individual vessel: Celtic Explorer: green, Magnus Heinason: black, Tridens: grey, Fridtjof Nansen: red, Brennholm: blue. March-April 2012.

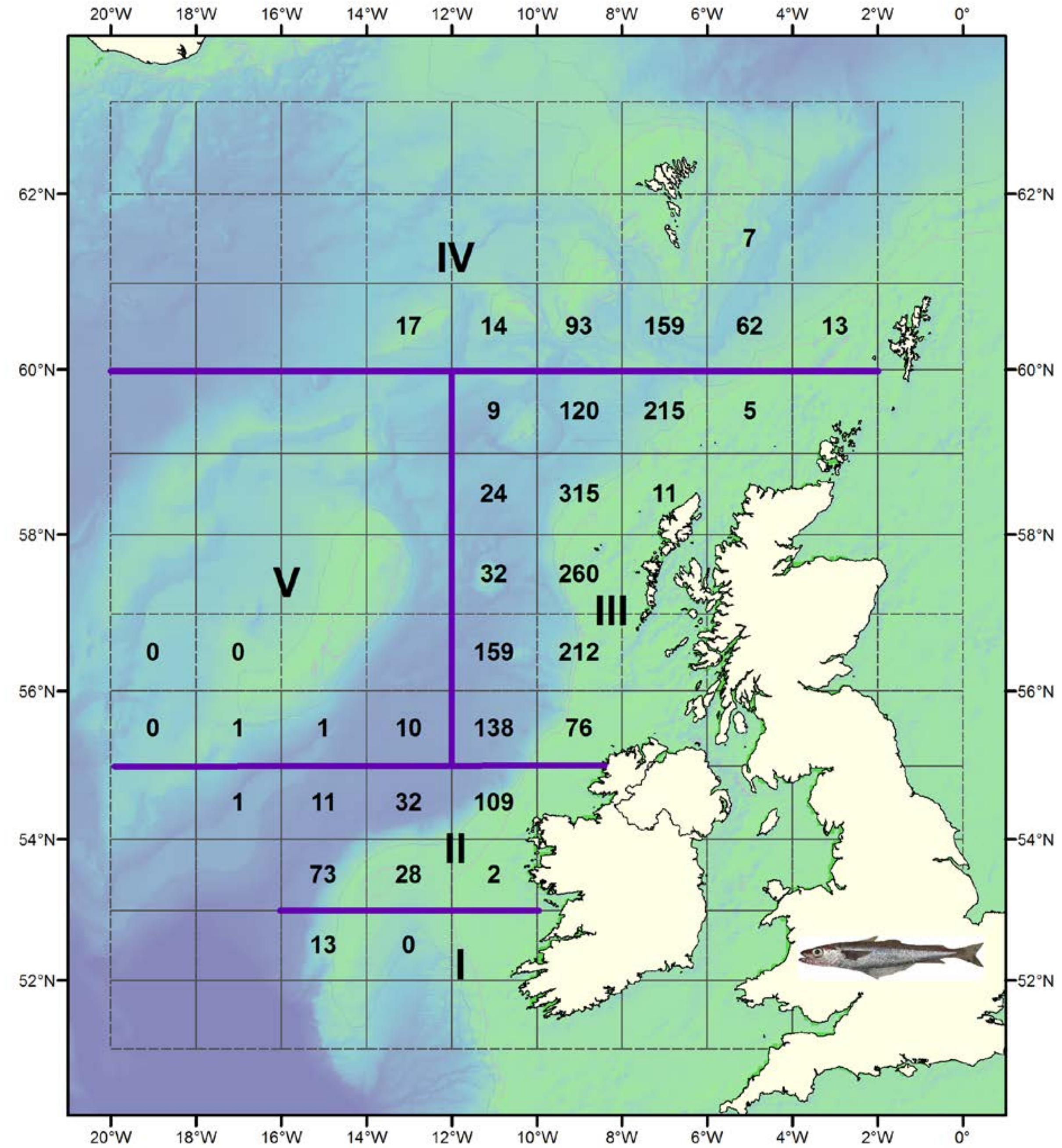
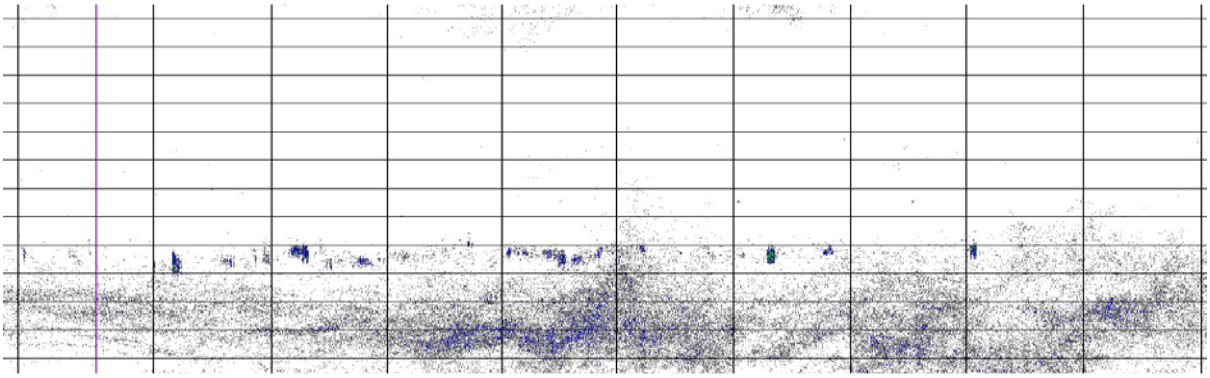
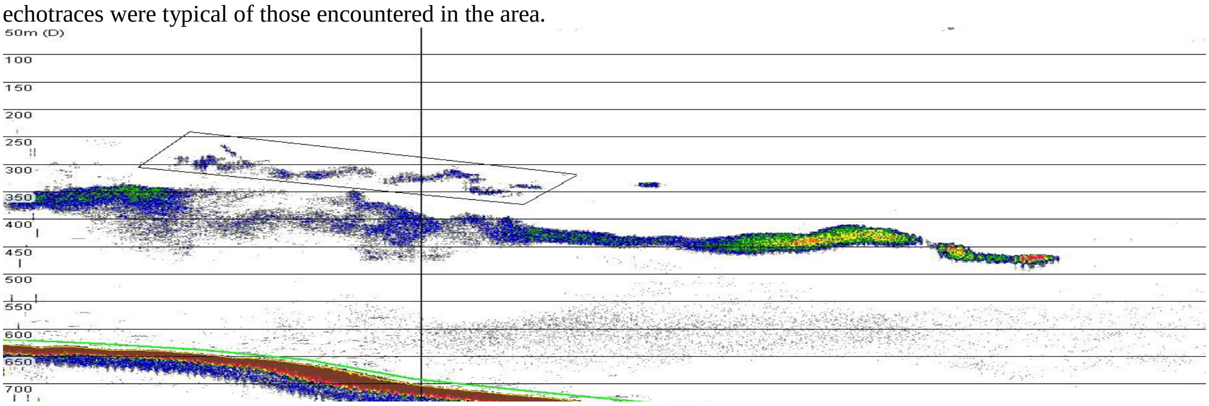


