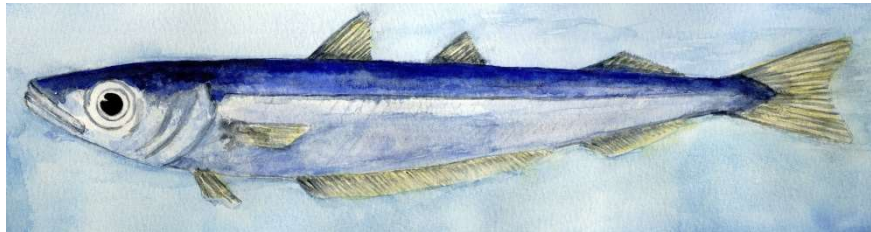# Working Document

## Working Group on International Pelagic Surveys
Bergen, Norway, January 2020

## Working Group on Widely Distributed Stocks
Tenerife, Spain, August 2019



## INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2019

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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 2019 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 | 28/3 – 11/4 |
| Magnus Heinason | Faroe Marine Research Institute, Faroe Islands | 29/3 – 08/4 |
| Tridens | Wageningen Marine Research, the Netherlands | 19/3 – 02/4 |
| Kings Bay | Institute of Marine Research, Norway | 25/3 – 07/4 |
| Miguel Oliver | Spanish Institute of Oceanography, Spain | 18/3 – 21/3 |

The survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 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 in 26 days, above the 21-day target threshold. However, the survey start was delayed by almost one week compared to 2018 and included additional effort by the Spanish survey in the Porcupine Sea bight.

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 with the exception of the Faroes (Figure 4). 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.

*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. 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 the Magnus Heinason (FO) to a depth of 200 m (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 9.0) 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 9.0) 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 (2.5.0) 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. 2.5.0) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On Miguel Oliver, acoustic data were scrutinised every 24 hrs on board using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: Müeller's pearlside, blue whiting and mesopelagic layer (mainly composed by krill and other mesopelagic fish species). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

*Acoustic data analysis*

Acoustic data were analysed using the StoX software package (V 2.7), 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) is used:

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

In StoX a 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 2019 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 V1.11) 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 7,610 nmi (nautical miles) of survey transects were completed across six strata, relating to an overall geographical coverage of 121,397 nmi² (Figure 1, Tables 3). The acoustic sampling effort area increased in 2019 to include the Porcupine sea bight area. Otherwise area coverage was comparable to 2018 (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 in 2019 was located in the 3 strata that covers the shelf edge area (Strata 1, 2 and 3) accounting for 95% of total biomass (Table 4). The Rockall Trough area alone (strata 3) accounted for 61% of the overall survey estimate; this is at a similar level to the two previous years. The Porcupine Bank (strata 2) increased by 57% and contained 21% of the stock compared to 13% in 2018. The three strata outside the core shelf edge area (stratum 4, 5, and 6) collectively decreased from around 12% in 2018 to 5% in 2019 (Table 4). The Rockall and Hatton Bank area (strata 5) contributed just 0.7% of the overall biomass of blue whiting in 2019, down from 4% in 2018. A decrease in salinity and temperature observed in 2017 persists through 2018 and 2019 (see next section).

The two northernmost strata (South Faroes (strata 4) and Shetland Channel (strata 6) accounted for the remaining 4.1% of the biomass (Table 4).

The highest $s_A$ value (98,698 m²/nmi² - sampling unit: one nautical mile) observed in the survey in 2019 was recorded by FV *Kings Bay* on the northern slope of Porcupine Bank in strata 2 (Figure 8a). An example of a typical high density layer of blue whiting observed in the Rockall Trough strata is shown in Figure 8b. A weak layer of blue whiting from the Rockall Bank strata is shown in Figure 8c. Juvenile blue whiting were mainly observed in the northern stratum (South Faroes and Faroe – Shetland Channel) and an example echogram is shown in Figure 8d. High density blue whiting registrations were observed in the Porcupine Sea bight by the RV *Miguel Oliver* (Figure 8e & 8f).

The vertical distribution of blue whiting observed in 2019 did not extend deeper than 750 m as observed in 2018. However, schools in the Porcupine sea bight were observed down to a depth of 600 m.

*Stock size*

The estimated total biomass of blue whiting for the 2019 international survey was 4.2 million tonnes, representing an abundance of $36.9 \times 10^9$ individuals (Table 4). Spawning stock was estimated at 4.17 million tonnes and $35.8 \times 10^9$ individuals (Table 5).

*Stock composition*

Individuals of ages 1 to 13 years were observed during the survey.

The main contribution (82%) to the spawning stock biomass were the age groups 4, 5 and 6 with the five year olds (2014 year-class) being most abundant (47%), followed by the 2015 year-class (24%) and 2013 year-class (11%) (Table 5).

The highest mean weights of blue whiting were caught in the northern part of the Rockall Trough stratum 3 (Figures 9 and 10). Highest mean weight in 2019 was in strata 3 representing 121g.

Five year olds (the 2014 year-class) were dominant in all strata with the exception of strata 4 (south Faroes) and strata 6 (Faroe/Shetland Channel), where 1 year olds ranked highest (Figure 12). The proportion of 1 and 2-year-old fish was low in the total estimate in 2019 (Figure 13).

An uncertainty estimate at age based on a comparison of the abundance estimates was calculated for IBWSS for years 2017, 2018 and 2019 using StoX (Figure 11). By comparing the estimates of young year classes from 2017 to 2019 it appears that good cohort tracking is achieved in the survey for some year classes. For example, the relative abundance of two year olds in 2016 (2014-year class) was high; the strong abundance of this cohort is also seen in 2017 as three year olds, in 2018 as four year olds, and in 2019 as five year olds. Similarly, the 2015 year-class were picked up as two year olds in 2017, and subsequently the three and four year olds in 2018 and 2019 respectively are relatively strong. The CV of the abundant age groups 3 to 6 was below 0.25 in 2019 (Figure 11).

The CV of the total estimate of both biomass and abundance were 0.17, which is higher than last year (0.125) and slightly higher than the years before when the CV varied around 0.16.

The survey time series (2004-2019) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

*Hydrography*

A total of 118 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 16-19 respectively. A decrease in salinity and temperature observed in 2017 persists through 2018 and 2019. This is thought to limit the western extent of the blue whiting spawning distribution on the Rockall and Hatton Bank areas (Hátún *et al.* 2009).

## Concluding remarks

### Main results

- Weather conditions were mixed with both good and bad periods. All vessels experienced poor weather conditions at some point during the survey, resulting in slower transect speeds.

- The total area surveyed was comparable but lower than in 2018. Corresponding acoustic sampling effort (transect miles) increased. Reduced area coverage can be accounted by the lack of blue whiting in western peripheral areas (stratum 5- Rockall). Acoustic sampling increased due to the presence of the RV *Miguel Oliver* and her coverage of the Porcupine sea bight. Coverage in the sea bight can be considered a new extension of the total survey area and is necessary to contain the stock in its southern boundary.

- Overall, biological sampling saw an increased number of measured fish but a lower number of aged individuals compared to 2018.

- The International Blue Whiting Spawning Stock Survey 2019 shows an increase in total stock biomass of 4% with a corresponding decrease in total abundance of 9% when compared to the 2018 estimate.

