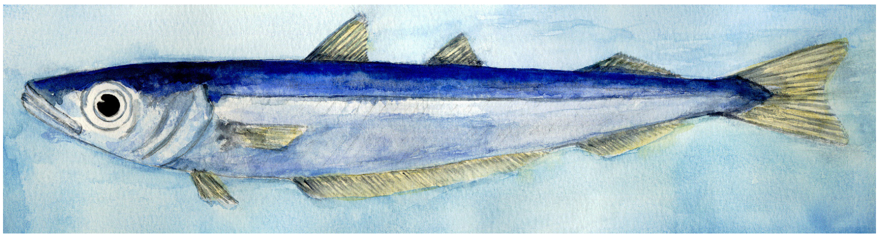
Working Document

Working Group on International Pelagic Surveys

Copenhagen, Denmark, 19-23 January 2015

Working Group on Widely Distributed Stocks

San Sebastian, Spain, 26-31 August 2015



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2015

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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 International Pelagic Surveys (WGIPS) and continued by correspondence until the start of the survey. During the survey effort was refined and adjusted by the coordinator based on real time observations. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Fritjof Nansen	PINRO, Murmansk, Russia	23/3 – 10/4
Celtic Explorer	Marine Institute, Ireland	23/3 – 10/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	25/3 – 8/4
Tridens	Institute for Marine Resources & Ecosystem Studies (IMARES), the Netherlands	23/3 – 8/4
G.O. Sars	Institute of Marine Research, Norway	25/3 – 7/4

The survey design used and described in ICES (2014) allowed for a flexible setup of transects and good coverage of the spawning aggregations. Considering weather conditions were by no means optimal during the survey period the good quality coverage of the stock was achieved. Transects undertaken by all vessels were consistent in spatial coverage and timing, delivering full coverage of the respective distribution areas within 17 days.

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

Sampling equipment

All vessels employed a midwater trawl for biological sampling, the properties of which are given in Table 5. Acoustic equipment for data collection and processing are presented in Table 2. The survey and abundance estimates are based on acoustic data collected with scientific echo sounders using a frequency of 38 kHz. All transducers were calibrated with a standard calibration sphere (Foote et al. 1987) prior, during or directly after the survey. Acoustic settings by vessel are summarised 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 and MacLennan 2007. This year, no intercalibration was carried out due to weather induced time constraints.

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 1.

Hydrographic sampling

Hydrographic sampling by way of vertical CTD casts were carried out by each participant vessel at predetermined locations (Figure 2 and Table 1) capped at a maximum depth of 1000 m (Magnus Heinason 600m) in open water. Hydrographic equipment specifications are summarised in Table 5.

Acoustic data processing

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

On Fridtjof Nansen, the LSSS 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 5.4) 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 Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using Myriax's EchoView (V 6.1) 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 scrutinised every 24 hrs using Myrix's Echoview (V 6.1) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On G.O. Sars, 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.

Acoustic data analysis

The acoustic 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 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 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 following target strength (TS)-to-fish length (L) relationship (Pedersen et al. 2011) used is:

$$TS = 20 \log10 (L) - 65.2$$

For conversion from acoustic density (sA, m2/n.m.2) to fish density (ρ) the following relationship was used:

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

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.

This year the postcruise meeting participants were introduced to the StoX application, and had the opportunity during the meeting to run the application on an individual basis. StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application build with Java for easy sharing and further development in cooperation with other institutes.The Stox application produced comparable results as BEAM. In contrast to BEAM, StoX requires that the analysed survey is planned and run based on a statistical design. In the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990) is implemented.

Results

Distribution of blue whiting

In total 6,891 nmi (nautical miles) of survey transects were completed and the total area of all the sub areas covered was 123,840 nmi^2 (Figure 1, Tables 1 and 3). This represented a reduction of 16% in total surveyed transects and 1% in surveyed areas compared to last year. Coverage was considered sufficient and still takes into account expected distributions on the Rockall and Porcupine Banks.

In the Hebrides core area blue whiting distribution was more confined to the shelf edge and did not extend widely into the deep waters of the Rockall Trough as seen in the previous year. However, the maximum SA values observed in the survey were recorded in open water away from the shelf slope at 52,333 m^2/nmi^2 (northwest of the Hebrides) and 51431 m^2/nmi^2 (north of the Porcupine bank) (Figure 9).

The highest concentrations of blue whiting were recorded in the Hebrides core area but the corresponding biomass observed was 61% less than in the previous year. The same pattern was observed in the N. Porcupine and Rockall areas where 64% and 88% less biomass was observed respectively compared to last year. Quantities of blue whiting found in the South Porcupine and Faroe/Shetland area were comparable to 2014. Medium and high density registrations were firmly concentrated along the shelf slope extending maximum a few miles from the shelf edge (Figures 4 and 5).

Stock size

The estimated total abundance of blue whiting for the 2015 international survey was 1.38 million tonnes, representing an abundance of 16.6x10^9 individuals (Figure 6, Tables 3 and 4). Spawning stock was estimated at 1.1 million tonnes and 11.2x10^9 individuals. In comparison to the 2014 survey estimate, this represents a decrease of -58% in the observed stock biomass and a related decrease in stock numbers of 47%.

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Change from 2014 (%)
Biomass	Total	2.6	3.4	3.6	2.6	2	1.3	1.6	2.2	3.4	3.3	1.4	-58%
(mill. t)	Mature	2.4	3.3	3.6	2.6	2	1.3	1.5	2.2	3.2	3	1.1	-63%
Numbers	Total	29	34.7	33.5	22.1	15.2	9.3	12.1	18.2	27	31.1	16.6	-47%
(10^9)	Mature	26.7	33.8	32.9	21.7	15.0	8.9	9.7	16.5	24.4	26.4	11.2	-58%
Survey area (nm^2)		172,000	170,000	135,000	127,000	133,900	109,320	68,851	88,746	87,895	125,319	123,840	-1%

The Hebrides core area was found to contain 44% of the total biomass observed during the survey, which is lower than seen in previous years (48% of the stock found in this area in 2014; 73% in 2013; and 71% in 2012). Distribution of biomass within this core area tended more towards the southern part, as in 2014. The Faroes/Shetland and North Porcupine areas ranked second and third highest contributing 25% and 23% to the total respectively. Compared to the previous year (see text table below). Considerably less biomass was observed in the Rockall, Hebrides and North Porcupine areas in 2015, while a small increase was observed in the Faroes/Shetland area. In the South Porcupine area a small increase was observed, however, this area accounted for only 4% of the observed biomass. The breakdown of survey biomass by sub area is shown below:

		Biomass (million tonnes)				
		2014		2015		
	Sub-area		% of total		% of total	Change (%)
I	S. Porcupine Bank	0.03	1	0.06	4	90%
II	N. Porcupine Bank	0.86	27	0.31	23	-64%
III	Hebrides	1.54	48	0.61	44	-61%
IV	Faroes/Shetland	0.34	10	0.35	25	2%
V	Rockall	0.47	15	0.06	4	-88%

Stock composition

Individuals of ages 1 to 15 years were observed during the survey.

The stock biomass within the survey area is dominated by age classes 1, 2, and 4 of the 2014, 2013 and 2011 year classes respectively (Table 4 and Figure 10). The main contribution (80%) to the spawning stock biomass were the age groups 4, 2, 5 and 3, in order of importance (Table 4), with 4-year old fish contributing 32% to total biomass.

The contribution of the Hebrides core area which is historically the most productive area were consistently more than 50% of the SSB (spawning stock biomass) back in time. However, since 2013 this figure has dropped below 50% (48% in 2013, 44% in 2014). Similar to 2014, the North Porcupine area contained a significant portion of the spawning stock. Mean lengths and weights of the fish caught in the Hebrides area were highest in the entire survey (Figures 7 and 8). The Faroe/Shetland subarea was dominated by mainly 1 and 2 year old fish and Porcupine sub-areas were dominated by 2 and 4 year old fish. One year old fish was mainly observed in subarea IV (Faroes-Shetland). The oldest fish (>8+) were predominantly observed in the Hebrides core area (Figure 11).

The Faroese/Shetland sub-area was found to contain significant proportion of young blue whiting (1-3 years), all together 83% (288,400) of the total biomass and 83% (4831 million individuals) of the total abundance in that area. This is close to the proportions seen last year (70% and 85% respectively).

The large blue whiting found in previous years on the Rockall Bank were not observed this year. In 2015 only 18% (numbers) of the fish here were mature, compared to 97% in 2014.

Immature blue whiting were represented to various extents in all sub areas in 2015 (Figure 11). Maturity analysis of survey samples indicate that 9% of 1-year old, 66% of 2-year old and 83% of 3-year old fish were mature as compared to the 2014 estimates, where 14% of 1-year old fish, 56% of 2-year old fish and 90% of 3-year old fish were considered mature (Table 4). Overall, immature blue whiting from the 2015 estimate represented 17% (239,000t) of the total biomass and 32% (5380 million) of the total abundance recorded during the survey, compared to 7.4% (biomass) and 15% (abundance) respectively in 2014. Thus a drastic redusction in the mature portion of the blue whiting stock from 2014.

Hydrography

A combined total of 139 CTD casts were undertaken over the course of the survey (Table 1). Horizontal plots of temperature and salinity at depths of 50m, 100m, 200m and 500m as derived from vertical CTD casts are displayed in Figures 12-15 respectively.

Concluding remarks

Main results

- The 12th International Blue Whiting Spawning stock Survey 2015 shows a marked decrease in total stock biomass of 58% with a corresponding reduction in abundance by 47% when compared to the 2014 estimate.
- Weather conditions were moderate/poor for the duration of the survey and a period of about 48hrs was lost in a single consecutive period due to very poor conditions.
- Area coverage was comparable with the 2014 (1% reduction) whereas survey effort (transect mileage) was 16% lower. The reduction in transect mileage was a consequence of changes in transect spacing (from 10 to 15nmi) within the Hebrides area due to weather induced downtime. Survey effort was reallocated after careful consideration to ensure that full geographical coverage was maintained in the core spawning areas using the remaining available survey time.
- 80% of the total biomass was observed in target areas surveyed by more than one vessel.
- The survey was carried out over 17 days and well within the recommended 21 day time window.
- Estimated uncertainty around the mean acoustic density (spatio-temporal variability) is low in 2015 and at the same time the estimated stock size showed the sharpest decline in the time series.
- The stock biomass within the survey area was dominated by age classes 2, 4, 1 and 3 of the 2013, 2011, 2014 and 2012 year classes respectively, contributing 70% of total stock biomass.

- Mean length (24.6cm from 28cm in 2014) and weight (83g from 120g) are lower than in 2014 and in previous years. This can be attributed to the increasing contribution of young fish within the standing stock.
- A strong signal of 1 and 2-year old fish (2014 and 2013 year classes) was evident across the entire survey area as well as in traditional young fish areas of Rockall and Faroes/Shetland. The core areas Hebrides and Porcupine contained notable amounts of 1 and 2 year old fish. The total biomass of immature fish represented 239,000t the same as in 2014 but this is much more prominent this year due to the reduced SSB.

Interpretation of the results

- The 2015 estimate of abundance can be considered as robust. Stock containment was achieved for both core and peripheral stock areas. Survey effort although reduced was carefully considered to ensure full coverage was achieved with the resources available and is not considered to be responsible for the large reduction in biomass observed this year.
- The bulk of the mature stock was located from the north Porcupine to the Hebrides core area in a narrow corridor close to the shelf edge. This is in contrast to the generally more dense and dispersed western distribution extending into the Rockall Trough observed in 2014 and was unexpected. However, a drastic 54% reduction of the spawing stock was observed in 2015, and this was mainly in the the Rockall area and in the Hebrides and north Porcuine areas, traditionally core areas at spawning time. This large reduction was not expected acknowledging the 2014 results.
- The estimated amount of immature blue whiting was on the contrary at a high level in 2015, similar to 2014, indicating recruiting year-classes. This was especially evident in the northern Faroe/Shetland area and in the Rockall area.
- Reports indicate that large volumes of blue whiting were taken by the international fleet working outside the Irish EEZ to the southwest of the Porcupine Bank again this year prior to the survey (Feb/Mar).
- Cohort tracking through the time series was not possible in 2015 as the age structure of the stock was notably different with the absence the previous year's strongest age classes namely the 4, 5 and 6 year old fish. As the survey area was covered using comparable effort, geographical coverage and timing it is difficult to ascertain the reasoning behind the absence of the preiously dominant age classes. However, the high intensity of fishing effort in the southwest of Ireland prior to the survey could be linked.