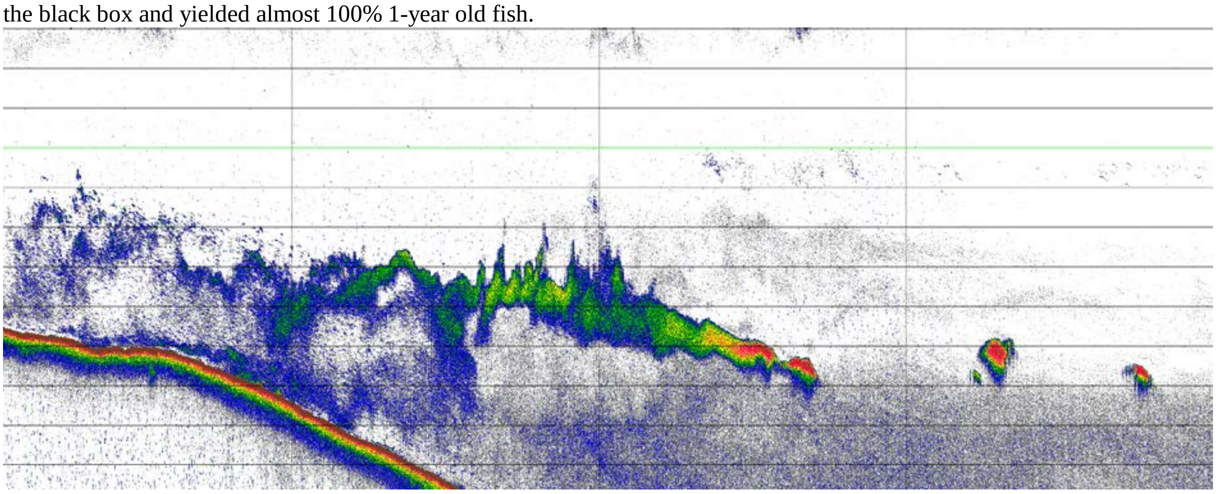
Figure 6. Blue whiting biomass by sub-area as used in the assessment.



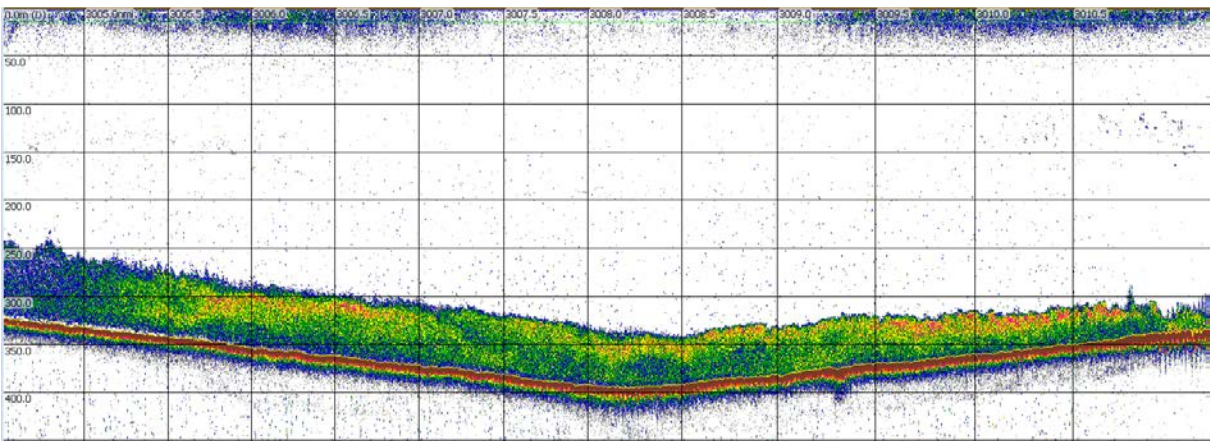
a). Low density blue whiting echotraces recorded to the southwest of the Rockall Bank by the RV *Celtic Explorer*. Such echotraces were typical of those encountered in the area.



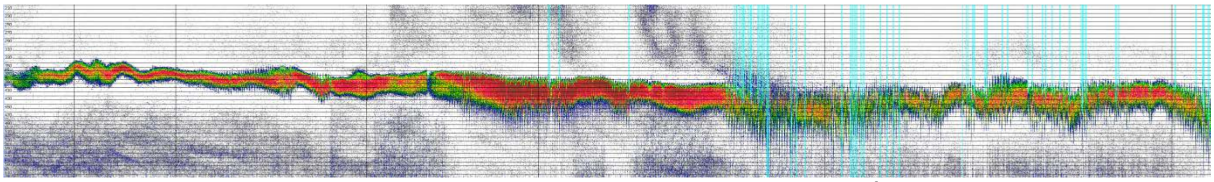
b). High density shelf edge echotrace recorded by the RV *Celtic Explorer*. The haul targeted the upper schools as outlined by the black box and yielded almost 100% 1-year old fish.



c) Blue whiting aggregation encountered by RV *Tridens* on 29.03. 14:41 UTC at 54°36’N 10°55’W.



d) Blue whiting school observed by RV *Tridens* on 28.03 at 6:44 UTC at 53.59N 14.15W.



e) Biggest blue whiting school observed in the survey (by RV *Tridens*), with a length of approximately 21 n.m., including Trawl 8, encountered on 01.04 at 5:40 UTC at 56.61N 10.27W.

Figure 7. Echograms of interest encountered during the combined International blue whiting survey in March-April 2012.

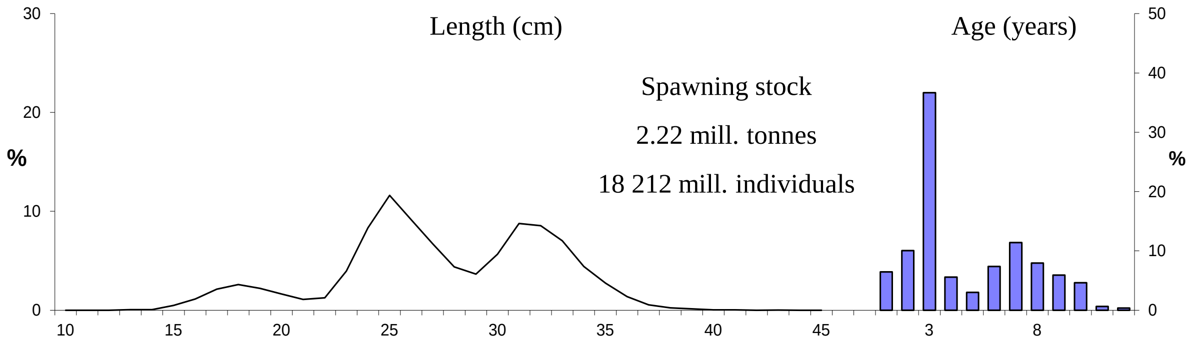


Figure 8. Length and age distributions (numbers) of total stock of blue whiting. Spawning stock biomass is given. March-April 2012.