- The survey was carried out over 26 days, above the 21-day time window target. These additional days can be accounted for the by the delayed start of the RV *Celtic Explorer* compared to previous years.

- Estimated uncertainty around the total stock biomass was higher than last year, CV=0.17 compared to 0.13.

- The stock biomass within the survey area was dominated by 4, 5 and 6-year-old fish contributing 82% of total stock biomass.

- There was no evidence of blue whiting below 750 m

- Immature fish (1-year-old) represent 0.7% of the TSB and 2.9% of TSN.

### Interpretation of the results

- The group considers the 2019 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Sampling effort (biological and acoustic), was comparable to previous years.

- Total stock biomass observed in 2019 is the highest in the overall time series (2004-present). Representing an increase in TSB of 4% compared to 2018 (4.0 mt and 4.2 mt respectively). The 2014-year class (5 year old fish) accounts for approximately 46% of the TSB and almost 2 million tons. 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.

- The Northern migratory stock and the Porcupine sea bight; Spatio-temporal survey data and biological data from trawl hauls (RV *Tridens* and RV *Miguel Oliver*) were comparable in terms of length cohorts. The eastward extension of the survey area is necessary to contain the northern stock. Comparative analysis of age readings is required.

### 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.

- The group recommends that the process of producing output reporting tables, figures and maps from StoX outputs files is standardised through scripting routines and developed by WGIPS for wider use.

- To facilitate the above process, we request that StoX developers look into the possibility of fixing the format of output tables of biomass and abundance to aid this process. Currently zero values in biomass and abundance tables (age and lengths) are omitted.

- Current XML file formats generated from ICES or PGNAPES data repositories are not cross compatible for combined use in StoX due to differences in formatting. As the group diverges from using PGNAPES as the sole data repository to using the ICES acoustic database members need to be clear during the planning phase on which repository they intend to use going forward. This issue requires attention during WGIPS in 2020 so as not to disrupt the process of global abundance estimation in 2020.
- It is recommended that all participants produce files types in both ICES and PGNAPES file formats for the 2020 post cruise meeting to facilitate cross compatibility testing within StoX.

## Achievements
- The Porcupine sea bight was covered synoptically, in close temporal progression by two survey vessels.

- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable to 2018.

# References

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**Table 1**. Country and vessel specific details, IBWSS March-April 2019.

|  | Celtic Explorer | Magnus Heinason | Tridens | Kings Bay | Miguel Oliver |
|---|---|---|---|---|---|
| Trawl dimensions |  |  |  |  |  |
| Circumference (m) | 768 | 640 | 860 | 832 | 752 |
| Vertical opening (m) | 50 | 42-45 | 30-70 | 45 | 30 |
| Mesh size in codend (mm) | 20 | 40 | 40 | 40 | 20 |
| Typical towing speed (kn) | 3.5-4.0 | 3.2-3.6 | 3.5-4.0 | 3.5-4.0 | 3.5-4.0 |
| Plankton sampling | - | 16 | - | - |  |
| Sampling net | - | WP2 plankton net | - | - |  |
| Standard sampling depth (m) | - | 200 | - | - |  |
| Hydrographic sampling |  |  |  |  |  |
| CTD Unit | SBE911 | SBE911 | SBE911 | SBE25 | SBE25 |
| Standard sampling depth (m) | 1000 | 1000 | 1000 | 900 | 520 |

**Table 2**. Acoustic instruments and settings for the primary frequency, IBWSS March-April 2019.

|  | Celtic Explorer | Magnus Heinason | Tridens | Kings Bay | Miguel Oliver |
|---|---|---|---|---|---|
| Echo sounder | Simrad EK 60 | Simrad EK60 | Simrad EK 60 | Simrad EK 80 | Simrad EK 60 |
| Frequency (kHz) | **38**, 18, 120, 200 | **38**, 200 | 18, **38**, 70, 120, 200, 333 | 18, **38**, 70 | **38**, 18, 70, 120, 200 |
| Primary transducer | ES 38B | ES 38B | ES 38B | ES 38B | ES 38B |
| Transducer installation | Drop keel | Hull | Drop keel | Drop keel | Hull |
| Transducer depth (m) | 8.7 | 3 | 8 | 8.5 | 6.5 |
| Upper integration limit (m) | 15 | 7 | 15 | 15 | 15 |
| Absorption coeff. (dB/km) | 9.9 | 10.1 | 9.5 | 9.59 | 9.2 |
| Pulse length (ms) | 1.024 | 1.024 | 1.024 | 1.024 | 1.024 |
| Band width (kHz) | 2.425 | 2.43 | 2.43 | 2.43 | 2.43 |
| Transmitter power (W) | 2000 | 2000 | 2000 | 2000 | 2000 |
| Angle sensitivity (dB) | 21.9 | 21.9 | 21.9 | 23 | 21.9 |
| 2-way beam angle (dB) | -20.6 | -20.8 | -20.6 | -20.7 | -20.6 |
| $S_v$ Transducer gain (dB) |  |  |  |  |  |
| $T_s$ Transducer gain (dB) | 25.85 | 25.64 | 26.52 | 24.06 | 24.68 |
| $s_A$ correction (dB) | -0.64 | -0.66 | -0.76 | 0.008 | -0.54 |
| 3 dB beam width (dg) |  |  |  |  |  |
| alongship: | 6.87 | 7.02 | 6.79 | 7.0 | 6.90 |
| athw. ship: | 6.91 | 7.00 | 6.81 | 7.0 | 7.10 |
| Maximum range (m) | 750 | 750 | 750 | 750 | 1000 |
| Post processing software | Echoview | Echoview | LSSS | LSSS | Echoview |

**Table 3**. Survey effort by vessel, IBWSS March-April 2019.

| Vessel | Effective survey period | Length of cruise track (nmi) | Trawl stations | CTD stations | Plankton sampling WP2-net | Aged fish | Length-measured fish |
|---|---|---|---|---|---|---|---|
| Celtic Explorer | 28/3-11/4 | 2282 | 7 | 24 | - | 350 | 3001 |
| Magnus Heinason | 29/3-8/4 | 1400 | 6 | 19 | 17 | 300 | 668 |
| Kings Bay | 25/3- 7/4 | 2185 | 11 | 27 | - | 330 | 1,091 |
| Tridens | 19/3-2/4 | 1473 | 10 | 28 | - | 798 | 800 |
| Miguel Oliver | 18/3-21/3 | 270 | 4 | 20 | - | 160 | 668 |
| Total | 28/3-11/4 | 7610 | 38 | 118 | 17 | 1938 | 6228 |