Recommendations

- The age structure of the blue whiting from commercial catches in international waters outside the Irish EEZ (southwest Porcupine Bank) prior to the survey warrants further investigation by WGWIDE. Do the missing survey age classes appear in significant numbers in catches from this area?
- The group recommends that StoX is used as the primary computation tool for blue whiting biomass from 2016 onwards and that a retrospective calculation of the entire time series (2004-2015) is carried out and presented at WGWIDE 2016.
- All participants with the capacity to do so are encouraged to collect WP2 and fluorescence data and submit the data to the database accordingly.
- It is the responsibility of individual survey participants to ensure that all data are screened prior to submission to the PGNAPES data base following the details outlined in the WGIPS survey manual.
- All group members are requested to supply maturity data to the database using a 7 point blue whiting maturity stage key in to ensure consistency across data submissions.
- As agreed during WGIPS 2015 meeting participants are asked to submit scrutinised inter-transect data to the database.

Achievements

- The entire survey area (c.124,000nmi²) was covered within 17 days and within the recommended 21 day maximum.
- Survey data were uploaded to the database prior to the meeting as agreed.
- A global estimate of abundance was run in parallel with Beam using StoX software and good agreement was achieved. StoX developers were on hand during the meeting to assist in user set up and a walk through processing tasks. This is an important step to avoid a situation where the group is reliant on a few users familiar with the software. The group will provide feedback to the developers to aid in the functionality of future versions.

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Table 1. Survey effort by vessel. March-April 2015.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling	Aged fish	Length-measured fish
Celtic Explorer	23/3-8/4	1467	10	27	-	0	1650
Magnus Heinason	26/3-6/4	1050	8	21	21	249	1002
G.O.Sars	26/3- 7/4	1514	13	25	18	774	2600
Tridens	24/3-7/4	1785	10	30	-	900	900
Fritjof Nansen	29/3-10/4	1620	7	36	-	500	1885
Total	23/3-10/4	7,436	48	139	39	2,423	8,037

Table 2. Acoustic instruments and settings for the primary frequency. March-April 2015.

	Fridtjof Nansen	Celtic Explorer	Magnus Heinason	Tridens	G.O. Sars
Echo sounder	Simrad EK60	Simrad EK 60	Simrad EK60	Simrad EK 60	Simrad EK 60
Frequency (kHz)	**38**	**38**, 18, 120, 200	**38**	18, **38**, 70, 120, 200, 333	18, 70, **38**, 120, 200, 333
Primary transducer	ES38B	ES 38B	ES38B	ES 38B	ES 38B
Transducer installation	Hull	Drop keel	Hull	Drop keel	Drop keel
Transducer depth (m)	5	8.7	3	8	8.5
Upper integration limit (m)	10	15	7	15	15
Absorption coeff. (dB/km)	10	9.9	10.2	10	8.4
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	2.43	2.43	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)	-20.6	-20.6	-20.8	-20.6	-20.8
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.52	25.89	25.57	26.26	25.22
s_A correction (dB)	-0.64	-0.8	-0.7	-0.53	-0.76
3 dB beam width (dg)					
alongship:	6.99	6.95	6.98	7	7.14
athw. ship:	6.99	6.98	7.07	6.95	7.07
Maximum range (m)	750	1000	750	750	750
Post processing software	LSSS	Myriax Echoview	Myriax Echoview	Myriax Echoview	LSSS

Table 3. Assessment factors of blue whiting for IBWSS March-April 2015.

Sub-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	9,149	0.51	0.54	94	0.1	0.1	96	104.8	28.2	6.2
II	N. Porcupine Bank	15,194	3.02	3.52	86	0.3	0.3	91	88.9	26.4	20.5
III	Hebrides	37,800	4.96	6.01	83	0.5	0.6	91	100.8	26.5	16.0
IV	Faroes/ Shetland	24,058	2.49	5.21	48	0.2	0.3	66	66.4	22	14.4
V	Rockall	37,638	0.23	1.31	18	0.0	0.1	42	43.1	19.3	1.5
Tot.		123,839	11.21	16.59	68	1.1	1.4	83	83.0	24.6	11.1

Table 4. Survey stock estimate of blue whiting, March-April 2015.

	Age in years (year class)										Numbe	Bioma	Mean	Prop.
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**			**weight**	**mature**
(cm)	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**		**($*10^{-6}$)**	**(10^6 kg)**	**(g)**	**(%)**
11.0 – 12.0	1										1	0	11	0
12.0 – 13.0	0										0	0	11	0
13.0 – 14.0	13										13	0.1	11	0
14.0 – 15.0	53										53	0.7	14	0
15.0 – 16.0	121	6									127	2.3	18	0
16.0 – 17.0	399	31									430	9.2	22	0
17.0 – 18.0	820	153									973	26.3	27	0
18.0 – 19.0	900	138		6							1044	32.8	32	13
19.0 – 20.0	796	110		0							906	33	37	14
20.0 – 21.0	319	75		0							394	17.2	44	14
21.0 – 22.0	95	199	17	0							311	16.9	54	52
22.0 – 23.0	13	784	86	0							883	54.5	62	62
23.0 – 24.0	0	1456	377	43							1876	126.8	68	74
24.0 – 25.0		1252	355	132	62						1801	136.9	76	75
25.0 – 26.0		399	424	410	91	7					1331	113.8	86	85
26.0 – 27.0		75	363	894	271	8					1611	148.9	92	94
27.0 – 28.0		31	154	943	354	47					1529	153.4	100	98
28.0 – 29.0		4	75	643	267	28					1017	111.8	110	100
29.0 – 30.0			14	425	239	63	16				757	93.5	124	100
30.0 – 31.0			0	132	188	37	0	4	4		365	51.8	142	100
31.0 – 32.0			0	59	83	28	9	7	14	38	238	38.4	161	100
32.0 – 33.0			0	20	41	28	3	19	45	71	227	42.5	187	100
33.0 – 34.0			0	0	42	17	38	23	23	38	181	35.2	197	100
34.0 – 35.0			6	6	29	31	18	6	26	62	184	41.9	226	100
35.0 – 36.0					12	19	3	15	23	65	137	32.8	240	100
36.0 – 37.0					3	6	15	5	38	16	83	20.4	249	100
37.0 – 38.0						12	7	0	18	22	59	15.8	270	100
38.0 – 39.0						4	10	0	0	12	26	8.3	313	100
39.0 – 40.0								0	9	1	10	2.6	249	100
40.0 – 41.0								0	0	0	0	0		100
41.0 – 42.0								0	8	0	8	2.8	337	100
42.0 – 43.0								3	0	2	5	2.4	520	100
43.0 – 44.0										0	0	0		100
44.0 – 45.0										0	0	0		100
45.0 – 46.0										8	8	3.9	465	100
TSN (10^6)	3530	4713	1871	3713	1682	335	119	82	208	335	16588	1377		
TSB (10^6 kg)	110.7	319	157.8	376	195.2	52	25.5	18.7	47.3	74.9	1377			
Mean length (cm)	18.4	23.2	25.3	27.5	28.6	31	34	33.9	34.9	34.7				
Mean weight (g)	31	68	84	101	116	155	215	230	228	225				
Condition (g/dm^3)														
% mature*	9	66	83	95	97	99	100	100	100	100				
SSB	10.4	209.4	131.1	357.4	189.1	51.6	25.5	18.7	47.3	74.9	1115.5			

Table 5. Country and vessel specific details, March-April 2015

Parameter	Fritjof Nansen	Celtic Explorer	Magnus Heinason	Tridens	G.O. Sars
Trawl dimensions					
Circumference (m)	716	768	640	1120	832
Vertical opening (m)	50	50	40	30-70	45
Mesh size in codend (mm)	16	20	40	±20	40
Typical towing speed (kn)	3.2-3.9	3.5-4.0	3.0-4.0	3.5-4.0	3.0-3.5
Plankton sampling	0	0	21	0	25
Sampling net	-	-	WP2 plankton net	-	WP2 plankton net
Standard sampling depth (m)	-	-	200	-	400
Hydrographic sampling					
CTD Unit	SBE19plus	SBE911	SBE25	SBE911	SBE911
Standard sampling depth (m)	1000	1000	600	1000	1000

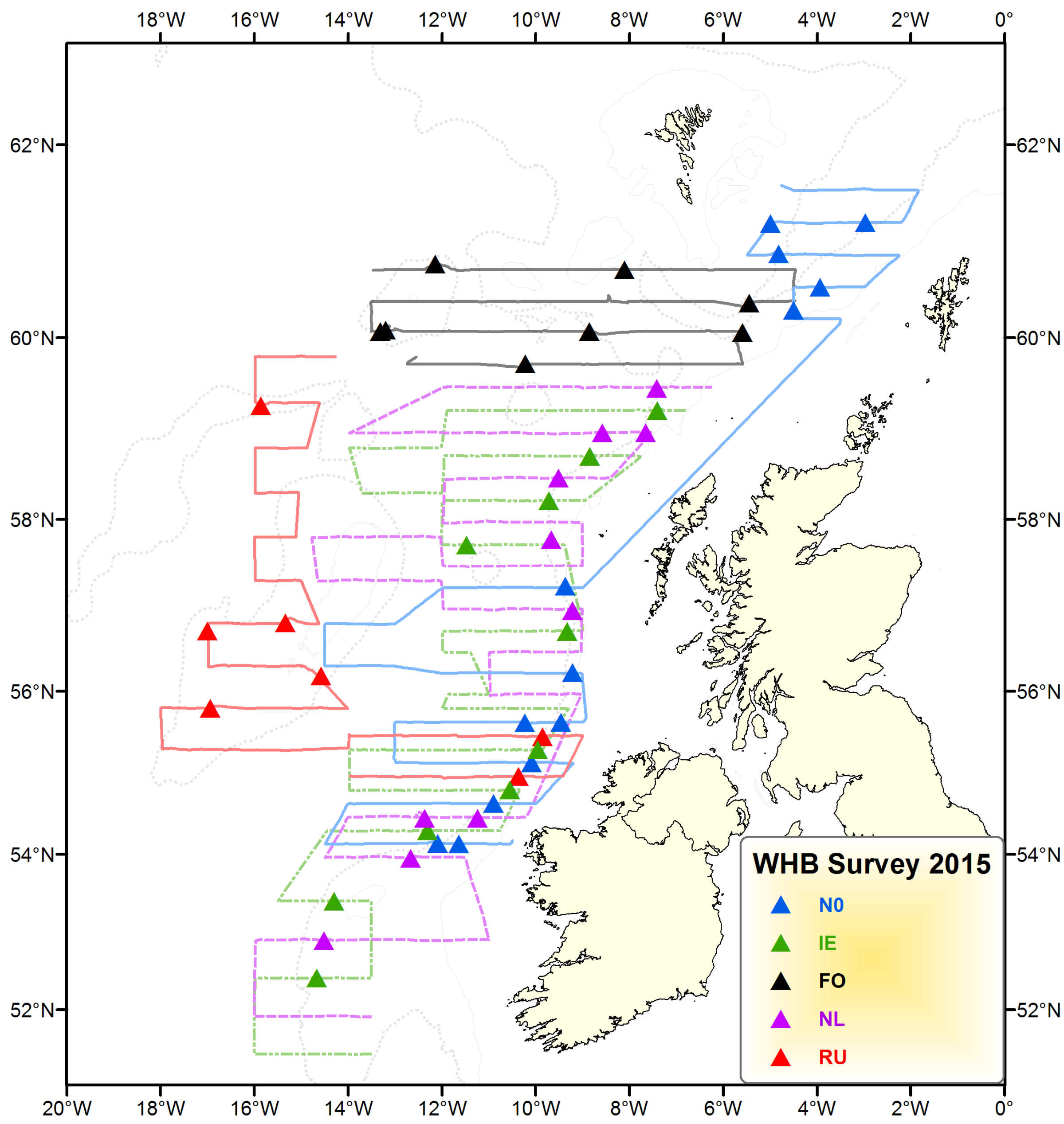


Figure 1. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2015. IE: Ireland (Celtic Explorer); FO: Faroe Islands (Magnus Heinason); NL: Netherlands (Tridens); RU: Russia (Fritjof Nansen); NO: Norway (G.O. Sars).

