Working Document

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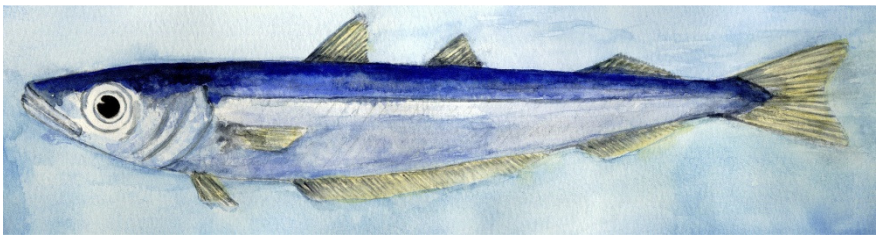

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2018

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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 survey coordinator (Norway) using real time observations. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Celtic Explorer	Marine Institute, Ireland	20/3 – 06/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	28/3 – 11/4
Tridens	Wageningen Marine Research, the Netherlands	20/3 – 4/4
Kings Bay	Institute of Marine Research, Norway	23/3 – 4/4

The survey design was based on methods described in ICES Survey design Manual (2015). Overall weather conditions were mixed with periods of poor and good weather. All vessels experienced some downtime due to poor weather conditions. The entire survey was completed within 20 days, below the 21 day target threshold.

Cruise tracks and survey strata are shown in Figure 1. Trawl stations for each participant vessel are shown in Figure 2 and CTD stations in Figure 3. All vessels worked in a northerly direction (Figure 4). Communication between vessels occurred daily via email to the coordinator exchanging up to date information on blue whiting distribution, echograms, fleet activity and biological information.

Sampling equipment

Vessels employed a midwater trawl for biological sampling, the properties of which are given in Table 1. Acoustic equipment for data collection and processing are presented in Table 2. Survey abundance estimates are based on acoustic data collected from calibrated scientific echo sounders using an operating frequency of 38 kHz. All transducers were calibrated using a standardised sphere calibration (Demer et al. 2015) prior, during or directly after the survey. Acoustic settings by vessel are summarised in Table 2.

Biological sampling

All components of the trawl haul catch were sorted and weighed; fish and other taxa were identified to species level. The level of biological sampling by vessel is shown in Table 3.

Hydrographic sampling

Hydrographic sampling (vertical CTD casts) was carried out by each vessel at predetermined locations (Figure 3 and Table 3). Depth was capped at a maximum depth of 1000 m in open water, with the exception of a dedicated hydrographic transect where full depth was achieved. Not all pre-planned CTD stations were undertaken due to weather restrictions.

Plankton sampling

Plankton sampling by way of vertical WP2 casts were carried out by Kings Bay (NO) and Magnus Heinason (FO) to depths of 400m and 200m respectively (Table 3).

Acoustic data processing

Echogram scrutinisation was carried out by experienced personnel, with the aid of trawl composition information. Post-processing software and procedures differed among the vessels;

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using EchoView (V.8) post-processing software for the previous days work. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species (daylight only) and blue whiting.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using EchoView (V 8) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside and mesopelagic species, blue whiting and krill (krill/mesopelagics). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

On Tridens, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.0) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On Kings Bay, the acoustic recordings were scrutinized using LSSS (V. 2. 0.0) 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

Acoustic data were analysed using the StoX software package (V 2.6), as the standard adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning_/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Baseline survey strata, established in 2017, were adjusted based on survey effort and observations in 2018 (Figure 1). The strata and transects used are shown in Figure 1 and 5. Length and weight data from trawl samples were equally weighted and applied across all transects within a given stratum (Figure 5).

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:

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

In StoX a super-individual table is produced where abundance is linked to population parameters like age, length, weight, sex, maturity etc. This table is used to split the total abundance estimate by any combination of population parameters. The StoX project folder for 2018 is available on request.

Estimate of relative sampling error

For the baseline run, StoX estimates the number of individuals by length group which are further grouped into population characteristics such as numbers at age and sex.

A total length distribution is calculated, by transect, using all the trawl stations assigned to the individual transects. Conversion from NASC (by transect) to mean density by length group by stratum uses the calculated length distribution and a standard target strength equation with user defined parameters. Thereafter, the mean density by stratum is estimated by using a standard weighted mean function, where each transect density is weighted by transect distance. The number of individuals by stratum is given as the product of stratum area and area density.

The bootstrap procedure to estimate the coefficient of variance (RStoX V1.9) randomly replaces transects and trawl stations within a stratum on each successive run. The output of all the runs is stored in a RData-file, which is used to calculate the relative sampling error.

Results

Distribution of blue whiting

In total 7,296 nmi (nautical miles) of survey transects were completed across six strata, relating to an overall geographical coverage of 128,030 nmi² (Figure 1, Tables 3). Acoustic sampling effort and area coverage were comparable to 2017 (Table 7). The stock was considered well contained within core and peripheral abundance areas (Rockall Bank and south Porcupine Bank). The distribution of blue whiting as observed during the survey is shown in Figures 6 and 7.

The bulk of the stock was located in the 3 strata bordering the shelf edge (Strata 1, 2 and 3) accounting for 88% of total biomass (Table 4). The Rockall Bank (strata 5) accounted for only 4% of the biomass in 2018 (Table 4). The two northernmost strata (South Faroes strata 4 and Shetland Channel strata 6) accounted for the remaining 8% of the biomass (Table 4). In 2018, the north Porcupine Bank strata (strata 2) increased by nearly 130% and contained 13% of the stock as compared to 6% in 2017 (Table 4).

The two highest s_A values observed in the survey were recorded by the Celtic Explorer in the southern Rockall Trough, strata 3 (Figure 8c) and the western Porcupine Bank (strata 1) accounting for 41,974 m²/nmi² and 36,693 m²/nmi² (sampling unit: one nautical mile and 50 m vertical depth channel) respectively. The third highest value was recorded by Tridens in the southern Rockall Trough, strata 3 in close proximity to that recorded by the Celtic Explorer and accounted for 34,547 m²/nmi² (Figure 8d).

The vertical distribution of blue whiting extended to deeper than has been previously observed during the survey time series. In the northern and western Porcupine Bank (strata 1&2) aggregations of blue whiting were observed to extend below the current acquisition floor of 750m (Figure 8a). These aggregations were positively identified as blue whiting by trawling. Although important, the acoustic density of blue whiting below 750 m was not considered as significant or widespread, and was restricted to a localised area.

Stock size

The estimated total biomass of blue whiting for the 2018 international survey was 4.04 million tonnes, representing an abundance of 40.6×10^9 individuals (Table 4). Spawning stock was estimated at 3.99 million tonnes and 40.0×10^9 individuals (Table 5).

Stock composition

Individuals of ages 1 to 18 years were observed during the survey.

The main contribution (86%) to the spawning stock biomass were the age groups 3, 4 and 5 with the four year olds (2014 year-class) being most abundant (50%), followed by the 2013 year-class (21%) and 2015 year-class (15%), (Table 5).

The Rockall Trough, historically the most productive stratum, accounted for upwards of 50% of the SBB in previous years, with the exception of 2013-2014 (48% and 44% respectively). In 2018, as in 2017, this stratum accounted for approximately 60% of SSB (Table 4). The highest mean weights of blue whiting were caught in the Rockall Trough stratum 3 (Figures 9 and 10).

In the northern area stratum 4 (South Faroes) reported an increase in abundance of 58% compared to 2017, while stratum 6 (Faroes/Shetland) saw a decrease in abundance of 31% (Table 4). When combined, both strata accounted for a comparable contribution to the total stock biomass as reported in 2017 (Table 4). Age group 1 (the 2017 year-class) dominated in the area south of the Faroes, followed by four year olds (Figure 12). Age groups 3-5 dominated in the Faroe-Shetland Channel, with one year olds present in smaller proportions (Figure12). The proportion of 2-year olds (2016 year-class) was low in this area in 2018 compared to 2017.

The bulk of the blue whiting observed in the 3 strata bordering the shelf edge (strata 1, 2 and 3) was dominated by 3 to 5 year olds, representing the bulk of biomass observed during the survey (Figures 12 and 13).

The proportion of blue whiting by number on the Rockall and Hatton Banks (strata 5) decreased from 6.6% in 2017 to 4.5% in 2018 following a similar pattern observed during 2016-2017 (Table 4). A decrease in salinity and temperature observed in 2017 persists in 2018 (see next section).

Four year olds (the 2014 year-class) were dominant in all strata with the exception of strata 4 (south Faroes), where 1 year olds ranked highest (Figure 12). The proportion of 1 and 2 year old fish was low in the total estimate in 2018 (Figure 13).

An uncertainty estimate based on a comparison of the abundance estimates by age was calculated for IBWSS for years 2016, 2017 and 2018 using StoX (Figure 11). It was possible to compare the progress of individual year classes, and by comparing the estimates of young year classes from 2016 to 2017 it appears evident that consistency from one year to the next is acceptable for some year classes. For example the two year olds in 2016 (2014 year class) was high and also as three year olds in 2017 and four year olds in 2018. It seems as the CV of the abundant age groups 3 to 5 was acceptable, below 0.2, in 2018 (Figure 11).

The survey time series (2004-2018) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A combined total of 101 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 16-19 respectively. In 2018, temperature and salinity for the combined area was comparable to observations in 2017. Indications of a small increase in salinity were observed in the deeper layers in 2018 (Figures 18-19).

Concluding remarks

Main results

- Weather conditions were mixed with both good and bad periods. All vessels experienced some weather induced downtime ranging from 24 hrs to 48 hrs.
- The total area surveyed was slightly lower than in 2017 and this can be accounted for in the western periphery of Rockall. Overall, acoustic sampling effort (track miles), trawling effort and biological metrics were comparable, if not higher, than in 2017.
- The International Blue Whiting Spawning stock Survey 2018 shows an increase in total stock biomass of 29% with a corresponding increase in total abundance of 15% when compared to the 2017 estimate.
- The survey was carried out over 20 days and thus within the recommended 21 day time window agreed by the group.
- Estimated uncertainty around the total stock biomass remains low, just above CV=0.12 which is lower than previous year (around 0.16).
- The stock biomass within the survey area was dominated by 3, 4 and 5 year old fish contributing 86% of total stock biomass.

- The presence of blue whiting below 750 m was not considered significant or widespread and is therefore considered to have had little impact on the overall estimate of abundance.
- The proportion of immature fish (1 year old) in the 2018 estimate is three times higher than in 2017 and is as usually most notable in the northern strata around the Faroes. No immature fish were observed from samples taken in the Rockall Bank and north Porcupine strata.