**Table 4**. Abundance and biomass estimates of blue whiting by strata in 2019 and 2018. IBWSS March-April 2019.

| Strata | Name | 2019 TSB ($10^3$ t) | 2019 TSN ($10^9$) | 2019 % TSB | 2019 % TSN | 2018 TSB ($10^3$ t) | 2018 TSN ($10^9$) | 2018 % TSB | 2018 % TSN | Difference 2019-2018 TSB | Difference 2019-2018 TSN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Porcupine Bank | 870 | 8,350 | 20.7 | 22.6 | 534 | 5,519 | 13.2 | 13.6 | 57% | 66% |
| 2 | N Porcupine Bank | 572 | 5,692 | 13.6 | 15.4 | 521 | 5,599 | 12.9 | 13.8 | 6% | 12% |
| 3 | Rockall Trough | 2,555 | 21,116 | 60.9 | 57.2 | 2,475 | 24,708 | 61.4 | 60.9 | -1% | -6% |
| 4 | South Faroes | 125 | 1,039 | 3.0 | 2.8 | 164 | 1,604 | 4.1 | 4.0 | -27% | -29% |
| 5 | Rockall Bank | 29 | 272 | 0.7 | 0.7 | 179 | 1,835 | 4.4 | 4.5 | -85% | -84% |
| 6 | Faroe/Shetland Ch. | 47 | 448 | 1.1 | 1.2 | 162 | 1,336 | 4.0 | 3.3 | -72% | -63% |
| | Total | 4,198 | 36,918 | 100 | 100 | 4,035 | 40,602 | 100 | 100 | 4% | -9% |

**Table 5**. Survey stock estimate of blue whiting, IBWSS March-April 2019.

| Length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | Number | Biomass | Mean weight | Prop Mature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | | (10^6) | (10^6 kg) | (g) | |
| 16-17 | 11 | | | | | | | | | | 11 | 0.3 | 28 | 0 |
| 17-18 | 50 | | | | | | | | | | 50 | 1.6 | 31 | 0 |
| 18-19 | 184 | | | | | | | | | | 184 | 6.1 | 33 | 50 |
| 19-20 | 233 | | | | | | | | | | 233 | 8.2 | 35 | 16 |
| 20-21 | 291 | | | | | | | | | | 291 | 13.5 | 46 | 23 |
| 21-22 | 173 | | | | | | | | | | 173 | 8.8 | 51 | 21 |
| 22-23 | 82 | 19 | 4 | | | | | | | | 104 | 6.5 | 62 | 46 |
| 23-24 | 81 | 89 | 2 | | | | | | | | 172 | 11.6 | 67 | 59 |
| 24-25 | 35 | 380 | 113 | | | | | | | | 528 | 38.3 | 73 | 95 |
| 25-26 | | 475 | 467 | 281 | 638 | 101 | | | | | 1,962 | 164.0 | 84 | 100 |
| 26-27 | | 146 | 948 | 2,125 | 2,069 | 209 | | | | | 5,497 | 506.0 | 92 | 100 |
| 27-28 | | 43 | 1,038 | 2,589 | 3,514 | 574 | | | | | 7,759 | 787.1 | 101 | 100 |
| 28-29 | | 14 | 421 | 2,348 | 4,765 | 406 | 31 | 7 | | | 7,991 | 889.8 | 111 | 100 |
| 29-30 | | 3 | 182 | 921 | 2,853 | 666 | 28 | | 7 | | 4,660 | 579.3 | 124 | 100 |
| 30-31 | | | 150 | 862 | 1,651 | 669 | 103 | 37 | | | 3,473 | 480.0 | 138 | 100 |
| 31-32 | | | | 380 | 758 | 257 | 170 | | | | 1,564 | 244.7 | 156 | 100 |
| 32-33 | | | 144 | 63 | 442 | 79 | 40 | 195 | | 18 | 982 | 181.9 | 185 | 100 |
| 33-34 | | | | 20 | 97 | 336 | 47 | 114 | | | 614 | 113.2 | 184 | 100 |
| 34-35 | | | | | 109 | 86 | 26 | 42 | | 5 | 269 | 57.5 | 214 | 100 |
| 35-36 | | | | | 68 | 2 | | 65 | | 2 | 137 | 32.6 | 238 | 100 |
| 36-37 | | | | | | | 15 | | 74 | 12 | 101 | 21.8 | 215 | 100 |
| 37-38 | | | | | | 22 | | 41 | 11 | 6 | 80 | 21.9 | 274 | 100 |
| 38-39 | | | | | 14 | 18 | | 13 | | | 46 | 10.0 | 218 | 100 |
| 39-40 | | | | | | 24 | | | | | 24 | 7.7 | 316 | 100 |
| 40-41 | | | | | | | | | | | 0 | - | | 100 |
| 41-42 | | | | | 8 | | | | | | 8 | 3.1 | 372 | 100 |
| 43-44 | | | | | | | | | 6 | | 6 | 2.4 | 397 | 100 |
| TSN(mill) | 1,129 | 1,169 | 3,468 | 9,590 | 16,979 | 3,434 | 484 | 513 | 99 | 144 | 36,918 | | | |
| TSB(1000 t) | 51.7 | 94.4 | 358.2 | 1,025.1 | 1,962.1 | 463.3 | 81.4 | 131.4 | 20.6 | 38.2 | 4,197.6 | | | |
| Mean length(cm | 20.1 | 25.0 | 27.1 | 27.9 | 28.4 | 29.5 | 31.7 | 33.4 | 36.2 | | | | | |
| Mean weight(g) | 46 | 81 | 103 | 107 | 116 | 135 | 168 | 256 | 209 | | | | | |
| % Mature | 8 | 99 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | | | |
| SSB (1000kg) | 4.3 | 93.4 | 349.5 | 1024.5 | 1961.4 | 463.3 | 81.4 | 131.4 | 20.6 | 38.2 | 4168.0 | | | |
| SSN (mill) | 93 | 1156 | 3384 | 9584 | 16973 | 3434 | 484 | 513 | 99 | 144 | 35862.1 | | | |

**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 |
| 2019 | 1,129 | 1,169 | 3,468 | 9,590 | 16,979 | 3,434 | 484 | 513 | 99 | 144 | 4,198 |

*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 |
| 2019 | 121, 397 | 7, 610 | 38 | 118 | 17 | 6 228 | 1 938 |