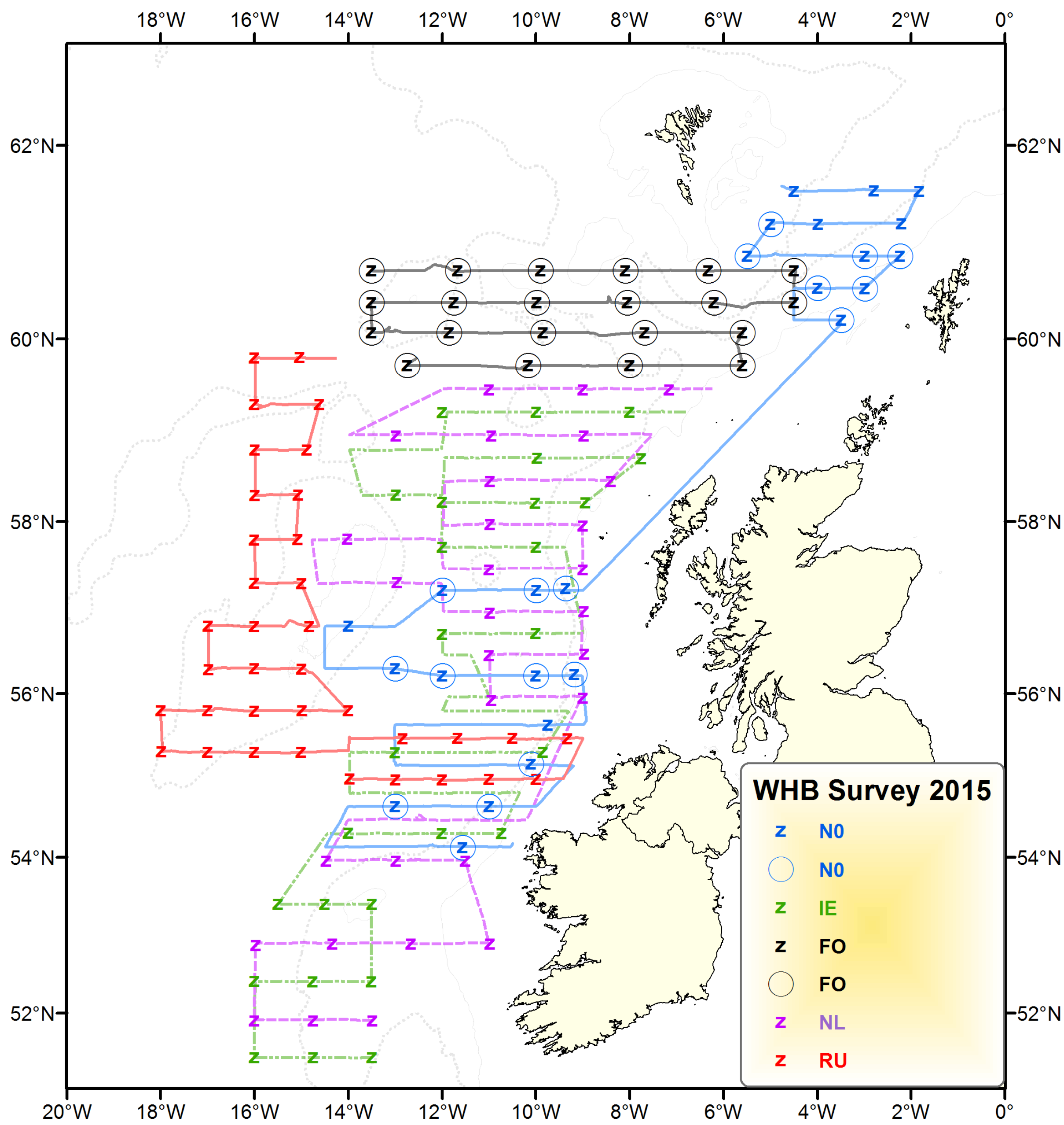


Figure 2. CTD stations overlaid onto vessel cruise tracks for the combined survey ('z'). Circles represent plankton trawls. green: Celtic Explorer; black: Magnus Heinason; purple: Tridens; red: Fritjof Nansen; blue: G.O. Sars. March-April 2015.

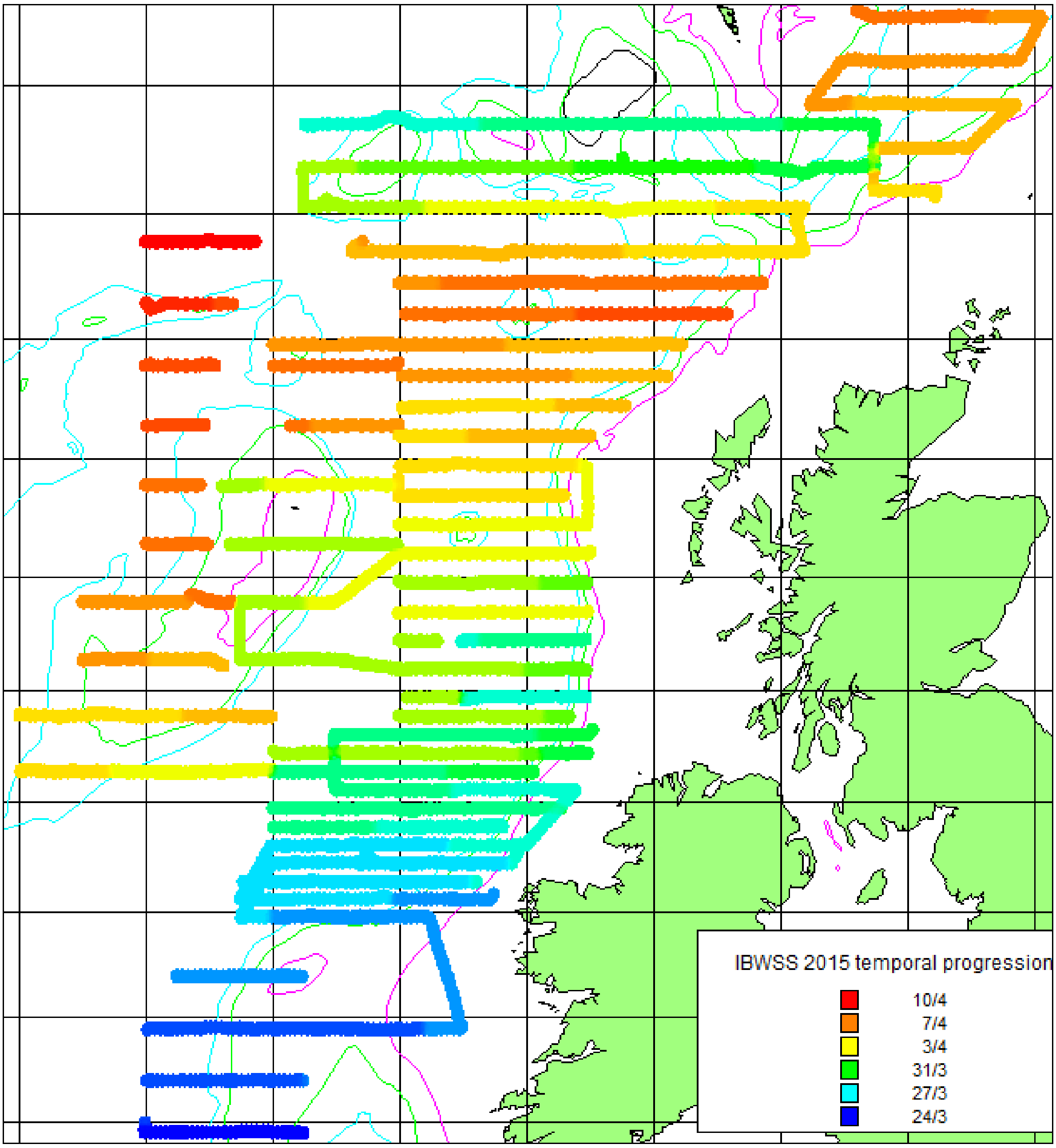


Figure 3. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS), 24. March – 10. April 2015.

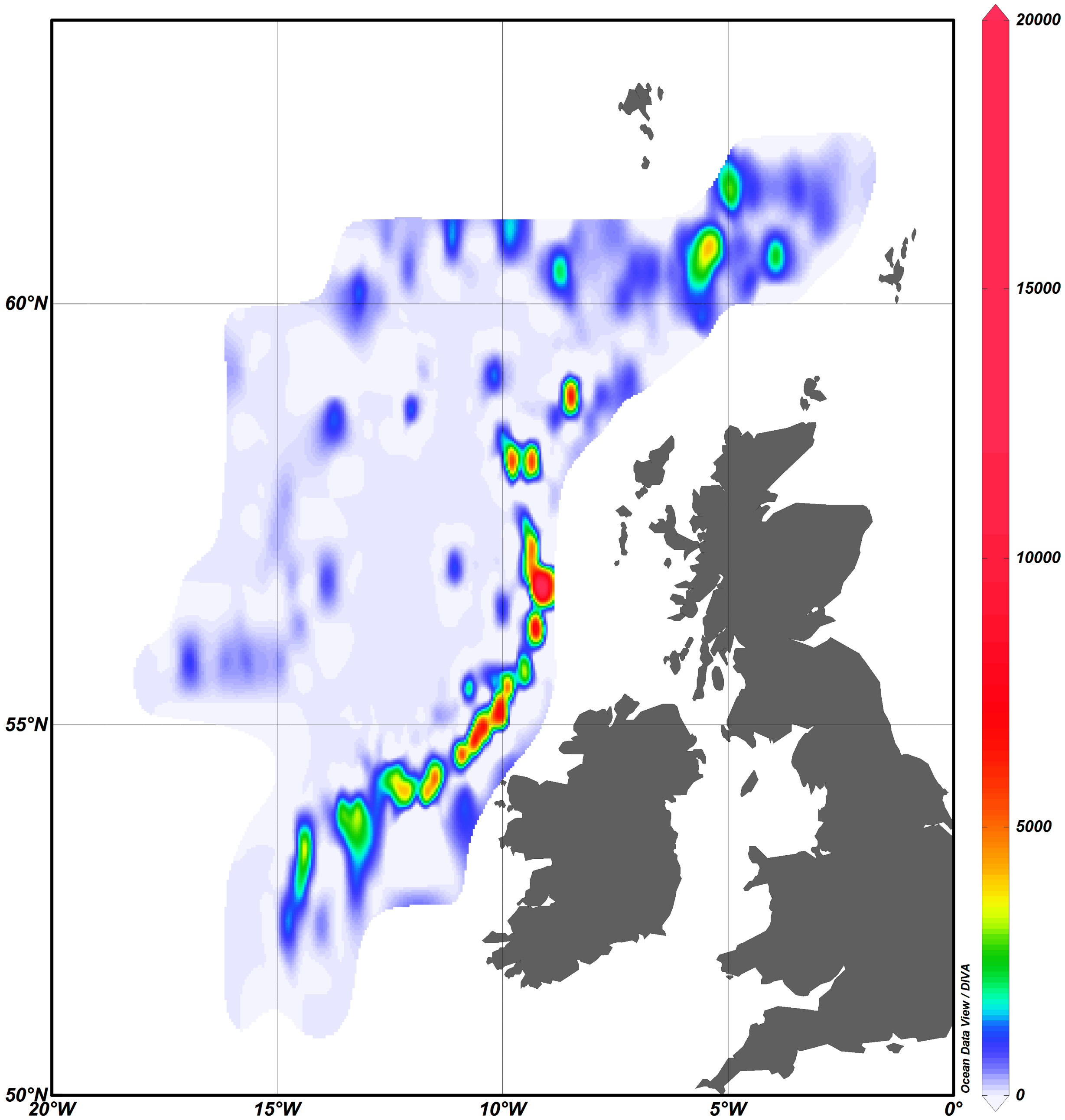


Figure 4. Map of blue whiting acoustic density (s_A, $m^2/n.m.^2$) , March–April 2015.

