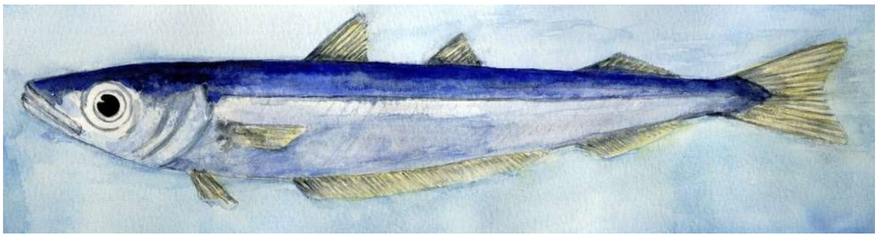
This is Supplementary Document 1
to ICES 2023 Report of Working Group of
International Pelagic Surveys (WGIPS)
https://doi.org/10.17895/ices.pub.23607303

Working Document

Working Group on International Pelagic Surveys
January 2023

Working Group on Widely Distributed Stocks
August 2022



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2022

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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 2022 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	23/3 – 31/4
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	25/3 – 05/4
Tridens	Wageningen Marine Research, the Netherlands	21/3 – 02/4
Vendla	Institute of Marine Research, Norway	24/3 – 05/4
Vizconde de Eza	Spanish Institute of Oceanography, Spain	2/3 – 6/3

Survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Overall, weather conditions were exceptional compared to 2021, with calm seas prevailing, providing optimal conditions for acoustic recordings. The entire survey was completed in 15 days, well below 21-day target threshold (Figure 4). Area coverage was considered comprehensive in both core and peripheral areas, with all vessels completing the planned routes, with the exception of the RV *Celtic Explorer* (Ireland) which returned to port 8 days early.

Spanish survey effort (Strata 1_south & 7) was excluded from the final estimate as it took place 21 days before the other vessels joined and so was considered temporally mismatched. This timing mismatch was due to vessel availability in the mackerel egg survey year. Replicate coverage was provided by the RV *Tridens* & RV *Celtic Explorer* as part of the main survey effort and are included in the final estimate.

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. 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). Hydrographic data collected during the Spanish survey was excluded due to the described temporal mismatch.

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 11.0) 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 (2.12) post processing software. Data was partitioned into the following categories: plankton, pearlside, 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 (2.12.0) post-processing software. Blue whiting were 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. 2.12.0) 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 12 hrs and scrutinised after the survey using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: Blue whiting and Müeller's pearlside 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 (V3.4.0) and R-StoX packages software package (RStoX Framework 3.4.0, RStoX Base 1.8.0 and RStoX Data 1.6.0). 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 2022 (Figure 1). Area stratification and transect design are shown in Figure 1 and 4. 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 2022 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 2022 international survey was 2.7 million tonnes, representing an abundance of 31.4×10^9 individuals (Table 4). This is a 15% increase in total stock biomass and a 56% increase in total stock numbers (TSN) from observations in 2021 (Table 4). The spawning stock biomass (SSB) was estimated at 2.4 million tonnes representing 23.9×10^9 individuals (Table 5). This is a 4% increase in the observed spawning stock biomass and a 33% increase in the spawning stock numbers (SSN) compared to last year. Overall, the increase in abundance in the 2022 estimate is driven by the increased numbers of one and two-year-old fish observed within the survey area.

Distribution of blue whiting

In total, 5,812 nmi (nautical miles) of survey transects were completed across seven strata, relating to an overall geographical coverage of 126,235 nmi² (Figure 1, Tables 3 & 7), Area coverage increased by 6% as compared to 2021. Acoustic sampling (transect miles) saw a decrease of 25% compared to 2021. This can be accounted for by early departure of the RV *Celtic Explorer* (8 days) and the omission of the Spanish data.

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 5 and 6. The vertical distribution of blue whiting observed in 2022 did not extend deeper than 650 m and so schools were considered vertically contained in the insonified layer.

Overall, the distribution of blue whiting was found further west into open water from the continental shelf edges than was observed in 2021. The main body of the spawning stock was located within Strata 1-3, accounting for 83.5% of TSB and 79% of TSN (Table 4). A second notable area of abundance, geographically distinct from the main body of the stock, was observed in the northern strata (4 & 6) accounting for 15.4% of TSB and 20.1% of TSN and composed of mainly 1- and 2-year-old fish.

Within the three core strata (1-3), fish distribution of biomass was variable with areas of high and low abundance. Porcupine Bank (Strata 1) saw a large increase in TSB of 90% compared to 2021 and a corresponding increase in TSN of 111%, whereas North Porcupine (Strata 2), saw a decrease of -20% of TSB and no change in TSN. An increase of 18% TSB and 69% TSN was recorded in Stratum 3 (Rockall Trough). The Porcupine Seabight (Stratum 7) reported low numbers compared to 2021 (TSB -91% & TSN -85%) indicating migrating fish had already moved northwards. Rockall Bank (Strata 5) saw a decrease of 91% TSB and 85% TSN as compared to observations in 2021.

Most notable was the increase in biomass observed in northern survey area; south Faroes and Faroe/Shetland Channel (Strata 4 & 6 respectively). The south Faroes strata showed an increase in TSB of 26% (154,000t to 193,000t) and 45% in TSN compared to 2021, whereas the Faroe/Shetland Channel saw an increase of 557% in TSB (34,000t to 226,000t) and 618% in TSN. Both strata were dominated by immature (1-year-old) and early maturing fish (2-year-old, 71% mature). Here it should be mentioned that the Faroes/Shetland strata was poorly covered last year due to severe storms.

Echograms

The highest s_A value (76,873 m²/nmi² - per 1 nmi EDSU) observed during the combined survey was recorded by FV *Vendla* in open water in the Rockall Trough (Figure 7a). The second highest density value, also recorded in Stratum 3, by the RV *Tridens* (66,484 m²/nmi² - per 1 nmi EDSU), Figure 7f. It is suggested that this was an active spawning aggregation due to the high proportion of spawning individuals in the catch. The third highest value (46, 968 m²/nmi² - per 1 nmi EDSU) was recorded by RV *Celtic Explorer* on the shelf edge in stratum 1 (Figure 7b).

Figure 7e provides an example from *RV Tridens* where blue whiting at the shelf edge is mixed with horse mackerel. The bluish-green layer near the bottom was assigned to horse mackerel and blue whiting according to the contribution in the catch.

Due to blue whiting recordings observed at the western edge of Rockall Bank, *RV Tridens* decided to extend transect a further 60nmi to the west (Figure 7g). Rockall Bank is gently sloping with a gradual transition to the ocean floor, while at the bank itself demersal fish (grey gurnard, haddock) may form an acoustic layer at the bottom, similar to a blue whiting layer. Distinguishing these species from blue whiting can be difficult and requires fishing.

Young blue whiting and heave observations by RV *Jákup Sverri* (Figures 7h, i). The RV *Jákup Sverri* observed scattering layers of blue whiting in Faroe-Shetland Channel stratum at depths between 250-500 m. The echosounder showed instances where fish 'disappeared' from a continuous scattering layer. The weather was excellent, calm seas and moderate ground swell, and the vessel was surveying at normal cruising speed (10-11 knots). The blue whiting registrations seem to disappear in the 350-500 m depth range in (Figure 7h) and in the 250-350 m depth range (Figure 7i). Monitoring showed that this occurrence was periodic. This special feature is not considered to be a weather induced artefact normally seen in bad weather i.e. aeration blocking the transmit/receive pulse. Firstly, weather conditions were excellent and secondly only the blue whiting layer was affected, with all other targets undisturbed on the echogram. This observation is thought to relate to a rapid change in tilt angle in response to an escape reaction when the fish detect the pressure wave transmitted from the ship's hull as it falls from the gentle groundswell. When the fish is startled it makes a short dive then settles to scan for potential danger, if none then resume normal behaviour. During this short dive the fish is tilted downwards and become "invisible" to the echosounder. The reason is that the tilted swimbladder produces a very low (minimal) dorsal aspect and therefore becomes invisible on the sounder for a few seconds. The blue whiting in the affected layers is young fish (1 and 2 year-olds).

Stock composition

Survey samples found fish ages from 1 to 14 years (10+ group) were observed during the survey (Table 5).

The main contribution to the spawning stock biomass was composed of the age groups 2, 4, 3 and 5 years, respectively. Combined these age cohorts represent 69% of TSB. In terms of abundance, 2-year-olds (2020 year-class) were most abundant (30%), followed by the 4-year-olds (17%), 3-year-olds and 5-year-olds (8%) respectively, (Table 5).

The largest mean length values of blue whiting by strata obtained from catches came from Stratum 5 and 1 (27.4 cm in both), Figure 8. Corresponding mean weights for Stratum 5 and 1 were 124 g and 108 g (Figure 9).

The bulk of the stock, located in the southern survey area, was composed of mixed age classes of 1 to 14 years, and dominated by mature individuals. In contrast, aggregations in the northern area were dominated by 1 & 2-year-old immature fish, most notably in Stratum 6 (Figure 11). The abundance of these two year classes were the highest in the time series and above the numbers observed associated with the 2014 record year class (Table 6, Figure 12).

Immature fish represented 12.6% of TSB and 23.8% of TSN. Over 71% of the 2-year old fish were mature contributing to the SSB of the stock (Table 5).

The CV of the total estimate of both biomass and abundance was 0.19, which is higher than the years before (2021= 0.14 and 2019= 0.16).

The survey time series (2004-2022) of TSN and TSB are presented in Figures 13 and 14 respectively and Table 6.

Hydrography

A total of 99 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, are in agreement with a reversing trend, with a more western extension of fish into the Rockall Trough than observed in recent years.

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 regarded as exceptional compared to 2021, with no weather induced downtime recorded.
- The total area surveyed increased from 2021 (7%), facilitated by good weather conditions and the more westward distribution of blue whiting in 2022. Acoustic sampling effort (miles) decreased by 25% and is a direct result of the early departure of the Irish vessel, and the omission of the Spanish data due to temporal mismatch as compared to 2021.
- In terms of biological sampling effort, the number of trawl stations and the total number of aged fish were comparable to 2021. The total number of measured fish was less than in 2021 and this can be accounted for by the reduced contribution by Ireland and Spain. The stock was considered representatively sampled in number, and across the distribution area.
- The International Blue Whiting Spawning Stock Survey 2022 shows a 15% increase in TSB and a corresponding 56% increase in TSN when compared to the 2021 estimate for comparable survey effort and coverage.
- In terms of abundance, 2-year-olds (2020 year-class) were most abundant (30%), followed by the 4-year-olds (17%), 3-year-olds and 5-year-olds (8%) respectively.
- Immature fish represented 12.6% of TSB and 23.8% of TSN and was made up of 1-year-old fish and 2-year-old fish, 23% of which were found to be immature.
- The abundance of these two year classes (2020 and 2021) were the highest in the time series and above the numbers observed associated with the 2014 record year class.
- Estimated uncertainty around the total stock biomass was CV=0.19 (CV=0.14 in 2021).
- The survey was carried out over 15 days, below the 21-day time window target. With core areas representatively sampled by multiple vessels.