Interpretation of the results

- The group considers the 2018 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Sampling effort (biological and acoustic), was comparable to the previous year.
- Total stock biomass observed in 2018 is the highest in the overall time series (2004-present). Representing an increase in TSB of 29% compared to 2017 (3.1 mt and 4.0 mt respectively). The 2014 year class (4 year old fish) accounts for approximately 50% of the TSB and over 2 mt. This year class is the largest observed in the survey time series.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and up to the Hebrides.
- Although not considered a reliable indicator of emerging year class strength this survey has in the past foreseen strong or weak signals from observations in the northern strata, as in 2016. The lack of abundance of two year olds in 2018, although not definitive, may indicate a poor emerging 2016 year class.

Recommendations

- The group recommends that coverage in the western Rockall/Hatton Bank (stratum 5) should be carried out based on real time observations. That is, effort should not be expended where no aggregations are evident. We propose that western extension of transects is terminated when no blue whiting is observed for 15 nmi consistent 'clear water' miles. This applies to peripheral regions to the west of the Rockall and Hatton Bank areas.
- In order to ensure vertical containment of aggregations, participants are asked to be aware when surveying strata 1 & 2 in 2019 and adjust data acquisition depth where applicable.
- The group recommends that standardised reporting tables, including maturity proportions by length and age, be discussed and agreed upon within internationally coordinated surveys (IBWSS, IESNS, IESSNS & HERAS) at WGIPS in January 2019 and put forward to StoX developers as routine output formats.
- To facilitate the process of calculating global biomass the group requires that all data be made available at least 72 hours in advance of the meeting start date.
- The group recommends that vessels report trawl positions in the daily report and that these are plotted along with cruise track progression by the coordinator.
- Survey participants are encouraged to attend the workshop on mesopelagic methods (WKMESOMeth) in Galway 2019 in order to harmonise the categorisation criteria for the collection of meaningful acoustic data on mesopelagic fish aggregations during the IBWSS survey.

Achievements

- The entire survey area (128,030 nmi²) was covered in 20 days in line with the group recommendation of 21 days.

- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable, if not higher, than in 2017.

References

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Table 1. Country and vessel specific details, IBWSS March-April 2018.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay
Trawl dimensions				
Circumference (m)	768	640	860	832
Vertical opening (m)	50	40-45	30-70	45
Mesh size in codend (mm)	20	40	40	40
Typical towing speed (kn)	3.5-4.0	2.9-3.1	3.5-4.0	3.5-4.0
Plankton sampling	-	16	0	22
Sampling net	-	WP2 plankton net	-	WP2 plankton net
Standard sampling depth (m)	-	200	-	400
Hydrographic sampling				
CTD Unit	SBE911	SBE911	SBE911	SBE25/SAI V SD208
Standard sampling depth (m)	1000	1000	1000	1000

Table 2. Acoustic instruments and settings for the primary frequency, IBWSS March-April 2018.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay
Echo sounder	Simrad EK 60	Simrad EK60	Simrad EK 60	Simrad EK 80
Frequency (kHz)	**38**, 18, 120, 200	**38**, 200	18, **38**, 70, 120, 200, 333	18, **38**, 120, 200
Primary transducer	ES 38B	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Hull	Drop keel	Drop keel
Transducer depth (m)	8.7	3	8	8.5
Upper integration limit (m)	15	7	15	15
Absorption coeff. (dB/km)	9.4	10.1	10	9.59
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	23
2-way beam angle (dB)	-20.6	-20.8	-20.6	-20.7
Sv Transducer gain (dB)				
Ts Transducer gain (dB)	25.65	25.67	26.49	24.06
s_A correction (dB)	-0.58	-0.73	-0.64	0.008
3 dB beam width (dg)				
alongship:	7.03	7.15	6.97	7.0
athw. ship:	7.09	7.08	6.96	7.0
Maximum range (m)	750	750	750	750
Post processing software	Echoview	Echoview	LSSS	LSSS

Table 3. Survey effort by vessel, IBWSS March-April 2018.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling WP2-net	Aged fish	Length-measured fish
Celtic Explorer	21/3-4/4	2442	14	35	-	600	1700
Magnus Heinason	30/3-8/4	1232	11	16	16	592	1415
Kings Bay	23/3- 4/4	1667	11	29	29	330	1,100
Tridens	20/3-4/4	1955	13	21	-	1097	1100
Total	21/3-8/4	7296	49	101	45	2619	5315

Table 4. Abundance and biomass estimates of blue whiting by strata in 2018 and 2017. IBWSS March-April 2018.

Strata	Name	2018				2017				Difference 2018-2017	
		TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB	TSN
1	Porcupine Bank	534	5 519	13.2	13.6	616	7 367	19.6	20.9	-33%	-35%
2	N Porcupine Bank	521	5 599	12.9	13.8	177	2 084	5.6	5.9	128%	133%
3	Rockall Trough	2 475	24 708	61.4	60.9	1 871	20 855	59.7	59.3	3%	3%
4	South Faroes	164	1 604	4.1	4.0	102	881	3.2	2.5	25%	58%
5	Rockall Bank	179	1 835	4.4	4.5	215	2 321	6.9	6.6	-36%	-31%
6	Faroe/Shetland Ch.	162	1 336	4.0	3.3	154	1 670	4.9	4.7	-18%	-31%
	Total	4 035	40 602	100	100	3 135	35 178	100	100	29%	15%

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2018.

					Age in years (year class)						Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2017	2016	2015	2014	2013	2012	2011	2010	2009		(10^6)	(10^6 kg)	(g)	
17-18	7										7	0.2	31	0
18-19	30										30	1.0	33	0
19-20	73	1									74	2.9	39	8
20-21	153										153	7.1	47	3
21-22	259	5									264	14.3	54	25
22-23	196	3			4						203	12.8	63	30
23-24	112	130	55	50							348	23.8	69	93
24-25	6	135	630	762	363						1 895	137.1	72	100
25-26		169	1 631	3 449	950	137					6 336	503.4	79	100
26-27		138	1 764	6 000	1 365	204	74				9 544	825.7	87	100
27-28		48	1 541	5 301	1 356	323	46	7			8 620	829.2	96	100
28-29			587	3 420	1 018	319	72				5 416	578.3	107	100
29-30			187	1 501	1 154	387	145		9		3 383	407.5	120	100
30-31			143	631	536	298	116	33	20		1 777	235.1	132	100
31-32			21	277	410	242	59	21	6		1 036	148.7	143	100
32-33			56	55	246	104	56	21	10	6	554	90.7	164	100
33-34				34	171	98	89		12	4	407	75.1	184	100
34-35				11	42	48	34	41		11	186	38.1	204	100
35-36					36		24	24	15	29	128	29.1	228	100
36-37					32		11	21		2	66	16.9	256	100
37-38						14	21			11	46	11.7	256	100
38-39						14				40	54	15.2	280	100
39-40								10		10	21	6.9	337	100
40-41					10		10	10		3	32	11.2	348	100
41-42											0	0.0	-	100
42-43											0	0.0	-	100
43-44										12	12	7.8	633	100
44-45										8	8	4.7	574	100
TSN(mill)	836	628	6 615	21 490	7 692	2 187	755	188	72	144	40 602			
TSB(1000 t)	46.4	50.6	591.4	2 024.2	836.3	274.2	118.4	36.7	12.9	38.2	4 034.5			
Mean length(cm)	21.3	25.0	26.5	27.0	27.9	29.2	30.6	33.5	32.0					
Mean weight(g)	55	81	89	94	109	125	157	195	178					
% Mature	23	99	100	100	100	100	100	100	100	100				
SSB (1000 t)	10.8	50.1	591.2	2024.2	836.0	274.2	118.4	36.7	12.9	38.2	3 993			
SSN (mill)	194	622	6613	21490	7689	2187	755	188	72	144	39 954			

Table 6. Time series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS. Total biomass in last column (1000 t).

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB
2004	1 097	5 538	13 062	15 134	5 119	1 086	994	593	164		3 505
2005	2 129	1 413	5 601	7 780	8 500	2 925	632	280	129	23	2 513
2006	2 512	2 222	10 858	11 677	4 713	2 717	923	352	198	31	3 512
2007	468	706	5 241	11 244	8 437	3 155	1 110	456	123	58	3 274
2008	337	523	1 451	6 642	6 722	3 869	1 715	1 028	269	284	2 639
2009	275	329	360	1 292	3 739	3 457	1 636	587	250	162	1 599
2010*											
2011	312	1 361	1 135	930	1 043	1 712	2 170	2 422	1 298	250	1 826
2012	1 141	1 818	6 464	1 022	596	1 420	2 231	1 785	1 256	1 022	2 355
2013	586	1 346	6 183	7 197	2 933	1 280	1 306	1 396	927	1 670	3 107
2014	4 183	1 491	5 239	8 420	10 202	2 754	772	577	899	1 585	3 337
2015	3 255	4 565	1 888	3 630	1 792	465	173	108	206	247	1 403
2016	2 745	7 893	10 164	6 274	4 687	1 539	413	133	235	256	2 873
2017	275	2 180	15 939	10 196	3 621	1 711	900	75	66	144	3 135
2018	836	628	6 615	21 490	7 692	2 187	755	188	72	144	4 035

*Survey discarded.

Table 7. Survey effort in the IBWSS.

Survey effort	Survey area (nmi²)	Transect n. miles (nmi)	Trawls	CTDs	Plankton	Bio sampling (WHB)	
						Measured	Aged
2004	149 000		76	196			
2005	172 000	12 385	111	248	-	29 935	4 623
2006	170 000	10 393	95	201	-	7 211	2 731
2007	135 000	6 455	52	92		5 367	2 037
2008	127 000	9 173	68	161	-	10 045	3 636
2009	133 900	9 798	78	160	-	11 460	3 265
2010	109 320	9 015	62	174	-	8 057	2 617
2011	68 851	6 470	52	140	16	3 810	1 794
2012	88 746	8 629	69	150	47	8 597	3 194
2013	87 895	7 456	44	130	21	7 044	3 004
2014	125 319	8 231	52	167	59	7 728	3 292
2015	123 840	7 436	48	139	39	8 037	2 423
2016*	134 429	6 257	45	110	47	5 390	2 441
2017*	135 085	6 105	46	100	33	5 269	2 477
2018*	128, 030	7 296	49	101	45	5 315	2 619

* No Russian vessel in 2016, 2017, 2018.