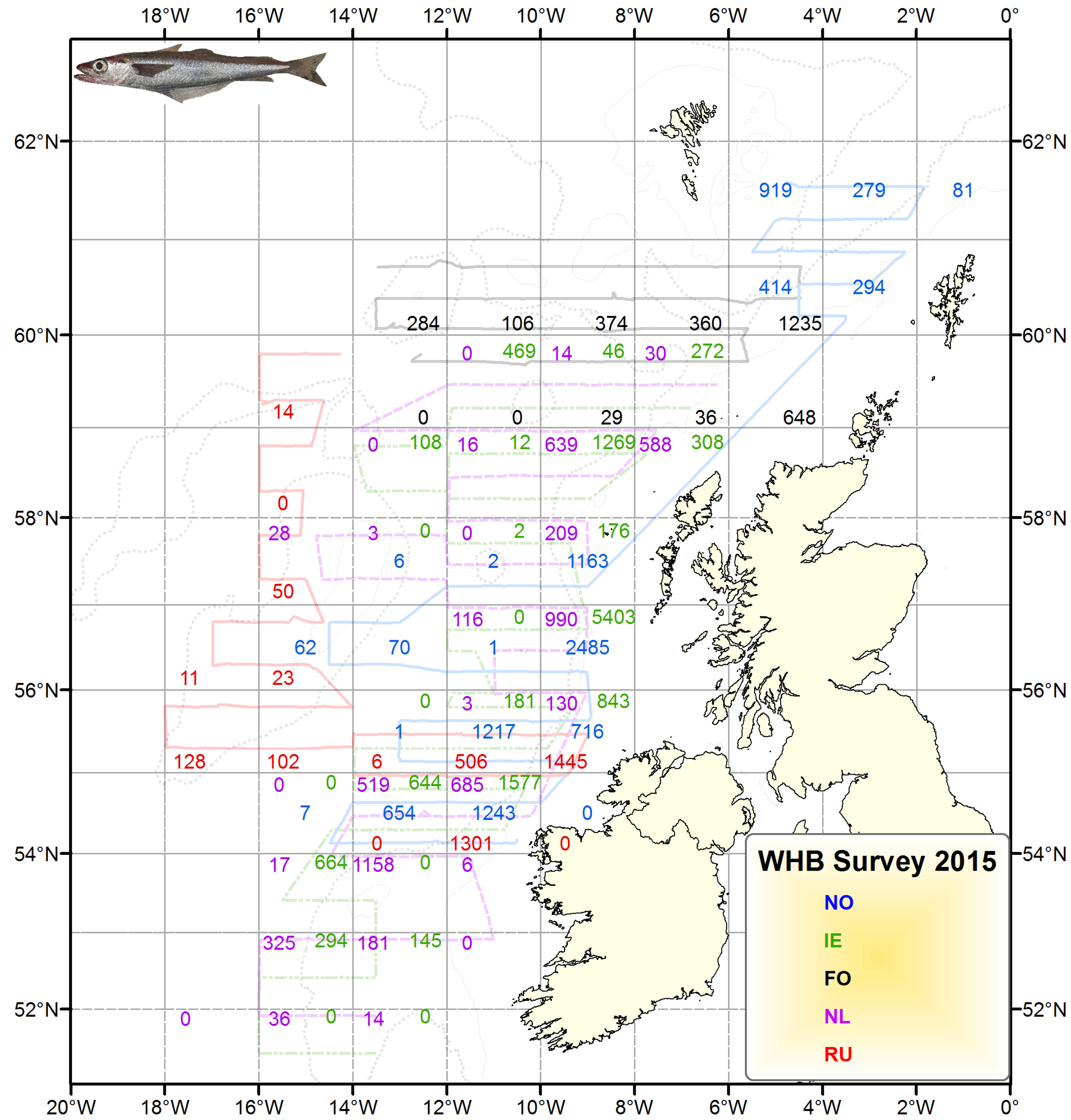


Figure 5. Mean blue whiting acoustic density (s_A, m^2/n.m.^{2}) for IBWSS 2015 by individual vessel: Celtic Explorer: green, Magnus Heinason: black, Tridens: purple, Fritjof Nansen: red, G.O. Sars: blue. March-April 2015.

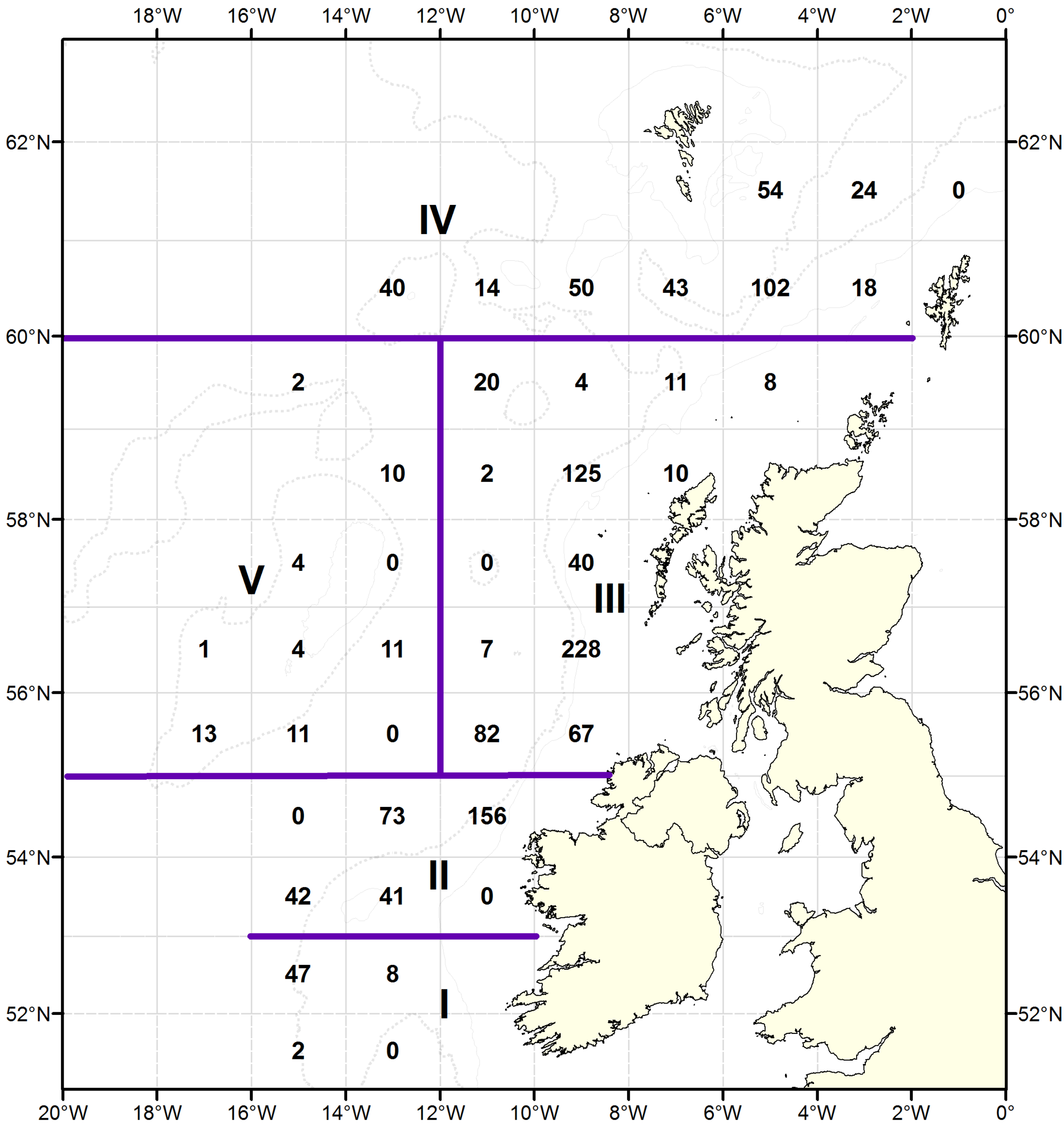


Figure 6. Blue whiting biomass (x1000t) from IBWSS 2015 by sub-area as used in the assessment.

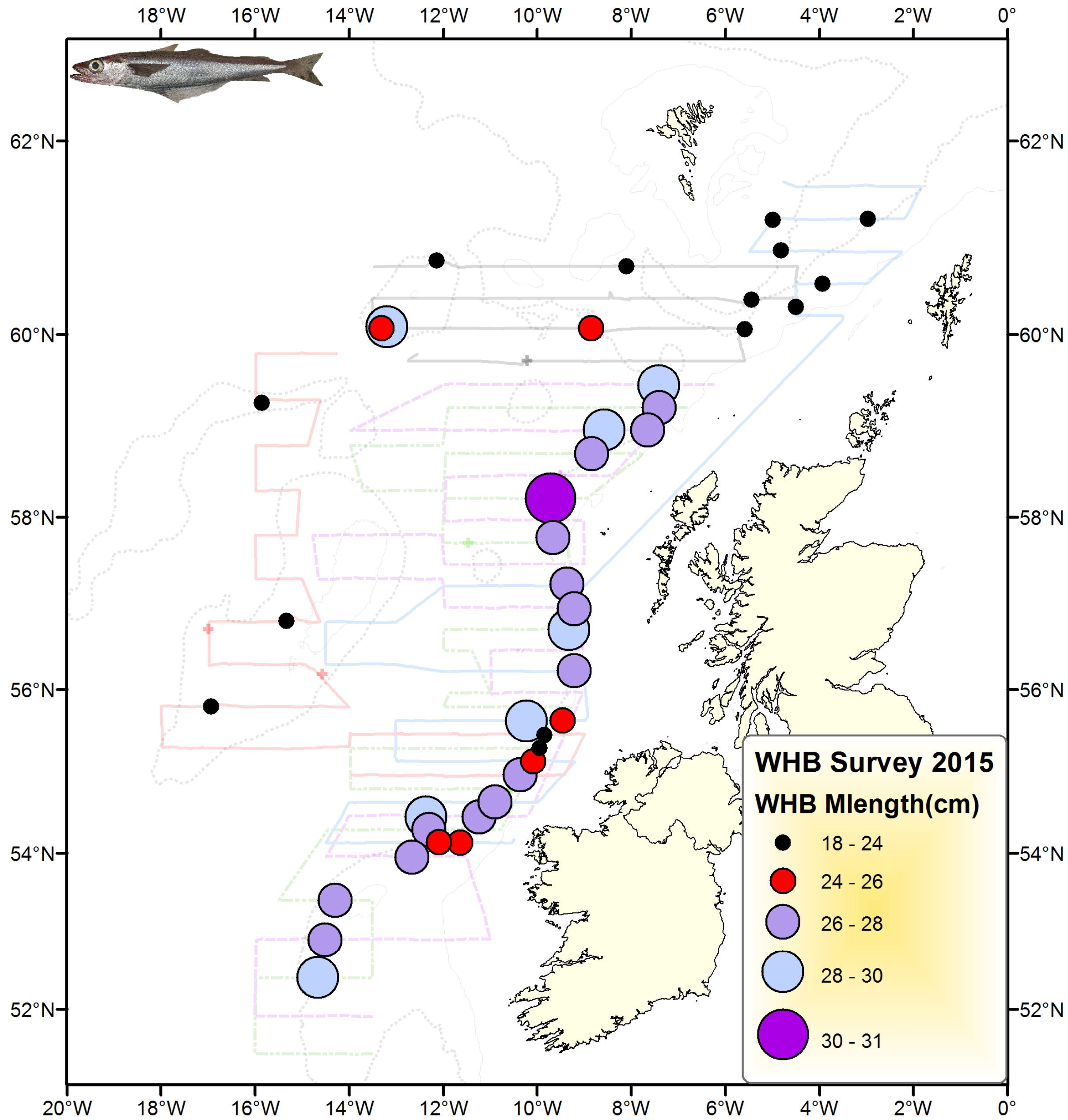


Figure 7. Mean length of blue whiting caught in trawl catches during IBWSS 2015 by individual vessels in March- April 2015. Crosses indicate hauls with zero blue whiting catches.