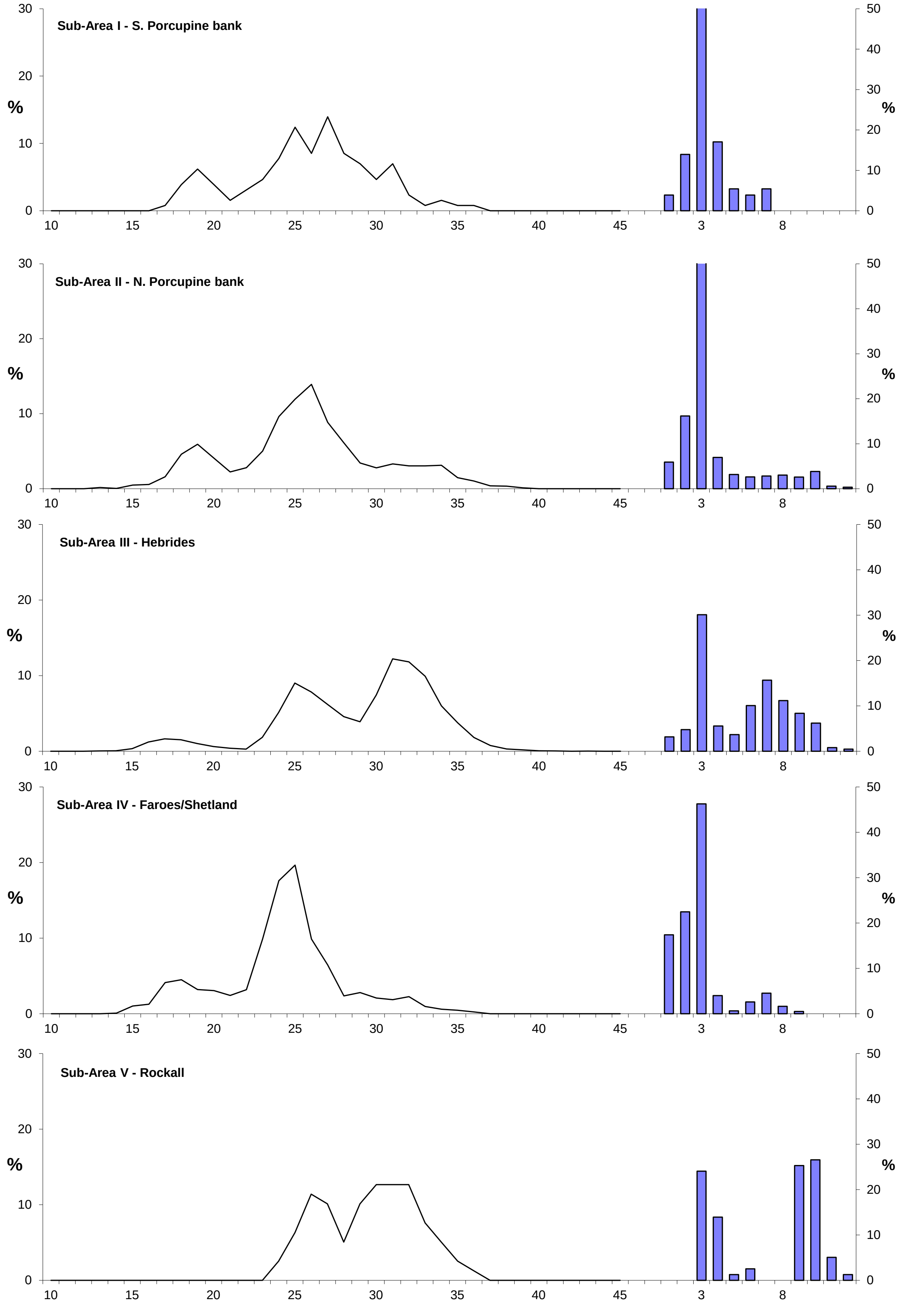


Figure 9. Length and age distribution (numbers) of blue whiting by covered sub-area (I–V). March-April 2012.

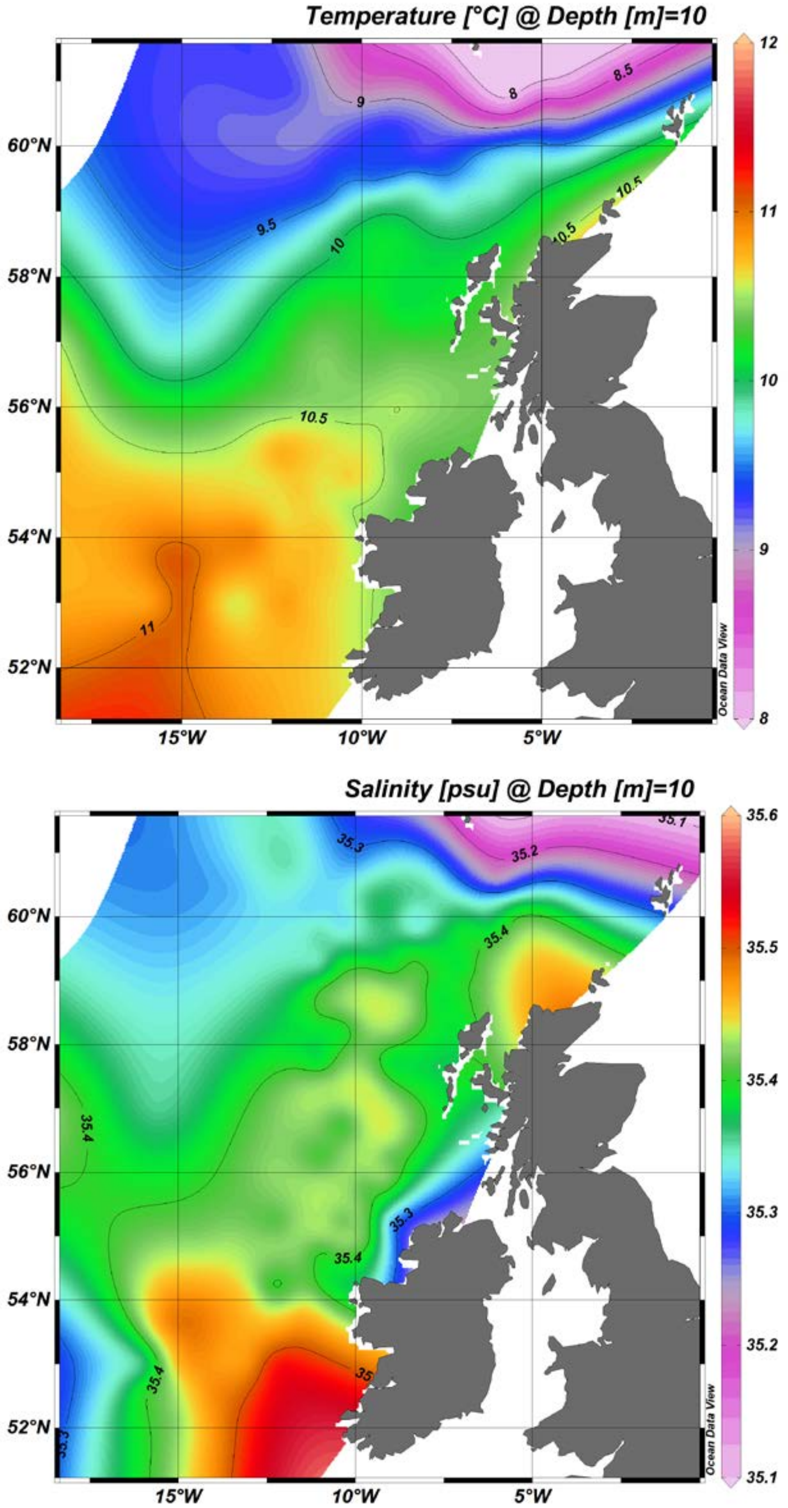


Figure 10. Horizontal temperature (top panel) and salinity (bottom panel) at 10m subsurface as derived from vertical CTD casts. March-April 2012.