Interpretation of the results

- The group considers the 2022 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Some gaps in coverage occurred in core stratum 3, but were considered as acceptable when compared against fish distribution.
- The bulk of SSB was distributed along the western and northern Porcupine Bank and the southern part of stratum 3 (Rockall Trough) and did not extend as far north as observed in 2021.
- Contribution of the 2020-year class to the TSB is significant and is larger than previous strongest year class in the time series (2014). This year class will be fully recruited to the spawning stock in 2023.
- Replicate survey effort was undertaken in the southern survey area with a 21-day temporal gap between surveys. Preliminary results indicate that fish present during the first survey were abscent during the second replicate, indicating a northward migration. Age composition of fish observed during the first survey mirror that of the main survey further north.

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 and transects are 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.
- 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 2023.
- With a UK vessel joining the survey in 2023, the group recommends that in the first year the vessel should provide replicate coverage within the Rockall Trough stratum. Further to discussions due to take place at WGIPS 2023.
- It is recommended that nations contribute in the collection of biological samples in 2023 and going forward for the genetic study on stock discrimination of blue whiting.

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.
- Survey area covered completed within 15 days.
- Good coverage of immature and emerging spawning fish (ages 1 & 2 years) in northern area.
- Genetic samples collected for stock discrimination project to determine extent of northern and southern blue whiting stocks.

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Table 1. Country and vessel specific details, IBWSS March-April 2022.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Trawl dimensions					
Circumference (m)	768	832	860	832	752
Vertical opening (m)	50	47	30-70	45	30
Mesh size in codend (mm)	20	45	40	40	20
Typical towing speed (kts)	3.5-4.0	3.5	3.5-4.0	3.5-4.0	4.0-4.5
Plankton sampling					
Sampling net	-	WP2 plankton net	-	WP2 plankton net	
Standard sampling depth (m)	-	200	-	400	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25
Standard sampling depth (m)	1000	500	1000	1000	500

Table 2. Acoustic instruments and settings for the primary acoustic sampling frequency, IBWSS March-April 2022.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Echo sounder	Simrad EK 60	Simrad EK80	Simrad EK 60	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 38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	8.7	6	8	8.5	5
Upper integration limit (m)	20	15	15	15	23.91
Absorption coeff. (dB/km)	9.8	10.3	9.5	9.5	9.5
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
Sv Transducer gain (dB)			27.28		
Ts Transducer gain (dB)	25.65	26.94	27.27	25.18	26.84
s_A correction (dB)	-0.65	-0.13	-0.01	-0.66	-0.03
3 dB beam width (dg)					
alongship:	6.97	6.47	6.86	7.01	6.41
athw. ship:	7.05	6.54	6.89	6.90	6.52
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 2022.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Mesopelagic sampling	Aged fish	Length-measured fish
Celtic Explorer	24/3-31/3	1 090	5	16	-	200	2 011
Jákup Sverri	25/3-5/4	1 433	9	25	-	550	1 460
Vendla	24/3- 5/4	1 755	21	31	-	609	2 009
Tridens	21/3-2/4	1 534	12	27	20	1 019	1 019
Vizconde de Eza*	02/3-06/3	378	2	9	-	80	464
Total	24/3-5/4	5 812	47	99	20	2 378	6 499

*RV *Vizconde de Eza* survey effort data reported but excluded from the final 2022 estimate due to temporal mismatch.

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

		2022				2021				Difference 2022-2021	
Strata	Name	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB	TSN
1	Porcupine Bank	510	4 714	18.9	15.0	270	2 232	11.4	11.1	89 %	111 %
2	N Porcupine Bank	599	6 469	22.1	20.6	746	6 500	31.6	32.3	-20 %	0 %
3	Rockall Trough	1 151	13 672	42.5	43.5	977	8 094	41.4	40.2	18 %	69 %
4	South Faroes	193	2 042	7.1	6.5	154	1 413	6.5	7.0	26 %	45 %
5	Rockall Bank	15	117	0.5	0.4	41	300	1.7	1.5	-65 %	-61 %
6	Faroe/Shetland Ch.	226	4 276	8.3	13.6	34	595	1.5	3.0	558 %	618 %
7	Porcupine Seabight	13	151	0.5	0.5	139	984	5.9	4.9	-91 %	-85 %
	Total	2 707	31 442	100	100	2 361	20 119	100	100	15 %	56 %

Table 5. Survey stock estimate of blue whiting (determined from StoX baseline output), IBWSS March-April 2022.

Length (cm)	Age in years (year class) 1 2021	2 2020	3 2019	4 2018	5 2017	6 2016	7 2015	8 2014	9 2013	10+	Number (10^6)	Biomass (10^6 kg)	Mean weight (g)	Prop Mature
14-15	39										39	1	13.6	0
15-16	277										277	5	18.6	0
16-17	664										664	14	21.5	0
17-18	757										757	19	25.6	0
18-19	986										986	31	31.2	0
19-20	780	33									813	30	36.8	0
20-21	568	50									618	27	42.9	7
21-22	345	665	67								1,077	53	49.3	42
22-23	25	2,706	82								2,813	156	55.5	72
23-24	19	3,498	335								3,852	243	63.2	67
24-25		1,697	567	70							2,335	166	71.1	77
25-26		366	1,051	599	74						2,090	165	78.9	94
26-27		218	1,076	1,437	148	32					2,911	256	87.8	99
27-28		52	1,018	1,155	513	87	21	2			2,847	272	95.6	99
28-29		28	465	1,237	591	122	142	5	3		2,594	282	108.7	100
29-30			148	504	455	772	57	249	0		2,185	271	124.1	100
30-31			15	204	505	416	127	532	9	19	1,828	248	135.9	100
31-32			6	213	140	141	273	309		28	1,110	164	147.6	100
32-33				30	50	161	110	368	18	55	792	132	166.7	98
33-34				9	63	76	66	147	23	44	429	78	181.5	100
34-35					9	37	30	91			167	33	198.9	100
35-36					13	28	16	0	15		72	15	215.1	100
36-37					28	8	30	21		22	109	25	232.6	100
37-38							11	16	2	10	38	9	237.3	100
38-39								22		0	22	6	280.7	100
39-40							15				15	5	311.6	100
40-41							0				0	0	383.0	100
41-42											0	0	0.0	100
42-43										1	1	0	372.0	100
43-44														
44-45														
TSN(mill)	4,461	9,313	4,830	5,460	2,587	1,880	898	1,764	71	178	31,442			
TSB(1000 t)	143.0	579.9	412.0	553.5	310.2	256.8	138.5	269.8	12.3	31.3	2,707.3			
Mean length(cm	18.0	22.9	25.7	27.2	28.7	29.8	31.0	31.1	32.6					
Mean weight(g)	32	62	85	101	120	137	154	153	173					
% Mature	1	71	93	100	100	100	100	100	100	100				
SSB (1000kg)	1.3	409.2	383.8	552.4	310.2	256.8	138.5	269.8	12.3	31.3	2,365.6			
SSN (mill)	39	6,571	4,500	5,449	2,587	1,880	898	1,764	71	178	23,936.8			

Table 6. Time series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS, 2022. Total biomass in last column (1000 t).

	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

*Survey discarded.

Table 7. IBWSS survey effort time series.

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
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

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

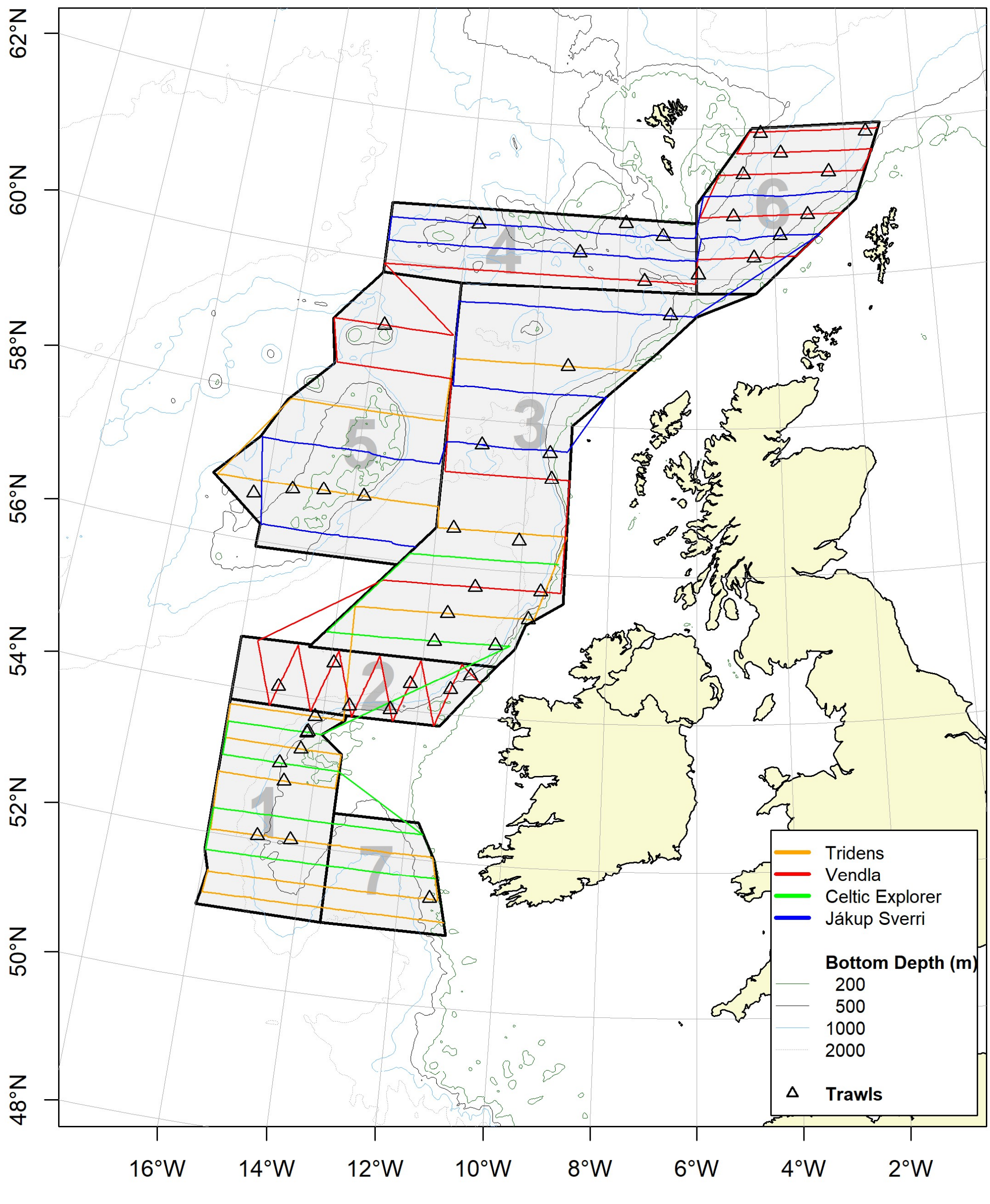


Figure 1. Strata, cruise tracks and trawl hauls for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2022. Faroe Islands (RV *Jakúp Sverri*); Ireland (RV *Celtic Explorer*); Netherlands (RV *Tridens)*; Norway (FV *Vendla*).

