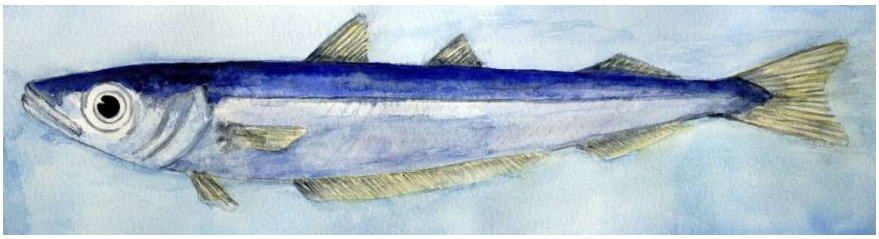
Working Document

Working Group on International Pelagic Surveys
January 2024

Working Group on Widely Distributed Stocks
August 2023



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2023

Jan Arge Jacobsen[3*], Ebba Mortensen[3*], Jens Arni Thomassen[3], Dan Askam[3], Costanza Cappelli[5], Lauren layton[7]
R/V *Jákup Sverri*

Bram Couperus[1*], Ronan Serre[1], Dirk Burggraaf[1], Felix Mueller, Thomas Pasterkamp[1], Dirk Tijssen[5],
R/V *Tridens*

Michael O'Malley[4,] Ciaran O'Donnell[4]* and Eugene Mullins[4]
R/V *Celtic Explorer*

Åge Høines[2^*], Ørjan Sørensen[2], Lea Marie Hellenbrecht[2], Tommy Gorm-Hansen Tøsdal[2], Christine Djønne[2]
M/S Vendla

Urbano Autón[6], Pablo Carrera[6]
R/V *Vizconde de Eza*

1 Wageningen Marine Research, IJmuiden, The Netherlands
2 Institute of Marine Research, Bergen, Norway
3 Faroe Marine Research Institute, Tórshavn, Faroe Islands
4 Marine Institute, Galway, Ireland
5 Danish Institute for Fisheries Research, Denmark
6 Spanish Institute of Oceanography, IEO, Spain
* Participated in post cruise meeting,
^ Survey coordinator

Material and methods

Survey planning and Coordination

Coordination of the survey was initiated at the meeting of the Working Group on International Pelagic Surveys (WGIPS) in January 2023 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	25/3 – 04/04
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	25/3 – 04/04
Tridens	Wageningen Marine Research, the Netherlands	25/3 – 31/03
Vendla	Institute of Marine Research, Norway	19/3 – 01/04
Vizconde de Eza	Spanish Institute of Oceanography, Spain	26/3 – 02/04

Survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Overall, weather conditions were mixed compared to 2022, with poor weather delaying the start of the survey by 4 days in the south for the Irish and Dutch vessels. Further north, further downtime was experienced by some vessels, accounting for slowed progress. The entire survey was completed in 17 days, within the agreed 21-day target threshold (Figure 4). Area coverage was considered comprehensive in both core and peripheral areas, with all vessels completing the planned routes. Spanish survey effort (Strata 1b) was included into the 2023 estimate as temporal alignment was achieved compared to 2022.

Vessel cruise tracks, trawl positions and survey stratification are shown in Figure 1. CTD and plankton stations are in shown in Figure 2. Communication between vessels occurred daily via email to the coordinator (Norway) exchanging up to date information on blue whiting distribution, echograms, fleet activity and biological information. Tridens keeps a weblog during the survey with echograms, catches and additional information.

Sampling equipment

All vessels employed a single 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 where possible. A summary of biological sampling by vessel is provided 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 the Faroese and Spanish vessels (500 m).

Plankton sampling

Plankton sampling, by way of vertical WP2 casts, was carried out by the RV *Jákup Sverri* (FO) to a depth of 200 m (Table 3). WP2 casts were also carried out by FV *Vendla* (NO), with a focus on sampling blue whiting eggs to a depth of 400 m.

Acoustic data processing

Echogram scrutinisation for blue whiting was carried out by experienced personnel, with the aid of trawl composition information. Post-processing software and procedures are described by vessel below;

On RV *Celtic Explorer*, acoustic data were backed up every 24 hrs and scrutinised using Echoview (V 13.0) post-processing software for the previous day's work. Data was partitioned into the following categories: blue whiting and mesopelagic fish species. For mesopelagic fish, categorisation was based on criteria agreed at WGIPS 2021 (ICES 2021, Annex 22).

On RV *Jákup Sverri*, acoustic data were scrutinised every 24 hrs on board using LSSS (2.14.1) post processing software. Data was partitioned into the following categories: plankton, mesopelagics/krill and blue whiting. Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

On RV *Tridens*, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.10.0) post-processing software. Blue whiting was identified and separated from other recordings based on trawl catch information and characteristics of the recordings. Recordings have been assigned to blue whiting and mesopelagic fish species, based on the criteria at WGIPS 2021 (ICES 2021, Annex 22).

On FV *Vendla*, the acoustic recordings were scrutinized using LSSS (V. 2.14.0) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On RV *Vizconde de Eza*, acoustic data were backed up every 24 hrs and scrutinised after the survey using Echoview (V 9.0) post processing software. Data were partitioned into the following categories: Blue whiting and Mueller's pearlside and boarfish which were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

Acoustic categorisation and targeted biological sampling of mesopelagic fish species is ongoing and will be further refined during future surveys. Progress updates will be reported through WGIPS.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V3.6.0) and R-StoX packages software package (RStoX Framework 3.6.0, RStoX Base 1.11.0 and RStoX Data 1.8.0). A description of StoX software package is provided by Johnsen et. al. (2019). Estimation of abundance from acoustic surveys using 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 2023 (Figure 1). Area stratification and transect design are shown in Figure 1 and 4. Within StoX, length and weight data from trawl samples were equally weighted and applied across all transects within a given stratum (Figure 4).

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) is used:

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

In StoX an impute super-individual table is produced where abundance is linked to population parameters including 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 2023 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 randomly replaces transects and trawl stations within a stratum on each successive run. The output of all runs are stored in a RData-file, which is used to calculate the relative sampling error.

Results

Stock size

The estimated total stock biomass (TSB) of blue whiting for the 2023 international survey was 2.5 million tonnes, representing an abundance of 29.9×10^9 individuals (Table 4). This is an 8% decrease in total stock biomass and a 5% decrease in total stock numbers (TSN) from observations in 2022 (Table 4). The spawning stock biomass (SSB) was estimated at 2.3 million tonnes representing 27.5×10^9 individuals (Table 5). This is a 1% decrease in the observed spawning stock biomass and a 15% increase in the spawning stock numbers (SSN) compared to last year. Spawning stock biomass, as determined from biological samples, showed a slight decrease in SSB with a moderate increase in SSN driven by recruitment of fish from the strong 2021-year class to the spawning stock.

Distribution of blue whiting

In total, 8,571 nmi (nautical miles) of survey transects were completed across six strata, relating to an overall geographical coverage of 147,968 nmi² (Figure 1, Tables 3 & 7), Area coverage increased by 17% as compared to 2022. Acoustic sampling (transect miles) saw an increase of 47% compared to 2022 (from 5,812 nmi to 8,571 nmi). The increase in acoustic sampling effort and area coverage can be accounted for by the below average effort in 2022, due to the early departure of the RV *Celtic Explorer* and the addition of Spanish survey effort this year in the south. The westward extension of blue whiting observed in 2023 was notable from previous years and required further survey effort to ensure containment in the west.

The stock was considered contained within core and peripheral abundance areas (Rockall Bank, Porcupine Bank and Porcupine Seabight). The distribution of blue whiting, as observed during the survey, is shown in Figures 5 and 6. The main body of the stock occurred between 54° to 57°N and schools in this stratum were observed to span the Rockall Trough from east to west. Blue whiting were observed in moderate numbers on the western flanks of the Rockall Bank (Stratum 5) for the first time in recent years.

Overall, the distribution of blue whiting was found further west into open water than observed in either 2021 or 2022, most notably in the Rockall Trough. This considered, the highest concentrations still occurred in the east at the continental shelf break in stratum 3.

The stock was distributed within core strata 1-3, totalling 77.5% of TSB and 78.8% of TSN (Table 4). A second area of abundance, somewhat geographically distinct from the main body of the stock, was observed in the northern strata (4 & 6) accounting for 13.8% of TSB and 12.8% of TSN and composed of mainly 2, 3, 4 and 1-year-old fish respectively.

The Rockall Trough (stratum 3) contained the highest abundance overall, accounting for 52% of TSB and 51% of TSN (Table 4), within this stratum the highest densities of fish were observed between 55°N to 58°N. Compared to 2022, this stratum saw a moderate increase in both TSB and TSN of 12%. The Porcupine Bank (Strata 1) saw a large decrease in TSB of 67% compared to 2022 and a corresponding decrease in TSN of 55%, indicating the bulk of the stock had already migrated northwards. The North Porcupine (Strata 2) saw a decrease of 21% of TSB and 5% in TSN. An increase of 12% TSB and TSN was recorded in Stratum 3 (Rockall Trough). The Rockall Bank (Strata 5) saw a marked increase of 1,162% TSB (from 15,000 t to 183,000 t) and an increase of 1,677% TSN as compared to 2022.

Last year the most notable change was the large increase in biomass observed in northern survey area; south Faroes and Faroe/Shetland Channel (Strata 4 & 6, respectively). In 2023, these strata also contained a relatively high proportion of the stock (13%) compared to 20% in 2022 (Table 4). The south Faroes strata showed a slight decrease in TSB of 4% (from 193,000 t to 186,000 t) and 6% in TSN compared to 2022, whereas the Faroe/Shetland Channel saw a decrease of 29% in TSB (from 226,000 t to 159,000 t) and 56% in TSN. Both strata were dominated by 2- and 3-year-old fish, followed by 4- and 1-year-old fish, respectively.

Echograms

The highest s_A value (91, 787 m²/nmi² - per 1 nmi EDSU) observed during the combined survey was recorded by FV *Vendla* in the North Porcupine stratum (Figure 7a). The second highest density value, was recorded in the Rockall Trough stratum, by the RV *Tridens* (65, 955 m²/nmi² - per 1 nmi EDSU), Figure 7b. The third highest value (56, 888 m²/nmi² - per 1 nmi EDSU) was recorded by RV *Celtic Explorer* on the shelf edge in the Rockall Trough stratum (Figure 7c). Blue whiting observations by RV Jákup Sverri (Figure 7d) on the Wywille Thompson ridge (in the Faroe-Shetland Channel stratum) showing a scattering layer of relatively high concentrations at depths between 400-500 m. The only significant concentrations of Blue Whiting observed by RV *Vizconde de Eza* were in the western part of the South Porcupine Bank at a depth of 400 m. (Figure 7e).

Stock composition

Survey samples found fish ages from 1 to 15 years (10+ group) during the survey (Table 5).