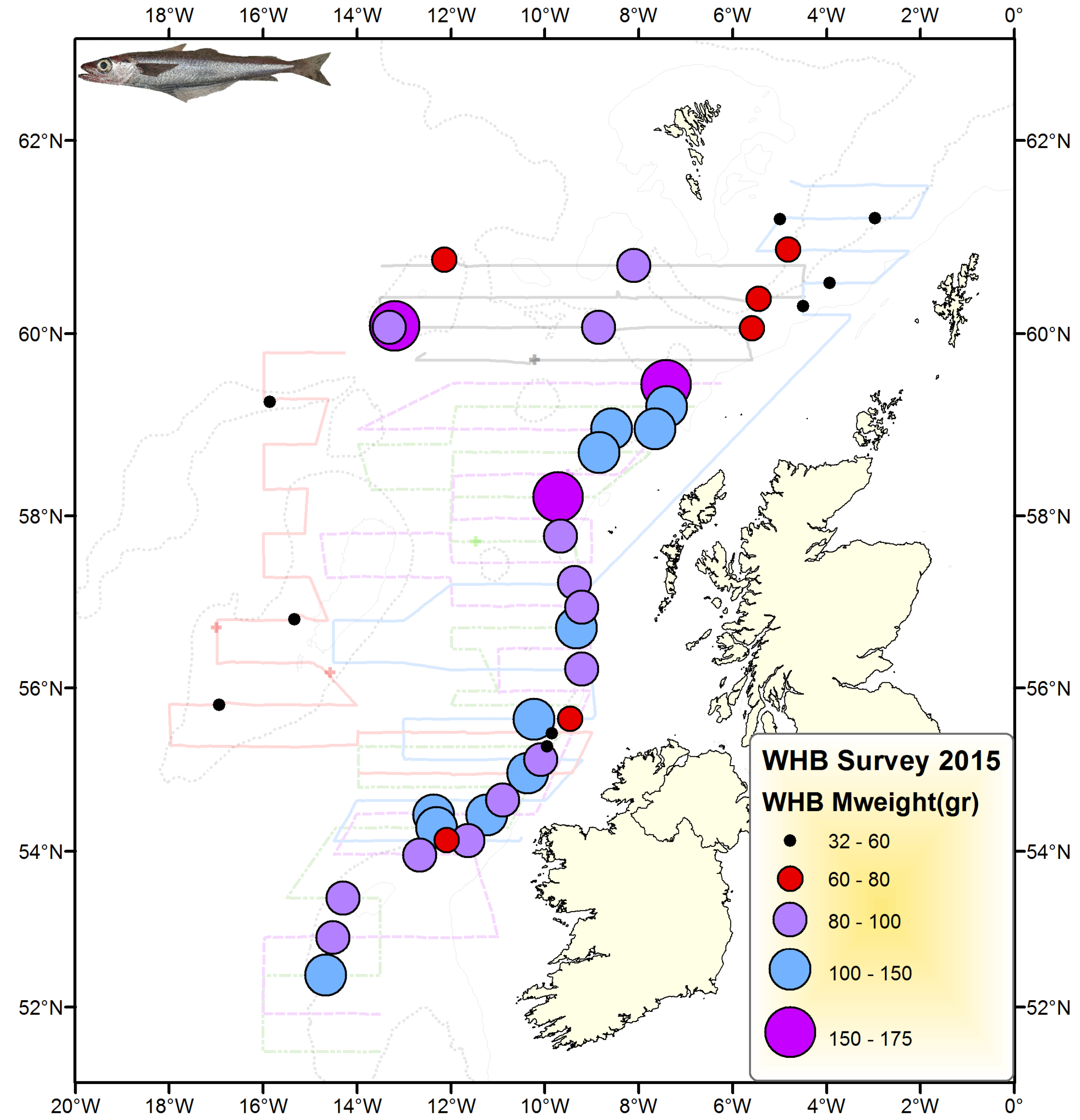
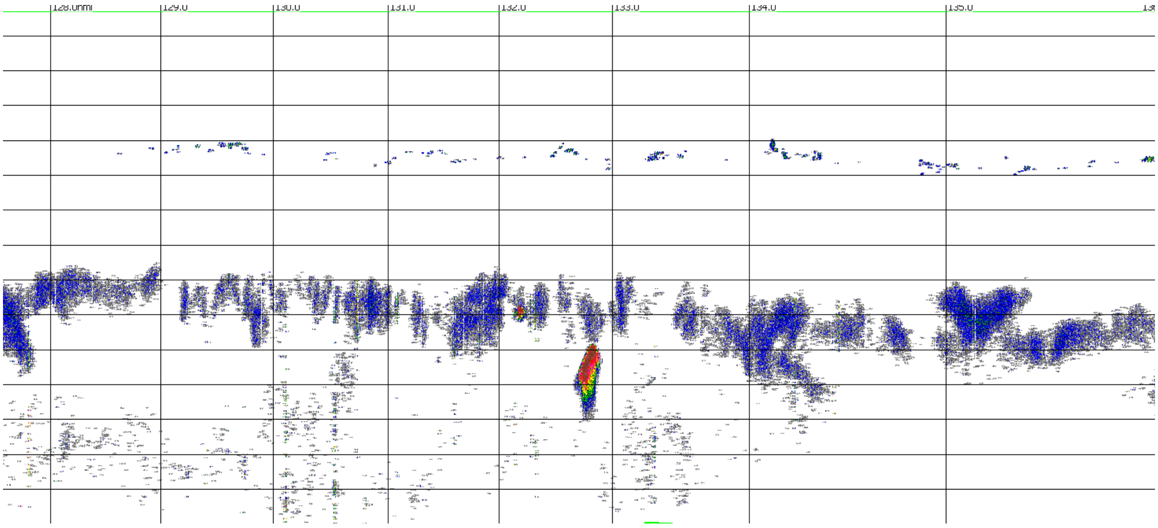
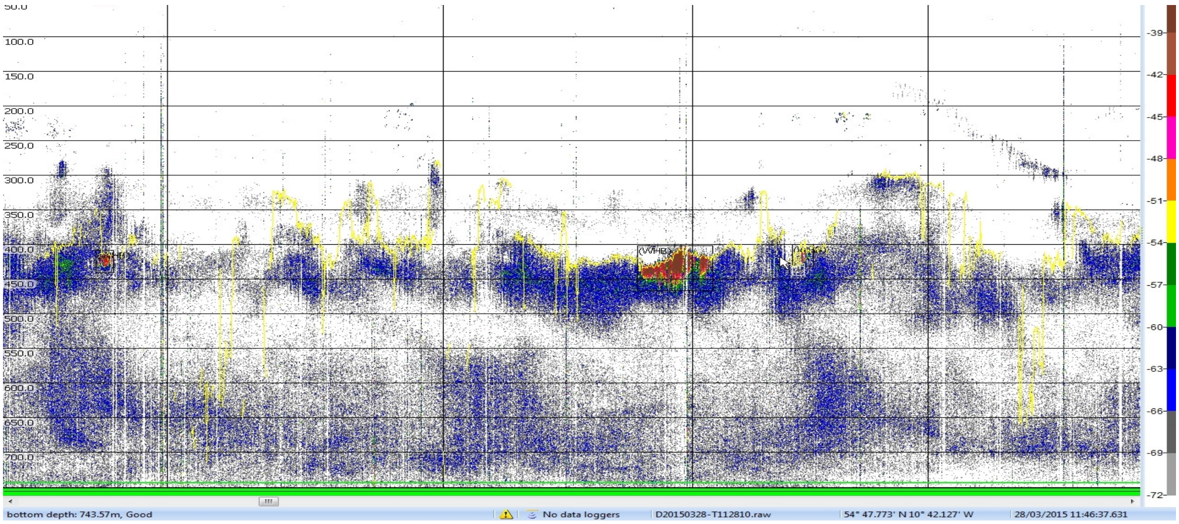


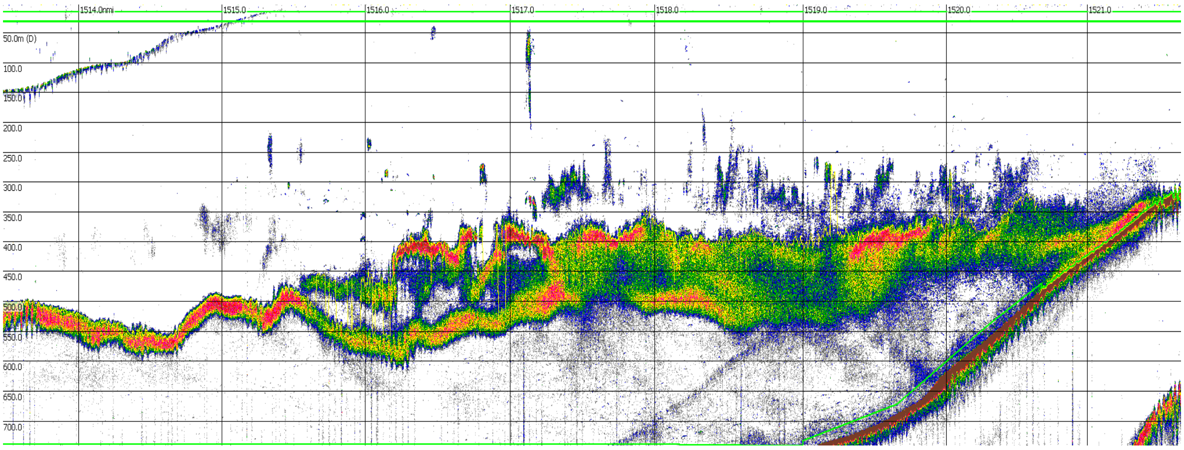
Figure 8. Mean weight of blue whiting caught in trawl catches during IBWSS 2015 by individual vessels in March- April 2015. Crosses indicate hauls with zero blue whiting catches.



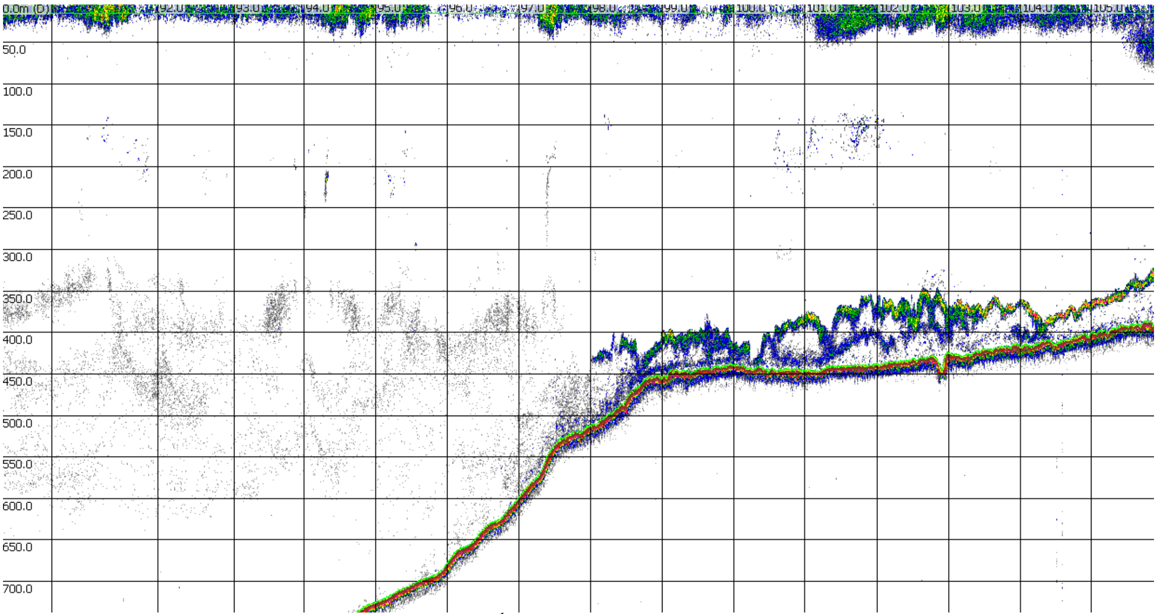
a). Highest acoustic density observed by interval in the 2015 IBWSS (s_A = 52,333 m^2/nm^2). The blue whiting echotraces were recorded by the RV Tridens west of the shelf break in open water at 58.97N 8.55W in the Hebrides target area. Echotraces were observed 15 nmi west of the shelf break in open water. The school was between 500-600m depth. Depth intervals represent 50m.



b). The highest density single blue whiting echotrace (s_A = 51,431 m²/mile²) recorded by the RV Celtic Explorer in open water to the north Porcupine sub area.



c). Large and expansive high density blue whiting echotrace recorded by RV Celtic Explorer in the Hebrides sub area.



d). Blue whiting schools observed on the 25th March by RV Tridens when approaching the shelf edge of the northern Porcupine Bank.