* End of Russian participation.
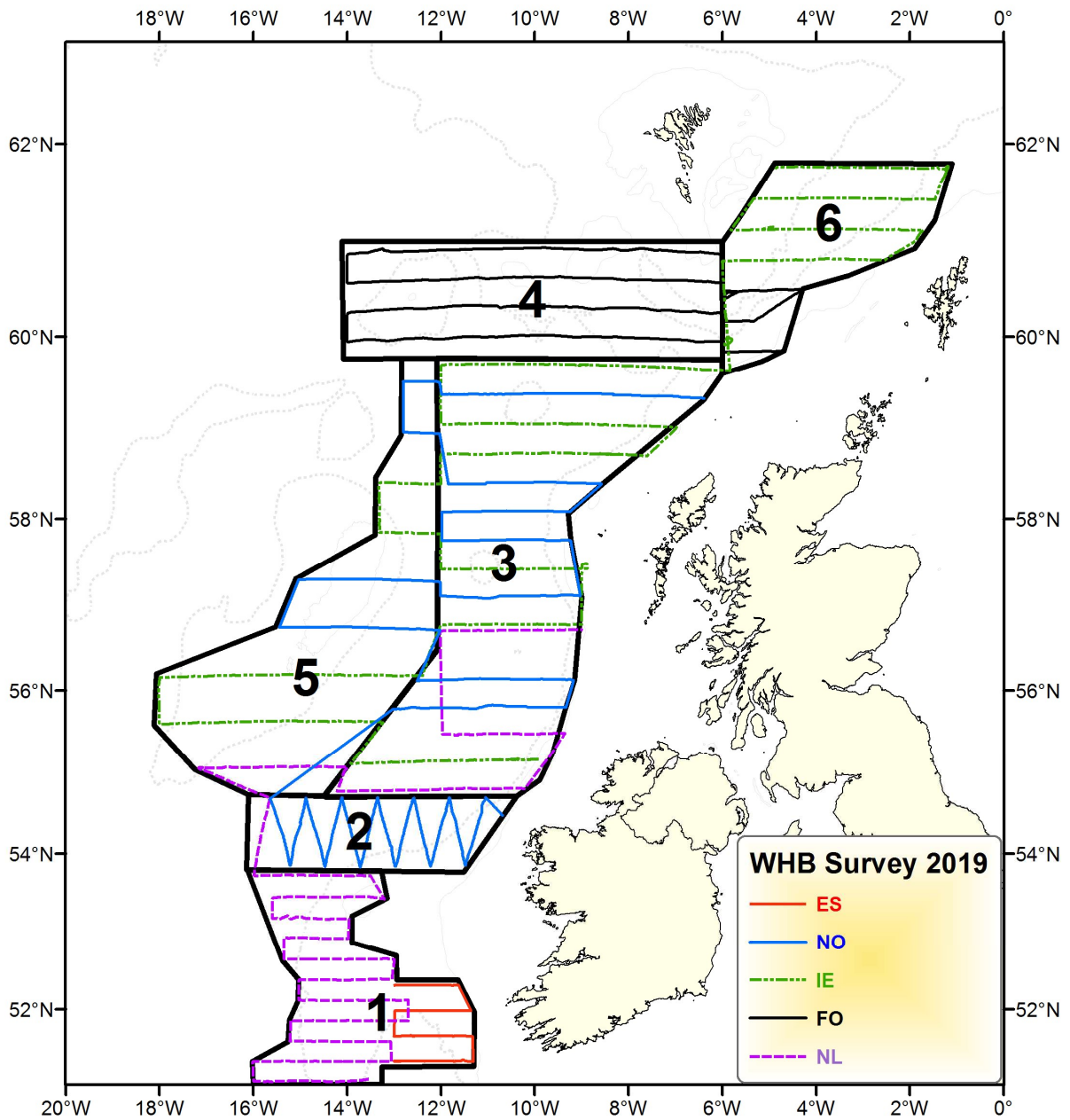
**Figure 1**. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.
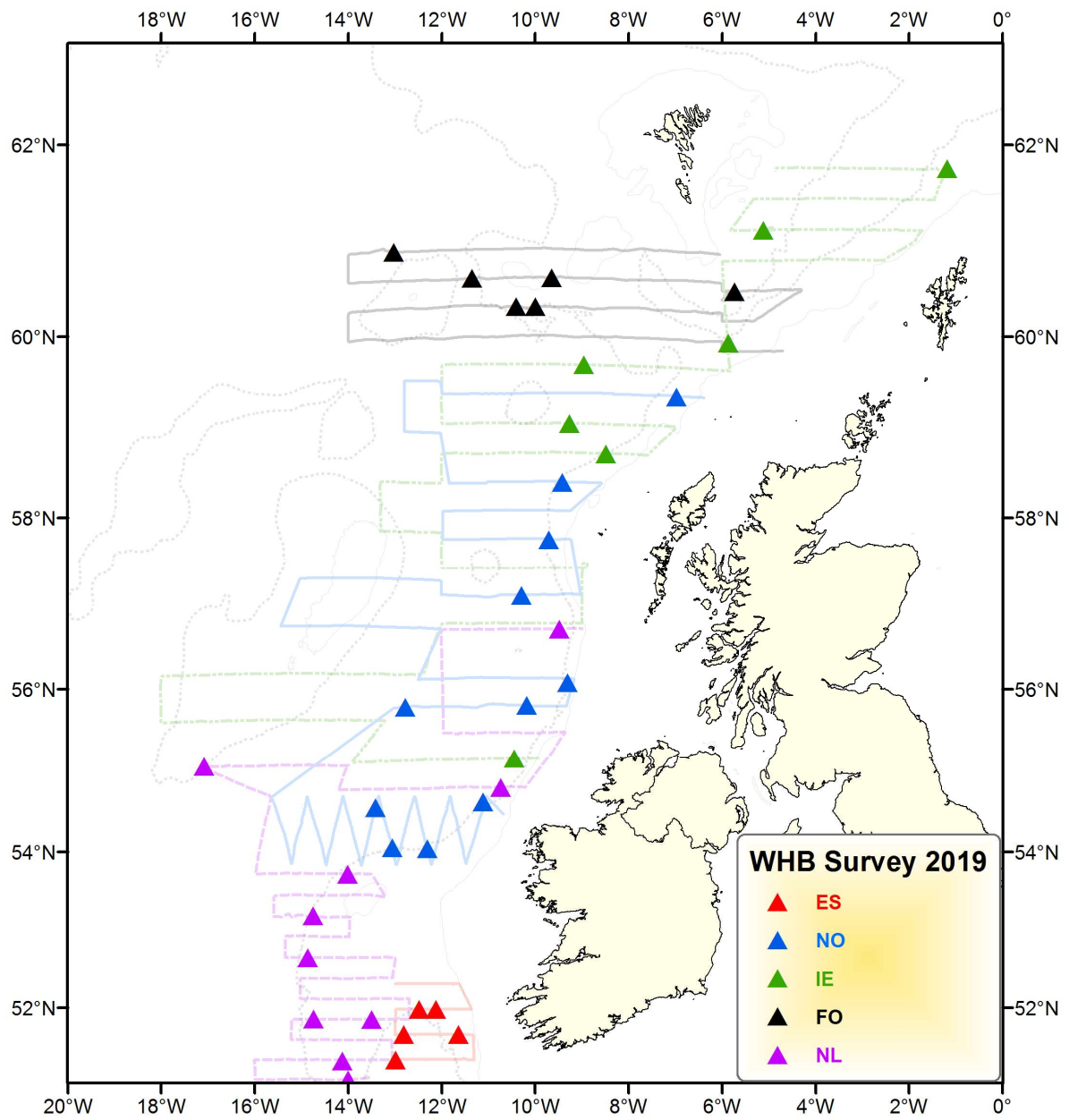
**Figure 2**. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019. IE: Ireland (RV *Celtic Explorer*); FO: Faroe Islands (RV *Magnus Heinason*); NL: Netherlands (RV *Tridens*); NO: Norway (FV *Kings Bay*); ES: Spain (RV *Miguel Oliver*).
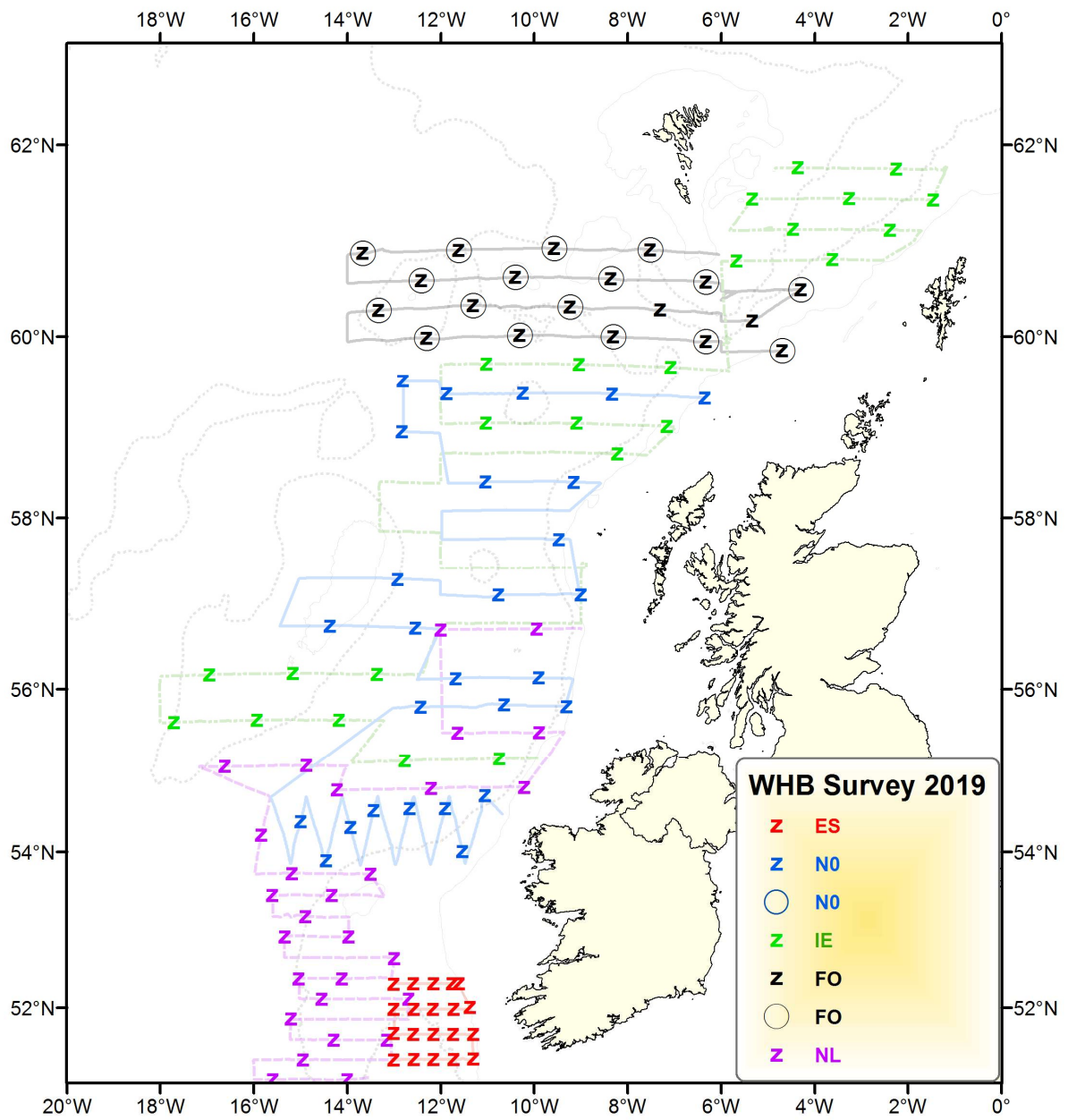
**Figure 3**. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019. Colour coded by vessel.
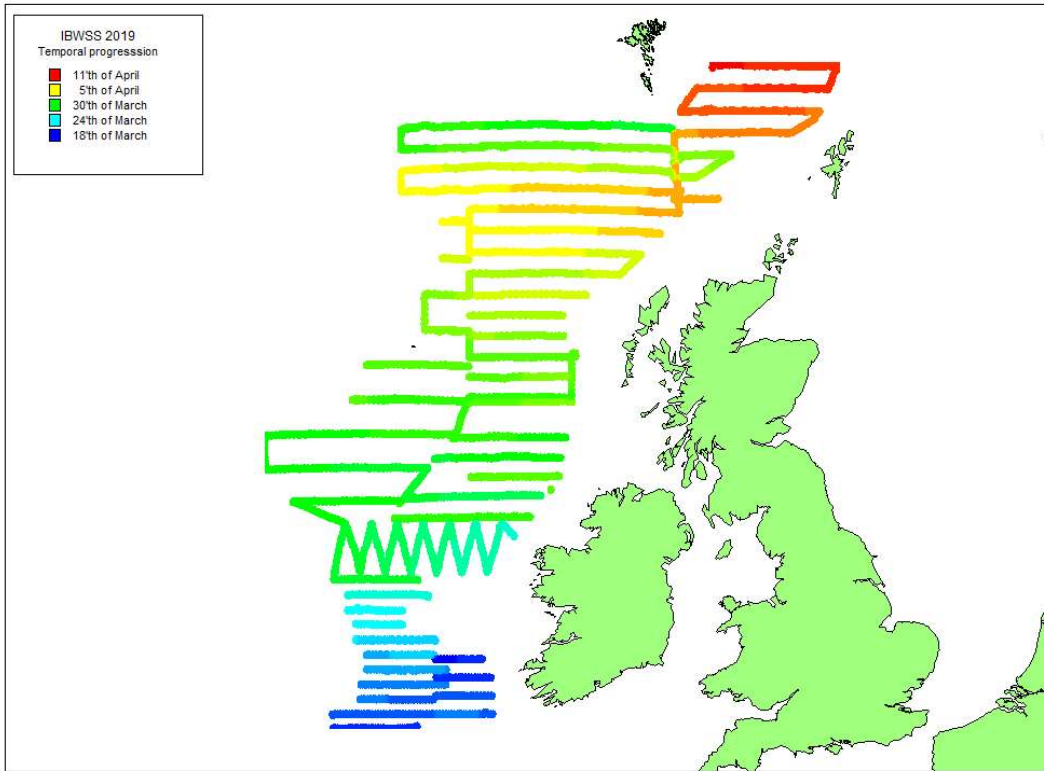
**Figure 4**. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.
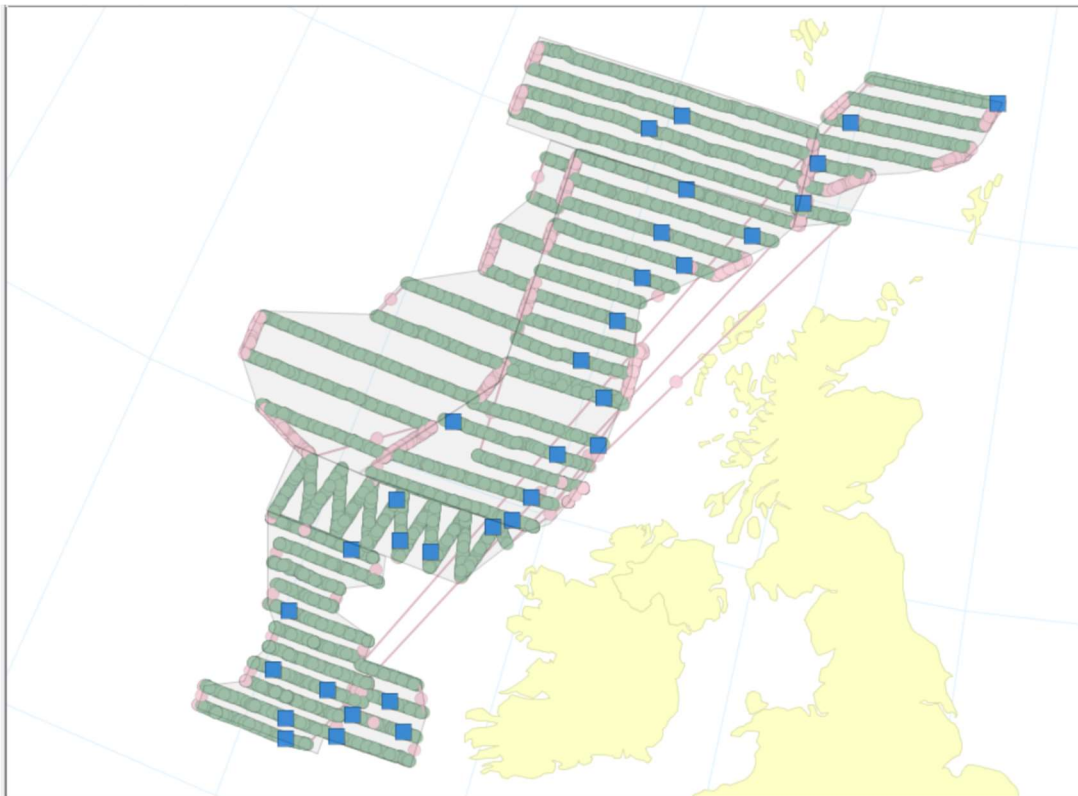