The main contribution to the spawning stock biomass was composed of the age groups 3, 2, 4 and 5 years, respectively. Combined these age cohorts represent 84% of TSB. In terms of abundance, 3-year-olds (2020 year-class) were most abundant (49%), followed by the 2-year-olds (27%), 4-year-olds (9%) and 5-year-olds (5%), respectively (Table 5).

The largest mean length value of blue whiting by strata obtained from catches came from Stratum 5 (25.5 cm), Figure 8. The largest mean weight came from Stratum 4 and was 96.3 g (Figure 9).

The bulk of the stock was composed of mixed age classes of 1 to 15 years, and dominated by mature individuals aged 3 and 4 (Figure 11). The aggregations in the northern area were dominated by 2 & 3-year-old fish with a relatively high proportion of mature individuals

(Figure 11). The abundance of these two year classes in 2023 were the highest in the time series and above the numbers associated with the 2014 record year class (Table 6, Figure 12).

Immature fish represented 5% of TSB and 7% of TSN. Over 87% of the 2-year old fish were mature contributing to the SSB of the stock (Table 5).

The CV of the total estimate of abundance was 0.16, which is lower than 2022 (2022= 0.19 and 2021= 0.14).

The survey time series (2004-2023) of TSN and TSB are presented in Figures 13 and 14 respectively and Table 6.

Hydrography

A total of 102 CTD casts were undertaken over the course of the survey (Table 1). Horizontal plots of temperature and salinity at depths of 50 m, 100 m, 200 m and 500 m as derived from vertical CTD casts are displayed in Figures 15-18, respectively. A decrease in salinity observed in 2017 persisted through 2018 and 2019, but seems to have reversed again in 2020 with an increasing trend (K.M. Larsen, pers. comm., Faroe Marine Research Institute). Pre-2020, this is thought to have limited the western extent of the blue whiting spawning distribution on the Rockall and Hatton Bank areas in recent years. Observations in 2022 and 2023 are in agreement with a reversing trend (in salinity mainly), with a more western extension of fish into the Rockall Trough than observed in recent years, with blue whiting approaching the eastern slopes of the Rockall Plateau in 2023.

Mesopelagic fish

Echogram scrutinisation for mesopelagic fish species was conducted by participants during the survey and will be uploaded to the ICES database after further analysis. Due to ongoing complexities regarding representative trawl catches these data are considered as experimental and outputs reported to the ICES database should be treated as such.

Concluding remarks

Main results

- Weather conditions were mixed and the survey start was delayed by 4 days in the southern area (Ireland & Netherlands).
- The total area surveyed and acoustic sampling effort increased from 2022 (17% and 48% respectively) and was required to contain the stock in the west and from contributions for the Spanish survey in the south.
- In terms of biological sampling effort, the number of trawl stations was reduced due to the mechanical breakdown on the RV *CE* that prevented any fishing for the duration of the survey. However, RV *Tridens* undertook trawling on some aggregations identified by the RV *CE*. The total number of fish aged and measured was comparable to 2022. The stock was considered representatively sampled in number, and across the distribution area.
- The International Blue Whiting Spawning Stock Survey 2023 shows an 8% decrease in TSB and a corresponding 5% decrease in TSN when compared to the 2022 estimate for comparable survey effort and coverage.
- In terms of abundance, 3-year-olds (2020 year-class) were most abundant (49%), followed by the 2-year-olds (27%), 4-year-olds (9%) and 5-year-olds (5%), respectively.
- Immature fish represented 5% of TSB and 7% of TSN. Over 87% of the 2-year old fish were mature contributing to the SSB of the stock.
- The abundance of the two year classes, 2 & 3-year-old fish, in 2023 were the highest in the time series and above the numbers observed associated with the previous 2014 record year class.
- Estimated uncertainty around the total stock abundance was CV=0.16 (CV=0.19 in 2022).
- The survey was carried out over 17 days, below the 21-day time window target. With core areas representatively sampled by multiple vessels.

Interpretation of the results

- The group considers the 2023 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata.
- Temporal progression was miss aligned due to poor weather delaying the vessels starting in the south leading to a mismatch timing in core regions. However, the group considers this as not ideal but acceptable nonetheless.
- The bulk of SSB was distributed from northern Porcupine Bank northwards in the Rockall Trough from 54°N to 57°N.
- Contribution of the 2020-year class remains significant as the largest and strongest year class in the time series, surpassing the previous in 2014. This year class is now considered fully recruited to the spawning stock.

Recommendations

- The group recommends that coverage in the western Rockall/Hatton Bank (stratum 5) should be carried out based on real time observations. Stock size and distribution in recent years combined with hydrographic conditions would indicate a period of westward expansion that requires monitoring.

- 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 and made available through the ICES database.
- Hydrographic and Plankton data along with Log book files formats should still be submitted in the PGNAPES format.
- The group recommends that the process of producing output reporting tables, figures and maps from StoX outputs files (StoX) are standardised in R code for consistency of reporting and replication.
- It is recommended that the effective timing of the survey starting point is maintained to begin around the 20th March in 2024.
- Faroes and Spain collect CTD data to 1,000 m in line with the other participants

Achievements

- Good stock containment within the survey area, with comprehensive trawl and biological sampling achieved.
- All survey data were uploaded to the ICES trawl-acoustic database in advance of the post cruise meeting, with the exception of the Spanish data, where corrected data was provided 7 days after the meeting.
- Survey area covered completed within 17 days.

References

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Table 1. Country and vessel specific details, IBWSS March-April 2023.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Trawl dimensions					
Circumference (m)	768	832	860	832	752
Vertical opening (m)	50	45	30-70	45	30
Mesh size in codend (mm)	20	45	40	40	20
Typical towing speed (kts)	3.5	3.4	3.5-4.0	3.5-4.0	3.5-4.0
Plankton sampling					
Sampling net	-	WP2 plankton net	-	WP2 plankton net	
Standard sampling depth (m)	-	200	-	400	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25Plus
Standard sampling depth (m)	1000	500	1000	1000	1000

Table 2. Acoustic instruments and settings for the primary acoustic sampling frequency, IBWSS March-April 2023.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Echo sounder	Simrad EK 60	Simrad EK80	Simrad EK 80	Simrad EK 80	Simrad EK 80
Frequency (kHz)	**38**, 18, 120, 200	18, **38**, 70, 120, 200, 333	18, **38**, 70, 120, 200, 333	18, **38**, 70	**38**, 18, 70, 120, 200
Primary transducer	ES 38B	38-7	ES 38B	ES 38B	ES 38-7
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	8.8	6	8	8.5	5
Upper integration limit (m)	20	15	15	15	23.91
Absorption coeff. (dB/km)	9.4	10	9.5	9.5	9.4
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	3.06	2.43	2.43	3.06
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	-20.4	-20.6	-20.7	-20.7
Ts Transducer gain (dB)	25.86	26.87	27.27	25.28	26.84
s_A correction (dB)	-0.66	-0.1377	-0.01	-0.66	-0.246
3 dB beam width (dg)					
alongship:	6.78	6.44	6.86	6.89	6.51
athw. ship:	6.91	6.40	6.89	6.85	6.6
Maximum range (m)	1000	750	750	750	1000
Post processing software	Echoview	LSSS	LSSS	LSSS	Echoview

Table 3. Survey effort by vessel, IBWSS March-April 2023. RV *Tridens* carried out 4 trawl hauls on the transects of RV *Celtic Explorer*.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Mesopelagic sampling	Aged fish	Length-measured fish
Celtic Explorer^	24/03-04/04	2 279	-	29	-	-	-
Jákup Sverri	25/03-04/04	1 688	8	26	-	548	1 931
Vendla	19/03- 01/04	2 558	18	31	-	527	1 723
Tridens	25/03-31/03	793	13	16	2	1 200	3 499
Vizconde de Eza*	26/03-02/04	1 253	3	-	-	90	645
Total	24/03-04/04	8 571	42	102	2	2 365	7 798

^ No trawl sampling carried out by Ireland due to mechanical failure of the net Sonde winch
*CTD data from the RV *Vizconde de Eza* not available due to failure of the equipment.

Table 4. Abundance and biomass estimates of blue whiting by strata in 2022 and 2021. IBWSS March-April 2023.

		2023				2022				Difference 2023-2022	
Strata	Name	TSB (10^3 t)	TSN (10^6)	% TSB	% TSN	TSB (10^3 t)	TSN (10^6)	% TSB	% TSN	TSB	TSN
1	Porcupine Bank	170	2,116	6.8	7.1	510	4,714	18.9	15.0	-67%	-55%
2	N Porcupine Bank	475	6,156	19.0	20.6	599	6,469	22.1	20.6	-21%	-5%
3	Rockall Trough	1,295	15,261	51.8	51.1	1,151	13,672	42.5	43.5	12%	12%
4	South Faroes	186	1,930	7.4	6.5	193	2,042	7.1	6.5	-4%	-6%
5	Rockall Bank	183	2,083	7.3	7.0	15	117	0.5	0.4	1,162%	1,677%
6	Faroe/Shetland Ch.	159	1,897	6.4	6.3	226	4,276	8.3	13.6	-29%	-56%
7	Porcupine Seabight	33	439	1.3	1.5	13	151	0.5	0.5	163%	190%
	Total	2,501	29,883	100	100	2,707	31,442	100	100	-8%	-5%

Table 5. Survey stock estimate of blue whiting (determined from StoX baseline output), IBWSS March-April 2023.

	Age in years (year class)										Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2021	2020	2019	2018	2017	2016	2015	2014	2013		(10^6)	(10^6 kg)	(g)	
14-15											0	0	0.0	0
15-16											0	0	0.0	0
16-17	1										1	0	26.0	0
17-18	30										30	1	25.2	0
18-19	148										148	4	29.4	31
19-20	305	48									354	13	36.3	35
20-21	242	70									312	14	43.7	23
21-22	148	551	78								777	39	50.3	71
22-23		2,364	218	9							2,591	148	57.0	91
23-24		3,135	1,349	14							4,497	285	63.3	93
24-25		1,504	3,932	253							5,690	394	69.3	95
25-26		328	5,063	410							5,801	444	76.5	93
26-27		110	2,627	527	119						3,383	292	86.4	94
27-28		25	1,014	560	169						1,768	178	100.9	96
28-29			297	439	155	24	107	20	30		1,071	125	116.6	97
29-30			127	231	222	140	42	8	39		810	108	133.9	100
30-31			43	151	453	190	70	39	10		955	142	148.6	100
31-32			12	120	123	82	80	28	91		536	86	161.3	97
32-33			12	8	51	172	158	16	159		575	98	170.9	100
33-34				20	46	33	49	83	51		281	52	184.3	99
34-35					14	28	8	9	94		153	35	228.9	93
35-36						19			13	29	61	14	234.9	100
36-37									13	13	25	6	240.0	100
37-38						8			8		16	6	348.5	100
38-39						16					16	5	283.5	100
39-40										13	13	4	352.0	100
40-41							6			13	19	7	379.0	100
41-42											0	0	0.0	100
42-43											0	0	0.0	100
43-44														
44-45														
TSN(mill)	873	8,135	14,771	2,744	1,352	711	520	202	508	67	29,883			
TSB(1000 t)	33.6	517.4	1,143.0	265.9	190.3	117.8	84.8	31.1	96.5	20.6	2,501.0			
Mean length(cm	19.4	22.9	24.9	27.0	29.2	31.0	30.5	31.3	32.0					
Mean weight(g)	39	63	77	103	138	172	158	159	183					
% Mature	23	87	96	97	99	97	99	100	99	100				
SSB (1000 t)	7.6	452.5	1098.2	256.6	188.7	114.0	84.3	31.1	95.7	20.6	2,349.3			
SSN (mill)	198	7,115	14,192	2,648	1,341	688	517	202	503	67	27,470.4			

Table 6. Time series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS, 2023. Total biomass in last column (1000 t). Note: * indicates survey excluded or not undertaken.