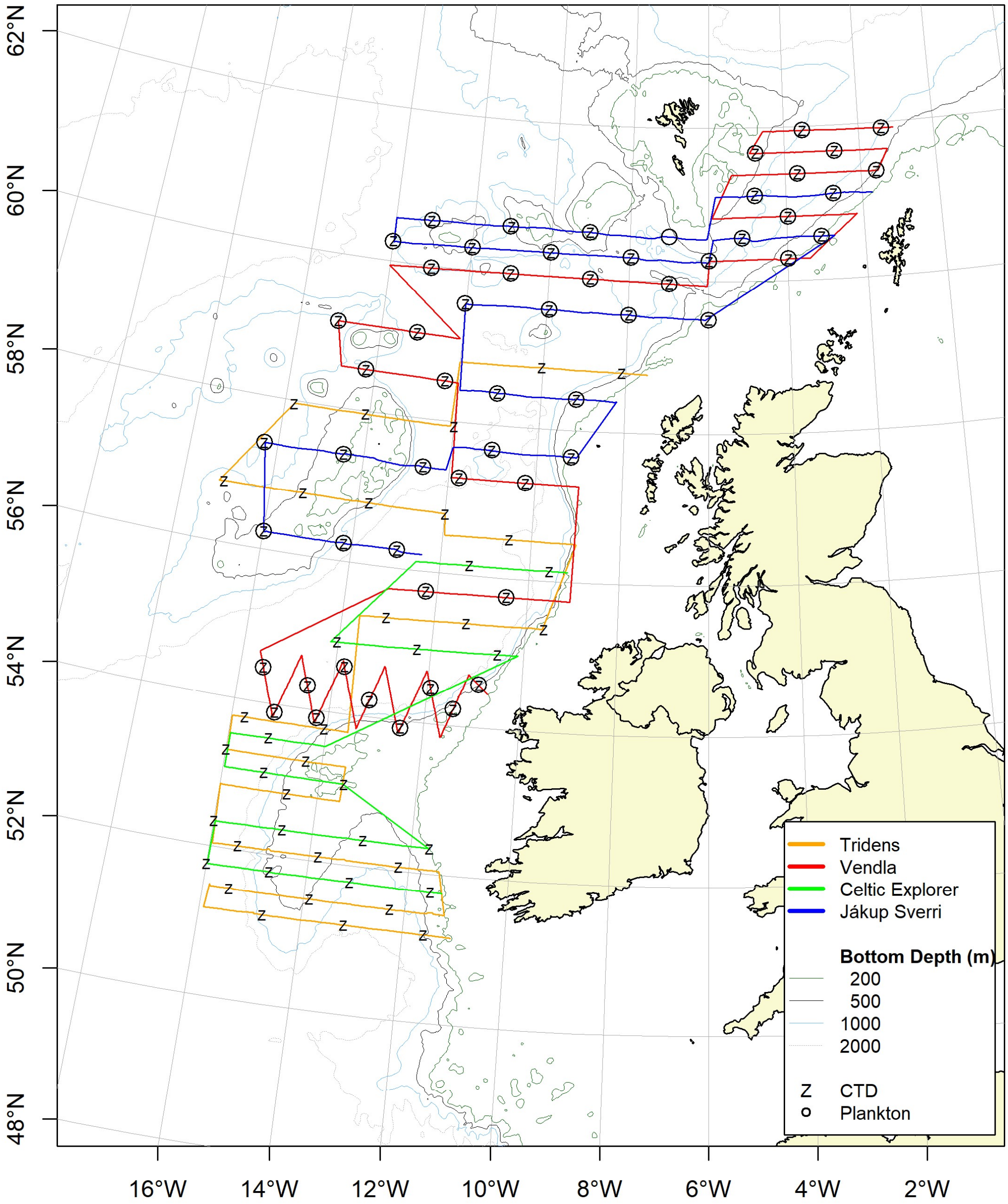


Figure 2. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2022.

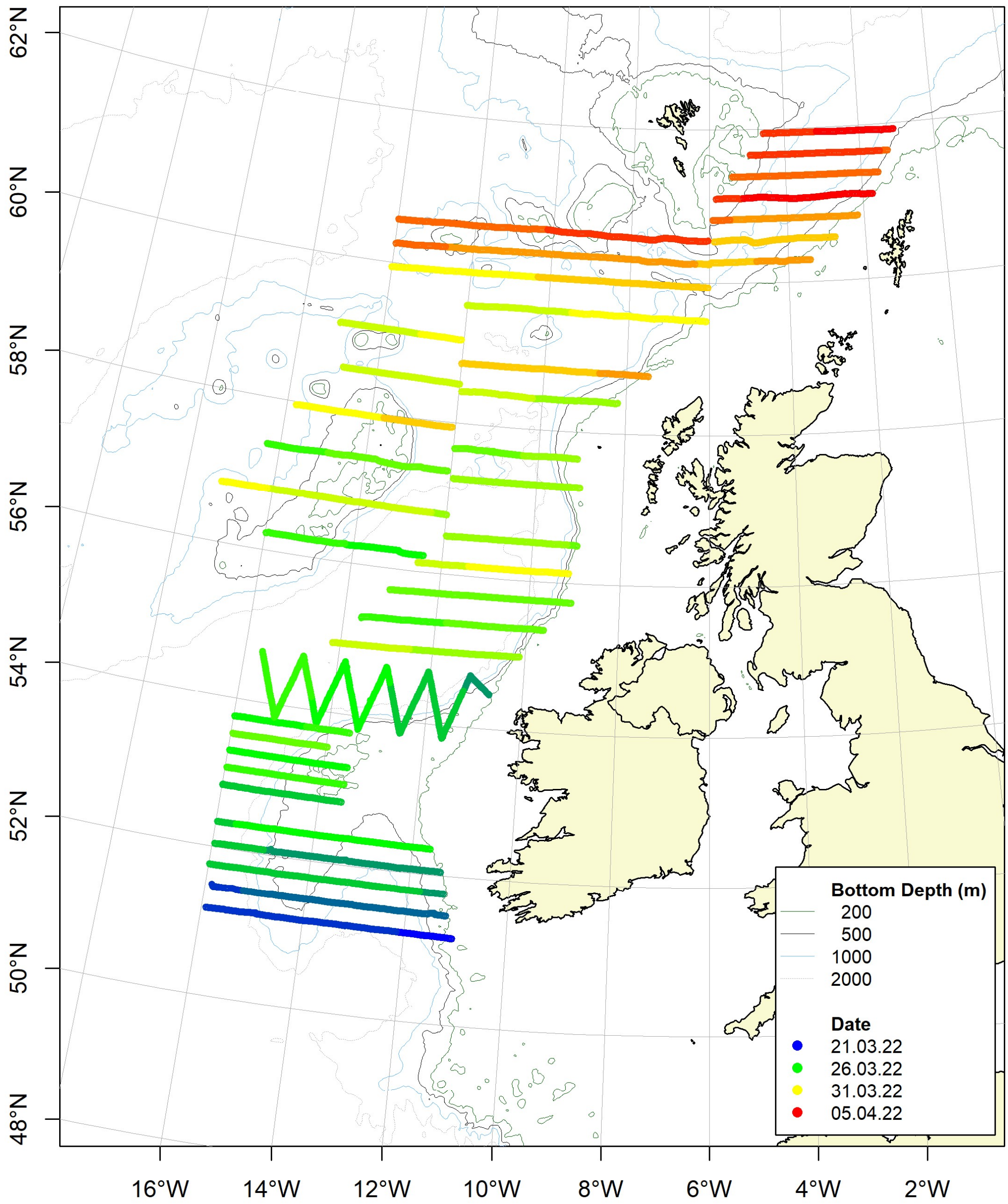


Figure 3. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2022.

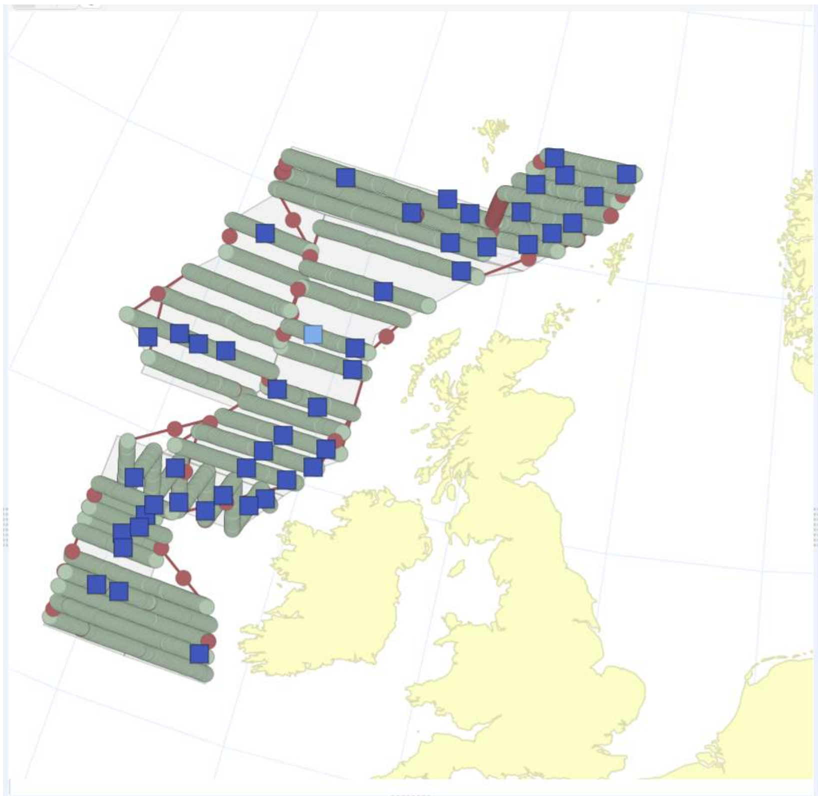


Figure 4. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (dark blue squares) used in the StoX abundance estimation. IBWSS March-April 2022.