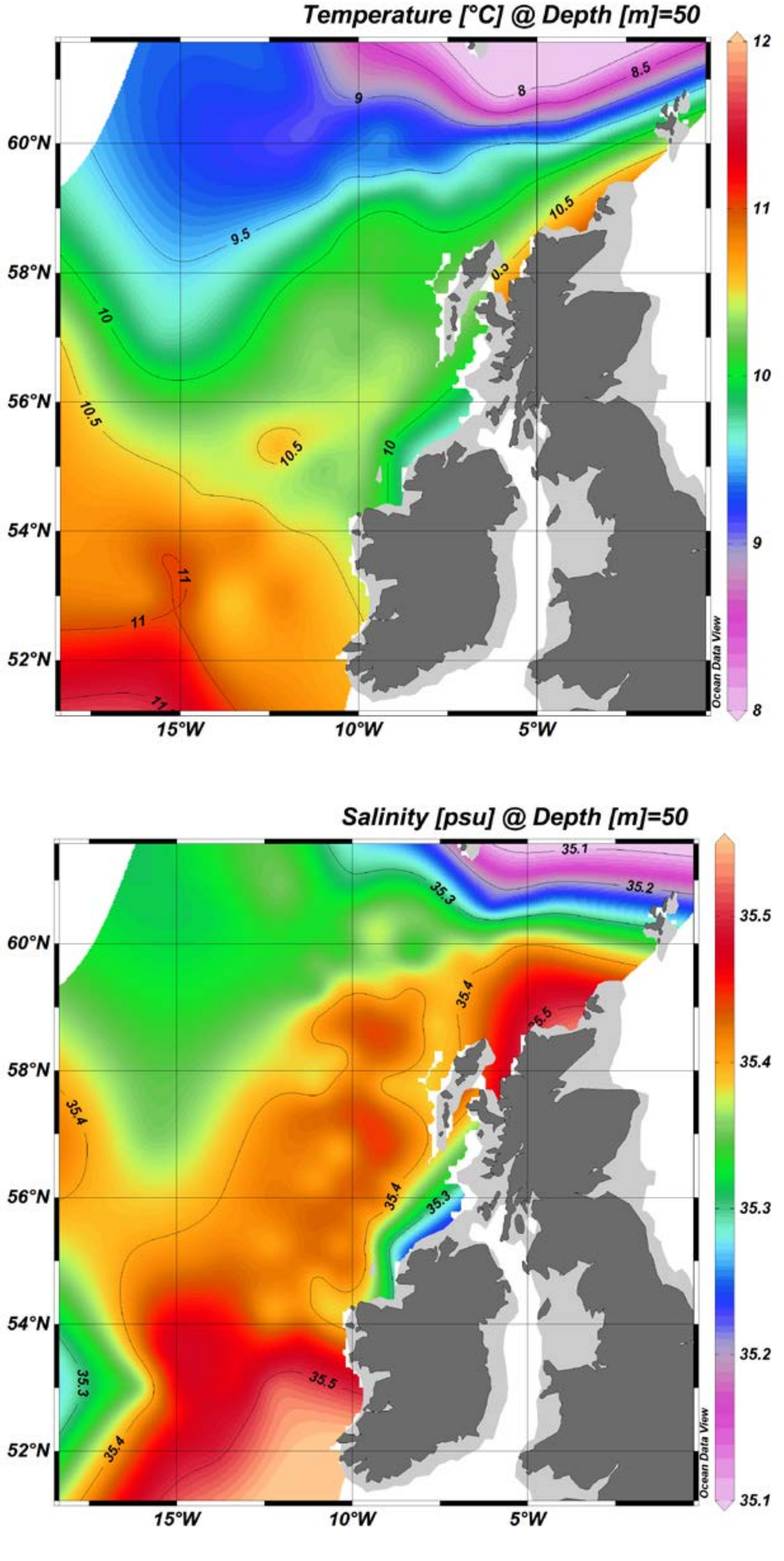


Figure 11. Horizontal temperature (top panel) and salinity (bottom panel) at 50m as derived from vertical CTD casts. March-April 2012.

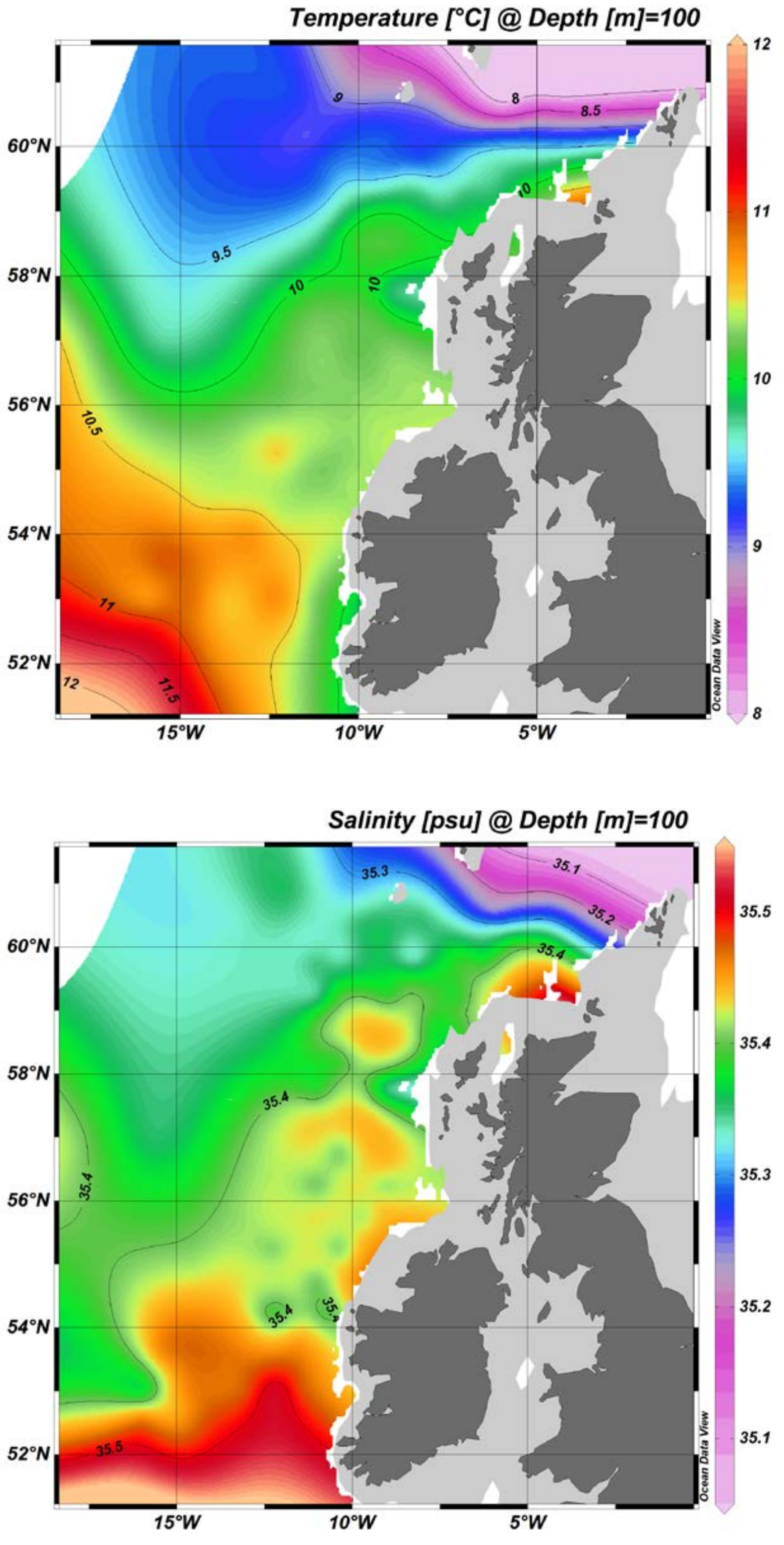


Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 100m as derived from vertical CTD casts. March-April 2012.