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
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
2019	1,129	1,169	3,468	9,590	16,979	3,434	484	513	99	144	4,198
2020*											
2021	1,948	2,095	2,545	2,275	3,914	3,197	3,379	463	189	114	2,357
2022	4,461	9,313	4,830	5,460	2,587	1,880	898	1,764	71	178	2,707
2023	873	8,135	14,771	2,744	1,352	711	520	202	508	67	2,501

Table 7. IBWSS survey effort time series.

Survey effort	Survey area (nmi^2)	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
2019	121 397	7 610	38	118	17	6 228	1 938
2021	118 169	7 794	45	102	8	12 019	2 089
2022^	126 235	5 812	47	99	57	6 499	2 372
2023	147,968	8 571	42	102	54	7 798	2 365

* End of Russian participation, ^ excluding Spanish effort due to temporal mismatch.

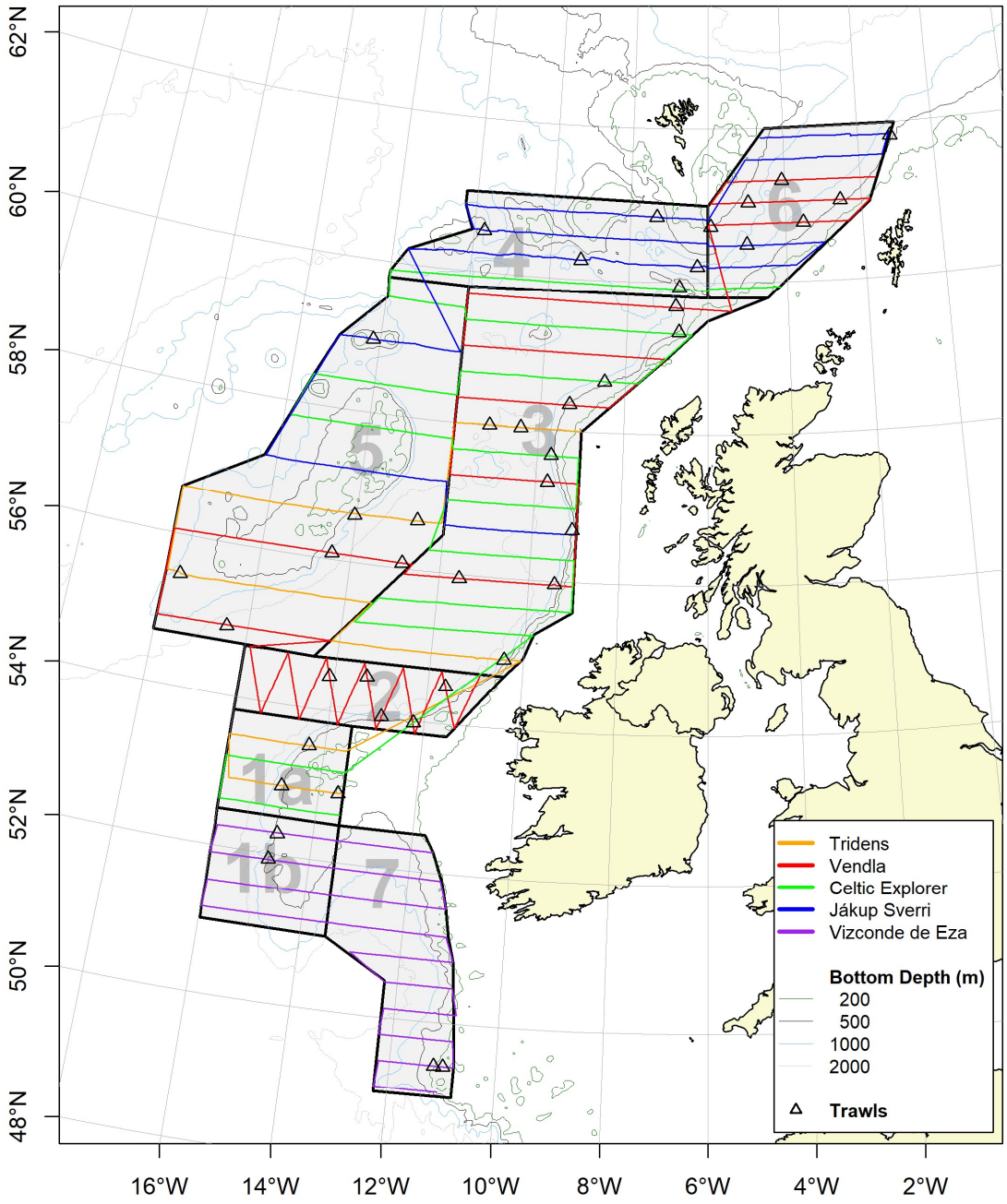


Figure 1. Strata, cruise tracks and trawl hauls for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2023. Faroe Islands (RV *Jákup Sverri*); Ireland (RV *Celtic Explorer*); Netherlands (RV *Tridens)*; Norway (FV *Vendla*); Spain (RV *Vizconde de Eza*).

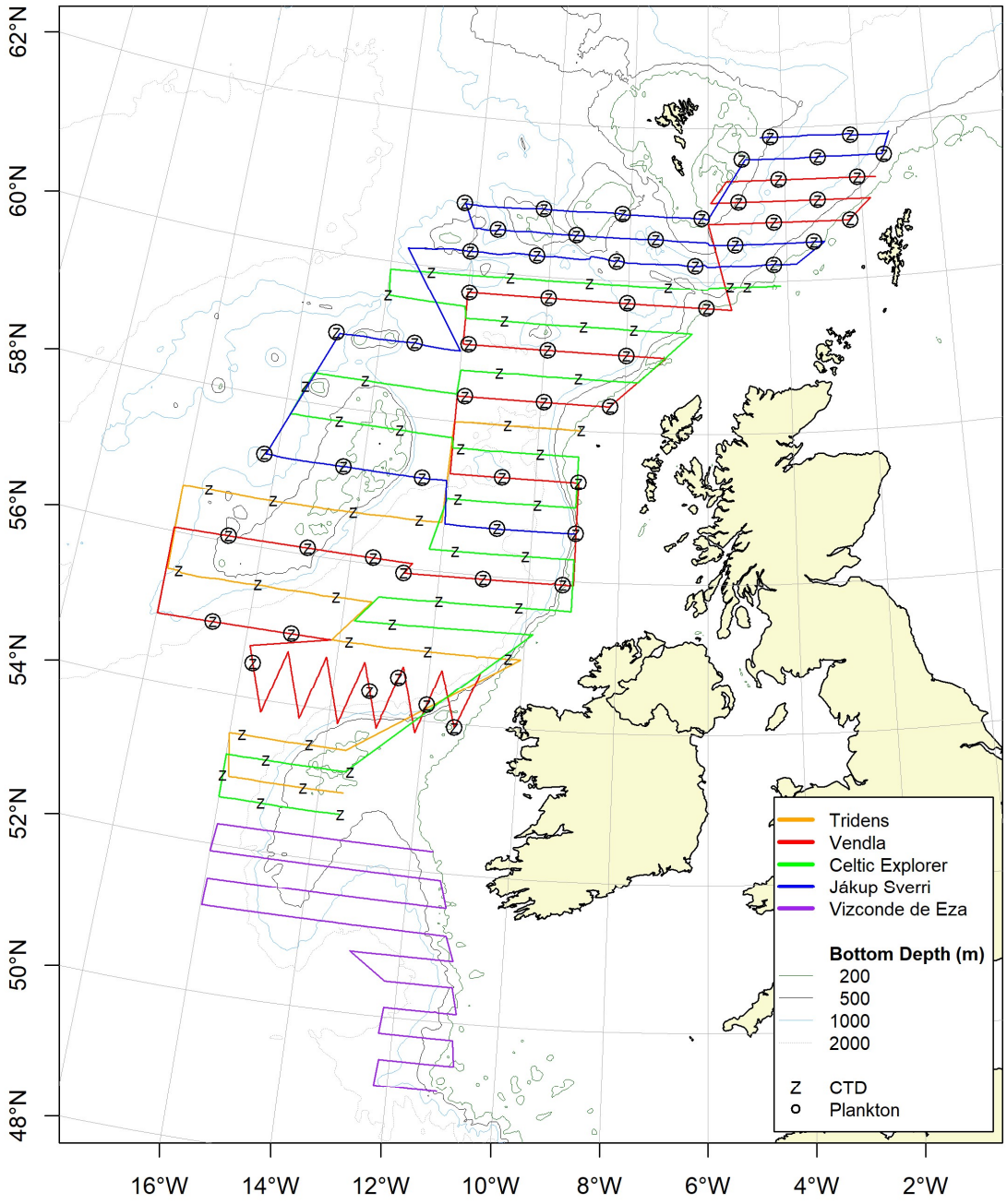


Figure 2. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2023.