**Figure 5**. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (blue squares) used in the StoX abundance estimation. IBWSS March-April 2019.
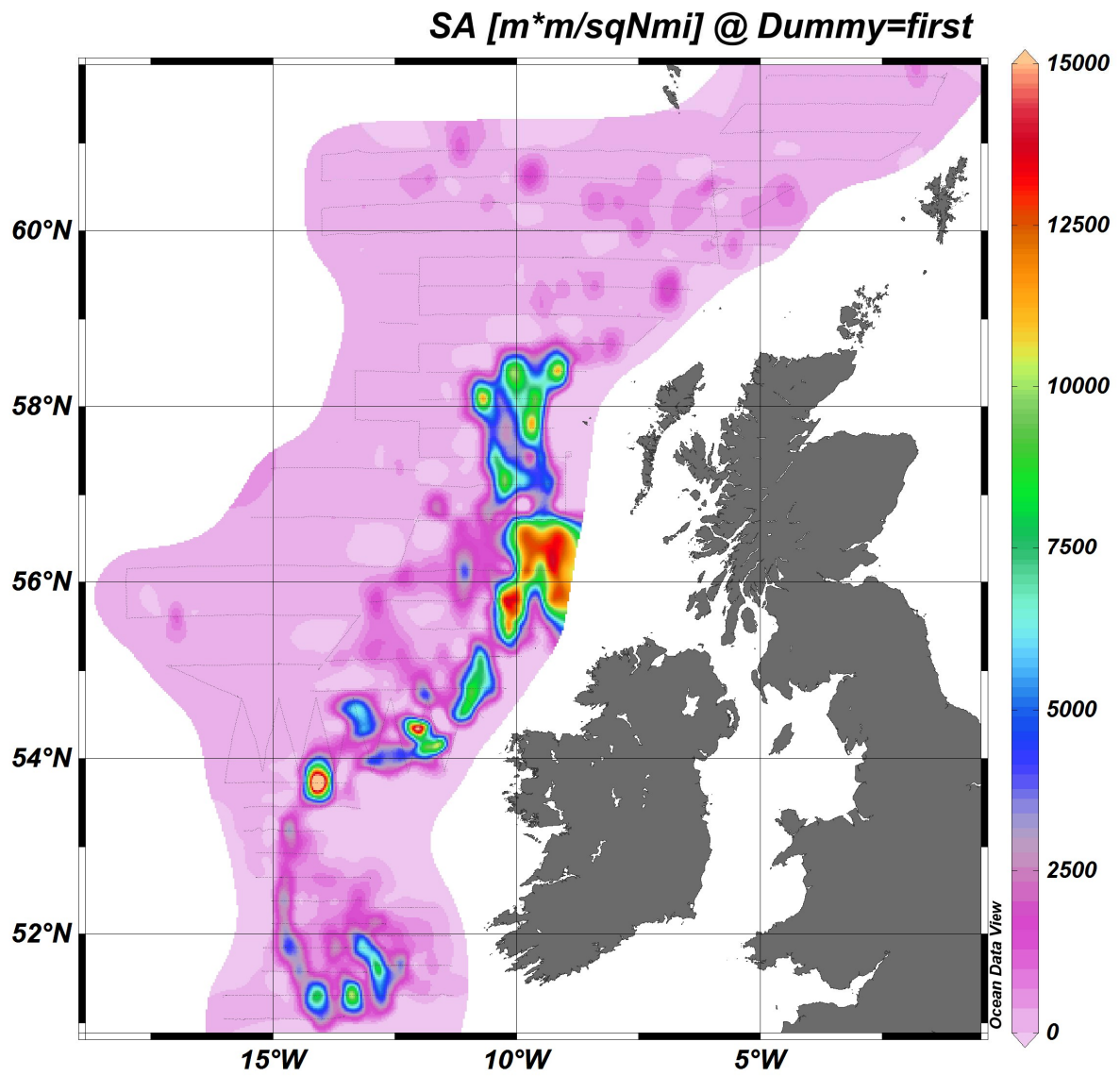
**Figure 6**. Map of acoustic density ($s_A$ m$^2$/nmi$^2$) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.
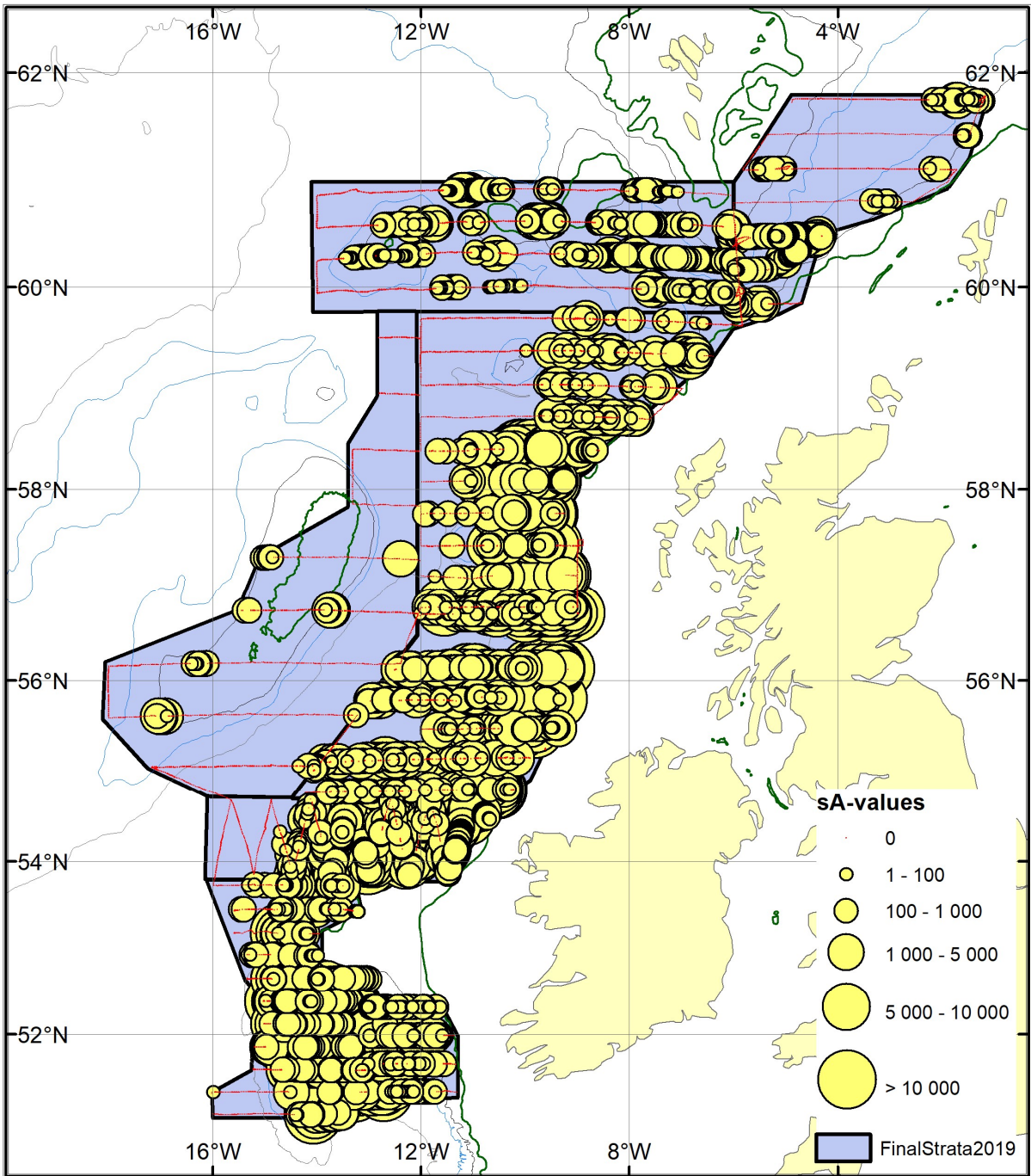
**Figure 7**. Map of acoustic density ($s_A$ m$^2$/nmi$^2$) of blue whiting by 1 nmi (circle scaled by acoustic density). IBWSS March-April 2019.
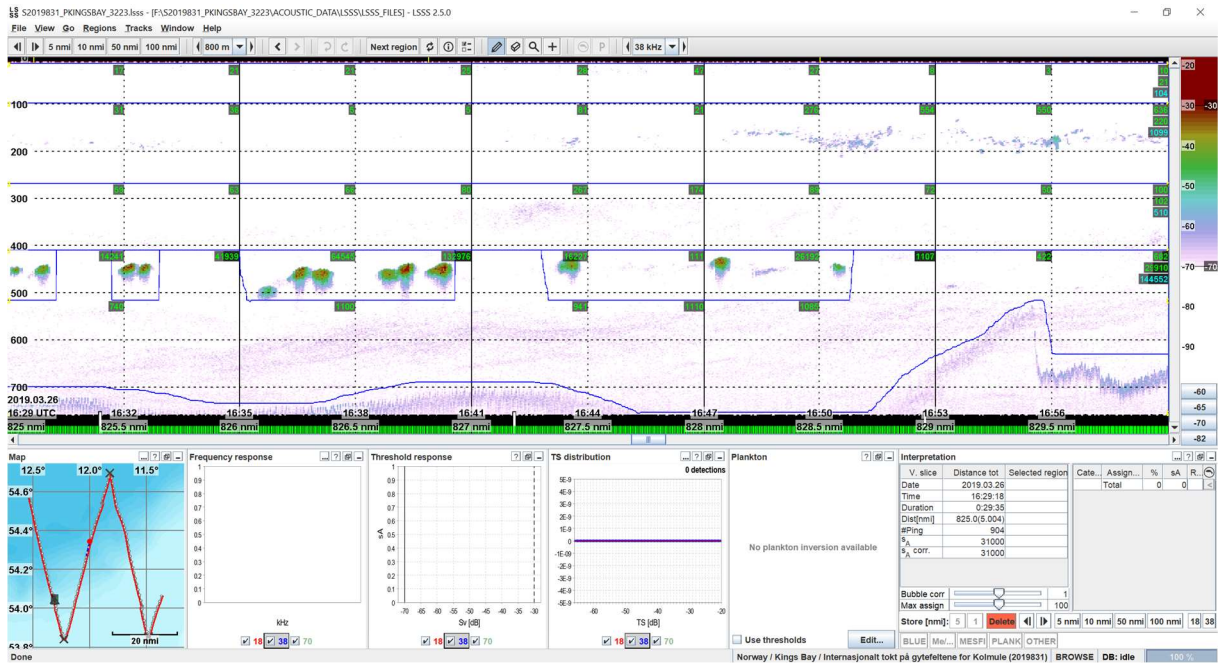
a) High density blue whiting registrations recorded on western Porcupine Bank area (strata 2) FV *Kings Bay*, Norway.
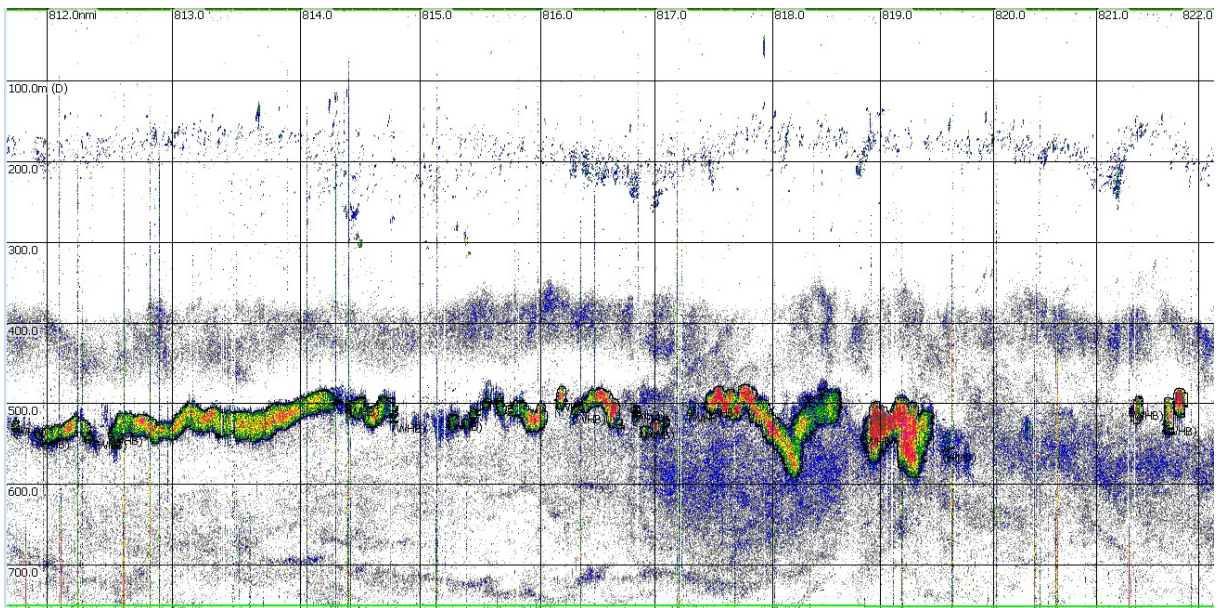