Figure 9. Echograms of interest encountered during the combined International blue whiting survey in March-April 2015.

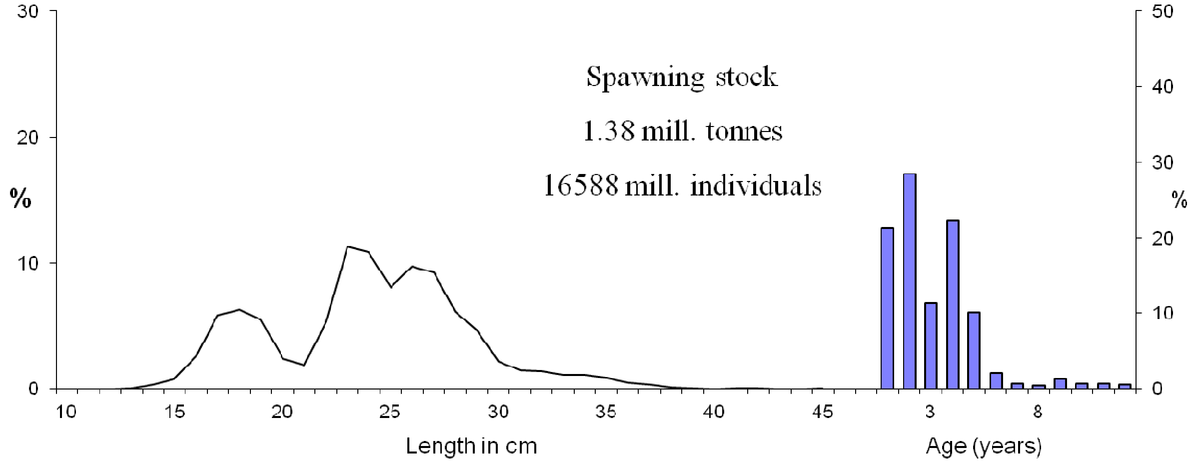


Figure 10. Length and age distributions (numbers) of total stock of blue whiting. Spawning stock biomass is given. March-April 2015.

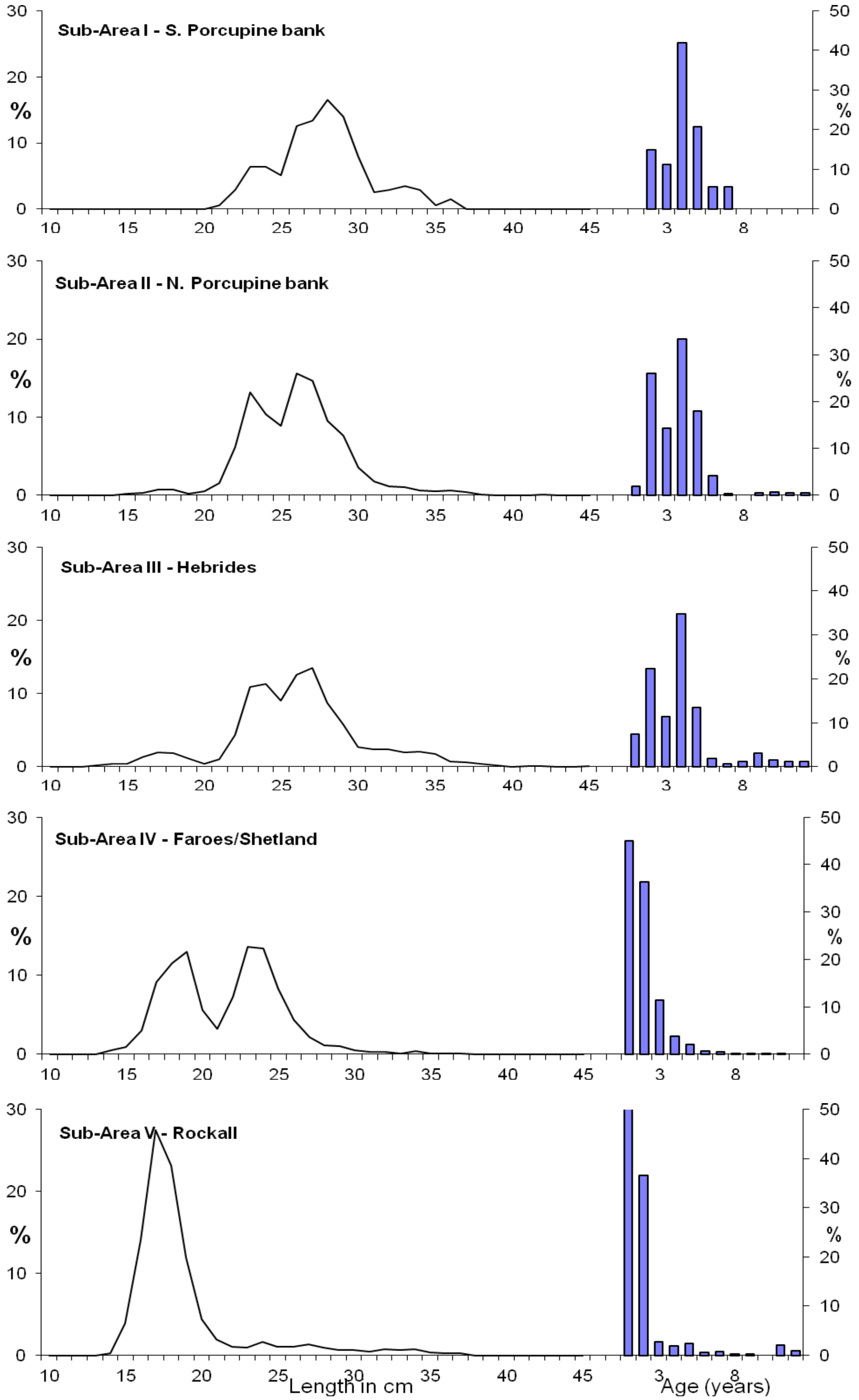


Figure 11. Length and age distribution (numbers) of blue whiting by covered sub-area (I–V). March-April 2015.

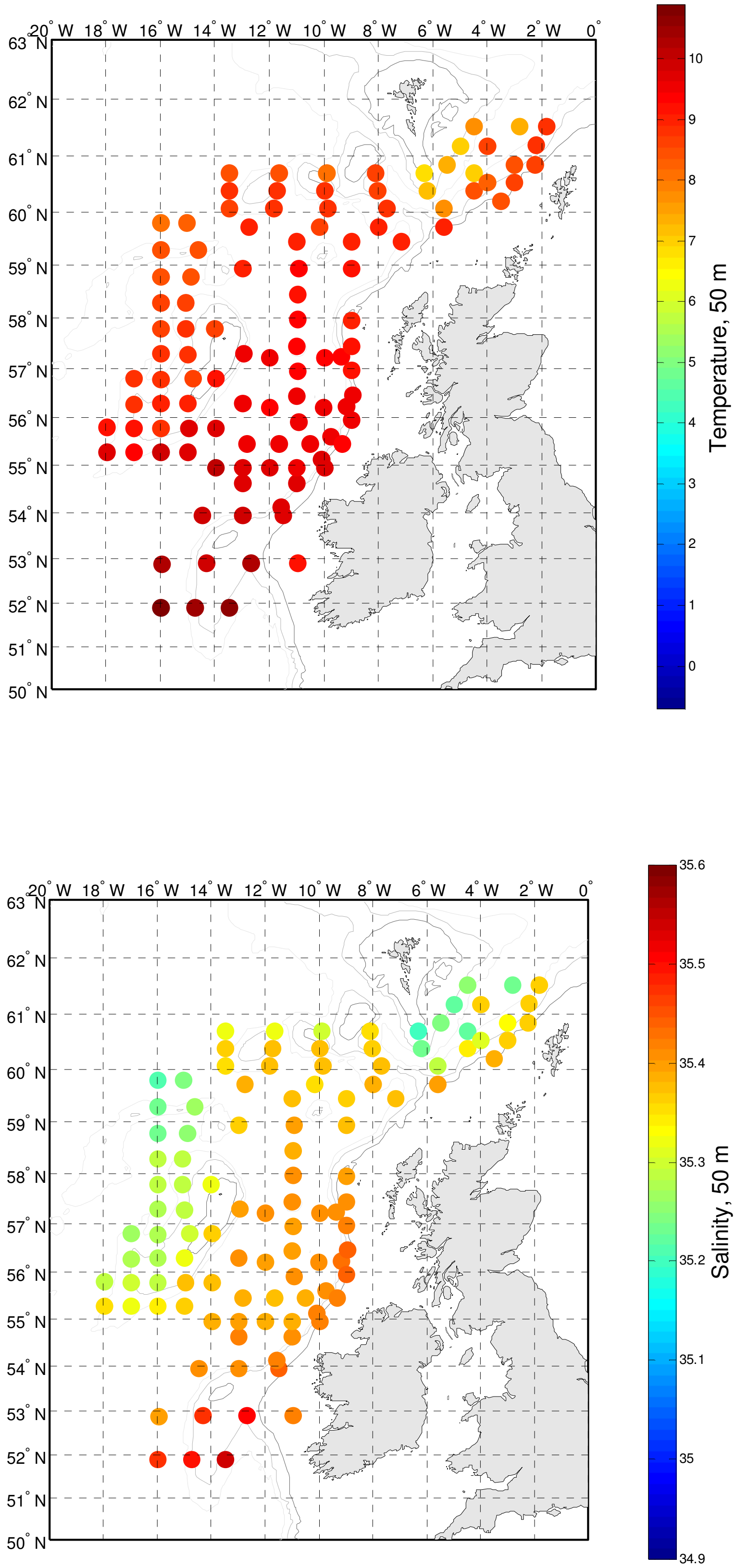


Figure 12. Horizontal temperature (top panel) and salinity (bottom panel) at 50m subsurface as derived from vertical CTD casts. March-April 2015.