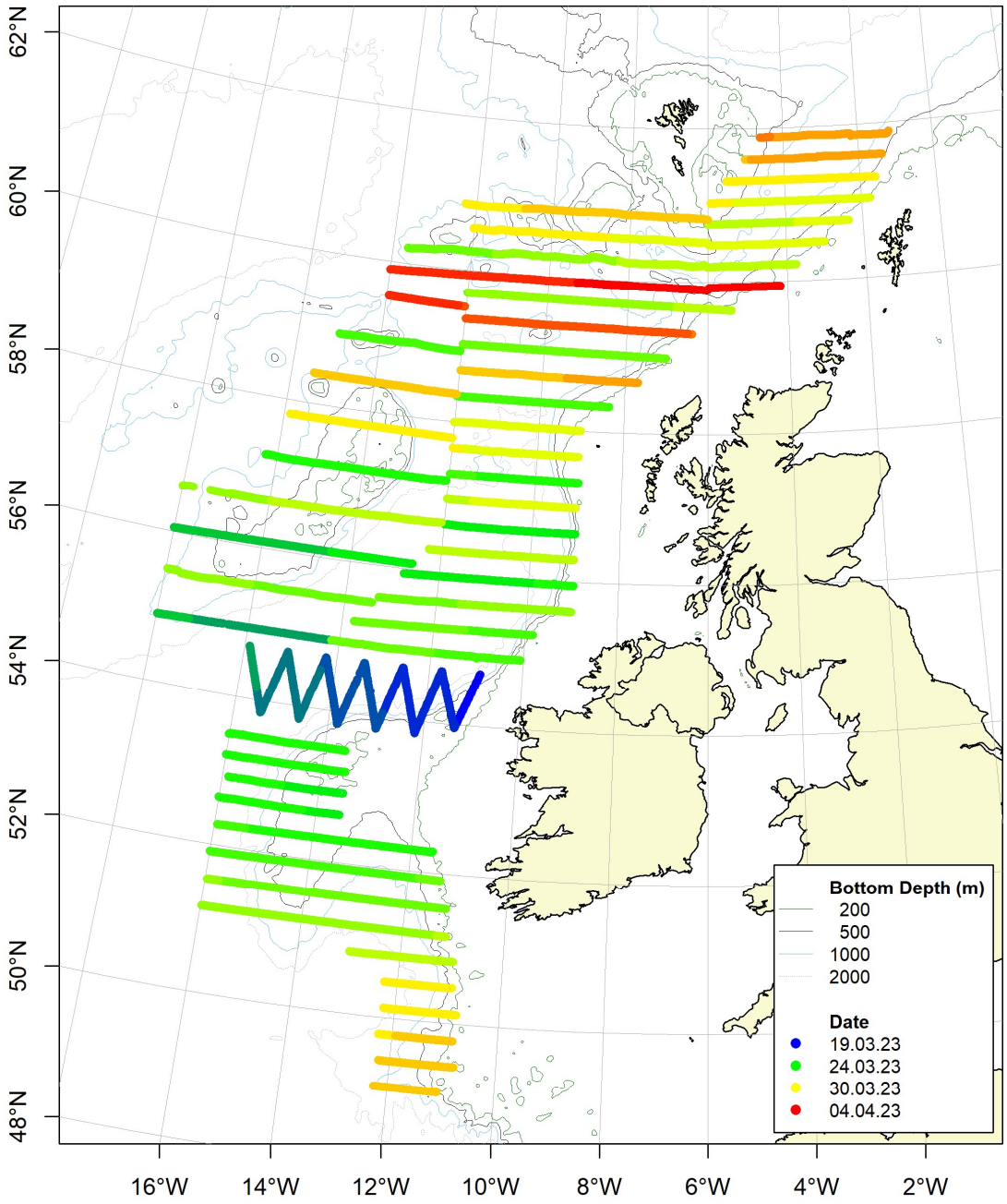


Figure 3. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2023.

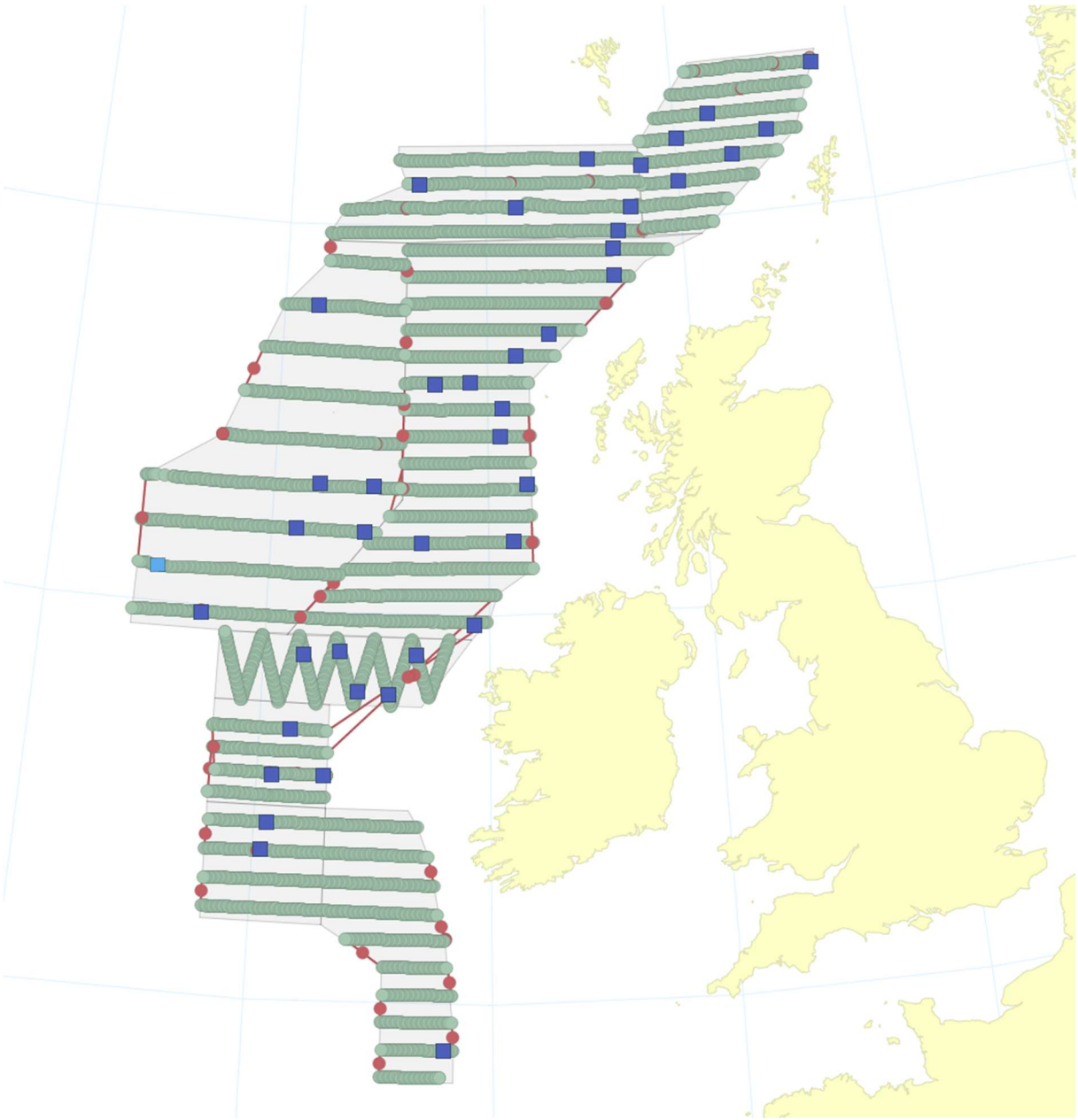


Figure 4. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (dark blue squares) used in the StoX abundance estimation. IBWSS March-April 2023.

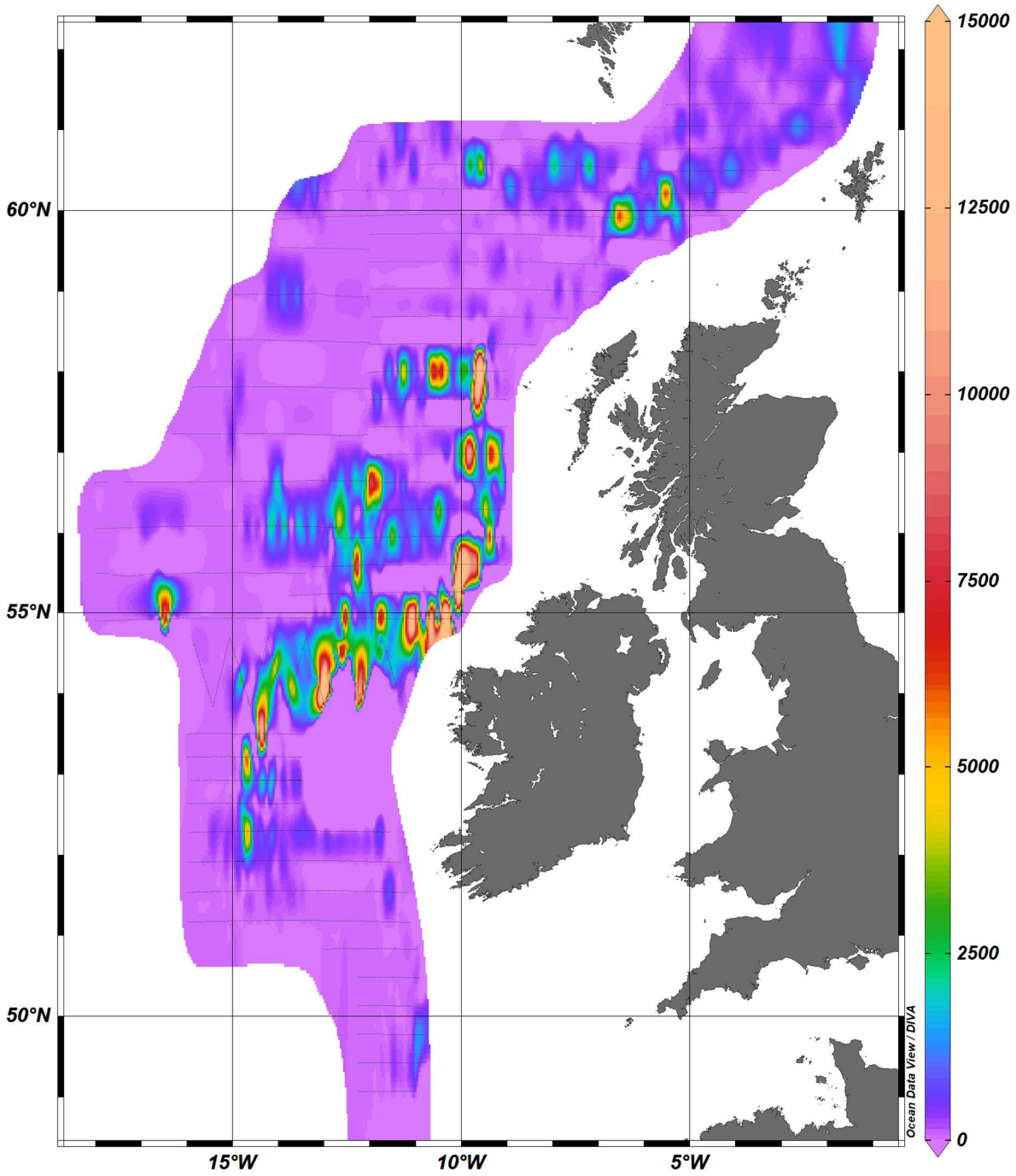


Figure 5. Acoustic density heat map (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2023.