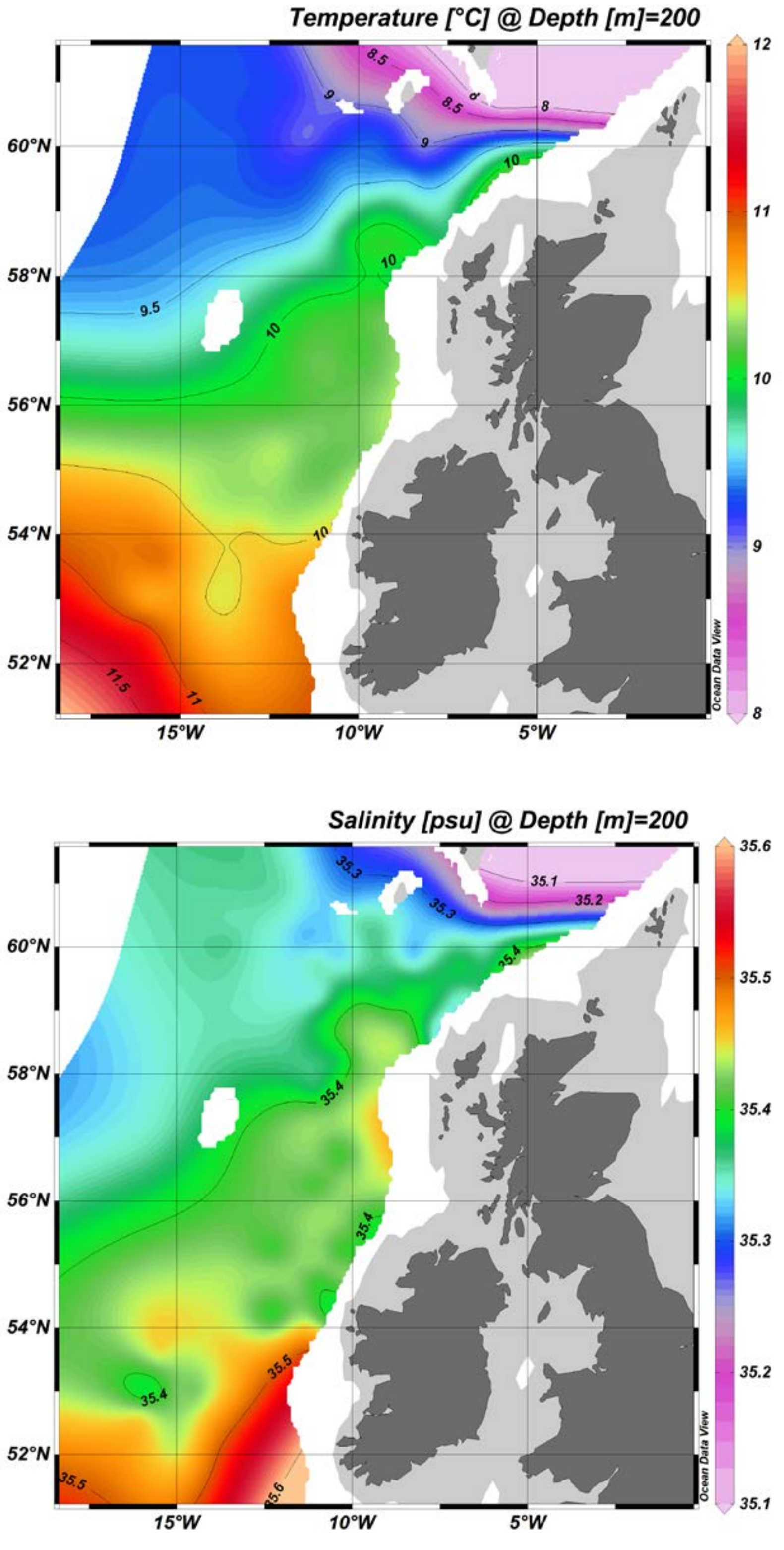


Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 200m as derived from vertical CTD casts. Yellow circles indicate CTD positions. March-April 2012.

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

Sascha Fässler and 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).

When calculating stock estimates from acoustic surveys, the data (acoustics density [s_A] allocated to blue whiting, in units of m^2/n.m.^{2}) from each vessel are expressed as average values over so-called EDSUs (equivalent distance sampling unit) ranging between 1 and 5 n.m. Acoustic density for each survey stratum (subarea with similar fish length distributions) is calculated as an average across all observations (EDSUs) within a stratum, weighted by the length of survey track behind each observation. Normally, these values are then converted to stratum-specific biomass estimates based on information on mean length-at-age of fish in the stratum and the assumed acoustic target strength of the fish; the total survey biomass estimate is the sum of stratum-specific estimates. In the precision estimation exercise routinely performed for the International Blue Whiting Spawning stock Survey (IBWSS), the whole estimation procedure is not repeated, but instead, uncertainty in global mean acoustic density estimates is characterized. As mean size of blue whiting does not vary very much in the survey area, uncertainty in mean acoustic density provides a conservative estimate of uncertainty in total-stock biomass.

Bootstrapping is used to estimate uncertainty in the mean acoustic density. It is calculated 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 2012 survey as well as eight earlier international surveys. Mean acoustic density over the survey area was 651.6 m^2/n.m.^{2} (as compared to 562.8 m^2/n.m.^{2} in 2011) with 95% confidence interval being 609.4 (lower) and 699.7 (upper) m^2/n.m.^{2}. Relative to the mean, the approximate 95% confidence limits are –6.5% and +7.4%, and 50% confidence limits are –2.3% and +2.2%. This level of uncertainty in acoustic densities is the lowest observed in the time series so far. It is about half as large as those observed in previous years with the exception of 2007 when a much higher uncertainty was recorded. Overall mean acoustic density has shown a consistent decrease annually since 2007 to 2010 and is now showing an increasing trend over the last two years.

Figure 2 summarizes the results and puts them in the biomass context. The overall trend indicates a continued decrease year-on-year in biomass from 2007–2011 for this stock. The uncertainty around the decline in biomass from 2008 to 2011 is more than could be accounted for from spatial heterogeneity alone and is regarded as statistically significant. The biomass estimate from 2010 was omitted in the assessment process due to coverage problems in the survey and a resulting possibility of biomass underestimation. The 2012 estimate shows an increasing trend of the stock as determined from survey data for the first time again since 2007.