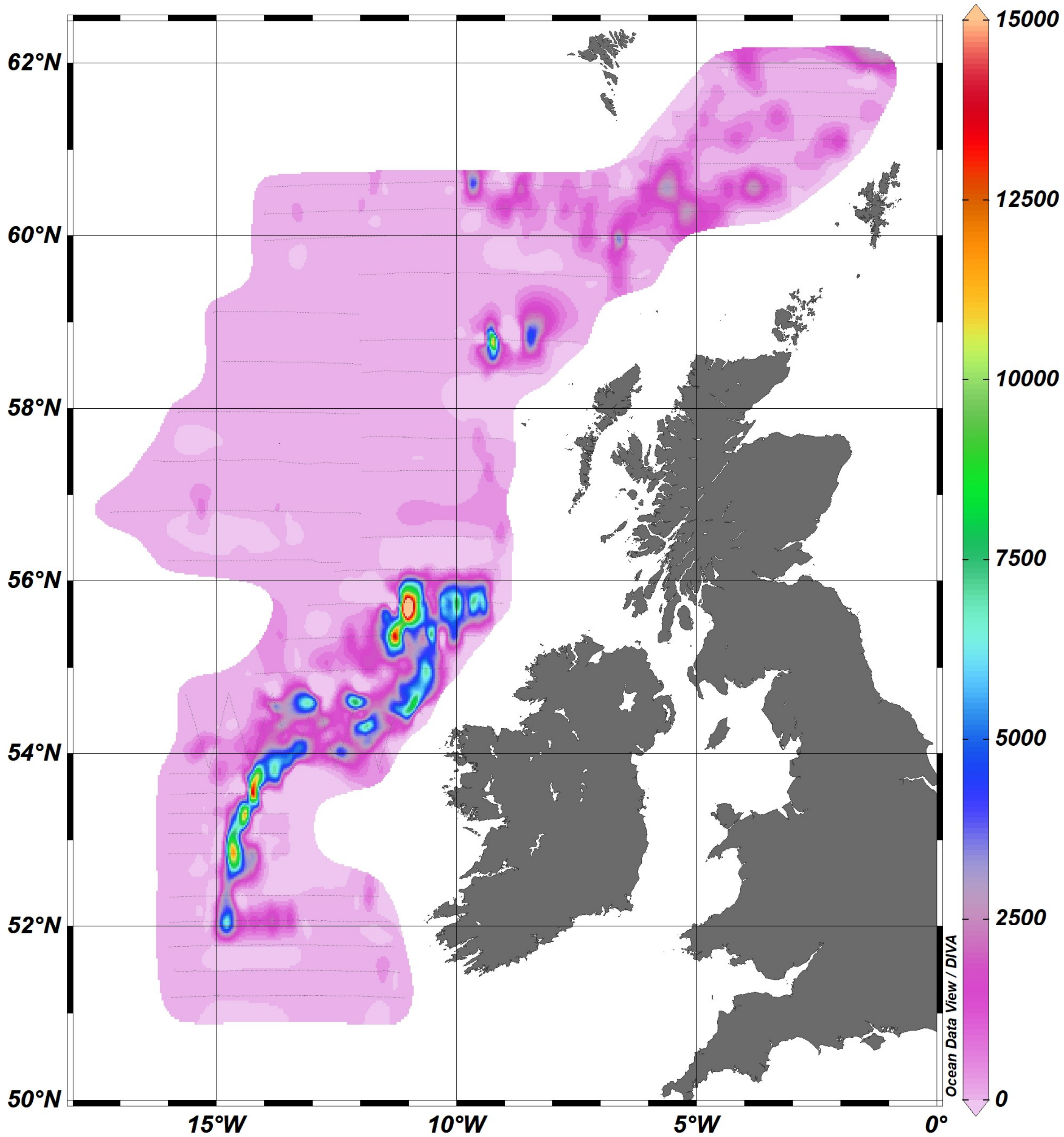


Figure 5. Acoustic density heat map (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2022.

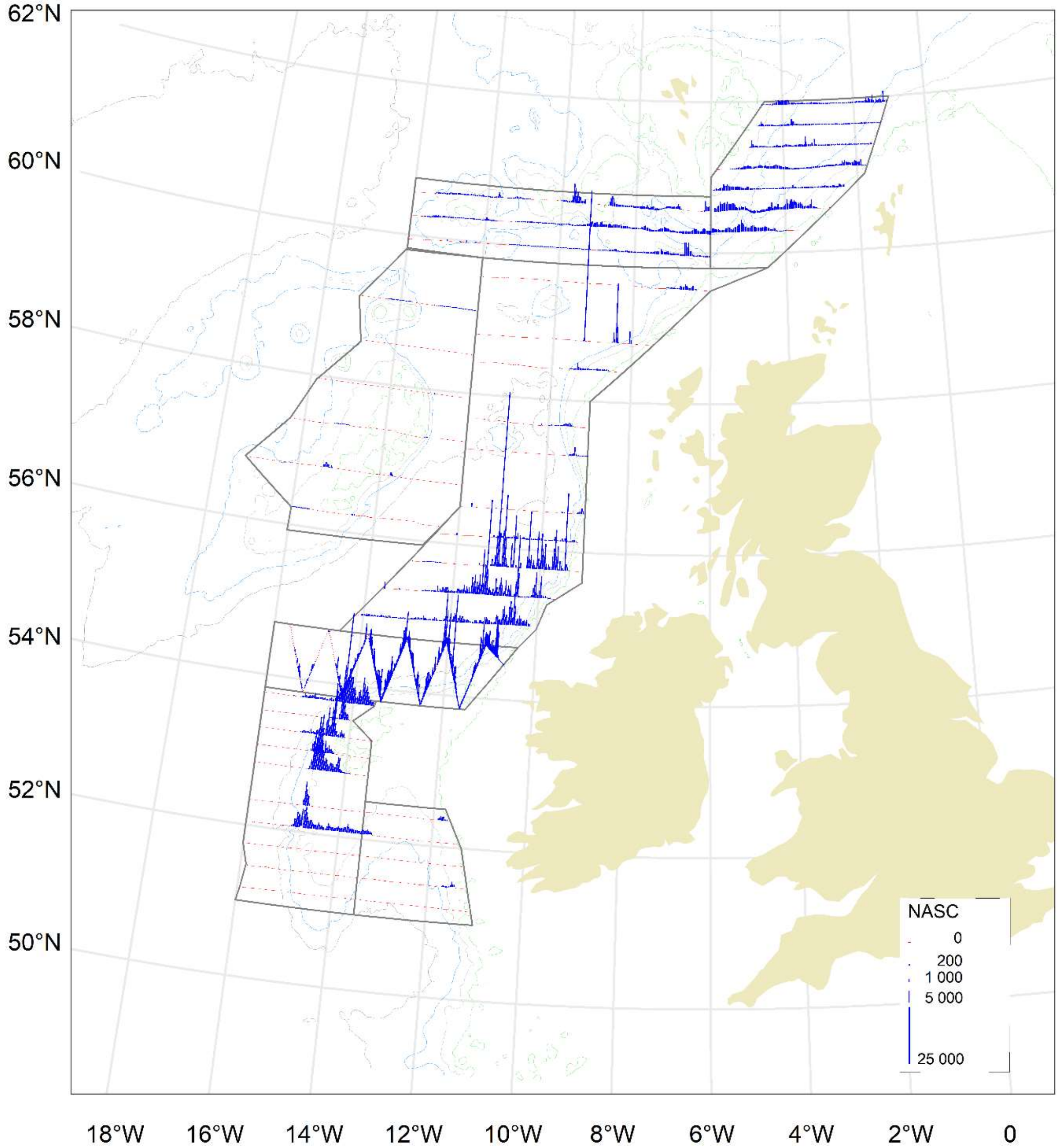
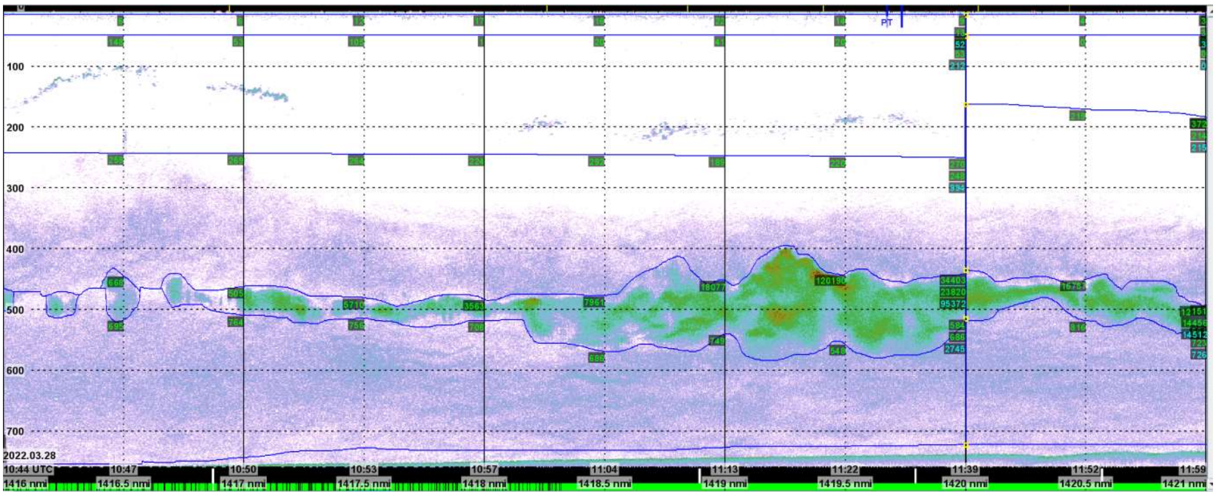
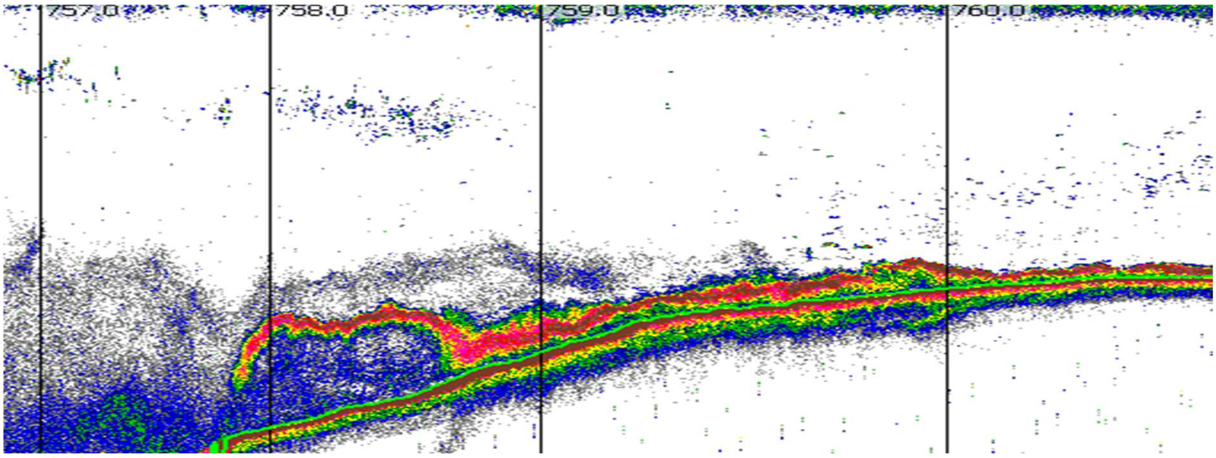


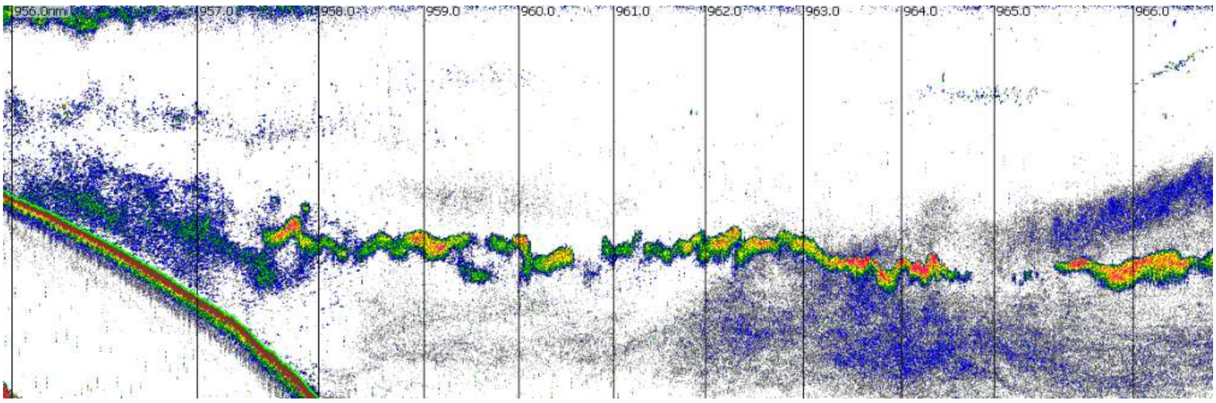
Figure 6. Map of proportional acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi sampling unit. IBWSS March-April 2022.



a) High density blue whiting per 1nmi log interval recorded in open water 50 nmi off the shelf edge in the southern Rockall Trough (Stratum 3) FV *Vendla*, Norway.