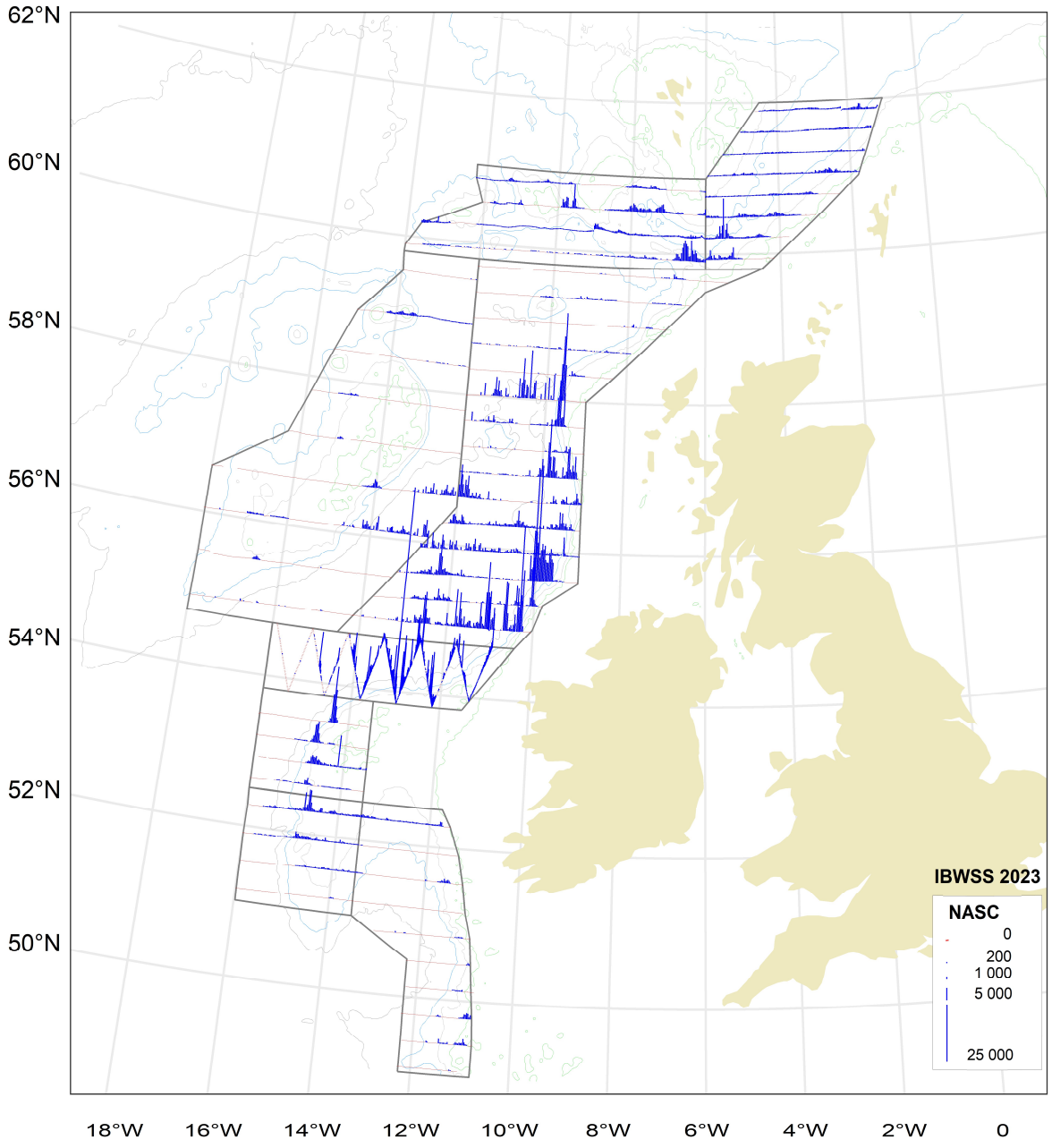
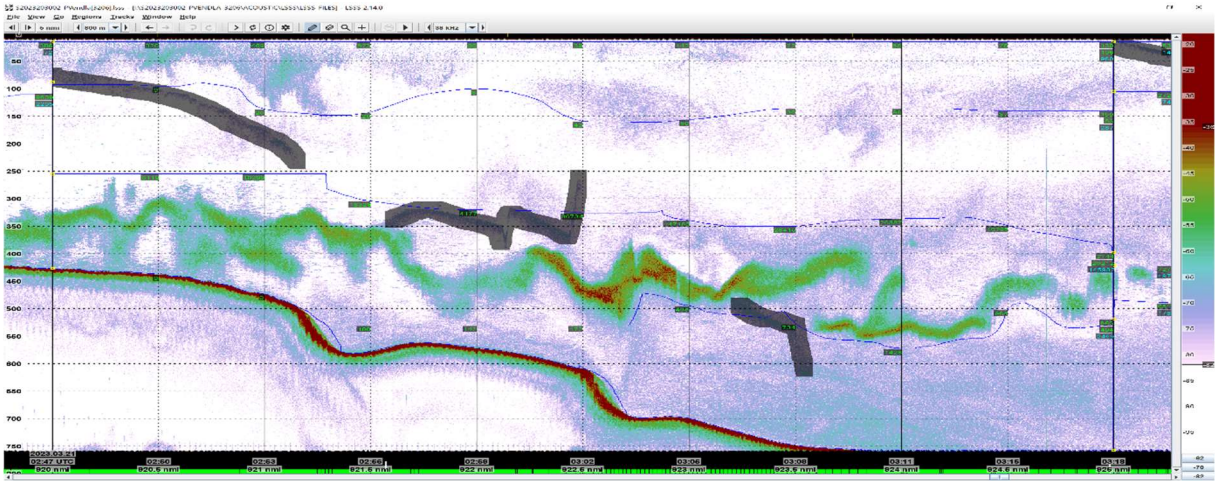
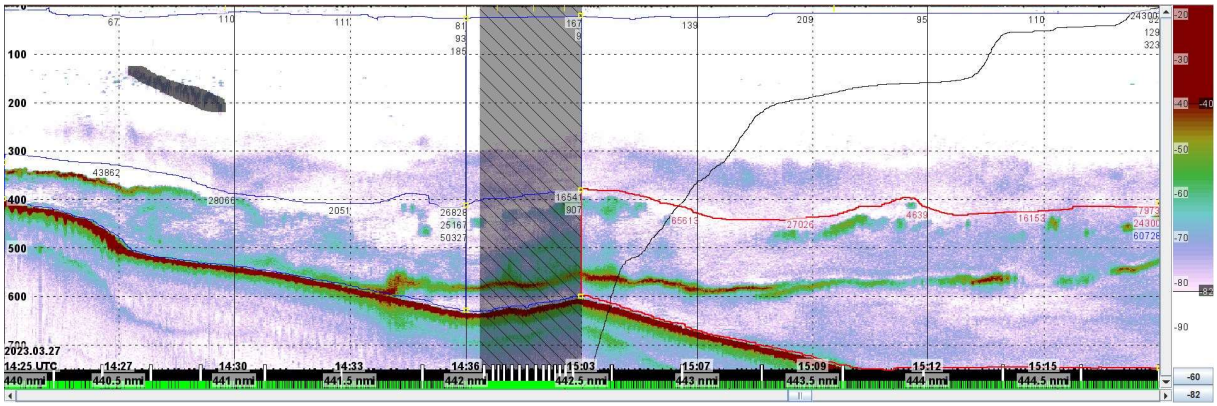


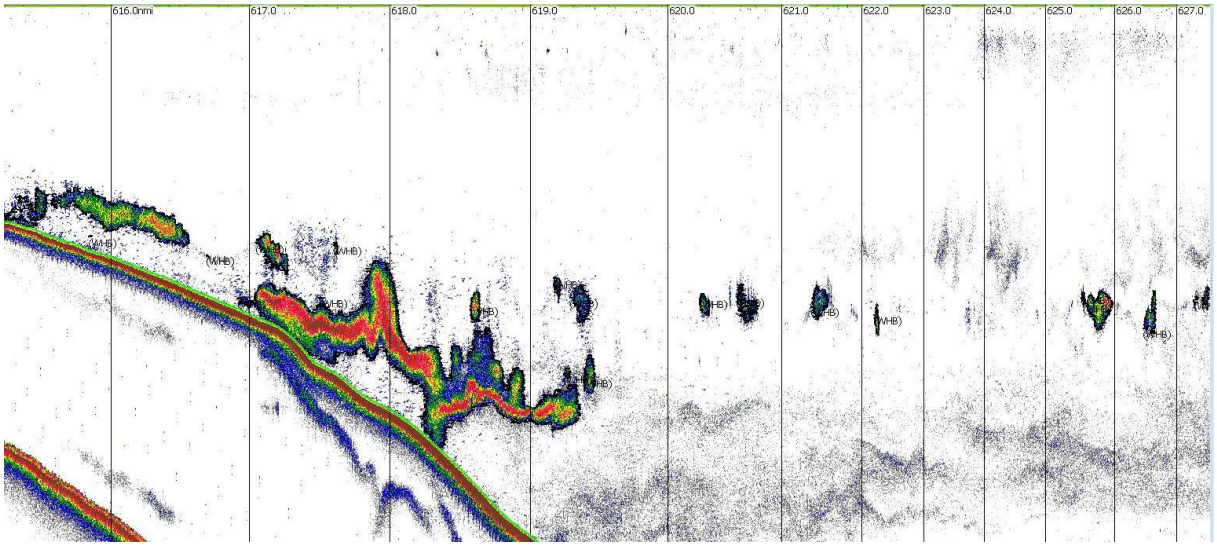
Figure 6. Map of proportional acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi sampling unit. IBWSS March-April 2023.



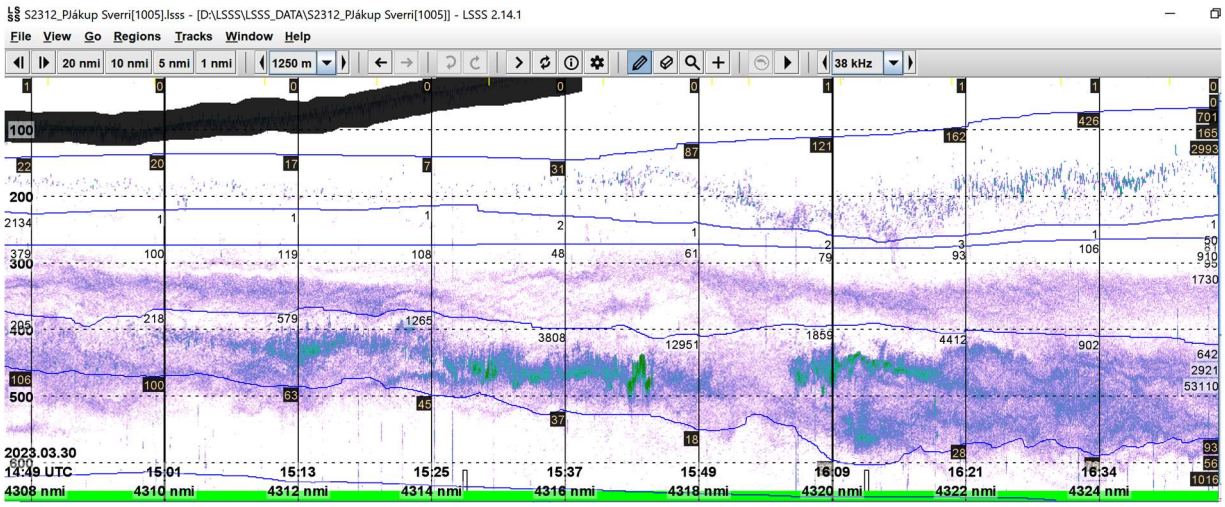
a) Highest density blue whiting per 1nmi log interval (91,787) recorded in during the IBWSS survey in the North Porcupine area (Strata 2) FV *Vendla*, Norway.