b) High density blue whiting layer per 1 nmi log interval at 500- 600 m recorded by the RV *Celtic Explorer* in the Rockall Trough area (strata 3).
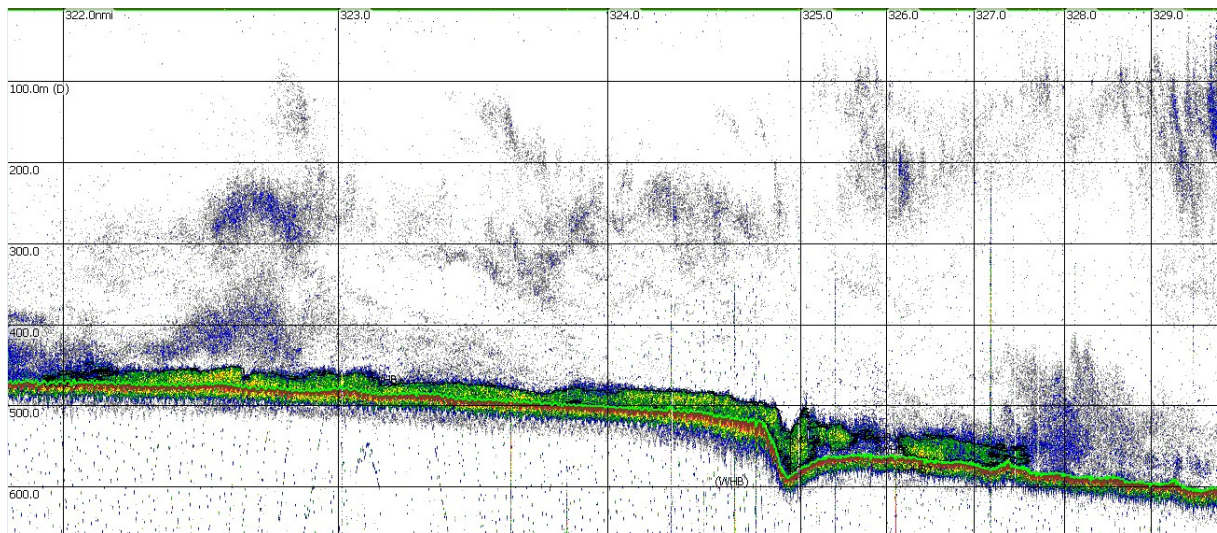
c) Low density blue whiting layer per 1nmi log interval close to the bottom at 450 – 550 m recorded by the RV *Celtic Explorer* in the Rockall Bank area (strata 5).
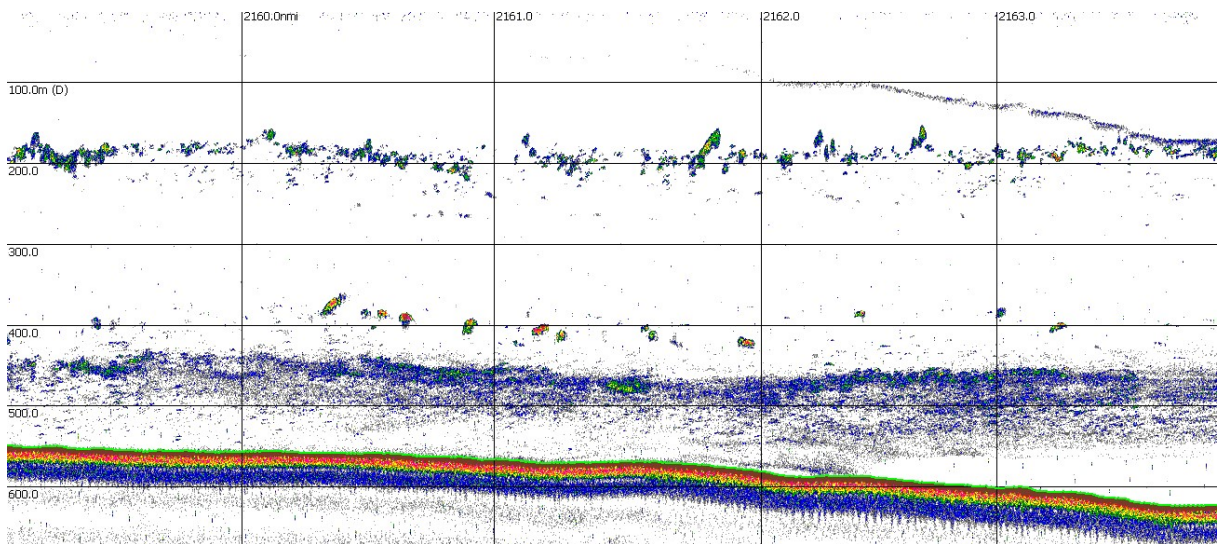