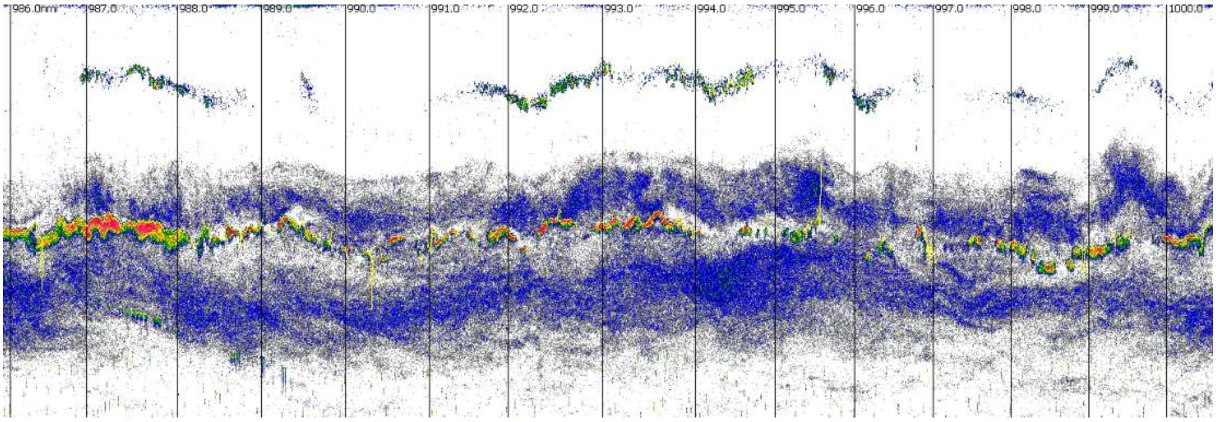


b) Single highest density blue whiting layer (s_A value (46,968 m²/nmi²) recorded by the RV *Celtic Explorer* on the western Porcupine Bank area (Stratum 1). Catch composed of fish 2-9 years old and spent fish.

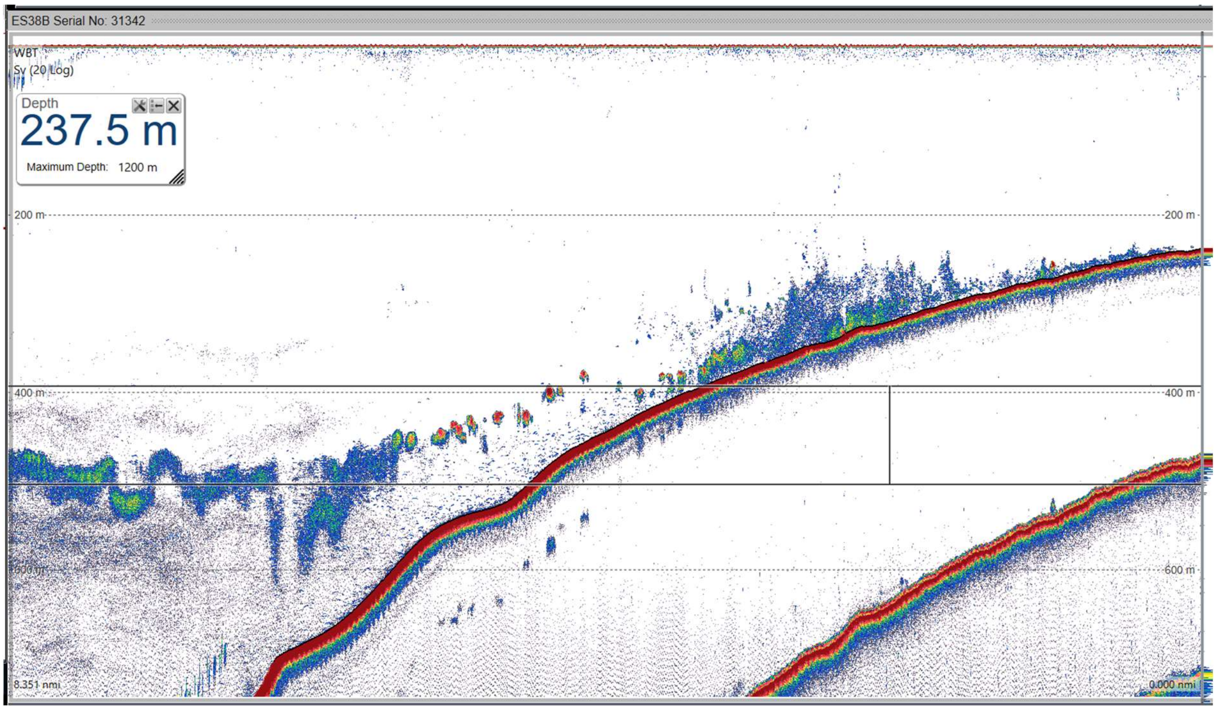


c) High density blue whiting layer per 1nmi log interval observed during the survey recorded by the RV *Celtic Explorer* on the shelf margin in the Rockall Trough (Stratum 3) in 350 – 450 m. Catch composed of fish 2-8 years old, mainly spent fish with some active spawning individuals.

Figure 7. Echograms of interest encountered during the IBWSS, March-April 2022. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU). All echograms presented at 38 kHz, except h) and i) representing 38 and 18 kHz.

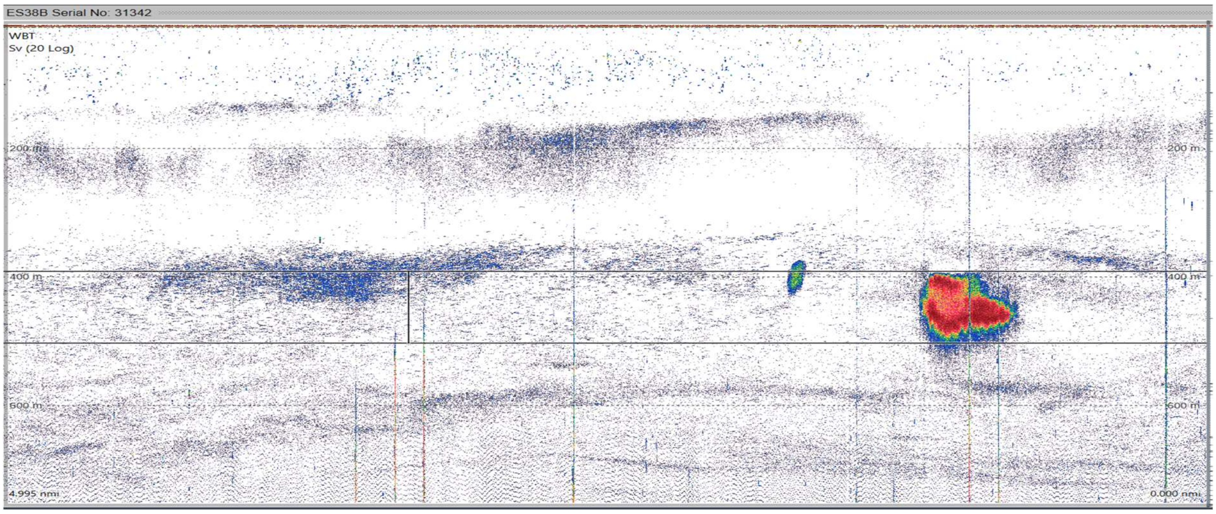


d) High density blue whiting layer per 1nmi log interval observed during the survey recorded by the Celtic Explorer in open water in the Rockall Trough (Stratum 3) in 350–450 m. Catch composed of fish 2-8 years old, mainly spent fish with some active spawning individuals. Mesopelagic fish present in upper echogram at 100-200 m.

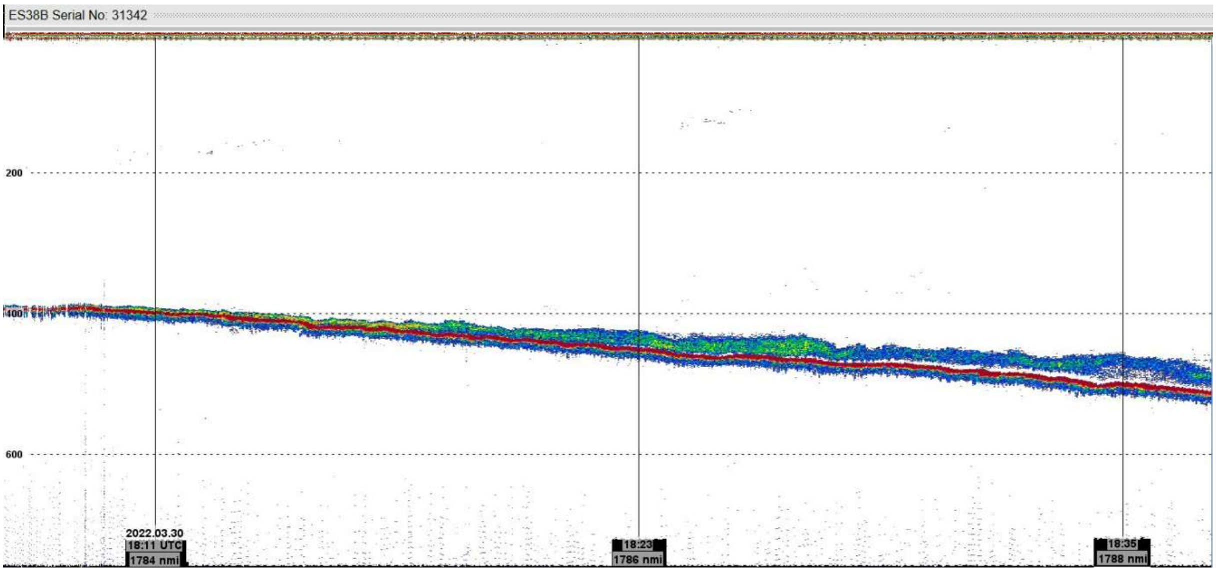


e) Blue whiting mixed with horse mackerel at the shelf edge at 55.22N-9.45W on 28 March (*Tridens*, haul 8 – 1000kg blue whiting and 600kg horse mackerel. Fishing took place at 300-350m. It is assumed that the red schools in midwater is blue whiting. The bluish, green layer at the bottom was assigned to the mix of blue whiting and horse mackerel.

Figure 7. cont.