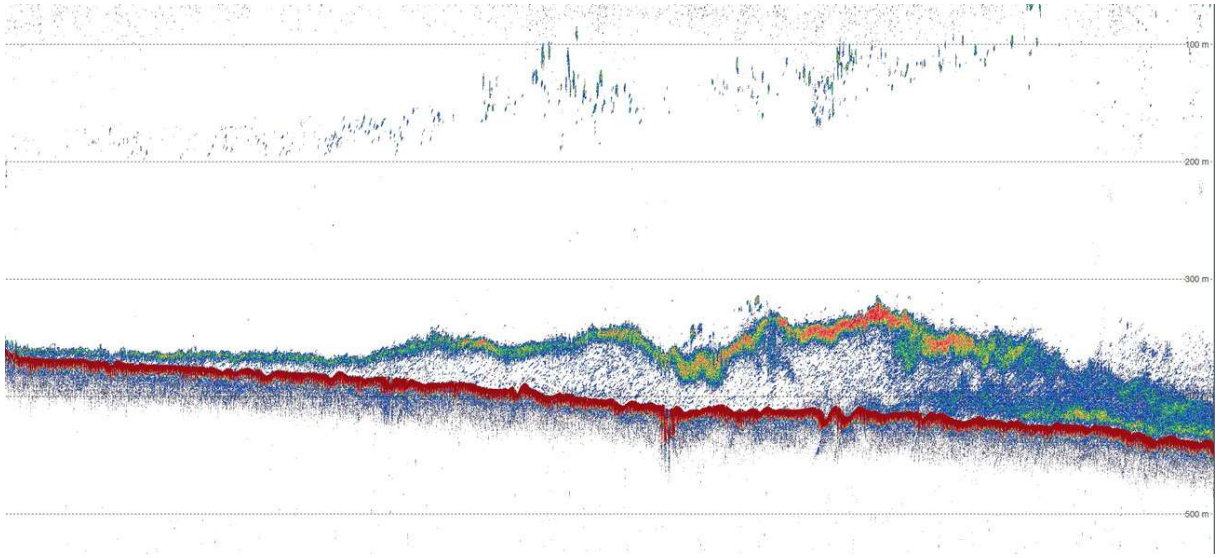
b) Single highest density blue whiting layer (s_A value 65955 m²/nmi²) by 1nmi recorded by the RV *Tridens* at the shelf edge at 54.56N-10.25W (Stratum 3).



c) High density blue whiting layer per 1nmi log interval (56, 888) observed during the survey recorded by the RV *Celtic Explorer* on the shelf margin in the southern Rockall Trough (Stratum 3) in 300 – 400 m.



d) Acoustic registrations (38 kHz) of blue whiting with the Faroese Jákup Sverri on 30 March, 2023 on the Wyville Thomson ridge.



e) Blue Whiting concentration recorded by RV *Vizconde de Eza* in the western shelf edge of South Porcupine Bank on 26 March 2023 (Stratum 1b)

Figure 7. Echograms of interest encountered during the IBWSS, March-April 2023. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU). All echograms presented at 38 kHz.

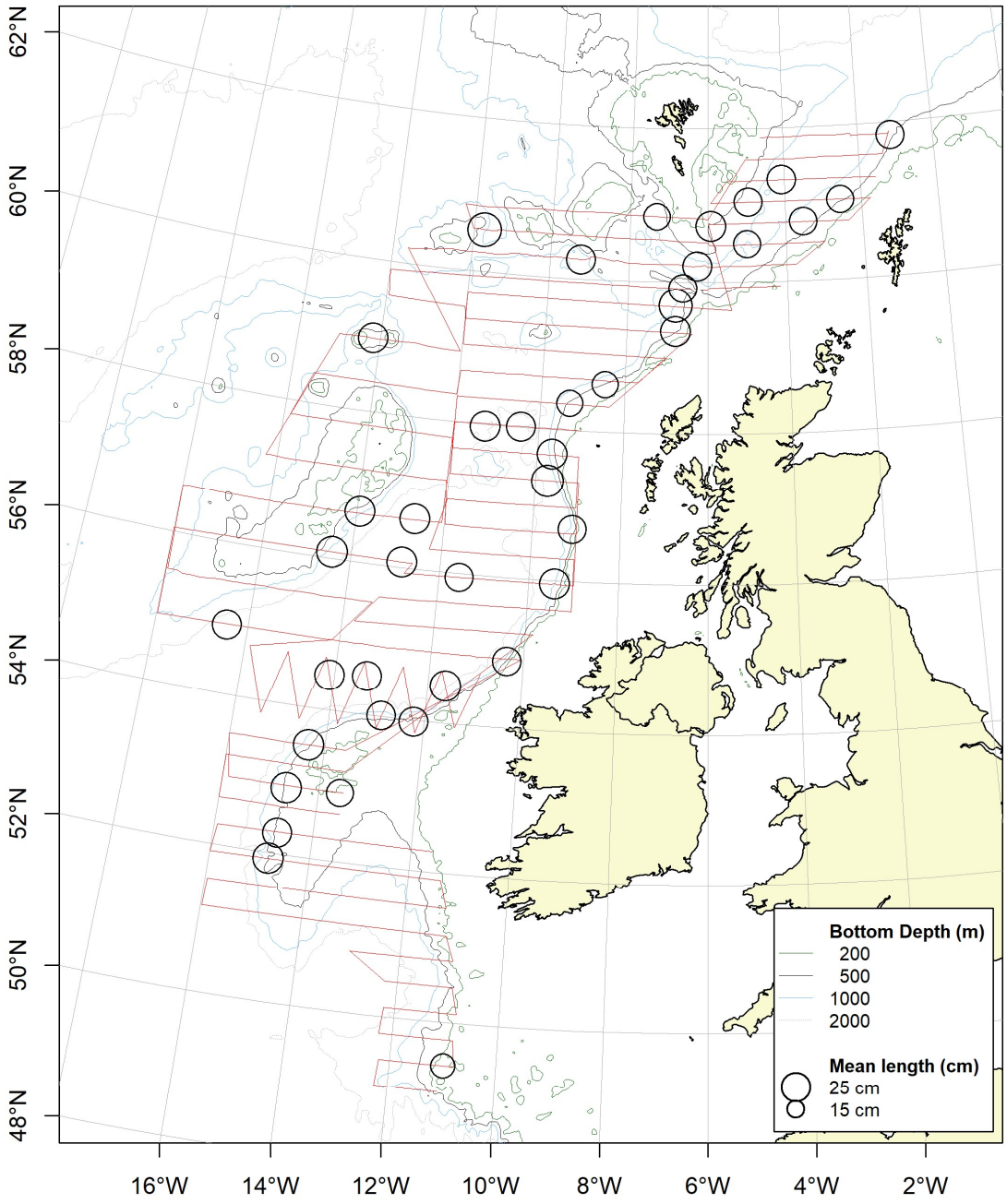


Figure 8. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2023.

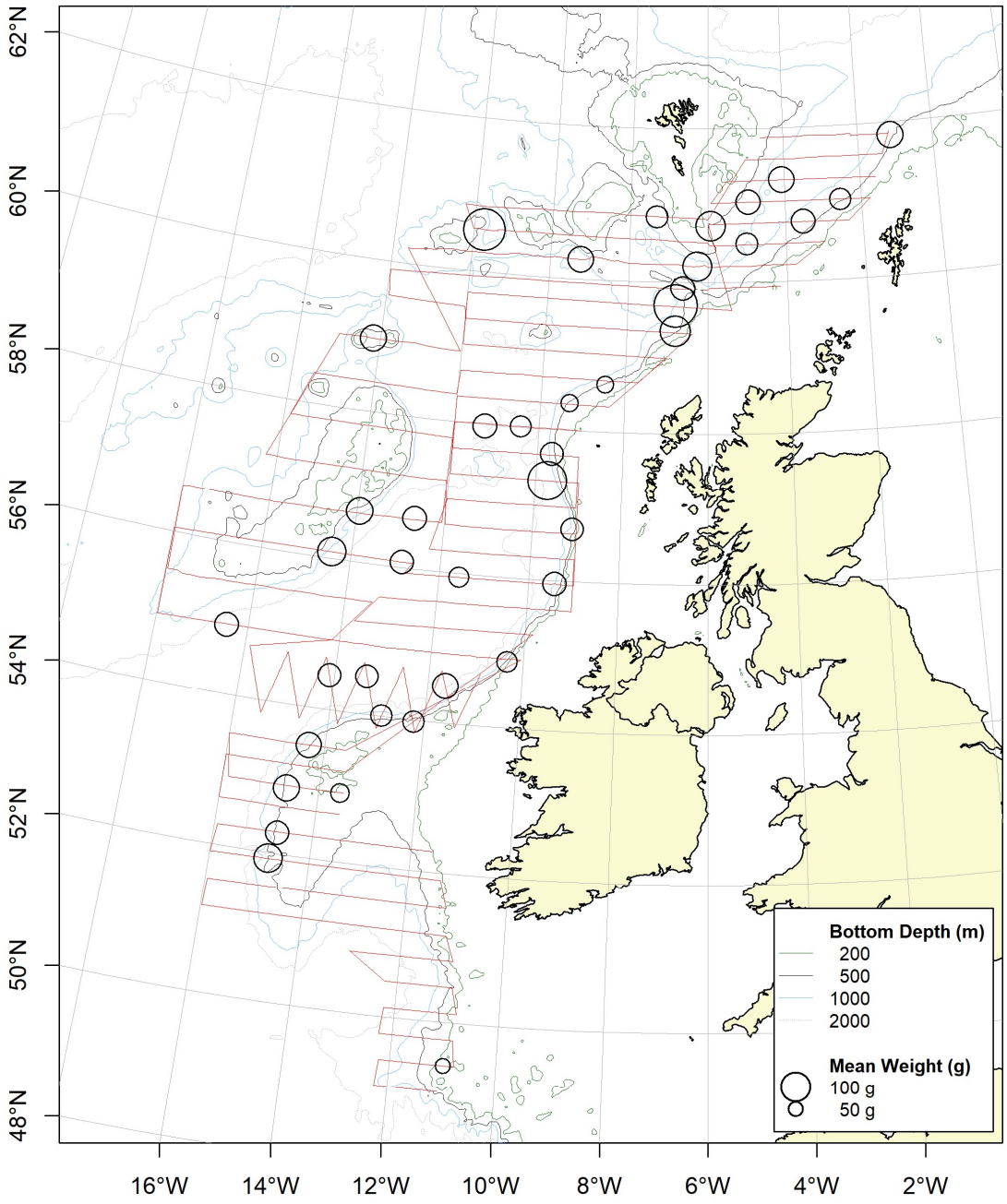


Figure 9. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2023.