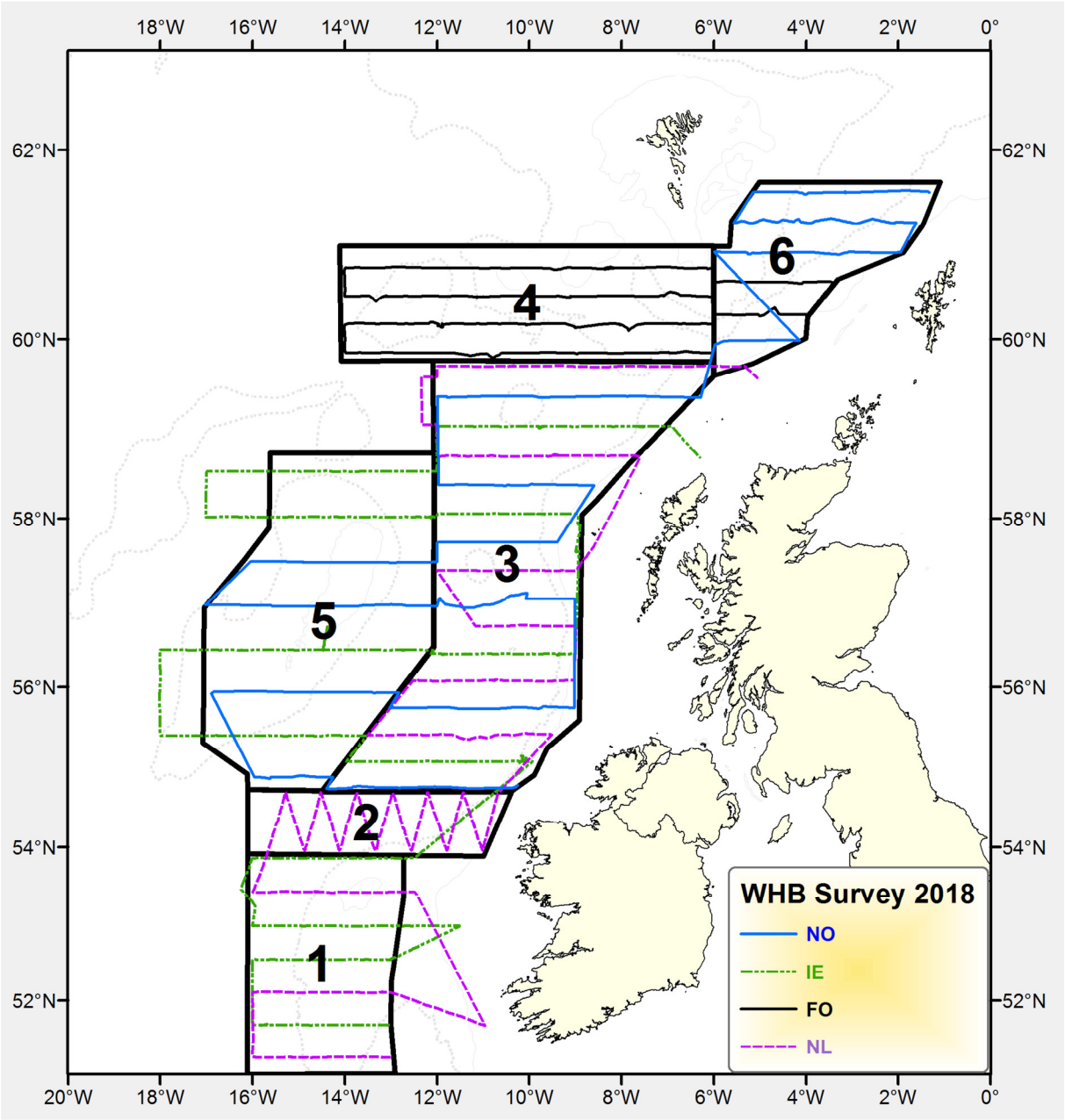


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018.

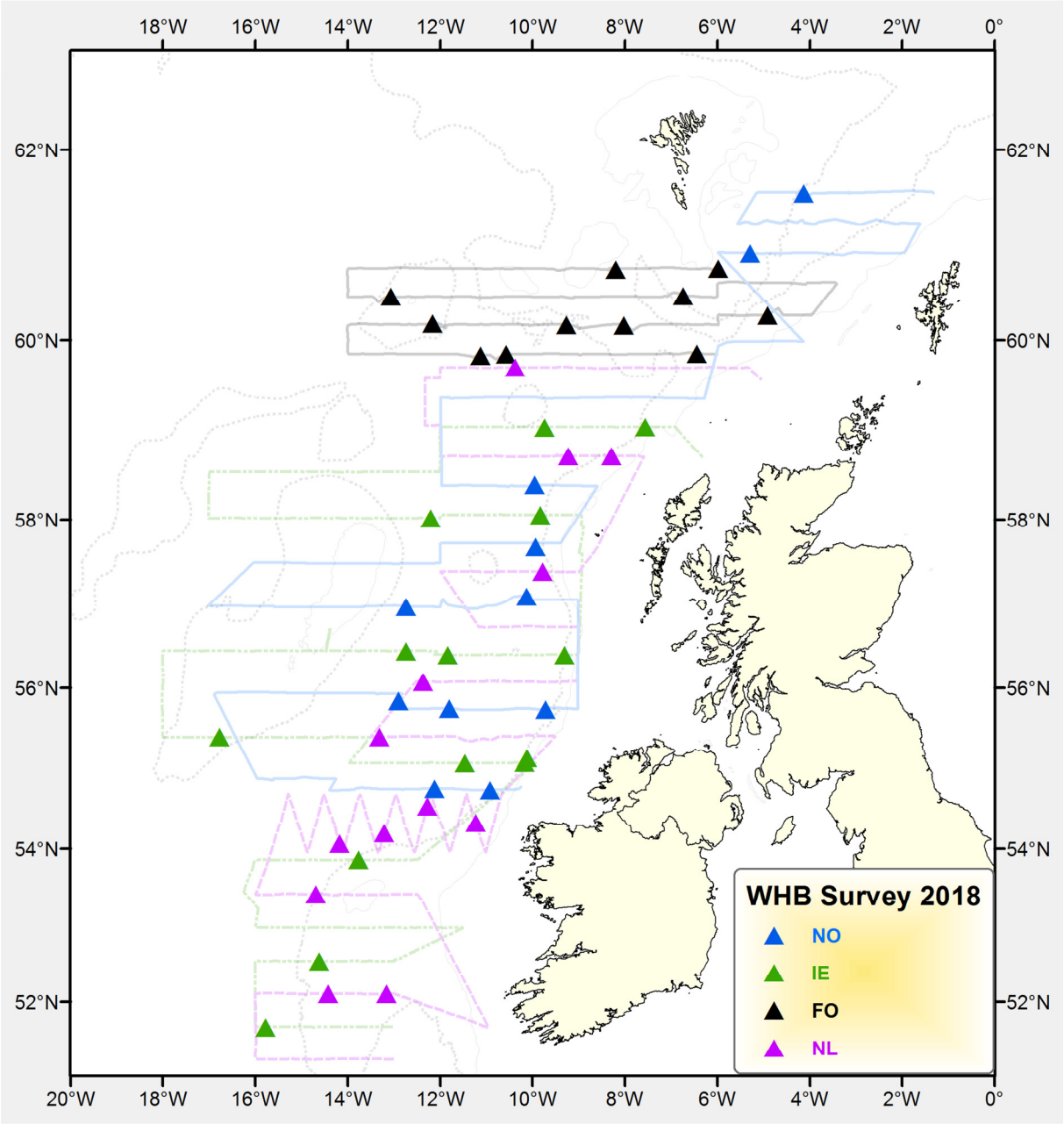


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018. IE: Ireland (Celtic Explorer); FO: Faroe Islands (Magnus Heinason); NL: Netherlands (Tridens); NO: Norway (Kings Bay).

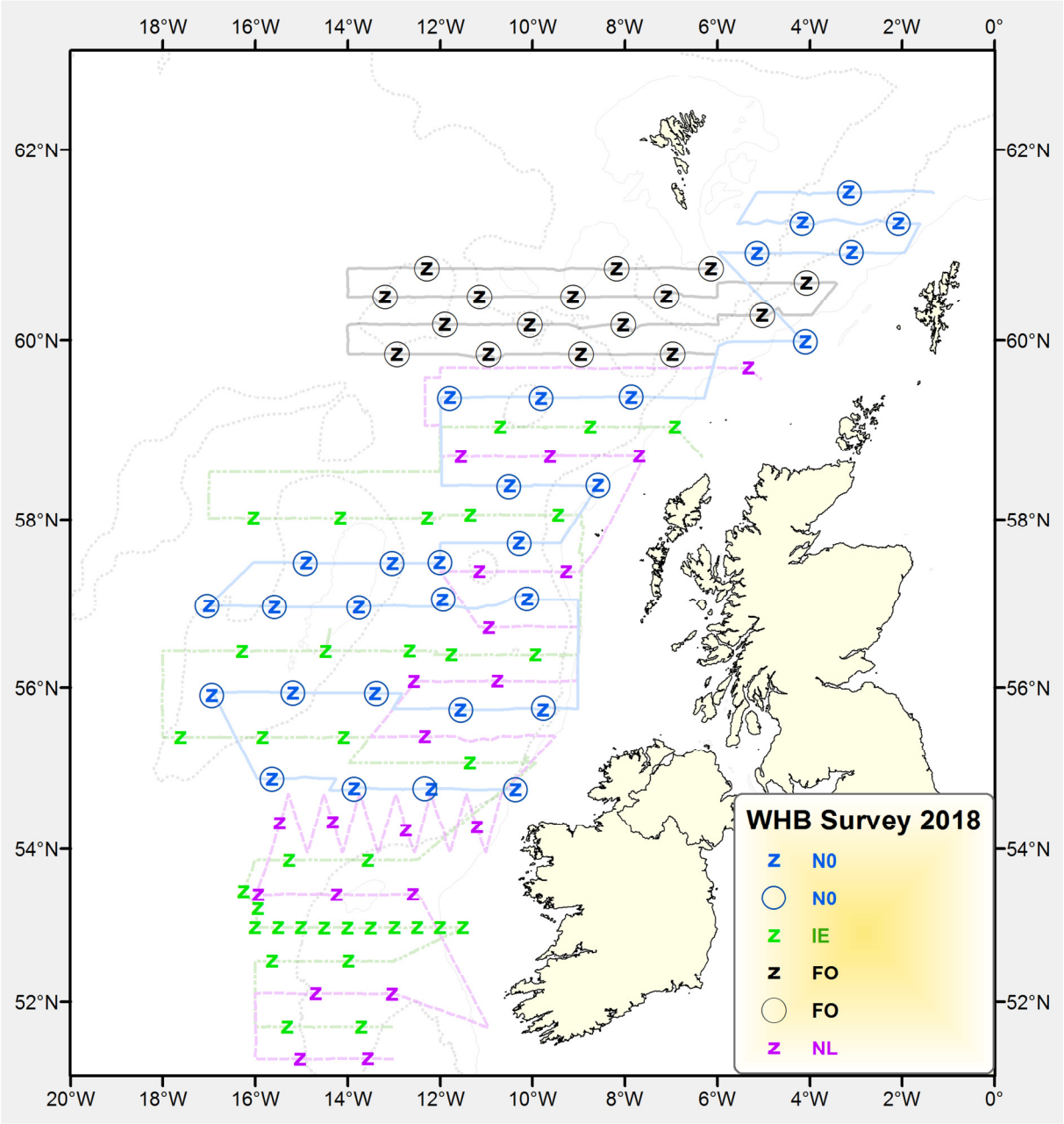


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (citrcles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018. Colour coded by vessel.