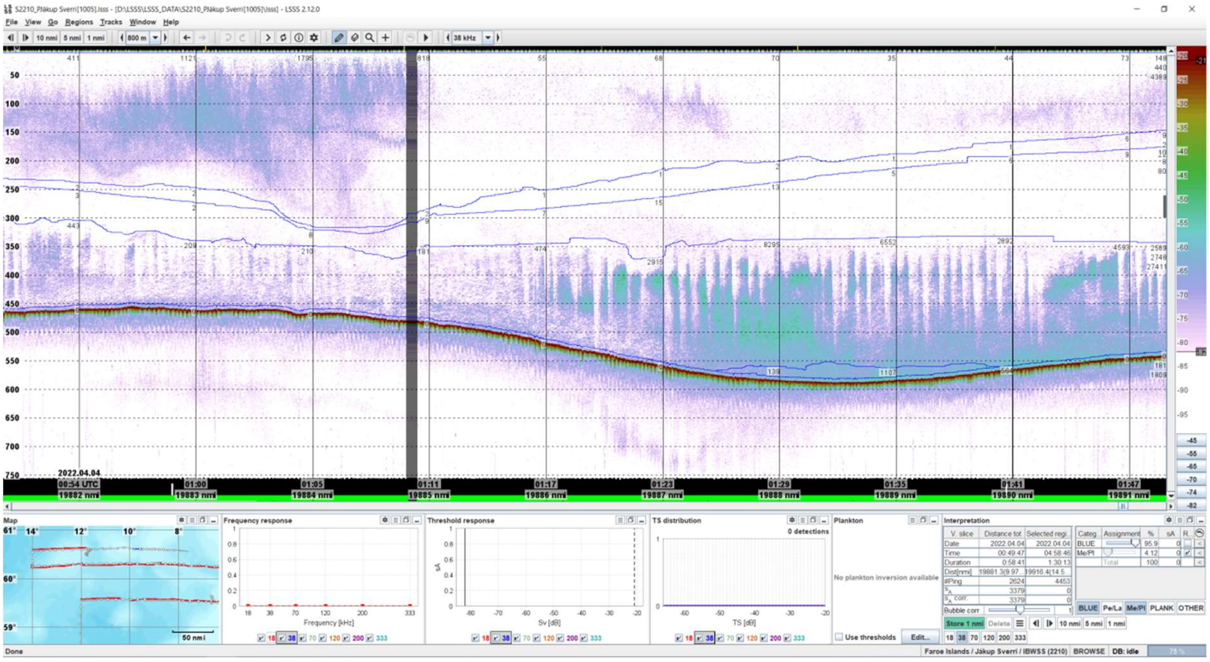


f) School of blue whiting on 1 April 2022 at 58.48N-9.11W, recorded by *Tridens*. The height of the schools is approximately 100m. The catch consisted of adults in the range of 23-34cm, spawning and close to spawning.

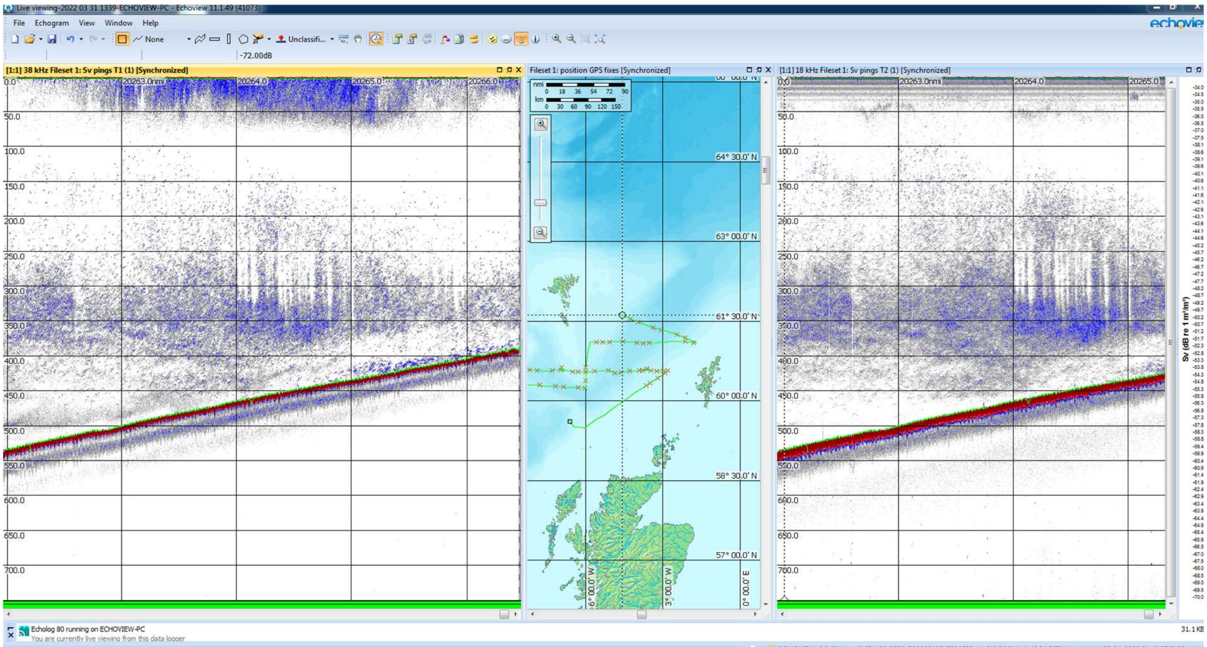


g) Blue whiting observed by *Tridens* at the western edge of Rockall Bank on March 30 at 56.46N-15.24W (catch 678kg blue whiting (15% silvery pout).

Figure 7. cont.



h) Acoustic registrations (38 and 18 kHz) of young (1- and 2-group) blue whiting with the Faroese Jákup Sverri on 04 April, 2022 in the Faroe-Shetland Channel.



i) Acoustic registrations (38 and 18 kHz) of young (1- and 2-group) blue whiting with the Faroese Jákup Sverri on 05 April, 2022 on the Faroese side of the Faroe-Shetland Channel.

Figure 7. cont.

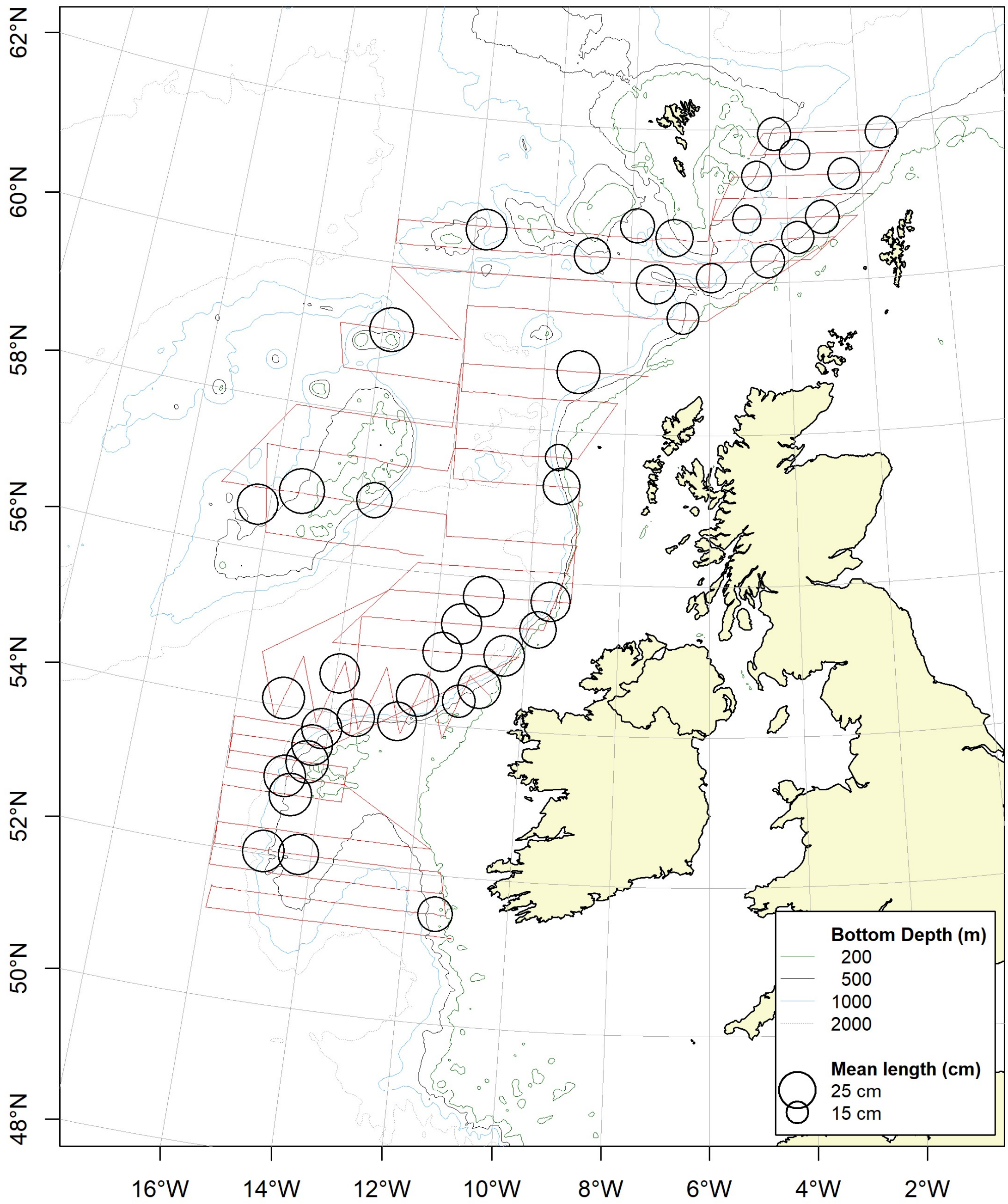


Figure 8. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2022.

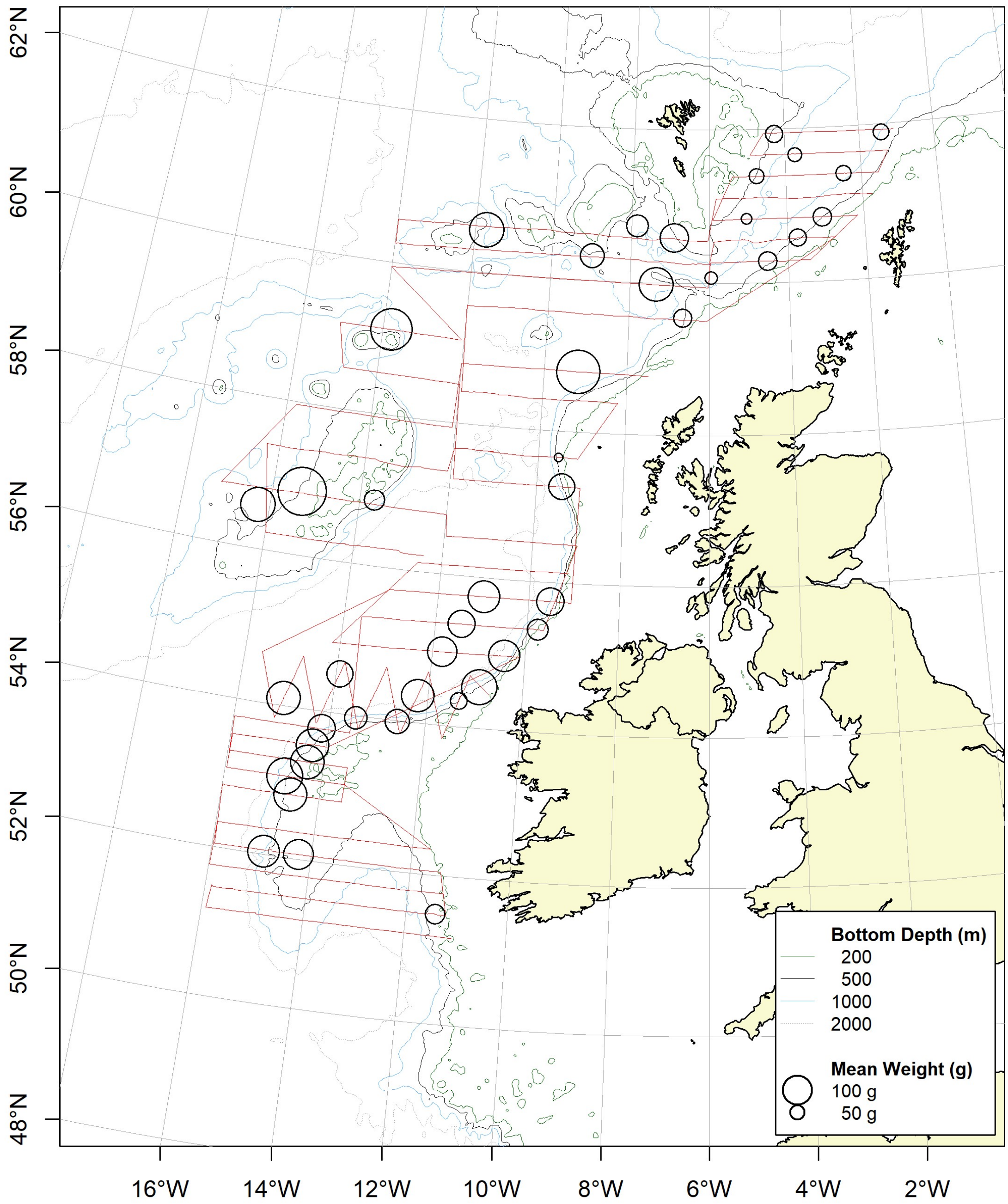


Figure 9. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2022.