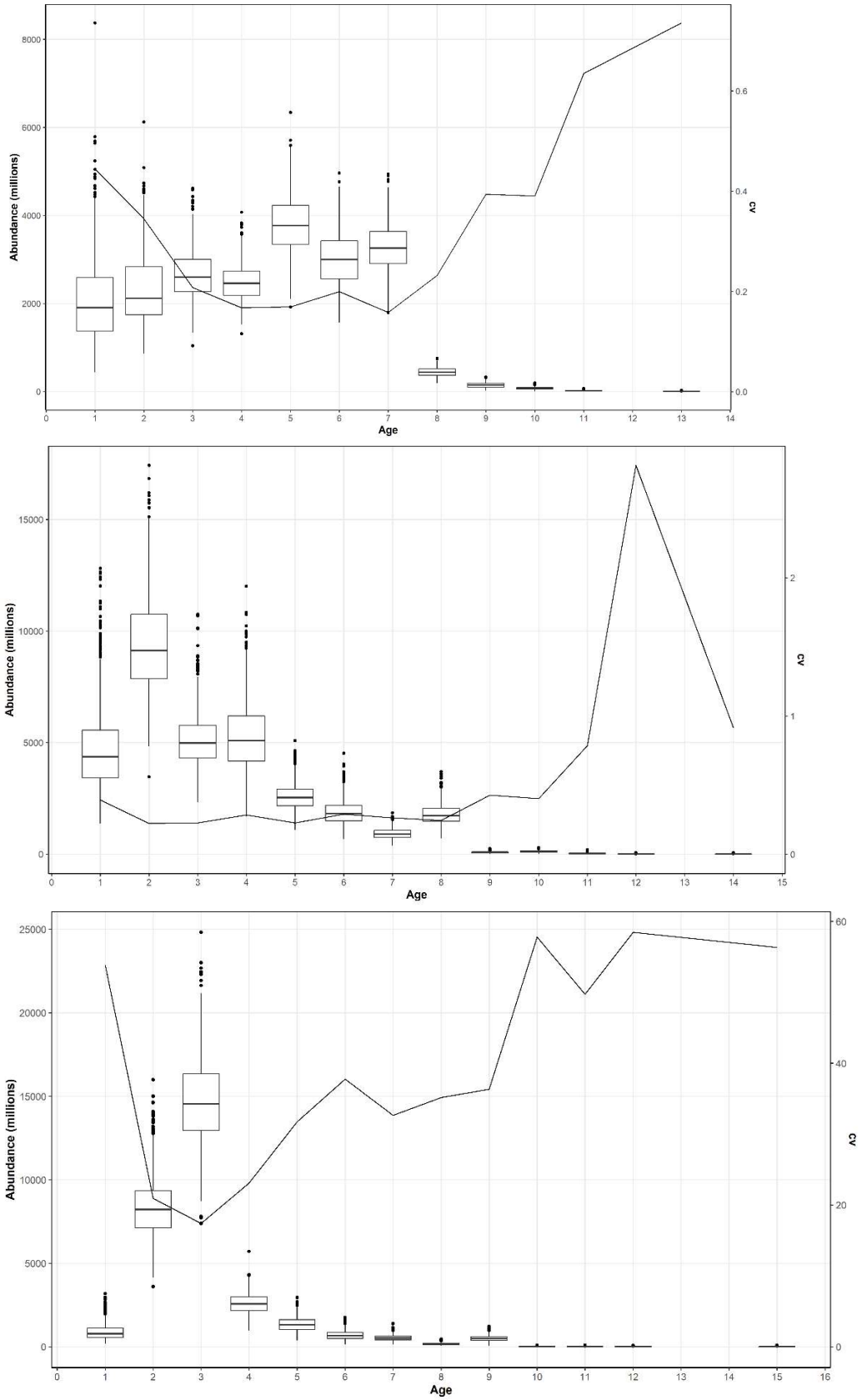


Figure 10. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2021 (top panel), 2022 (middle panel) and 2023 (lower panel). From StoX.

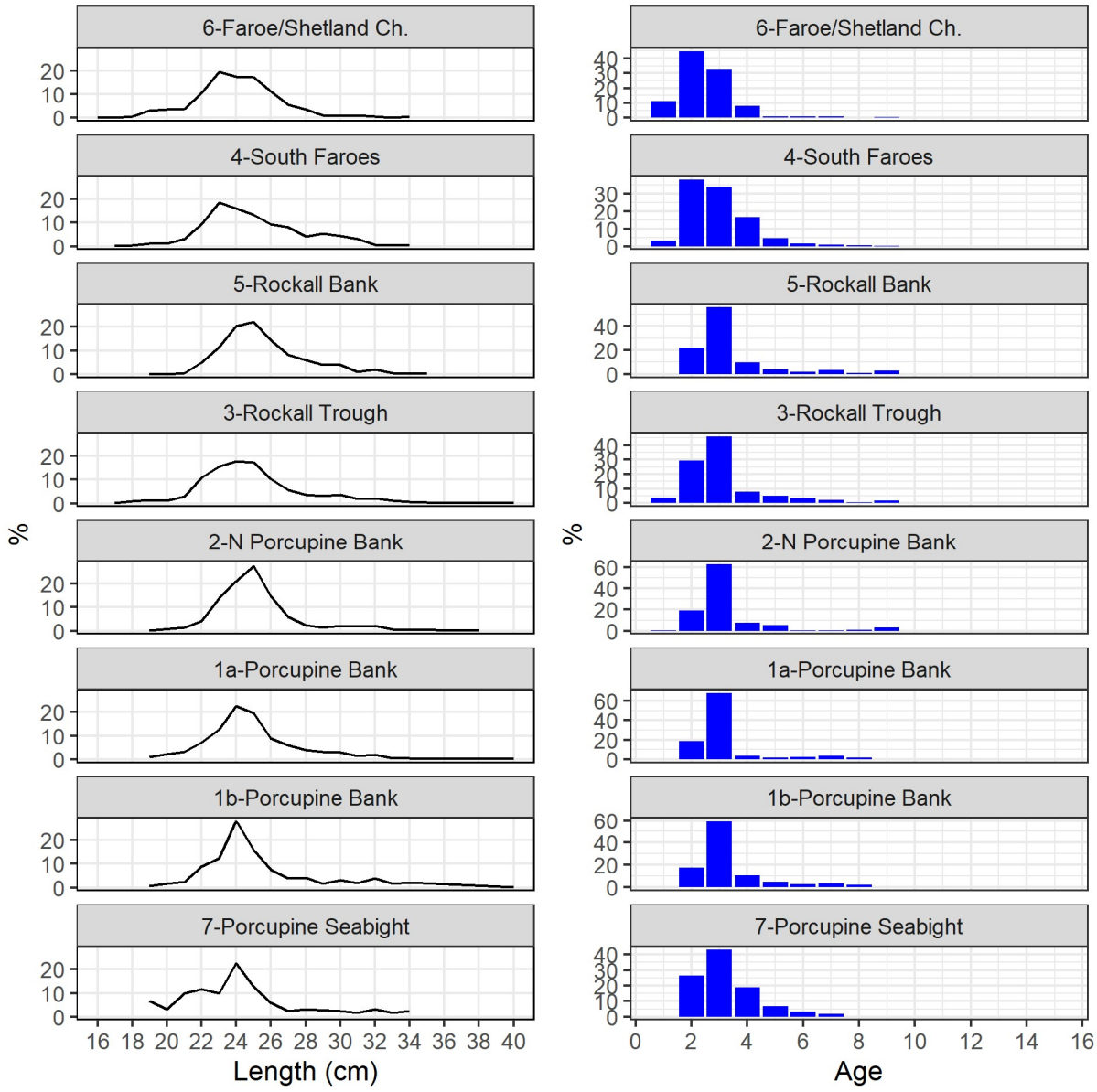


Figure 11. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2023.

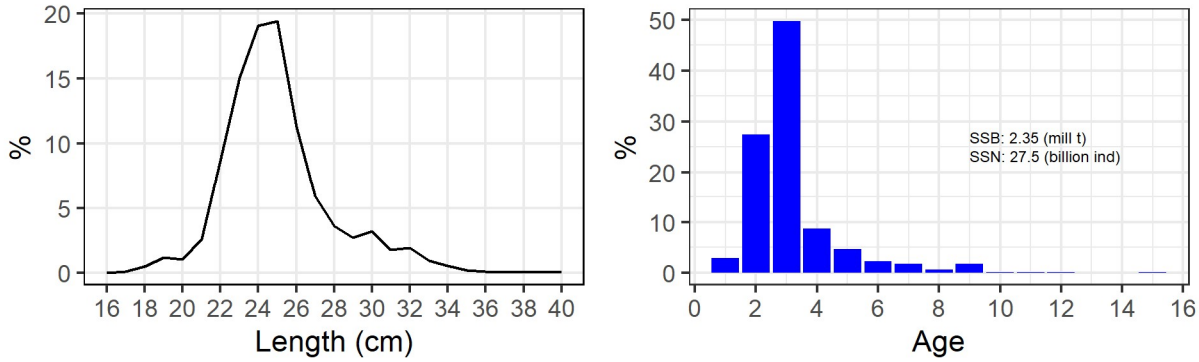


Figure 12. Length and age distribution (numbers) of total stock of blue whiting. March-April 2023.

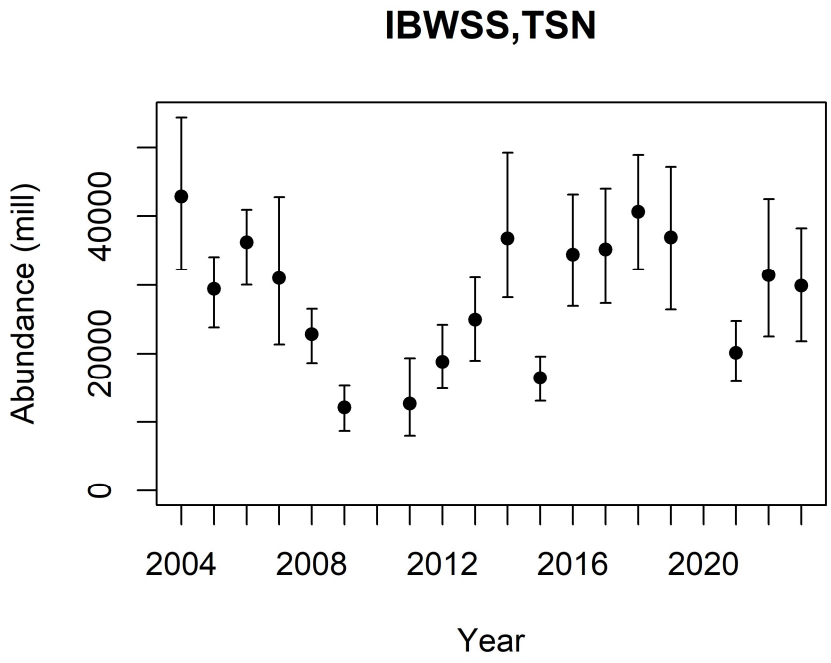


Figure 13. Time series of StoX survey indices of blue whiting abundance, 2004-2023, excluding 2010 and 2020.