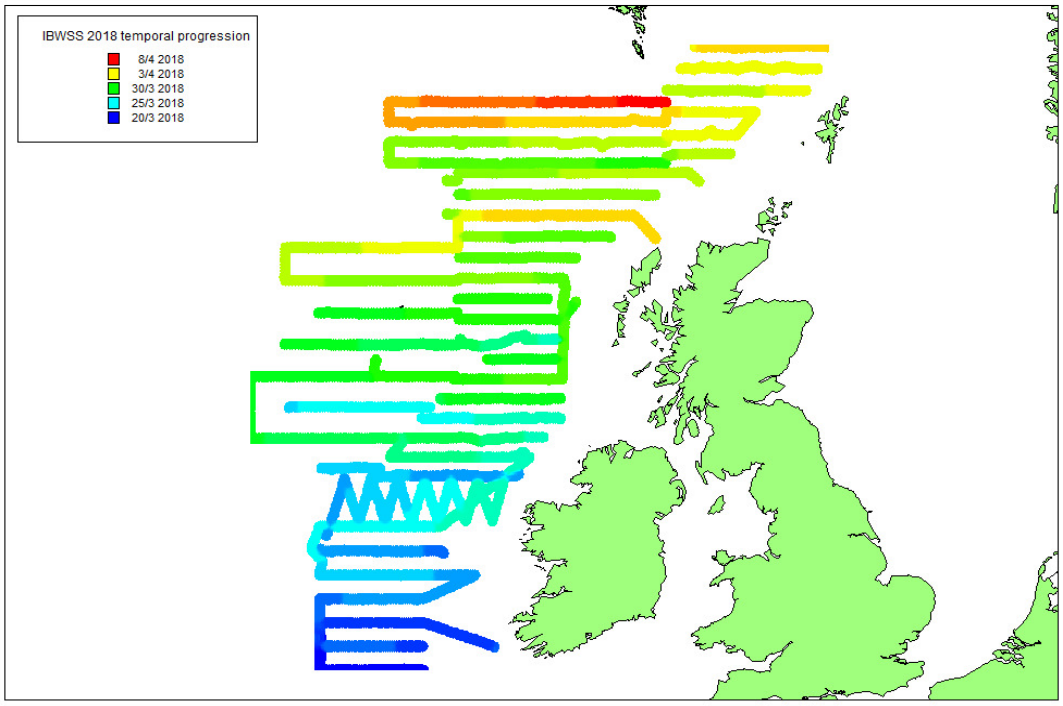


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018.

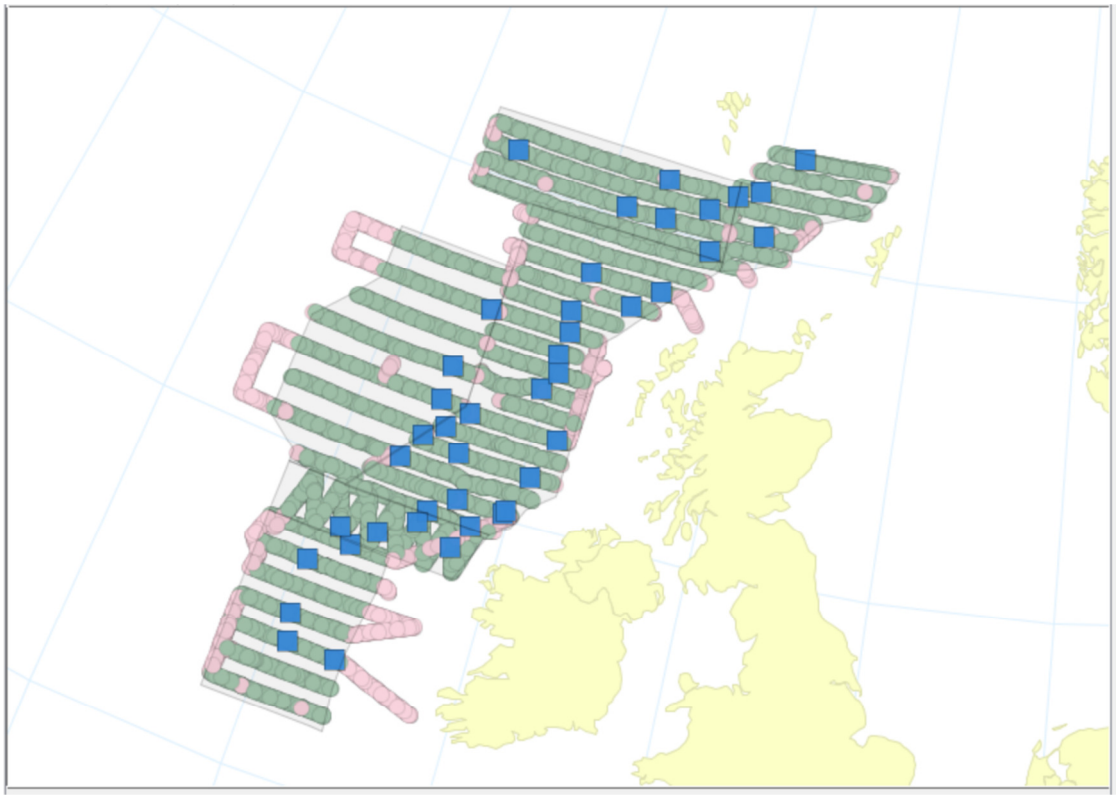


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (blue squares) used in the StoX abundance estimation. IBWSS March-April 2018.

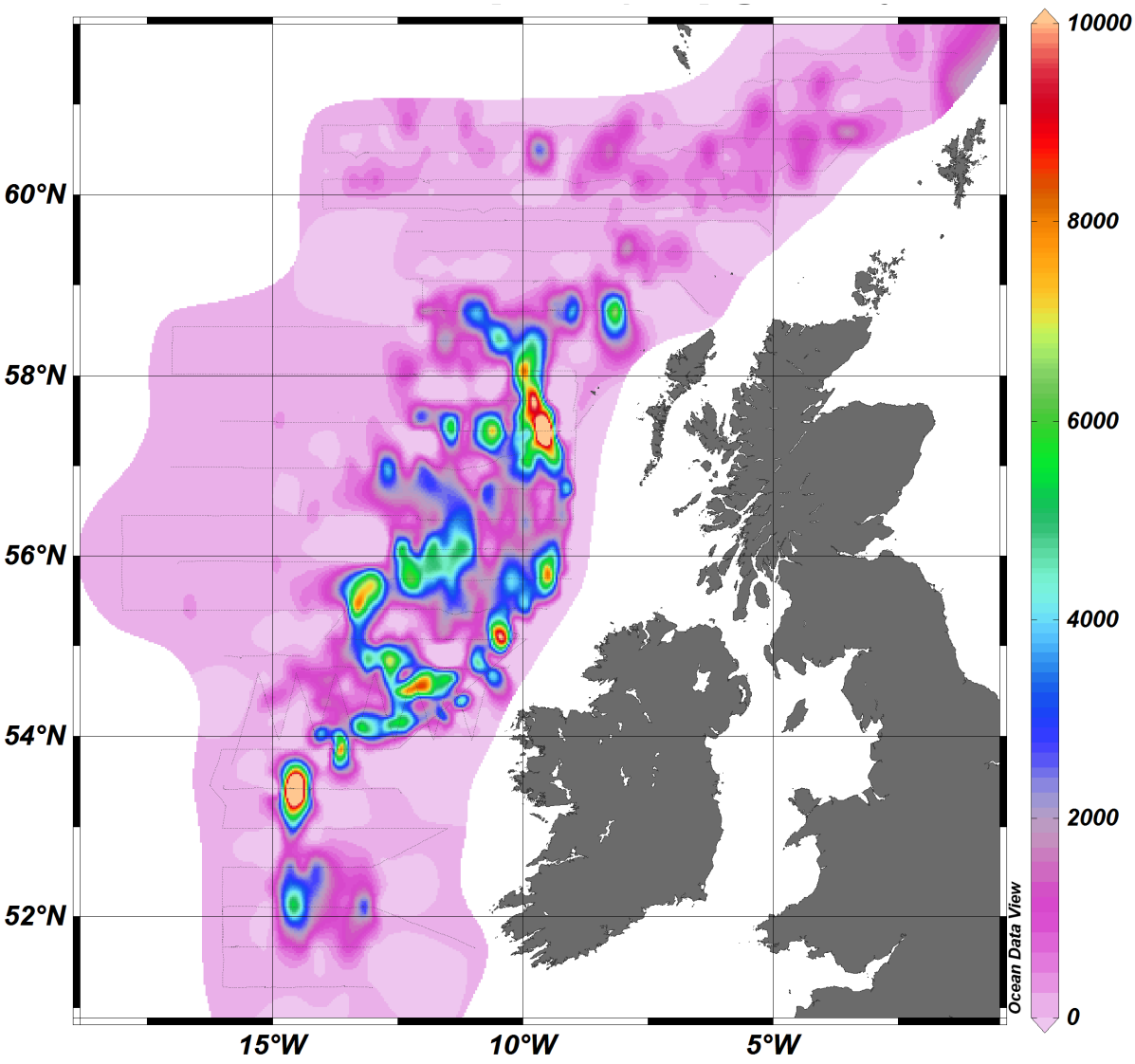


Figure 6. Map of acoustic density (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018.