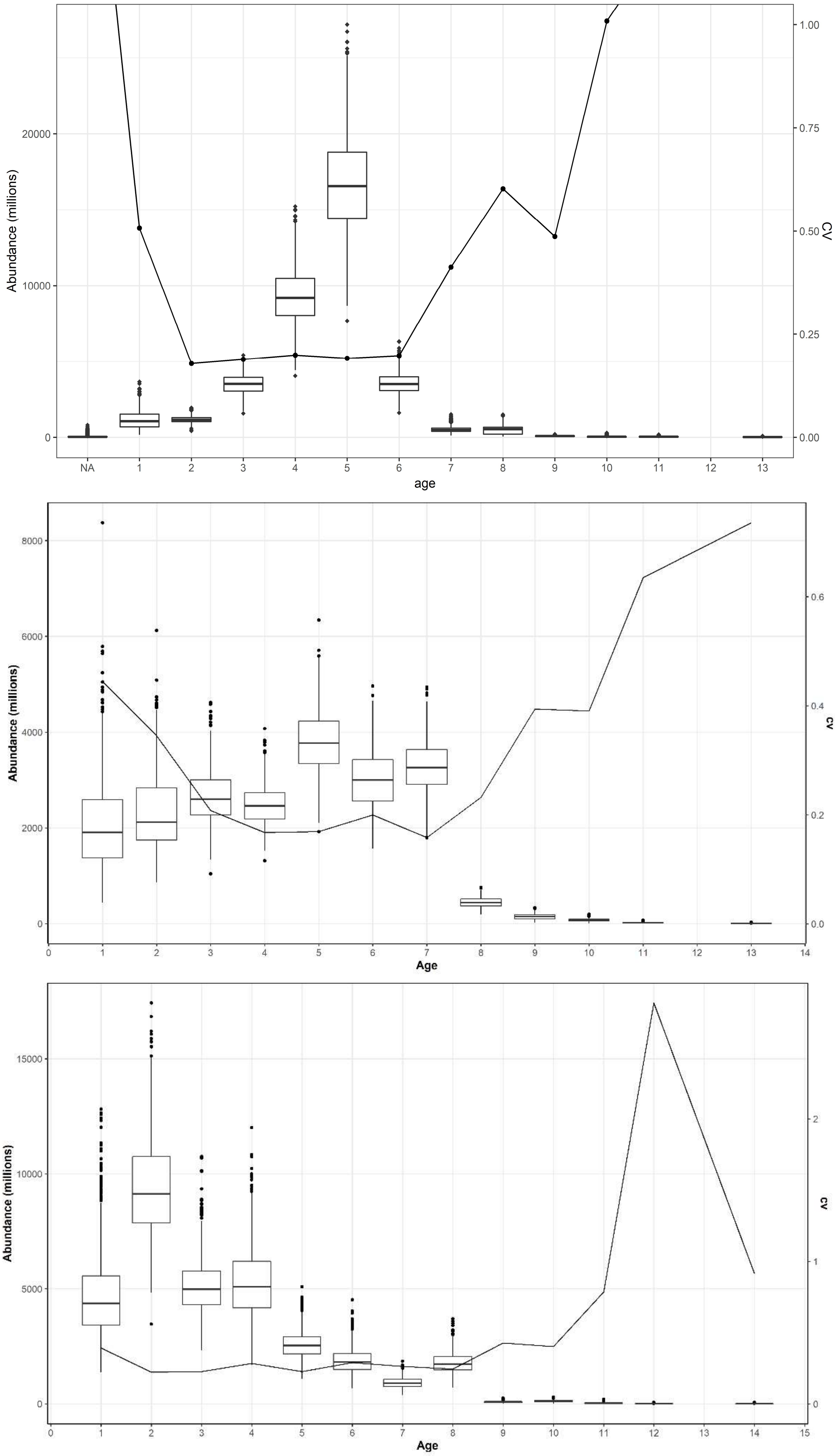


Figure 10. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2019 (top panel), 2021 (middle panel) and 2022 (lower panel). From StoX. No survey in 2020 due to Covid.

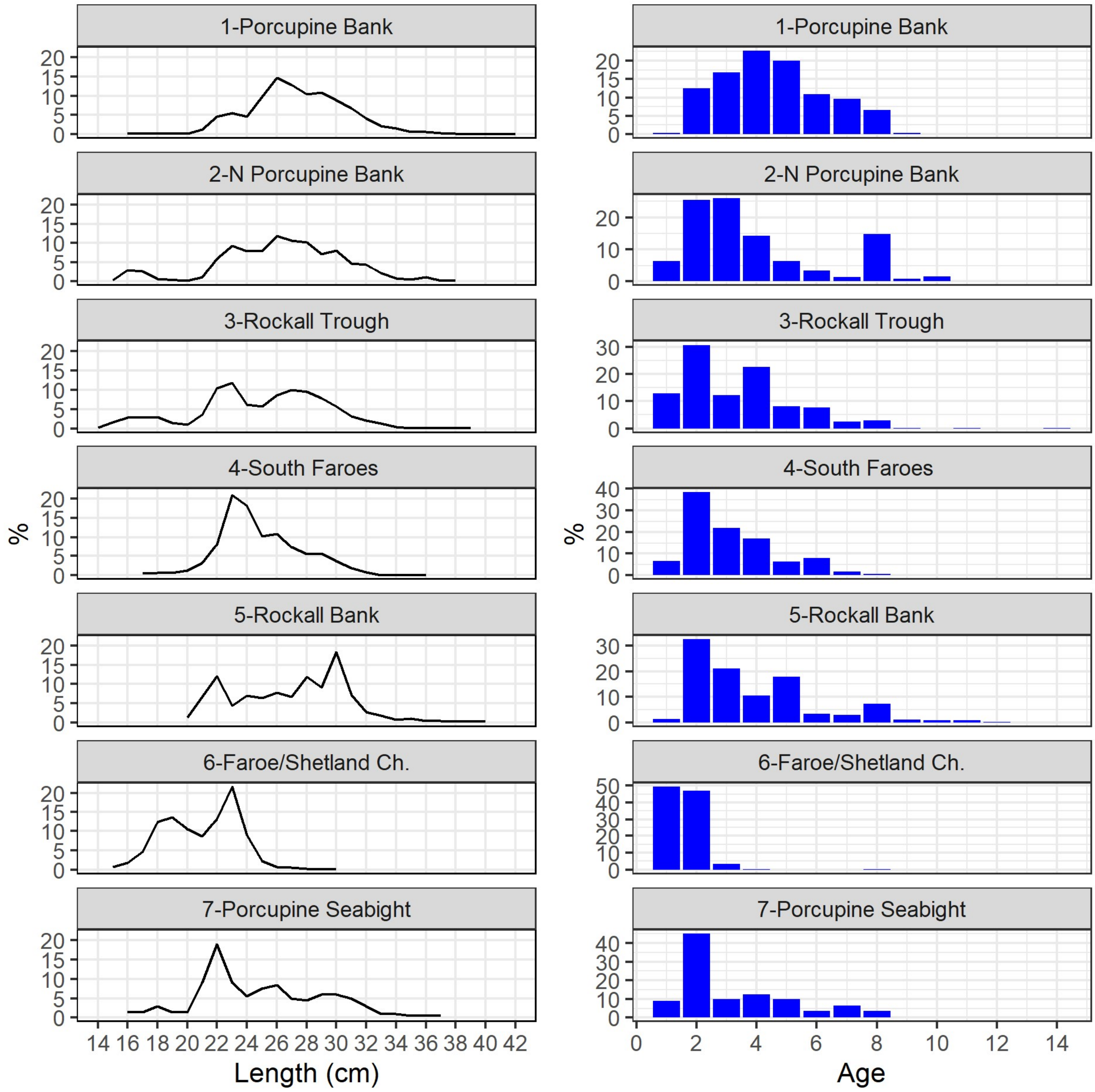


Figure 11. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2022.

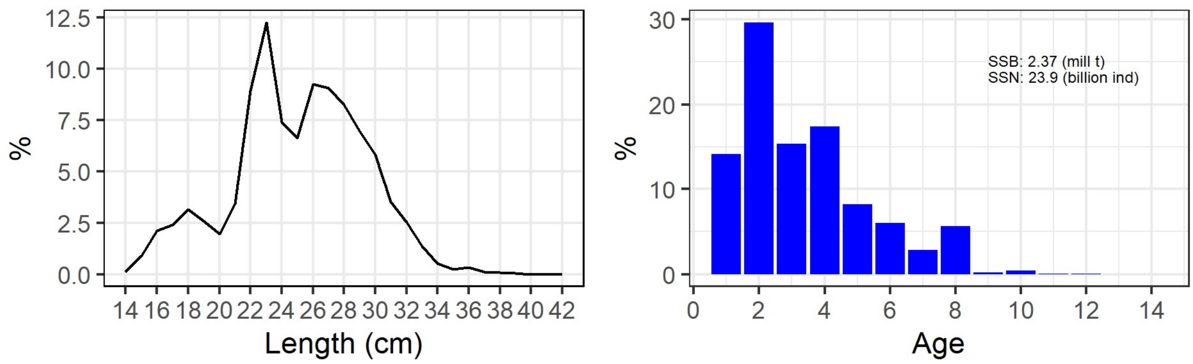


Figure 12. Length and age distribution (numbers) of total stock of blue whiting. March-April 2022.

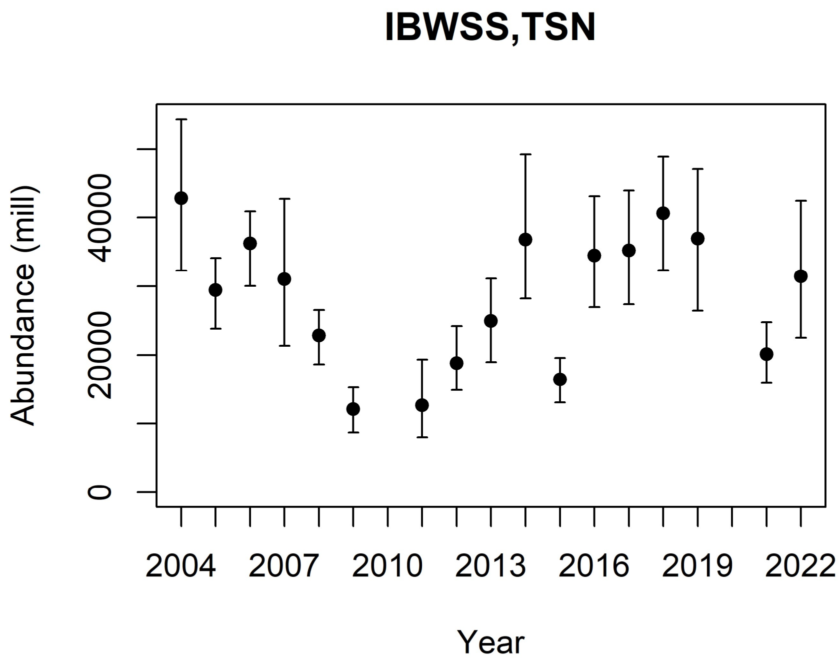


Figure 13. Time series of StoX survey indices of blue whiting abundance, 2004-2022, excluding 2010 and 2020.