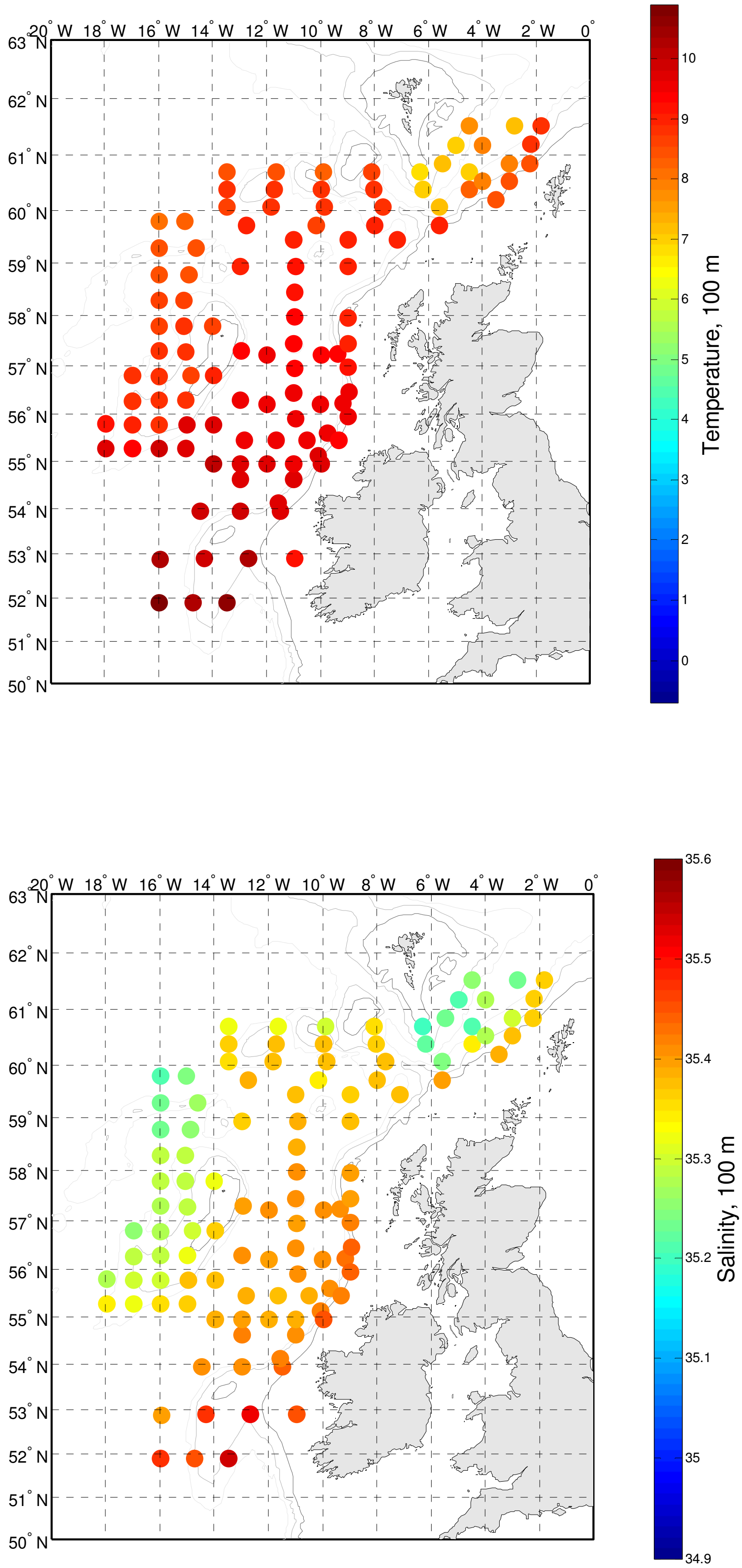


Figure 13. Horizontal temperature (top panel) and salinity (bottom panel) at 100m subsurface as derived from vertical CTD casts. March-April 2015.

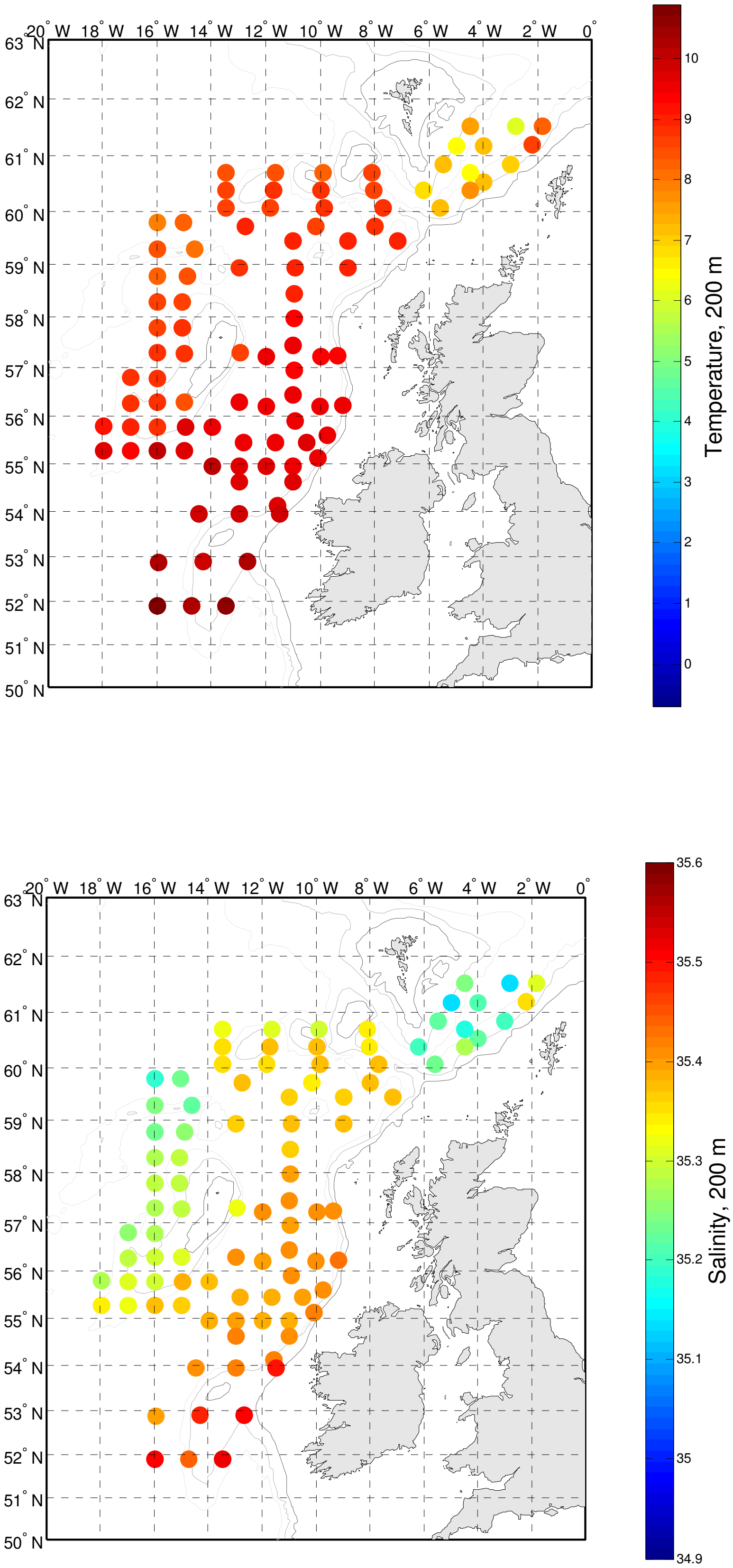


Figure 14. Horizontal temperature (top panel) and salinity (bottom panel) at 200m subsurface as derived from vertical CTD casts. March-April 2015.

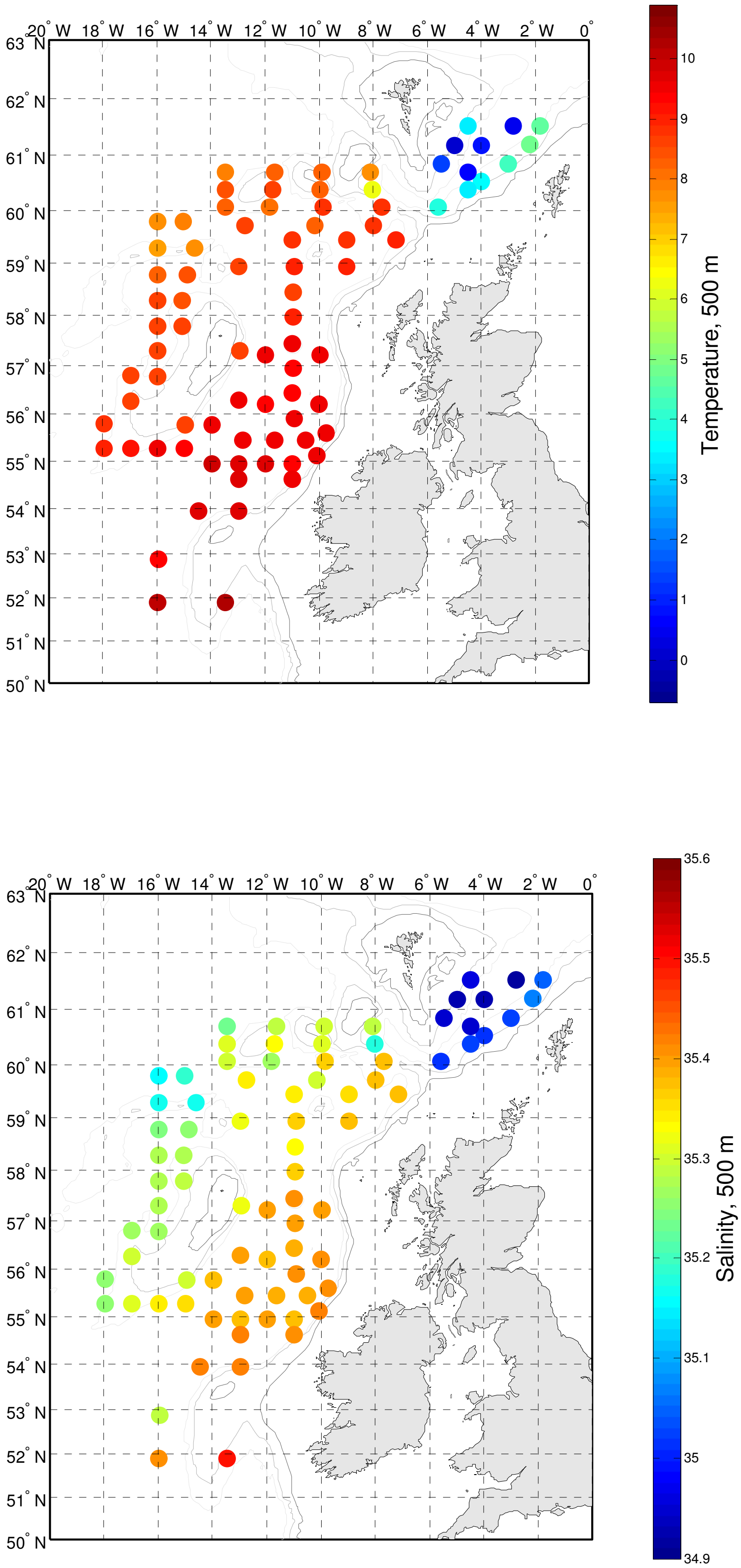


Figure 15. Horizontal temperature (top panel) and salinity (bottom panel) at 500m subsurface as derived from vertical CTD casts. March-April 2015.

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

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 2015 survey as well as nine earlier international surveys. Mean acoustic density over the survey area was 316.6 m^2/n.m.^{2} (as compared to 698.5 m^2/n.m.^{2} in 2014) with 95% confidence interval being 284.4 (lower) and 357.1 (upper) m^2/n.m.^{2}. Relative to the mean, the approximate 95% confidence limits are –10.1% and +12.8%, and 50% confidence limits are –3.8% and +3.5%. This level of uncertainty in acoustic densities is comparable to previous years. Overall, mean acoustic density has shown a consistent decrease annually from 2007 to 2010 and an increase thereafter until 2013. In 2014, the observed mean acoustic density has dropped slightly and this year it has decreased again considerably compared to last year.

Figure 2 summarises 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 2014 estimate showed a slightly decreasing trend in biomass when compared to the previous two years. This year, the biomass dropped again in a similar level previously observed in the years after 2007. However, the decline in biomass observed this year is the most sharpest in the time series.