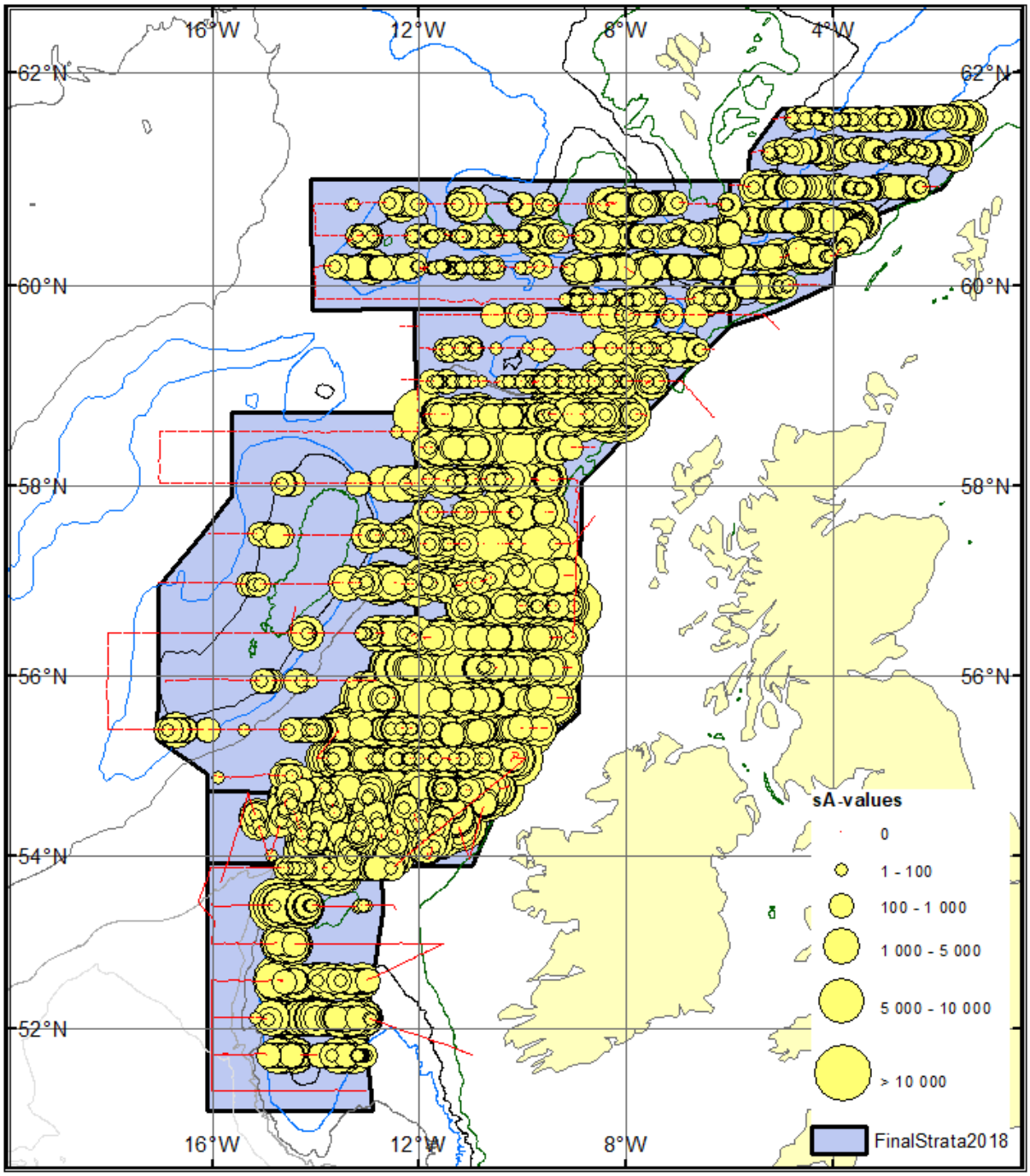
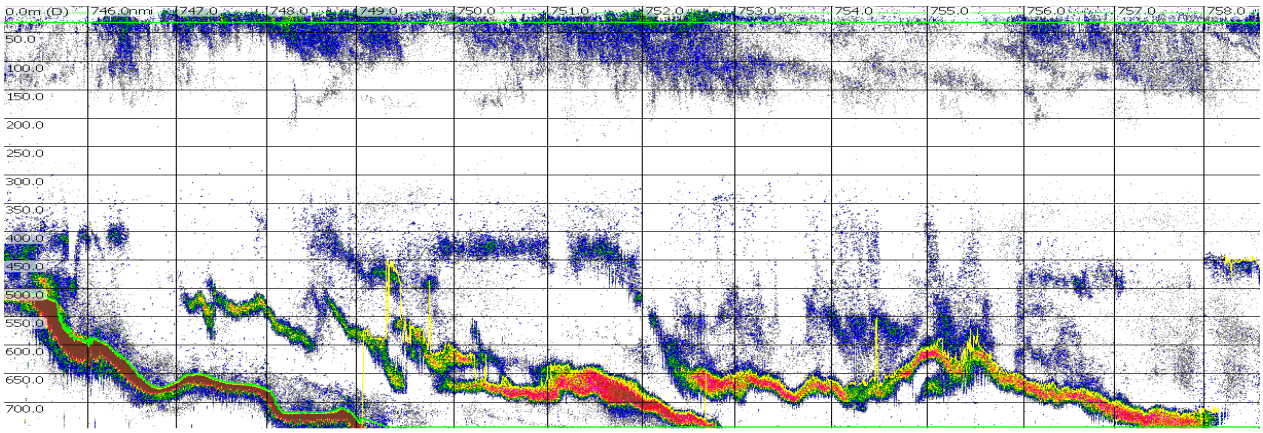
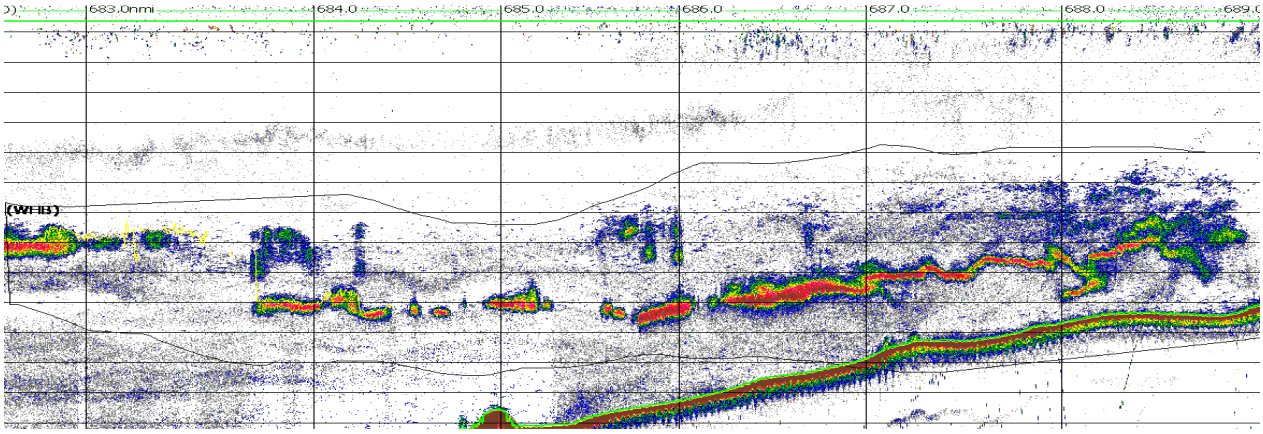


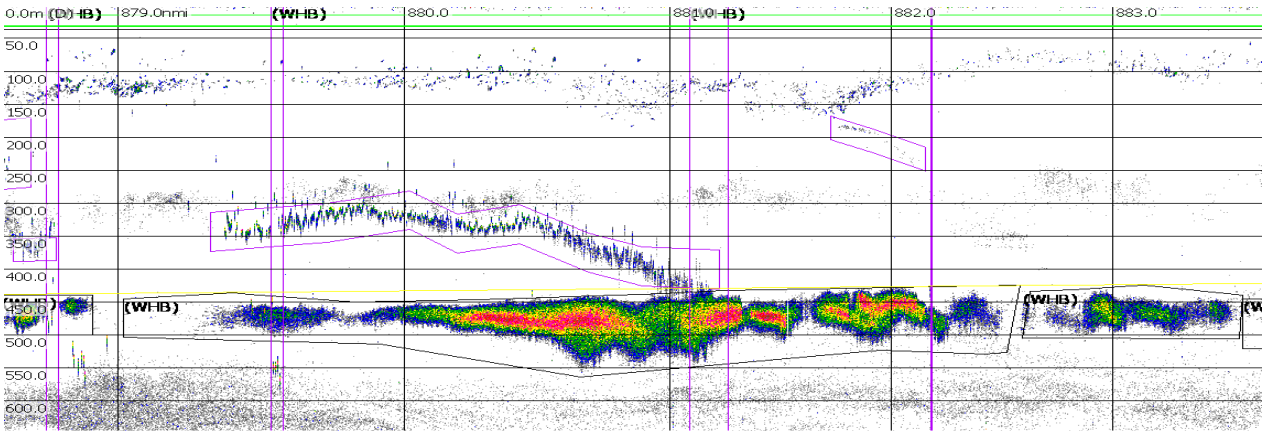
Figure 7. Map of acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi (circle scaled by acoustic density). IBWSS March-April 2018.



a) Deep and high density schools of blue whiting as observed by Celtic Explorer in the western Porcupine Bank area, strata 2. Note schools extende below the current 750m data acquisition floor.



b) High density blue whiting registrations recorded in northern Porcupine Bank area (strata 2) Celtic Explorer.



c) Single high density blue whiting aggregation per 1 nmi log interval recorded by the Celtic Explorer in the Rockall Trough Bank area (strata 3).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2018.

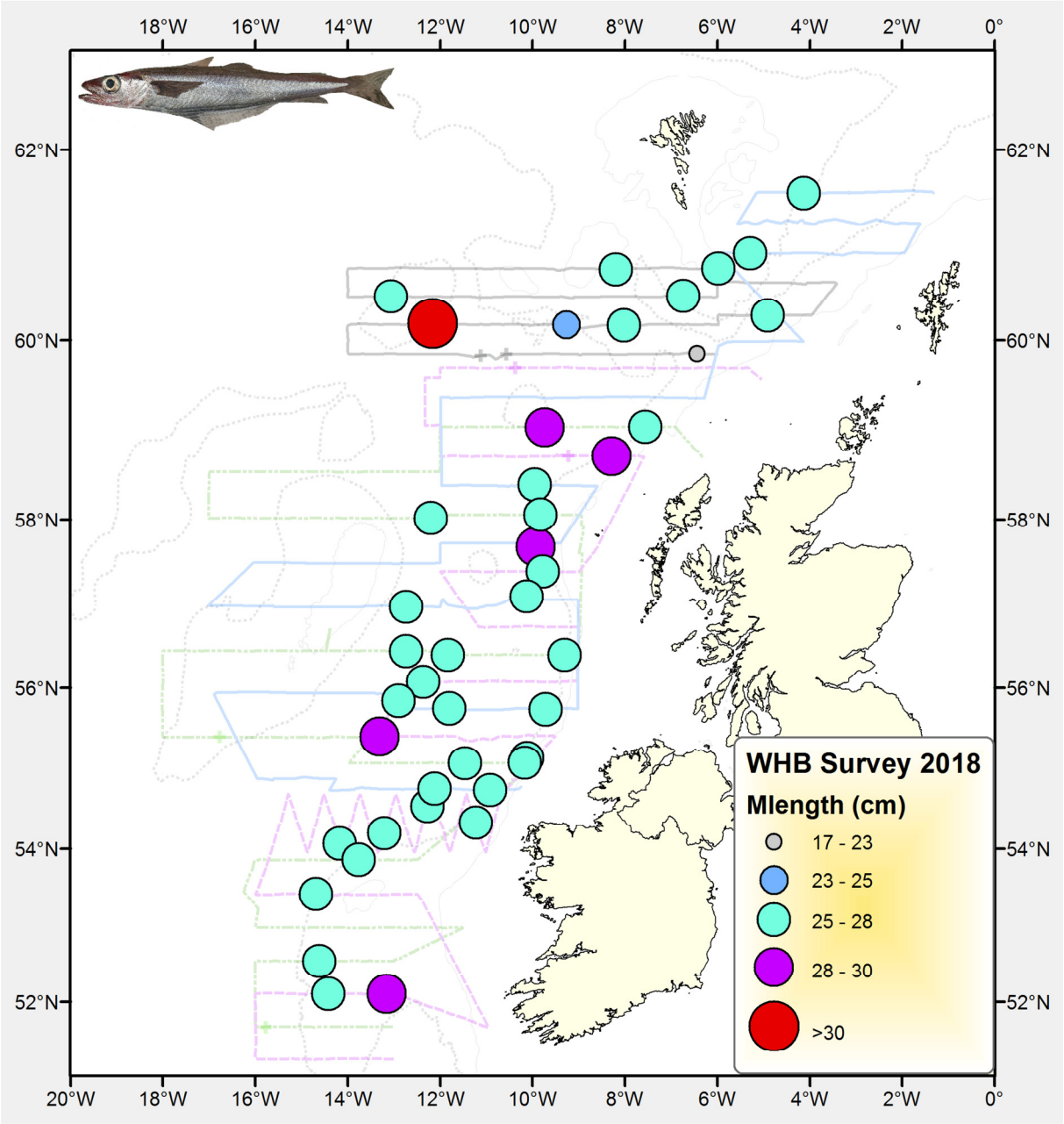


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2018. Crosses indicate hauls with zero blue whiting catches.