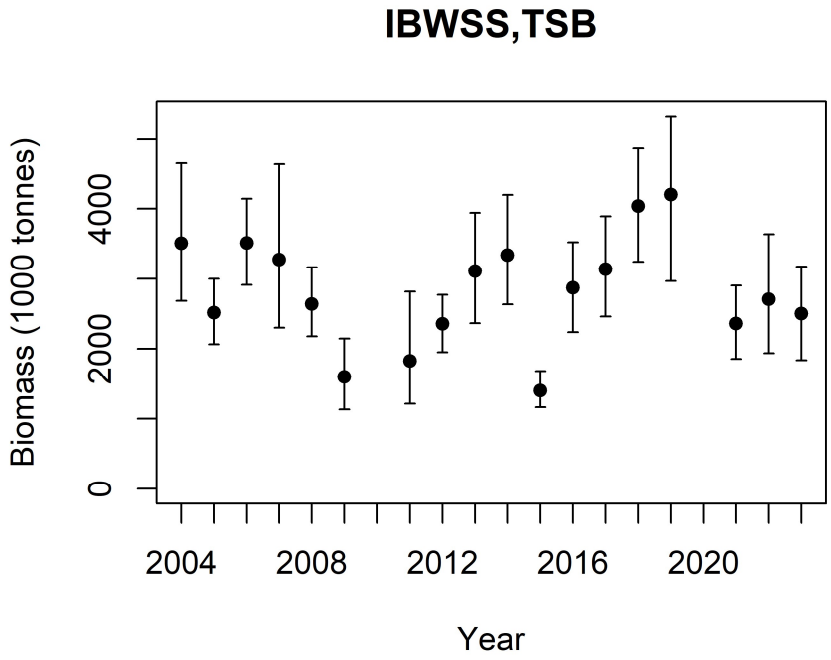


Figure 14. Time series of StoX survey indices of blue whiting biomass, 2004-2023, excluding 2010 and 2020.

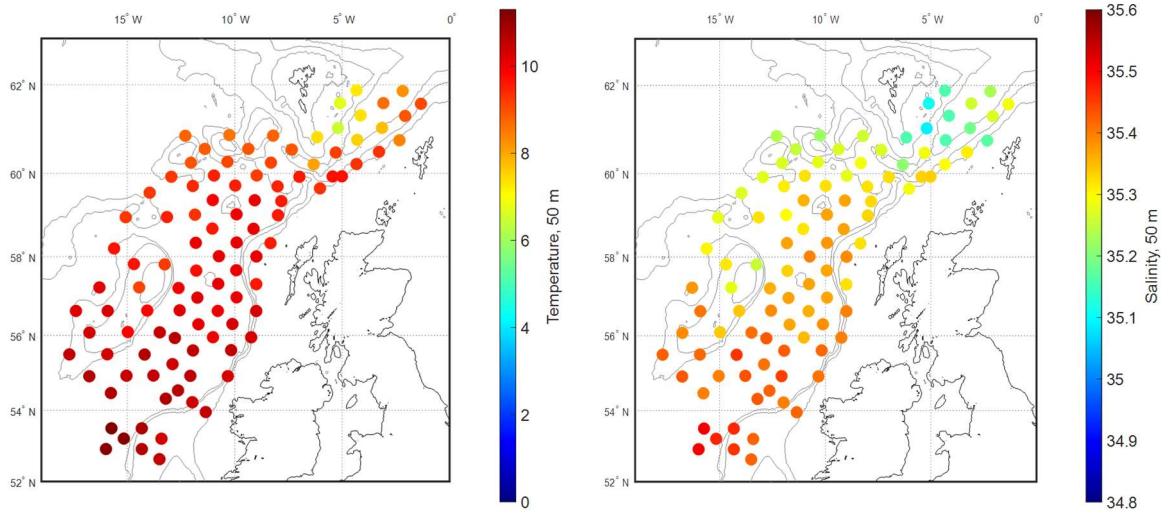


Figure 15. Horizontal temperature (left panel) and salinity (right panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2023.

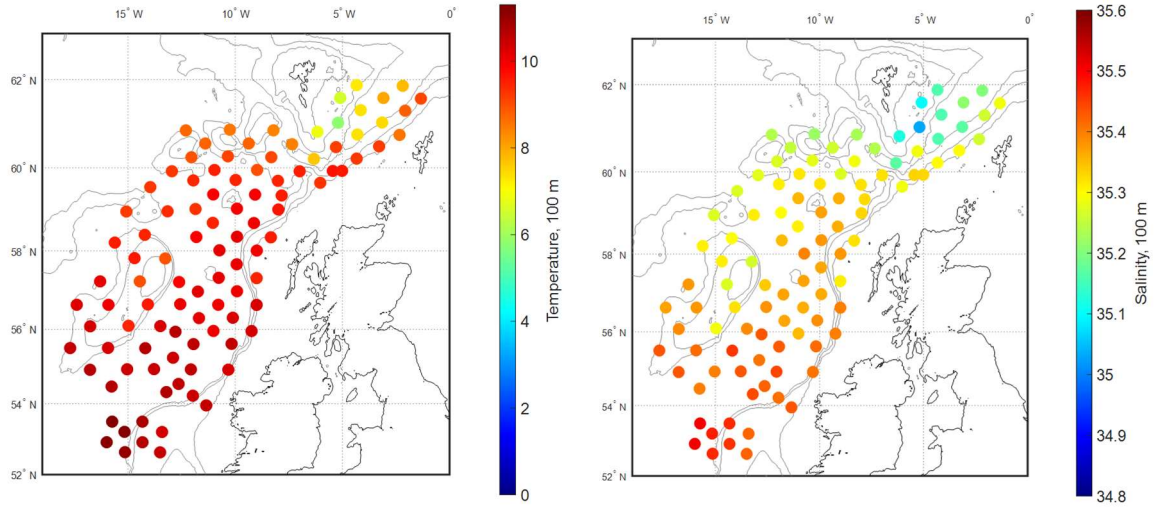


Figure 16. Horizontal temperature (left panel) and salinity (right panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2023.

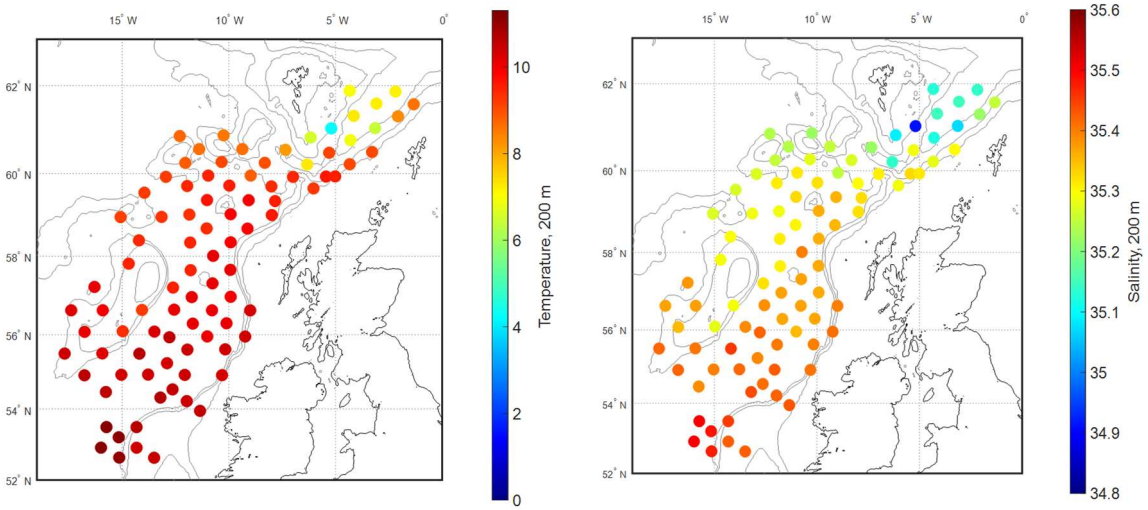


Figure 17. Horizontal temperature (left panel) and salinity (right panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2023.

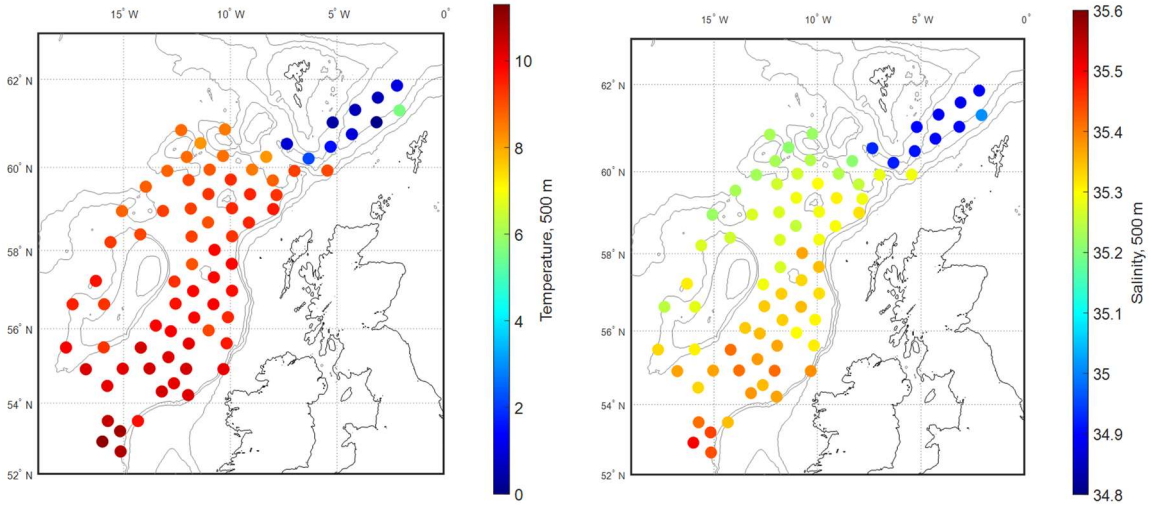


Figure 18. Horizontal temperature (left panel) and salinity (right panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2023.