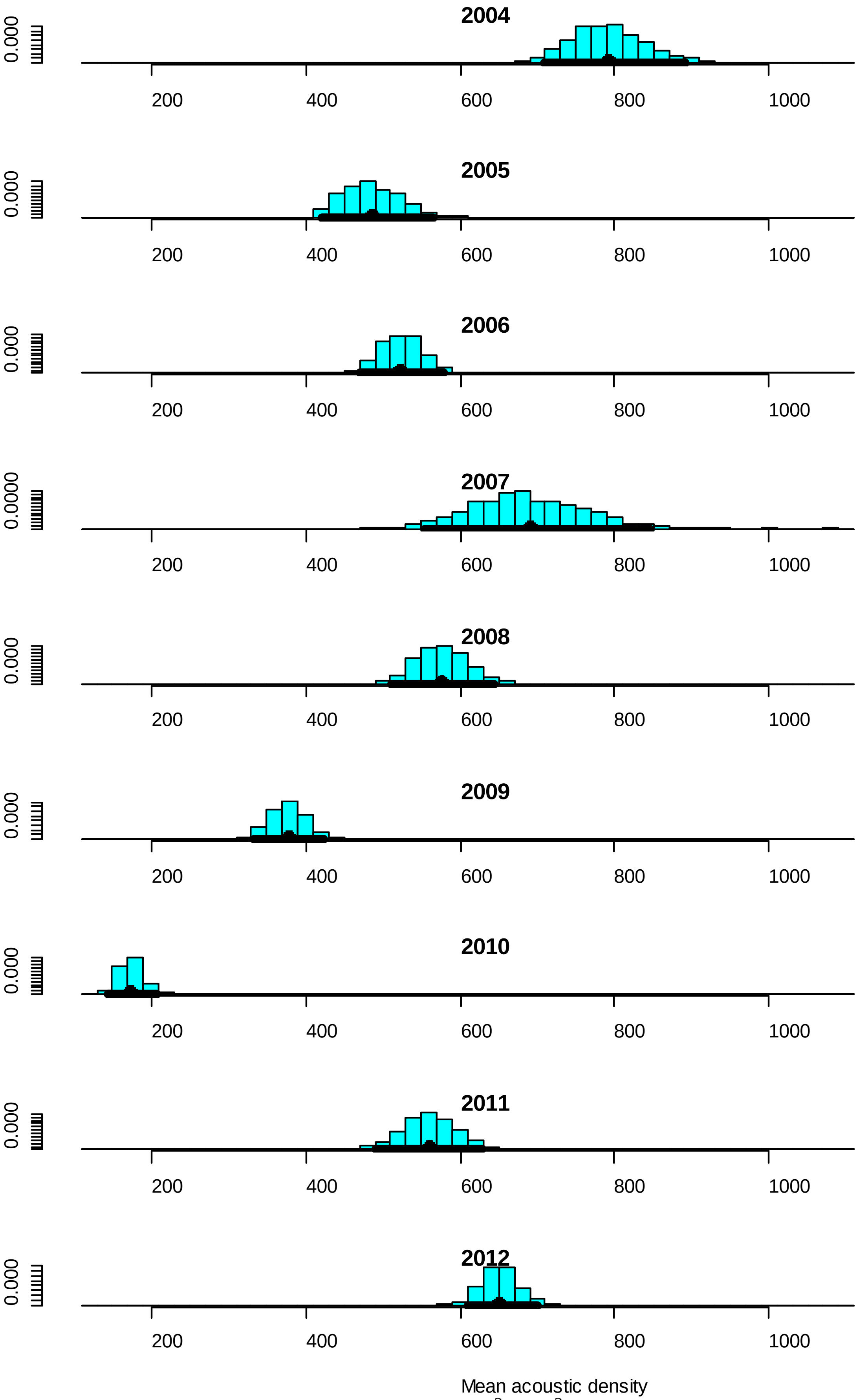


Figure 1. Distribution of mean acoustic density (in $m^2/n.m.^2$) by year based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

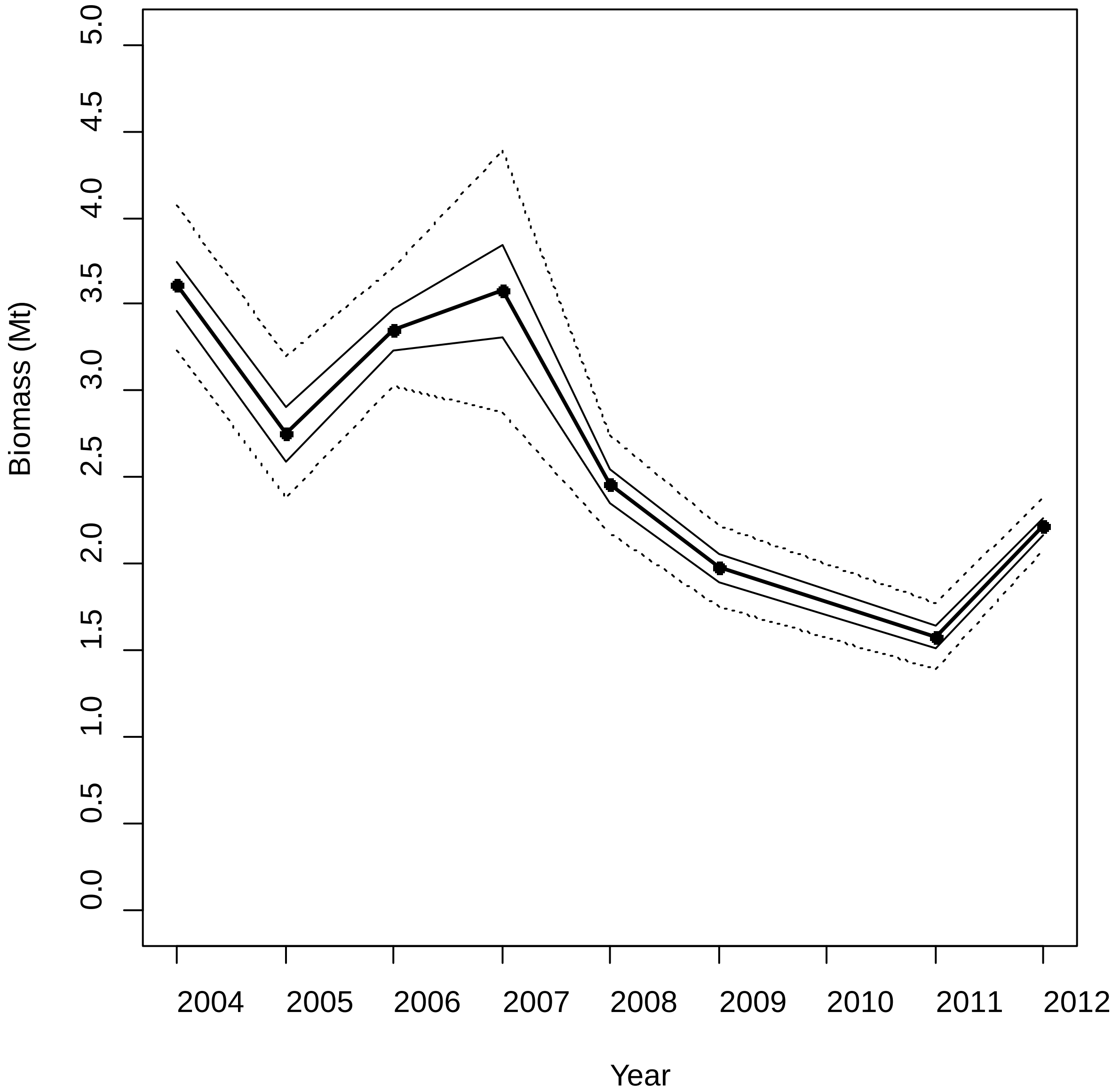


Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations 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.

Ciaran O'Donnell and Åge Høines

A review of consistency of age readings was carried out using data collected from all nations during 2012. Results show relatively good agreement across age classes and are generally well group when compared to previous years (Figure 1). A broad range of lengths were observed for the oldest (>10 yrs) and youngest (2-3 yrs) age classes which also corresponds to the dominate age groups within the stock. Three year old fish (2009 year class) had the broadest length range from 15-32.5cm and this can be attributed to the difficulty in aging younger fish due to the mis-interpretation of the Bailey ring. The oldest fish observed from samples was 13 years.

Exchange of expertise is encouraged and an age reading workshop has been recommended to further improve consistency.

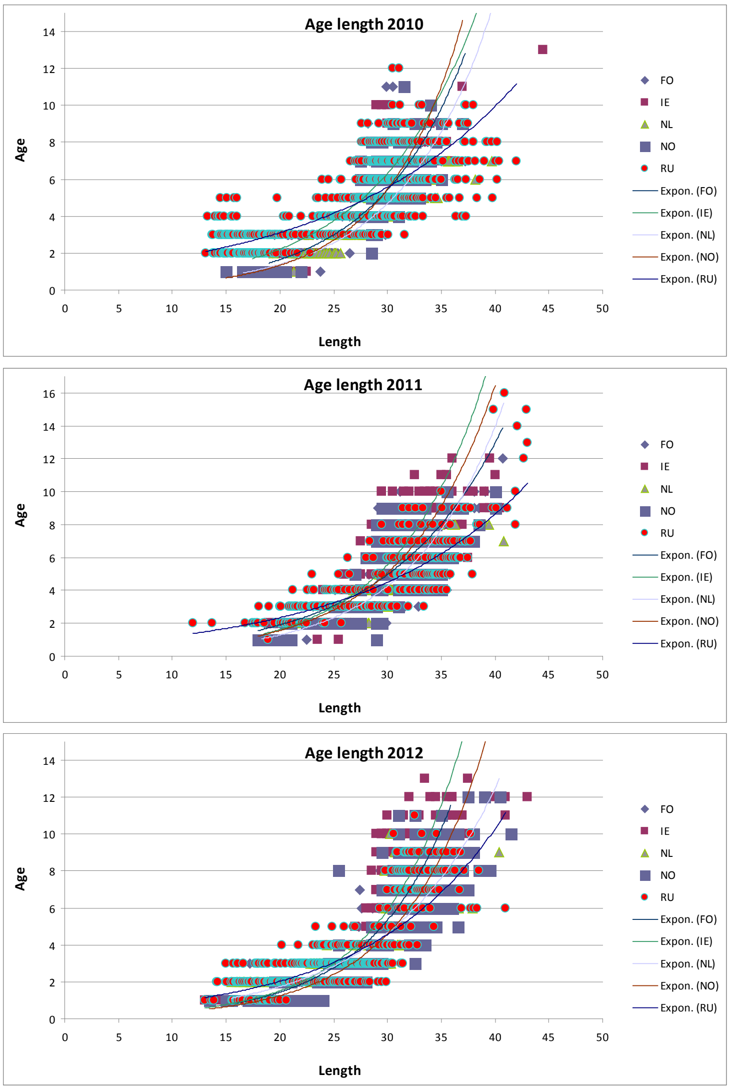


Figure 1. Profile of length at age by nation of blue whiting collected during individual surveys from 2010- 2012 (FO; Faroes, IE; Ireland, NL: Netherlands, NO; Norway and RU; Russia).