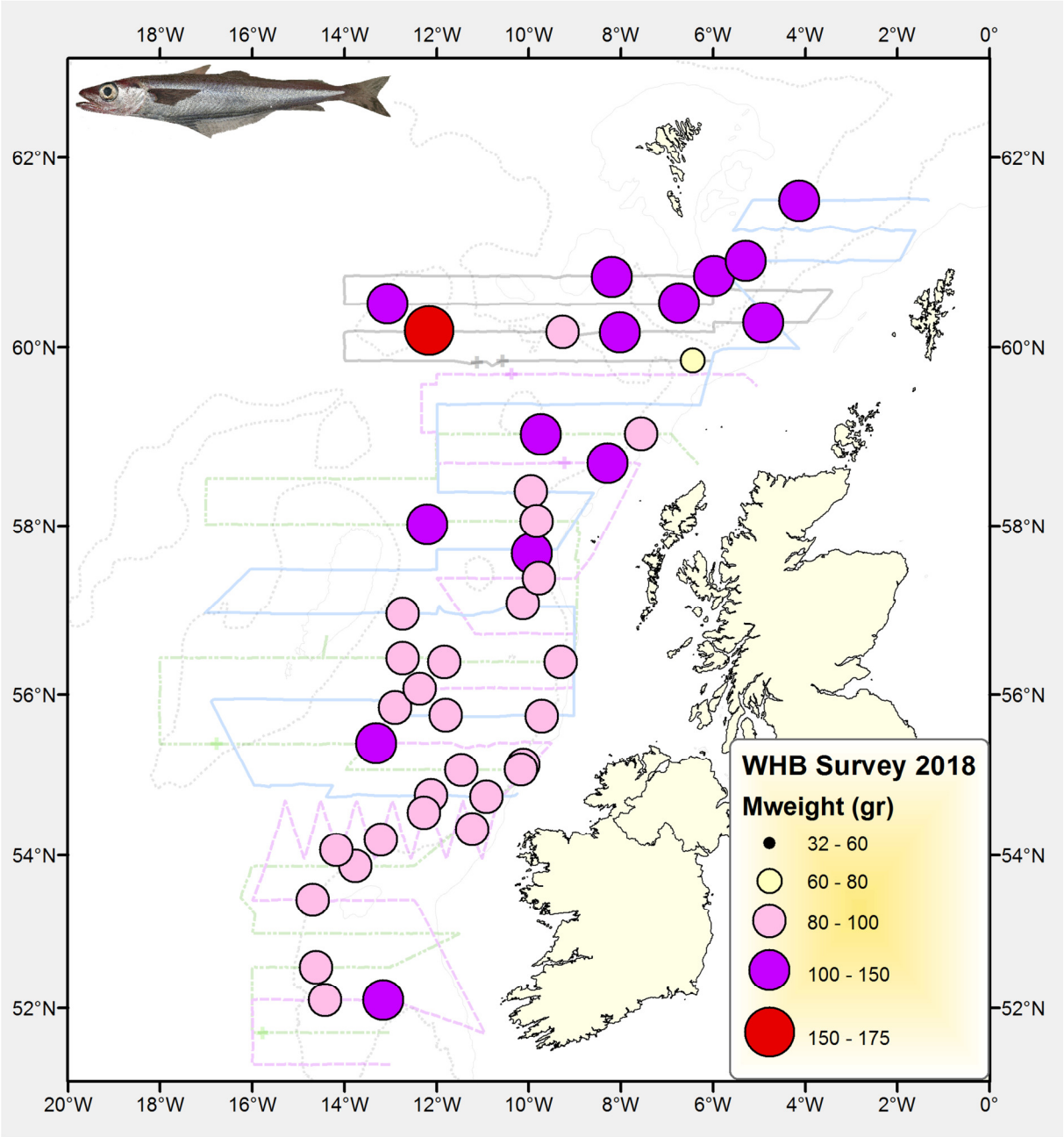


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2018. Crosses indicate hauls with zero blue whiting catches.

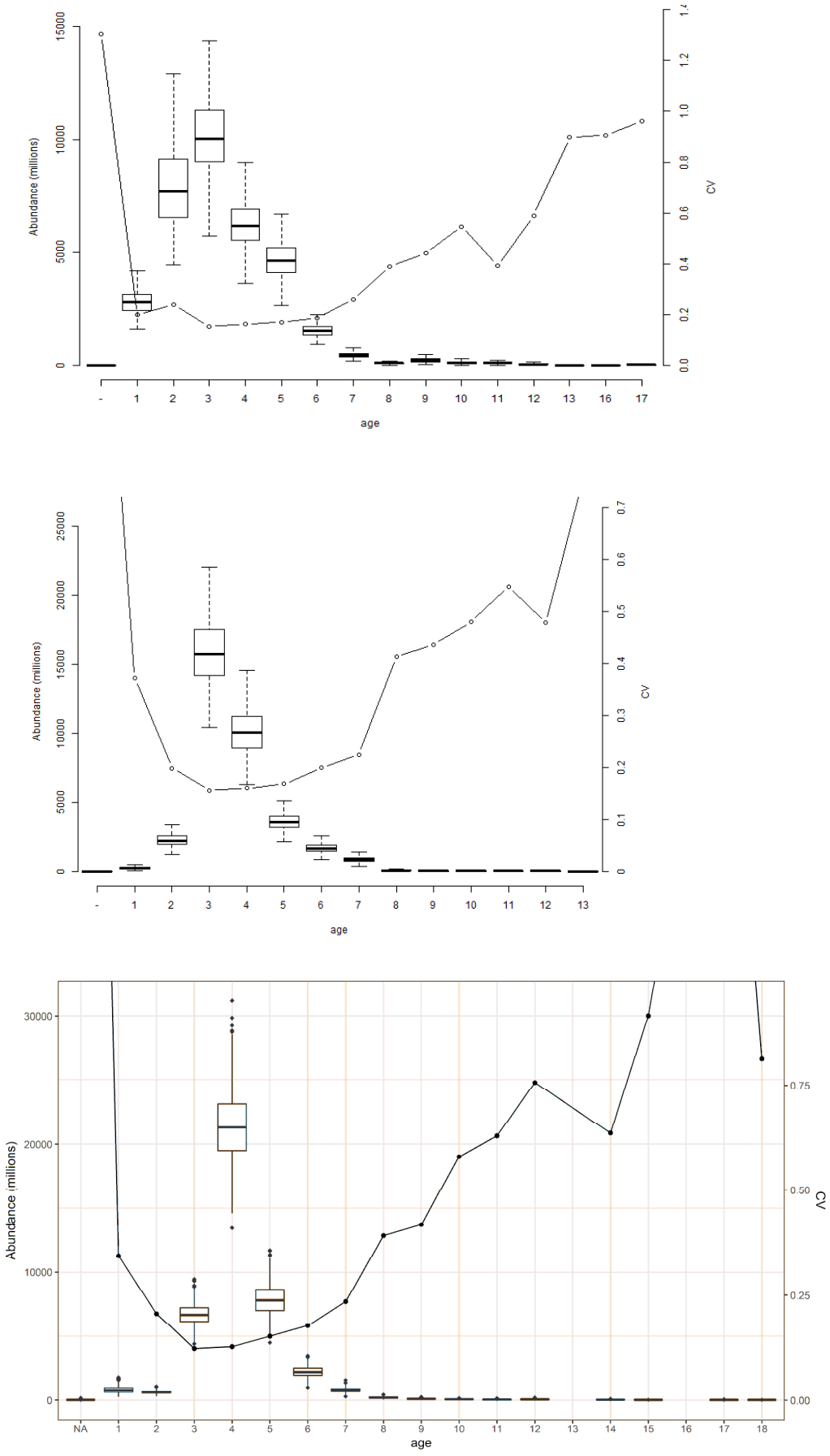


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2016 (top panel), 2017 (middle panel) and 2018 (lower panel). From StoX.