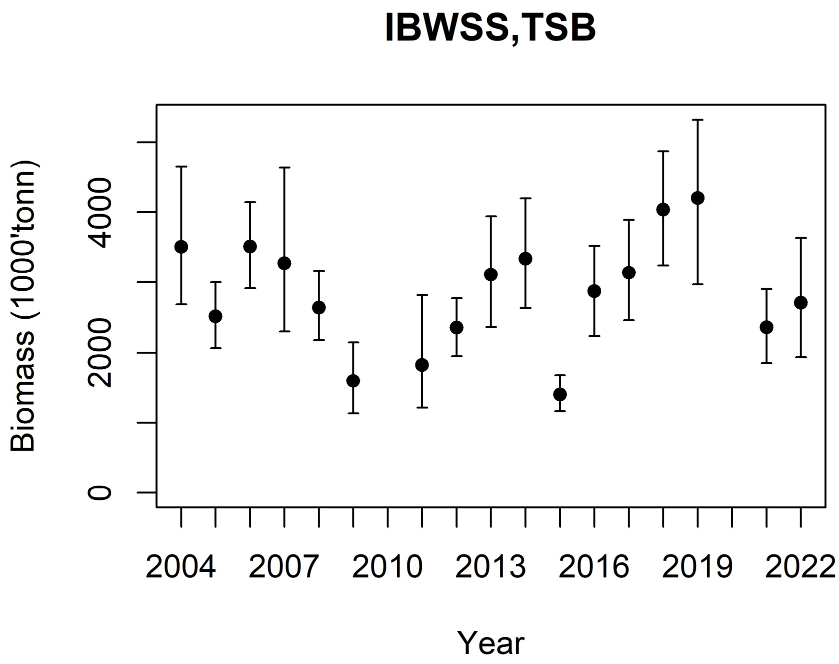


Figure 14. Time series of StoX survey indices of blue whiting biomass, 2004-2022, excluding 2010 and 2020.

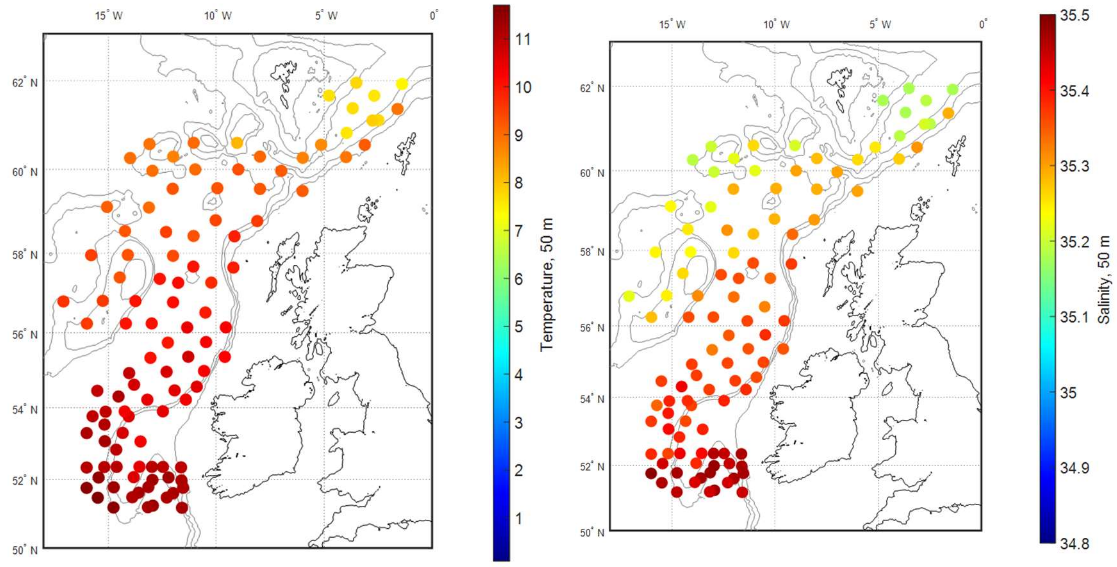


Figure 15. Horizontal temperature (left panel) and salinity (right panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2022.

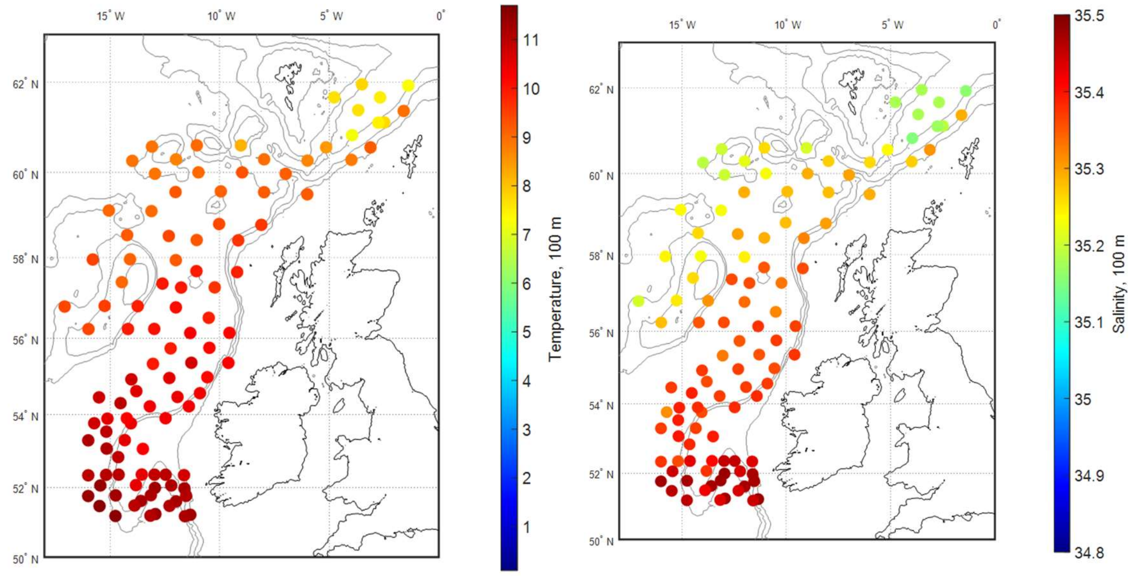


Figure 16. Horizontal temperature (left panel) and salinity (right panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2022.

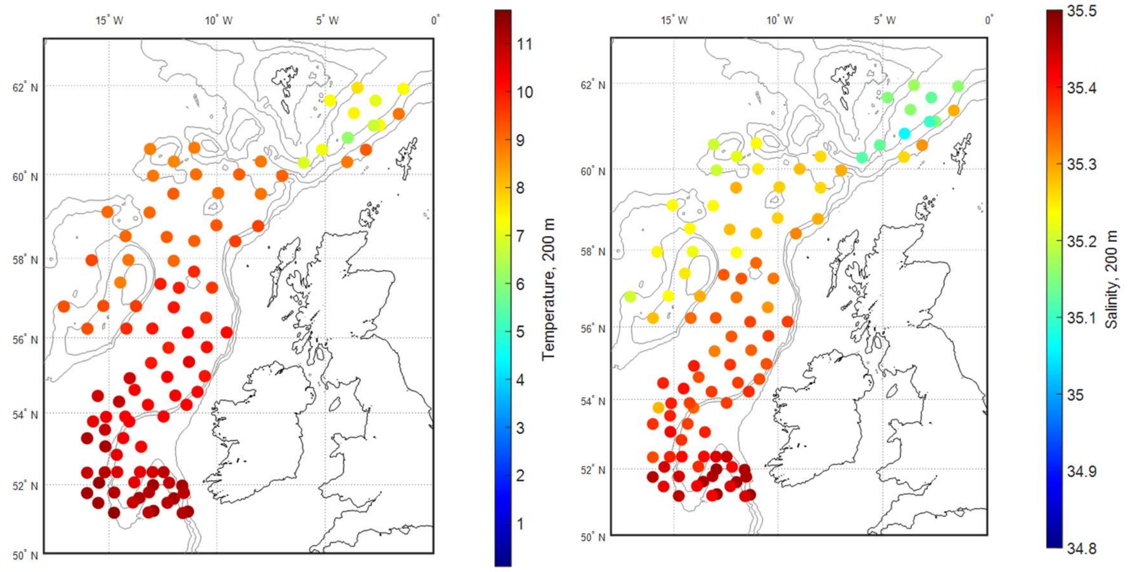


Figure 17. Horizontal temperature (left panel) and salinity (right panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2022.

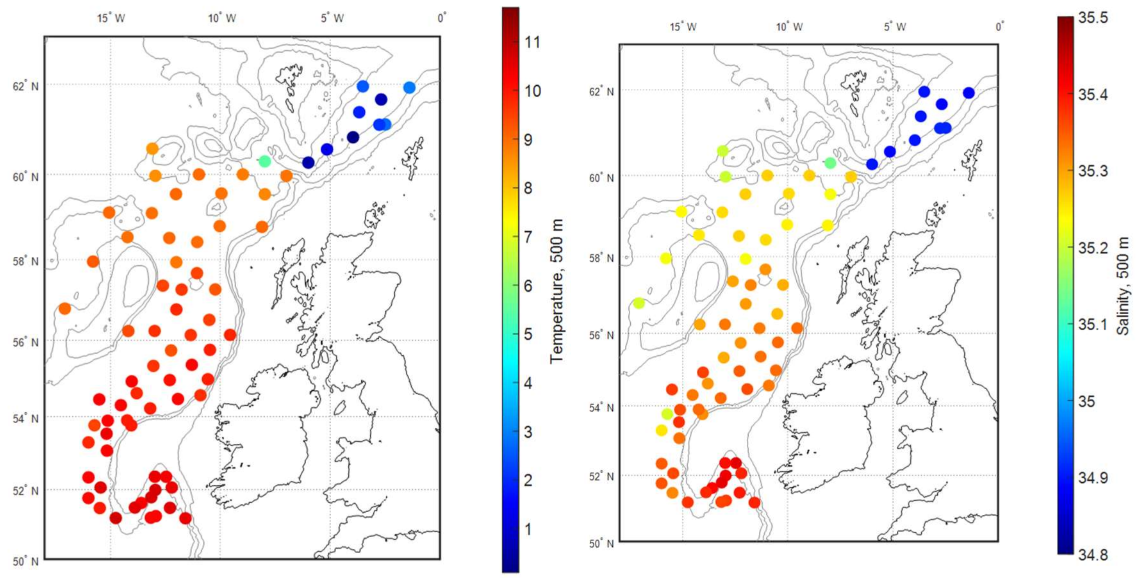


Figure 18. Horizontal temperature (left panel) and salinity (right panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2022.