Appendix 3. Inter-calibration exercise between the RV Celtic Explorer and RV Tridens

Sven Gastauer and Ciaran O'Donnell

Acoustic inter-calibration between R/V *Celtic Explorer* and R/V *Tridens* was conducted on 5 April between 16:00 and 21:00 close to the shelf slope in depths from 600-850 m. The exercise was centred around 59º 35'N & 006º 39'W. Two 10 n.m. transects were undertaken. The first transect was conducted with the *Tridens* acting as the lead vessel cruising at approximately 10 Kts while the C. Explorer maintained a position of 0.5n.m. astern and 0.5n.m. off *Tridens* starboard quarter. A second 10n.m. transect was then carried out with the *C. Explorer* as the lead vessel and *Tridens* following with the same approximate distance and position. Weather conditions were good with light NE winds of 10-15 knots and a northerly swell of 1-2 m.

The main acoustic features in the area were (1) a relatively constant area of blue whiting schools with variable density in depths between 250 and 520 m, (2) a layer of presumed macro-zooplankton from depths over 400 metres, partly mixed with the blue whiting layer in some areas, and (3) mesopelagic fish, in the uppermost of the echogram at 100 to 240 m and a plankton layer to the surface.

Data analysis focused on acoustic densities (c, $m^2/n.m.^2$) allocated to blue whiting (Figure 1). On both vessels the routine procedures were followed for scrutinizing the data. Recordings show variable agreement, as is to be expected from experience of previous exercises. The *Tridens* tended to record much higher acoustic densities during the first 1-12 n.m. than the Explorer, for distances of 12-20 n.m. acoustic densities are more comparable in value (Figure 2). However, it should be noted that this is more likely a result of the geographical distance between the ships on both transects and thus the density of schools observed rather than actual differences in recording capability. When comparing portions of the track which were more closely aligned *Tridens* appears to record higher acoustic densities than the *C Explorer* for similar observations. Again this may be accounted for by the spatial heterogeneity of the patchy schools encountered.

At the end of the acoustic inter-calibration a comparative trawl exercise was undertaken. Both vessels turned and towed in parallel over the reciprocal course at a distance of about 0.8 n.m. apart. Both vessels actively towed for 20 minutes with the trawl headline at c.320 m. *Celtic Explorers'* total catch was 500 kg and composed of blue whiting, *Tridens* had a very similar catch of 490 Kg.

Comparing the size distribution of catches both vessels recorded 15 different length groups (14.5-40 cm). However, *C Explorer* was observed to catch a more varied profile with 3 modal groups dominated by a larger mode of older fish (Figure 3). Mean length of blue whiting was 25.4 for *Tridens* and 29.3 for *C. Explorer. Tridens* catch was dominated by one mode of smaller, younger fish. Comparing trawl gear *Tridens* has a net with a vertical opening of c.90 m as compared to c.45 m for the *C Explorer.* Differences in catchability and of the schools encountered by the trawl are the most likely explanations for the differences in catch profile.

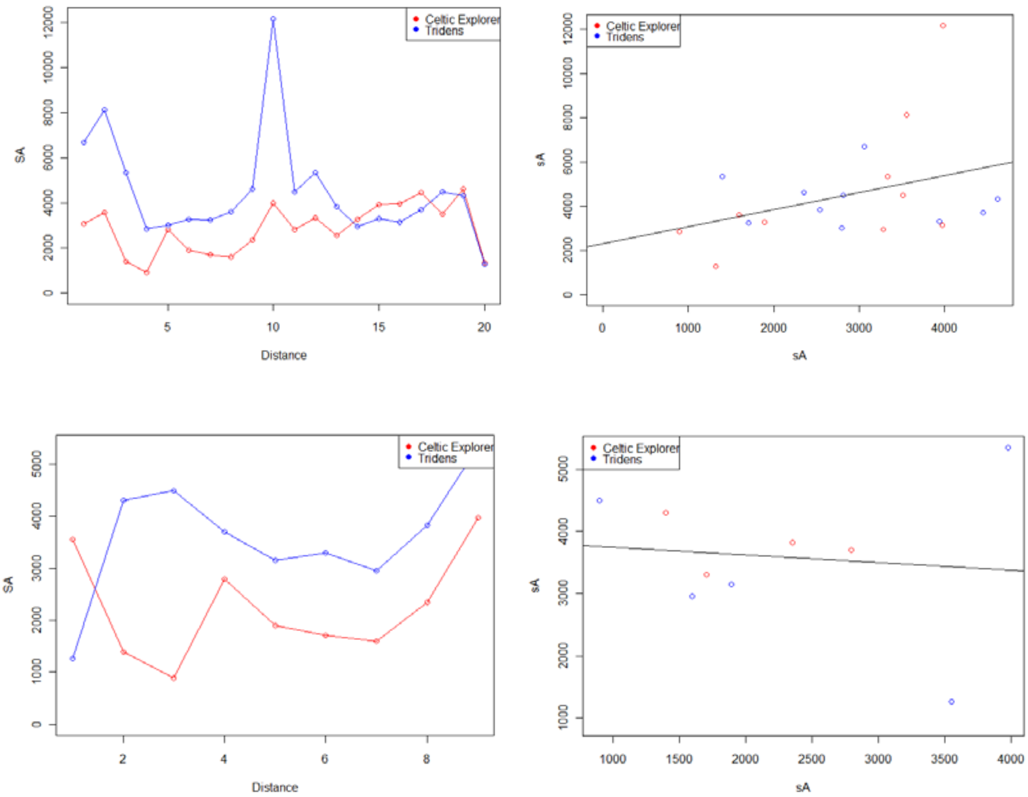


Figure 1. Comparison of blue whiting acoustic densities recorded by vessel for the entire exercise (upper panels) and for those most geographically aligned (lower panels).

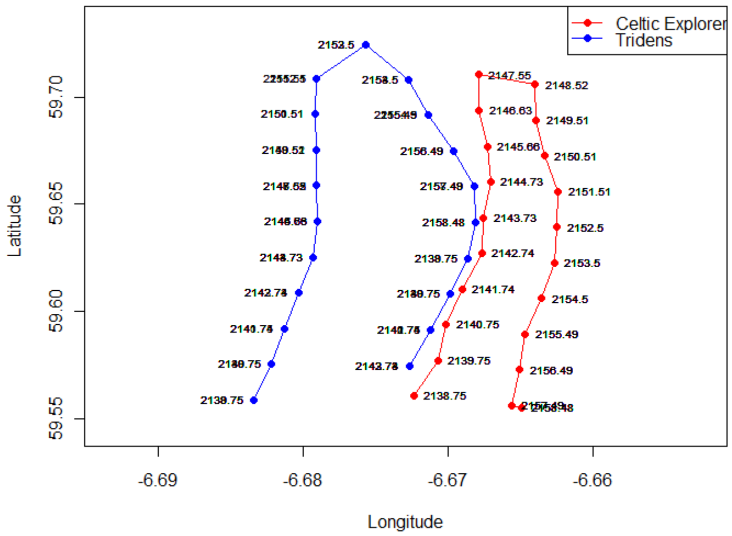


Figure 2. Plot of geographical positions by 1 n.m. log intervals during the inter-calibration track for the entire exercise