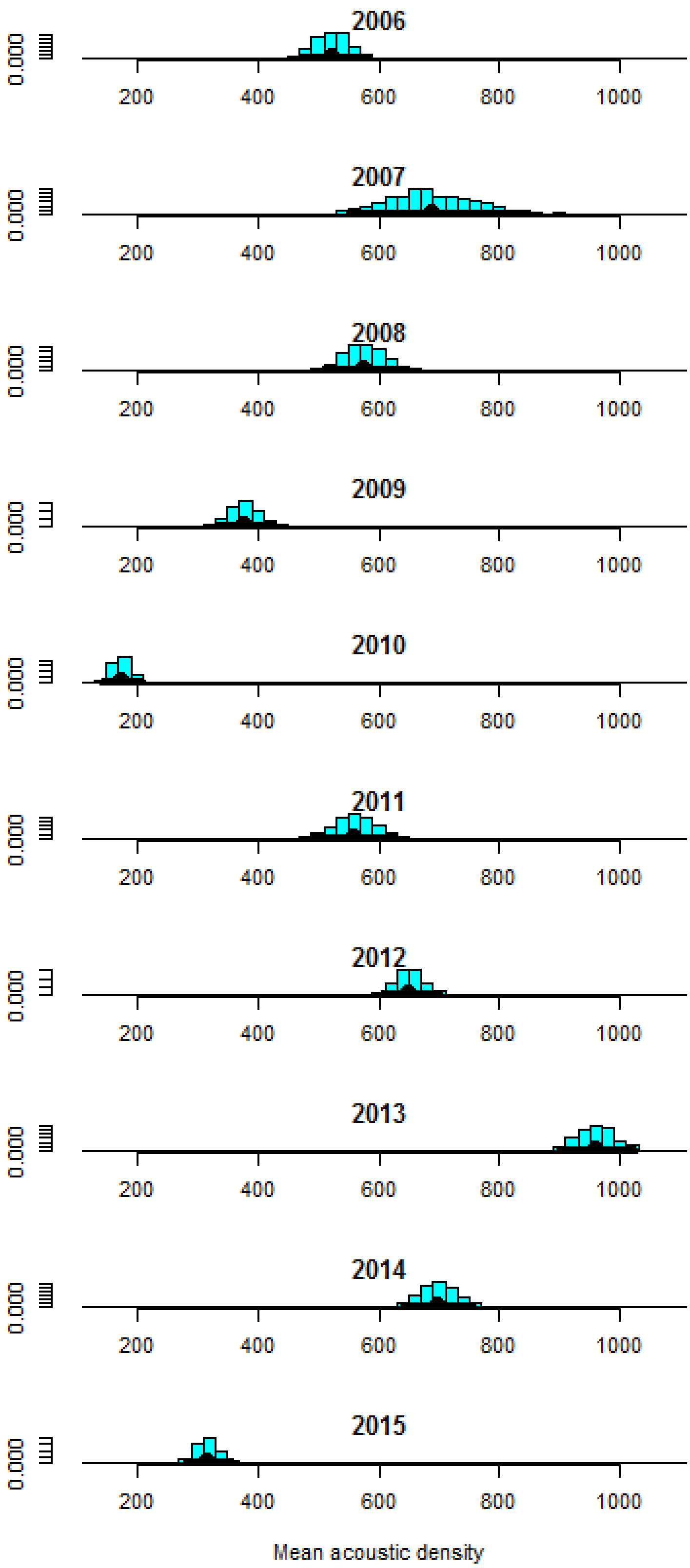


Figure 1. Distribution of mean acoustic density (in $m^2/n.m.^2$) by year based on 1000 bootstrap replicates of acoustic data from blue whiting surveys. Mean acoustic density is indicated with a black dot on the x-axis, while the horizontal bar shows 95% confidence limits.

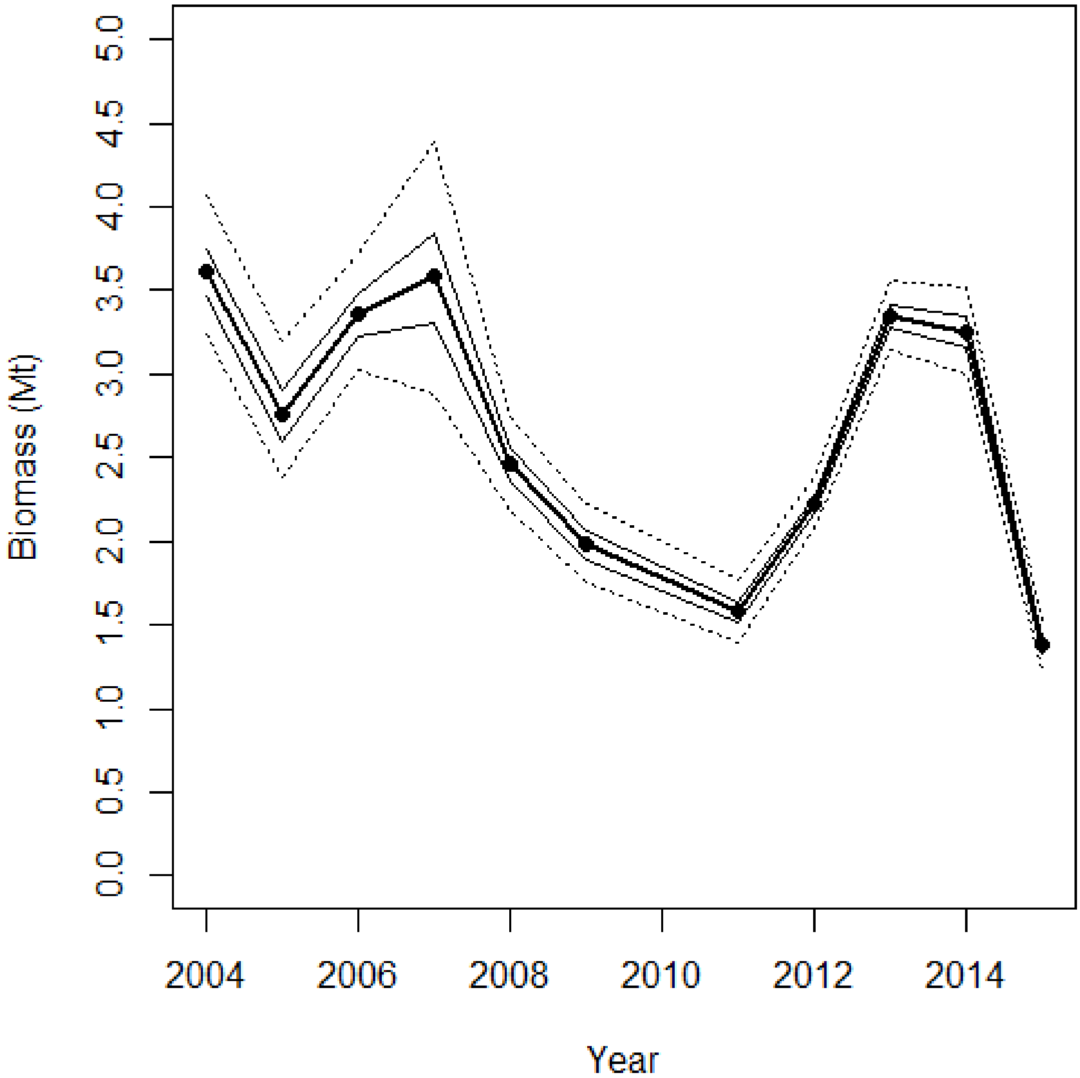


Figure 2. Approximate 50% and 95% confidence limits for blue whiting biomass estimates. The confidence limits are based on the assumption that confidence limits for annual estimates of mean acoustic density can be translated to confidence limits of biomass estimates by expressing them as relative deviations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

Appendix 2. Planned acoustic survey of the NE Atlantic blue whiting spawning grounds (IBWSS) in 2016

Five vessels representing the Faroe Islands, the Netherlands (EU-coordinated), Ireland (EU-coordinated), Norway and Russia are expected to participate in the 2016 spawning stock survey.

Survey timing and design were discussed during the meeting. The group decided that in 2016, the survey design should follow the principle of the one used during the four previous surveys. The focus will still be on a good coverage of the shelf slope in areas II and III. Survey design will remain adaptive to information received and will be finalized during the WGIPS 2016 meeting taking into account information from WGWIDE.

The design is based on variable transect spacing, ranging from 30 nmi in areas containing less dense aggregation (e.g. subarea I, south Porcupine), to a minimum of 10 nmi in the core survey area (subarea III, Hebrides) (Figure 4.1).

Survey extension in terms of coverage (51–61ºN) will be in line with the previous year to ensure containment of the stock and survey timing will also remain fixed as in previous years.

Preliminary cruise tracks for the 2016 survey are presented in Figure 1. Detailed cruise lines for each ship will be circulated by the coordinator (Ebba Mortensen, FAMRI) to the group as soon as final vessel availability and dates have been communicated (after WGIPS, latest by the end of January 2016).

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.

The survey will be carried out according to survey procedures described in the "MANUAL FOR INTERNATIONAL PELAGIC SURVEYS (IPS)" (WGIPS report 2012).

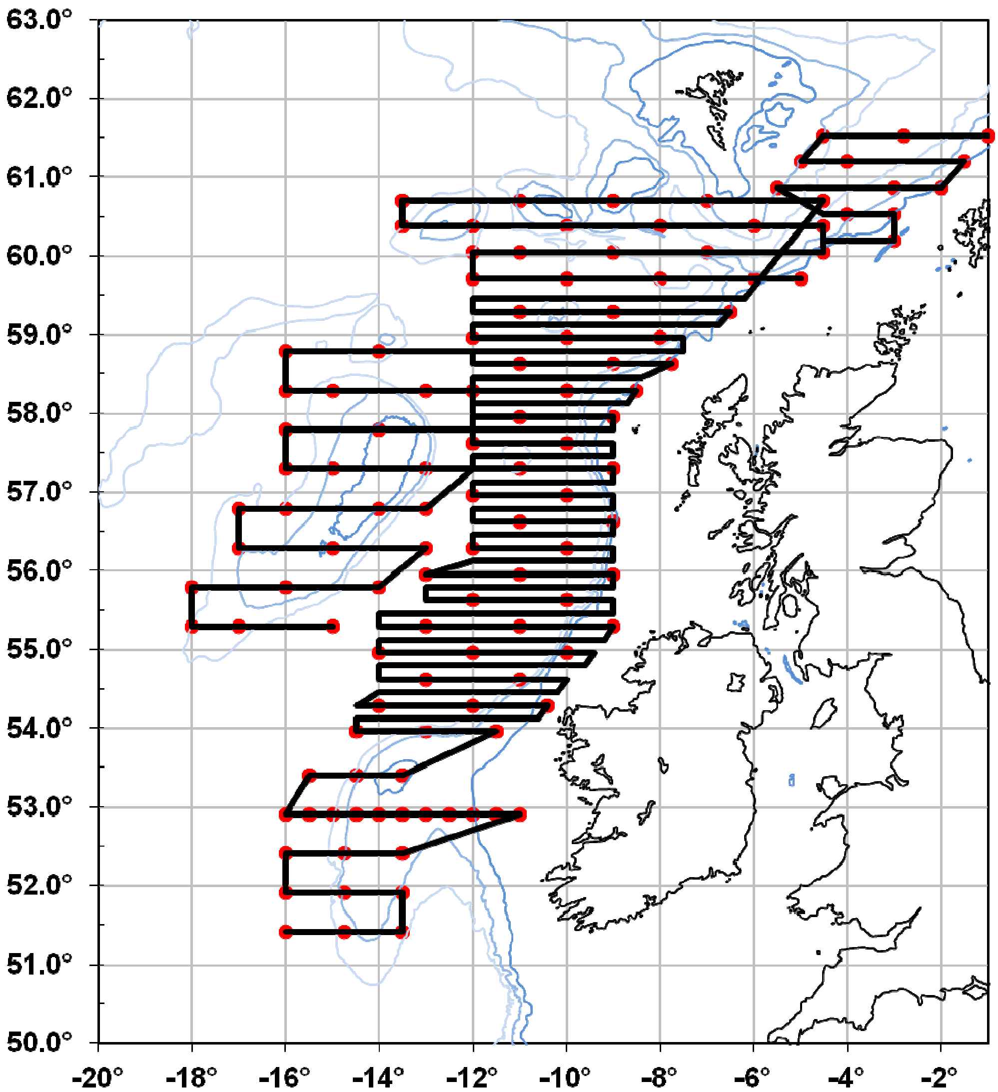


Figure 16. Preliminary survey tracks and CTD stations for the combined 2016 International Blue Whiting Spawning stock Survey (IBWSS).

Table 6. Preliminary individual vessel dates for the 2016 International Blue Whiting Spawning stock Survey (IBWSS). Final vessel dates will be submitted to the coordinator by the end of the WGIPS meeting in January 2016.

SHIP	NATION	ACTIVE SURVEY TIME (DAYS)	PRELIMINARY SURVEY DATES
Fritjof Nansen	Russia	19	18.3.2016 – 6.4.2016
Celtic Explorer	Ireland (EU)	14	23.3.2016 – 6.4.2016
G.O. Sars	Norway	14	23.3.2016 – 6.4.2016
Tridens	Netherlands (EU)	15	21.3.2016 – 5.4.2016
Magnus Heinason	Faroe Islands	12	23.3.2016 – 6.4.2016