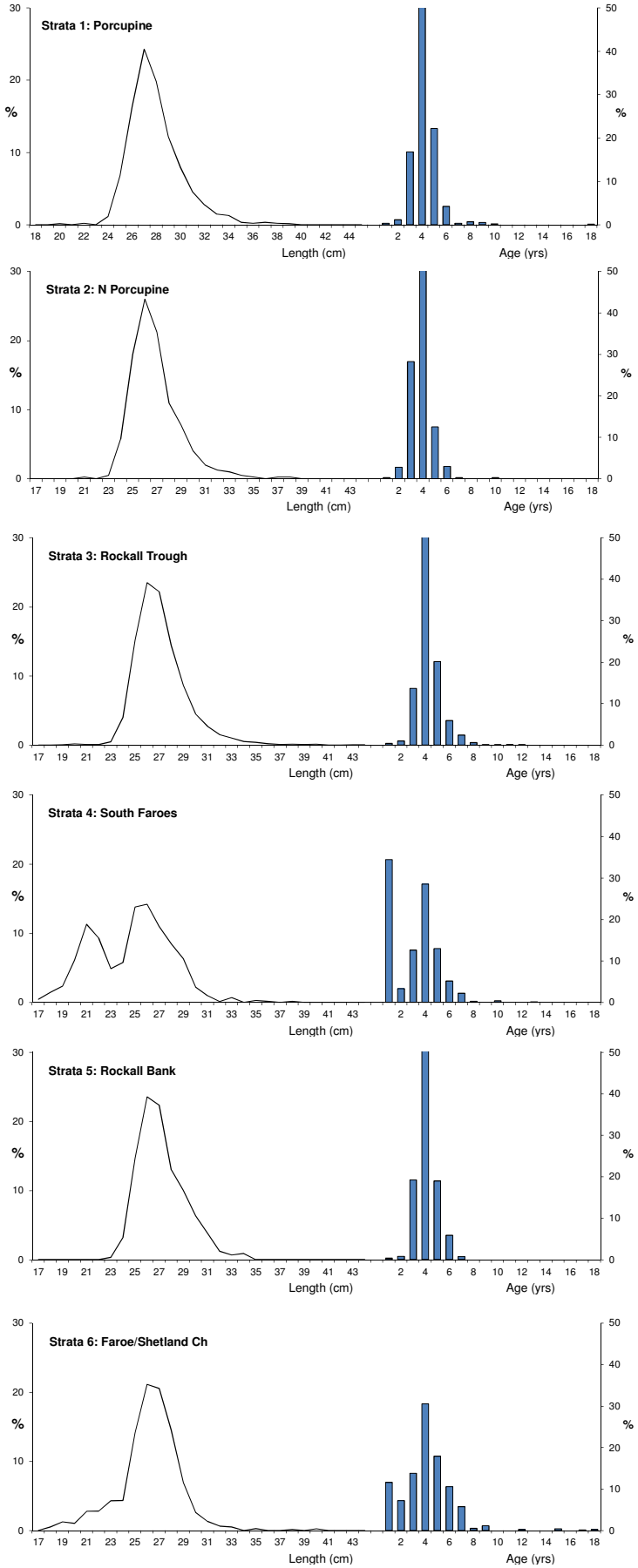


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2019.

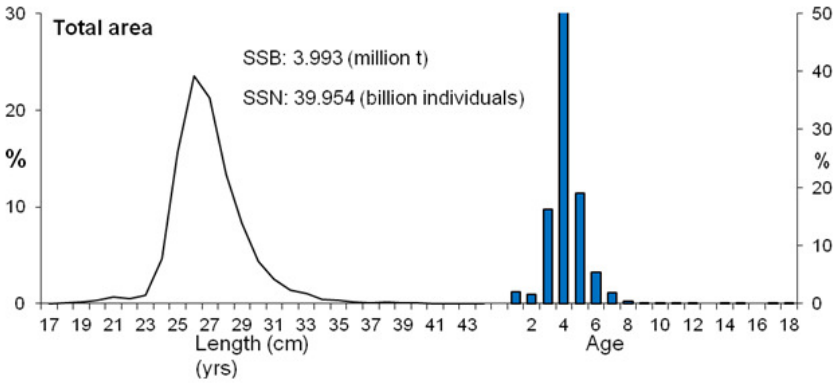


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2018.

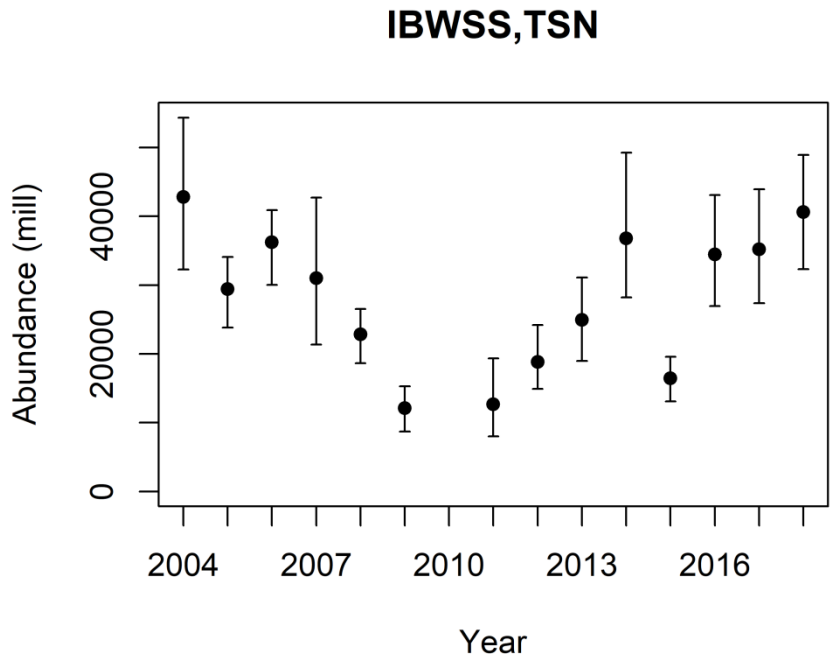


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2018, excluding 2010 due to data problems.

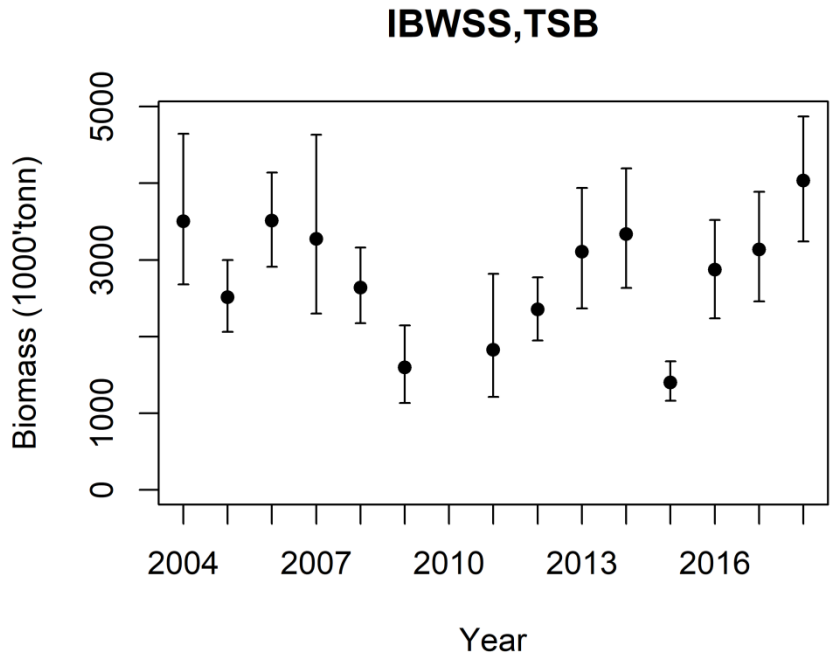


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2018, excluding 2010 due to data problems.