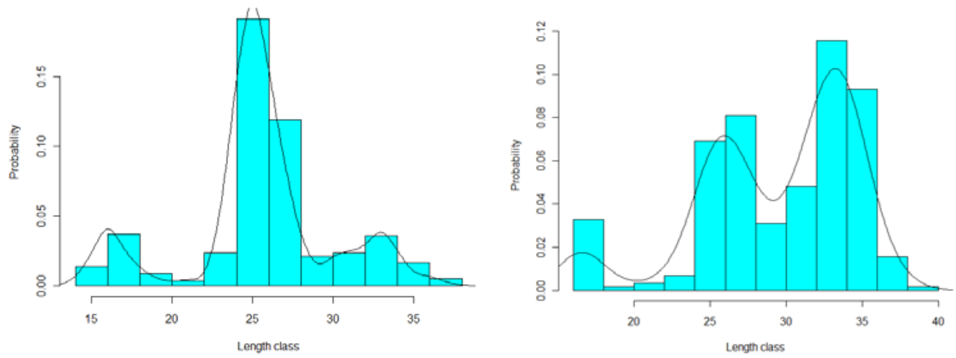


Figure 3. Length distributions from the trawls hauls by *Tridens* (left panel) and *Celtic Explorer* (right panel). Smoothing is obtained by normal kernel density estimates.

Appendix 4. Planned acoustic survey of the NE Atlantic blue whiting spawning grounds (IBWSS) in 2013

Sascha Fässler

Five vessels representing the Faroe Islands, the Netherlands (EU-coordinated), Ireland (EU-coordinated) Norway and Russia are scheduled to participate in the 2013 spawning stock survey.

Survey timing and design were discussed during the meeting. The group decided that in 2013, the survey design should follow the one used during the 2012 survey. The focus will be on a good coverage of the shelf slope in areas II and III, as it is evident that the bulk of the spawning aggregation was found there during the past few years when the stock size was declining (2008–2011). On the other hand, during the first four years of the internationally coordinated survey (2004–2007), when the size of the stock was high, blue whiting aggregations were distributed more evenly over the whole survey area. The adapted survey design in 2012 attempted to take into account this shift in stock distribution. The design is based on variable transect spacing, ranging from 30 n.m. in areas containing less dense aggregation (e.g. subarea I, south Porcupine), to 7.5 n.m. in the core survey area (subarea III, Hebrides) (Figure 1). From past surveys it was evident that huge areas in the west of the Rockall Trough contained, if at all, only sporadic and small blue whiting concentrations. The western borders of the transects in subarea III will therefore extend to just 11ºW in order to put more effort on the continental slope. To ensure transect coverage was not replicated, transects were allocated systematically with a random start location.

The aim is to have all but the Faroese vessel start surveying in the north of subarea II (North Porcupine) at the time when the Norwegian vessel begins the survey there (27.03.2013; Table 1). That way, the core survey subarea III can be covered synoptically by 4 vessels with a similar temporal progression.

It was decided that the Dutch and Russian vessels would start the survey in the southern subareas I and II (Porcupine). The Irish Celtic Explorer would first cover subarea IV (on southwest Rockall Bank). 2–4 days after beginning their individual surveys, these vessels will join the Norwegian vessel surveying the north of subarea II and afterwards area III from the south progressing northwards. Once the Norwegian vessel has finished surveying subarea III, she will continue northwards into the Faroese-Shetland channel and continue coverage in a north-eastern direction until time allows. The Faroese vessel will primarily survey subarea V (Faroese/Shetland) and join the other vessels in the north of area III once they are present there towards the end of the survey period. Survey extension in terms of coverage (52–61ºN) will be in line with the time-series to ensure containment of the stock and survey timing will also remain fixed as in previous years.

Key will be to achieve coverage of area III in a consistent temporal progression between vessels. It is therefore very important that all 4 vessels covering the core Hebrides area are present on station in the north of subarea II (just north of Porcupine Bank) on 27 March 2013 (Table 1). Nonetheless, if some vessels are found to lack behind others, the tight 7.5 n.m. transect spacing will allow for adaptation of the survey design without great loss of coverage. For instance, this may mean either skipping or extending some of the horizontal transects to catch up or keep pace with the other vessels. Biological sampling should be carried out following methods normally applied to sampling acoustic registrations.

Preliminary cruise tracks for the 2012 survey are presented in Figure 1. As survey coordinator in 2013, Sascha Fässler (Netherlands) has been tasked with coordinating contact between

participants prior to and during the survey. Detailed cruise lines for each ship will be circulated by the coordinator to the group as soon as final vessel availability and dates have been communicated (end of January 2013).

As the survey is planned with inter-vessel cooperation in mind it is vitally important that participants stick to the planned transect positioning to ensure that survey effort is evenly allocated and the situation observed in 2010 is not repeated.

Participants are also required to use the logbook system for recording course changes, CTD stations and fishing operations. An example format can be circulated to participants at the 2012 WGIPS meeting. The survey will be carried out 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).

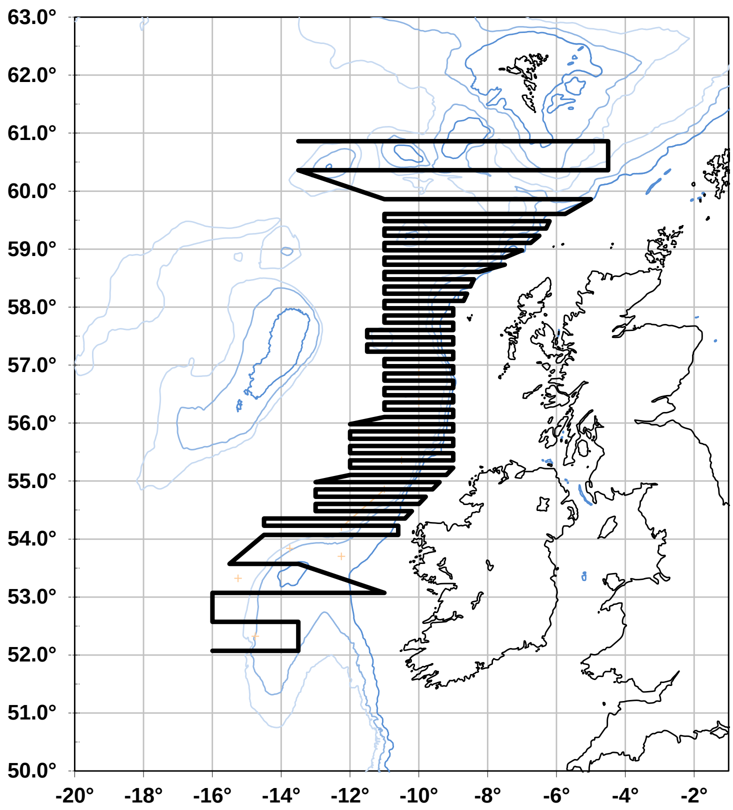


Figure 1. Preliminary survey tracks for the combined 2013 International Blue Whiting Spawning stock Survey (IBWSS). Additional transects in the Rockall and Faroes/Shetland areas will be planned later by the respective participants covering those areas.

Table 1. Individual vessel dates for the 2013 International Blue Whiting Spawning stock Survey (IBWSS).

Ship	Nation	Active survey time (days)	Preliminary survey dates
G.O. Sars	Norway	17	27.3.2013 – 12.4.2013
Fridjof Nansen	Russia	19	23.3.2013 – 10.4.2013
Celtic Explorer	Ireland (EU)	19	23.3.2013 – 10.4.2013
Tridens	Netherlands (EU)	17	25.3.2013 – 10.4.2013
Magnus Heinason	Faroes	17	27.3.2013 – 12.4.2013