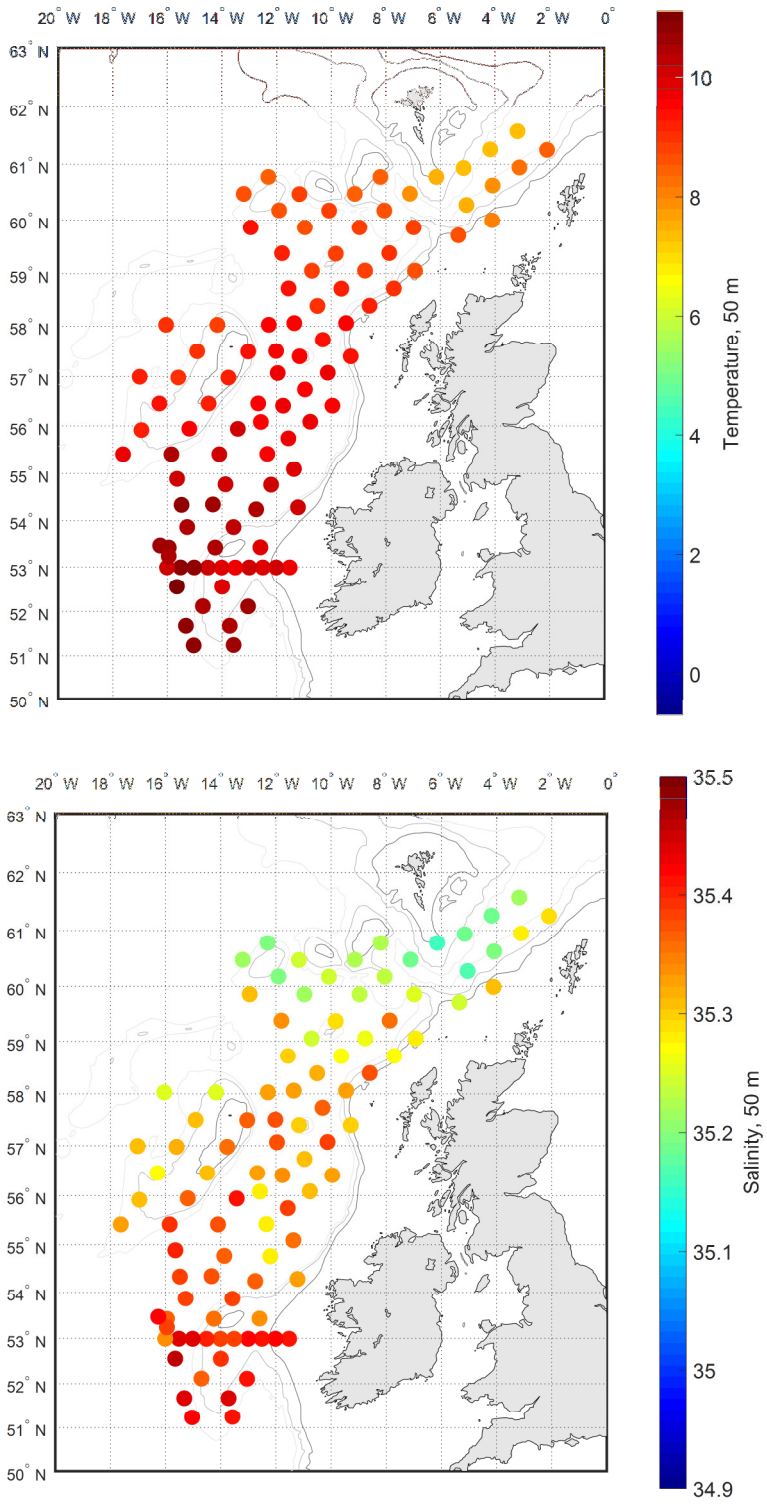


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

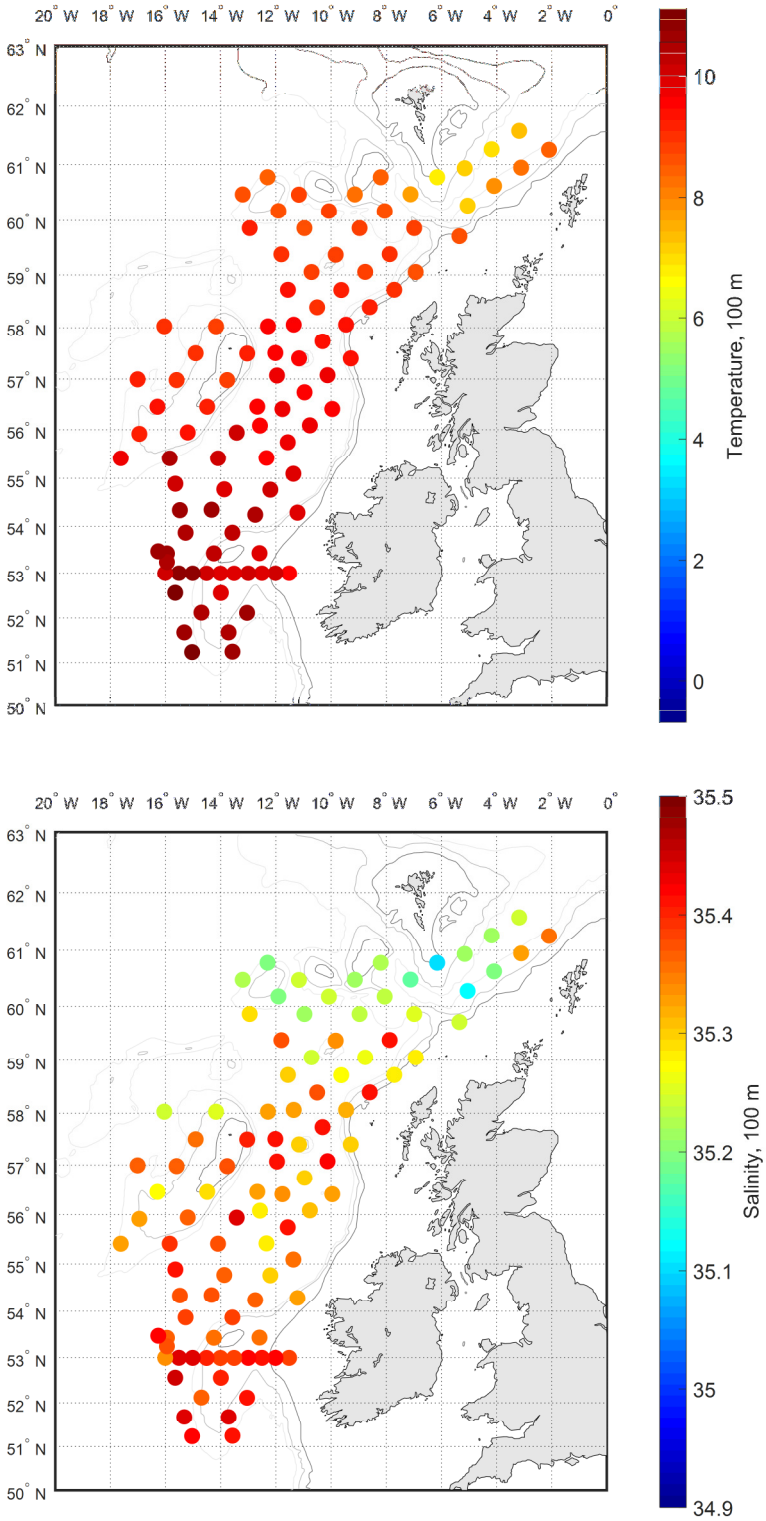


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

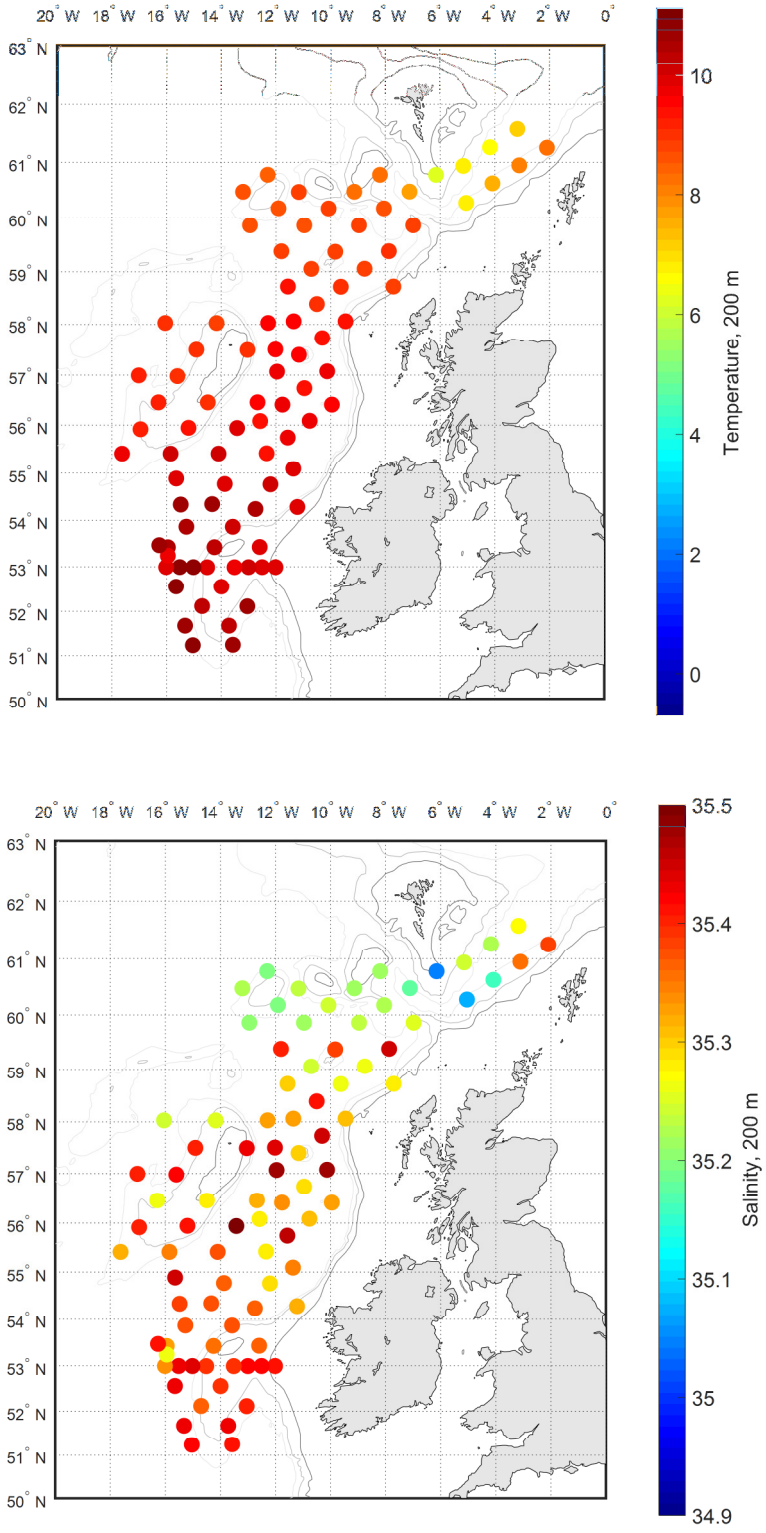


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

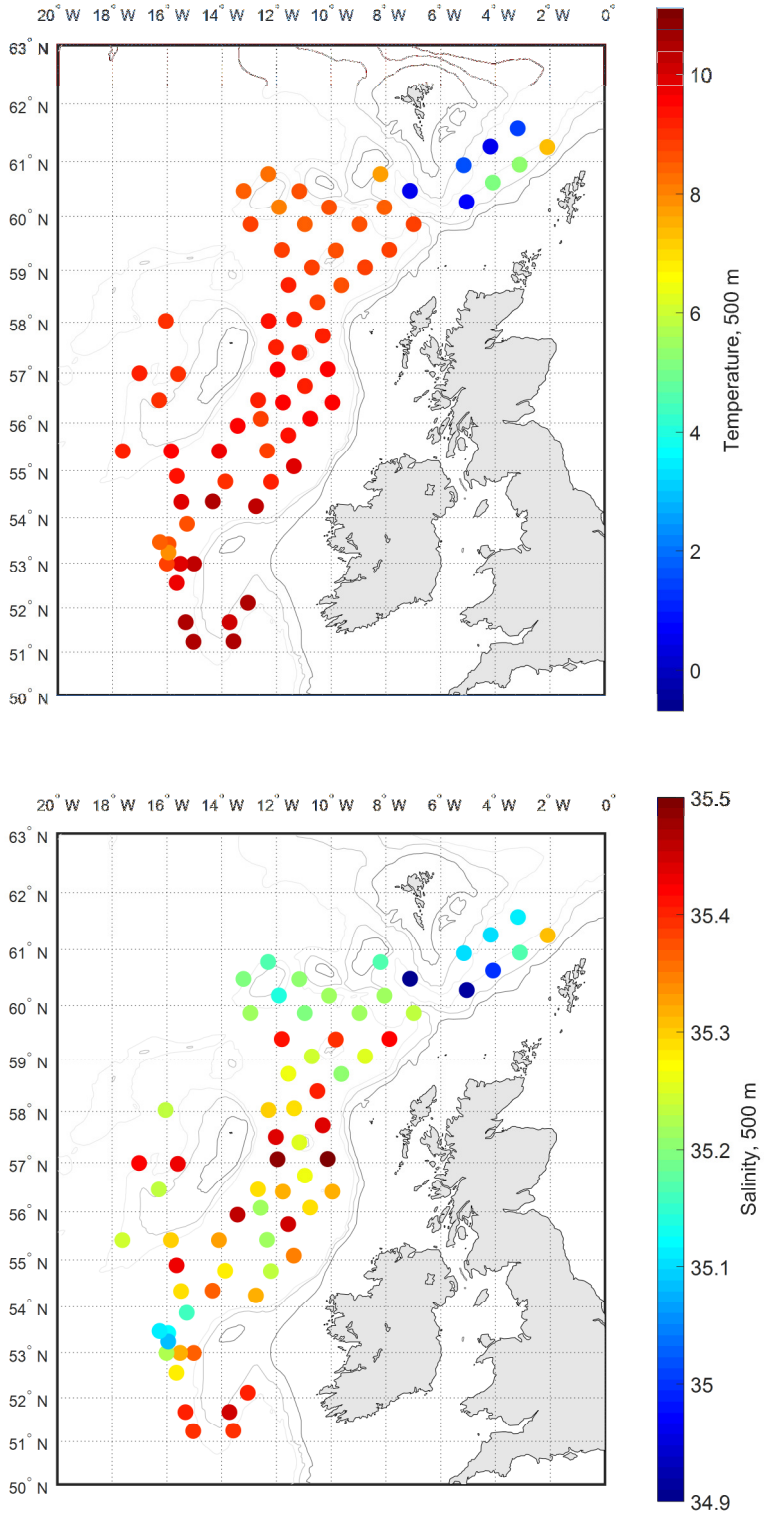


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.