d) Juvenile and adult blue whiting marks per 1nmi log interval at 400 m depth. A layer of mesopelagic fish is also evident at 150 – 200 m. Recorded by the RV *Celtic Explorer* in the Faroe – Shetland channel area (strata 6).
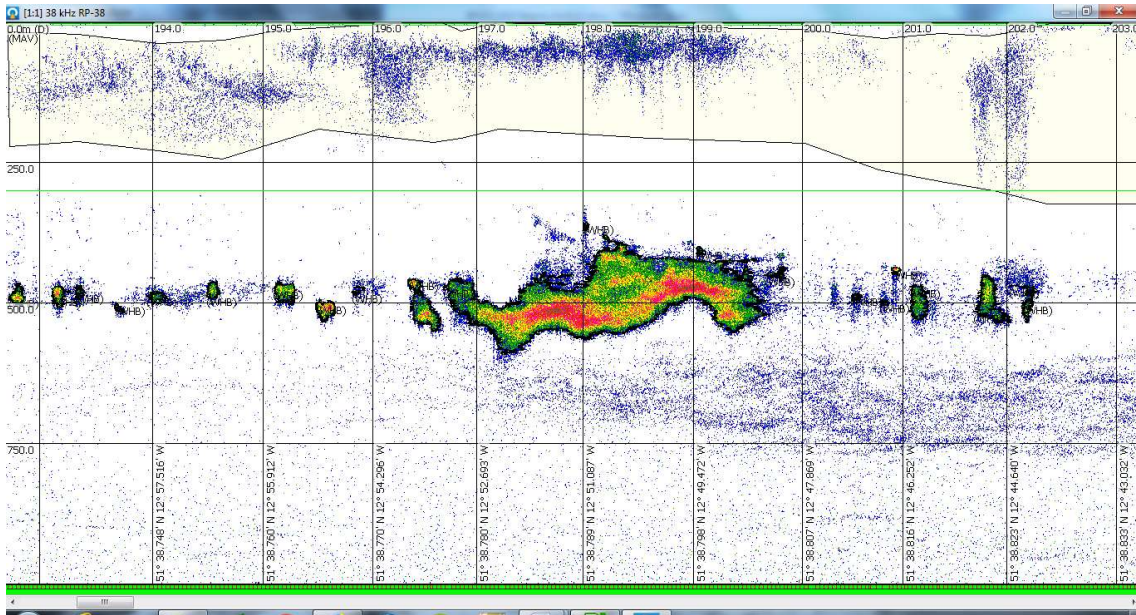
e) High density blue whiting schools-like at 500- 600 m recorded by the RV *Miguel Oliver* at night in the Porcupine Sea bight area (stratum 7).
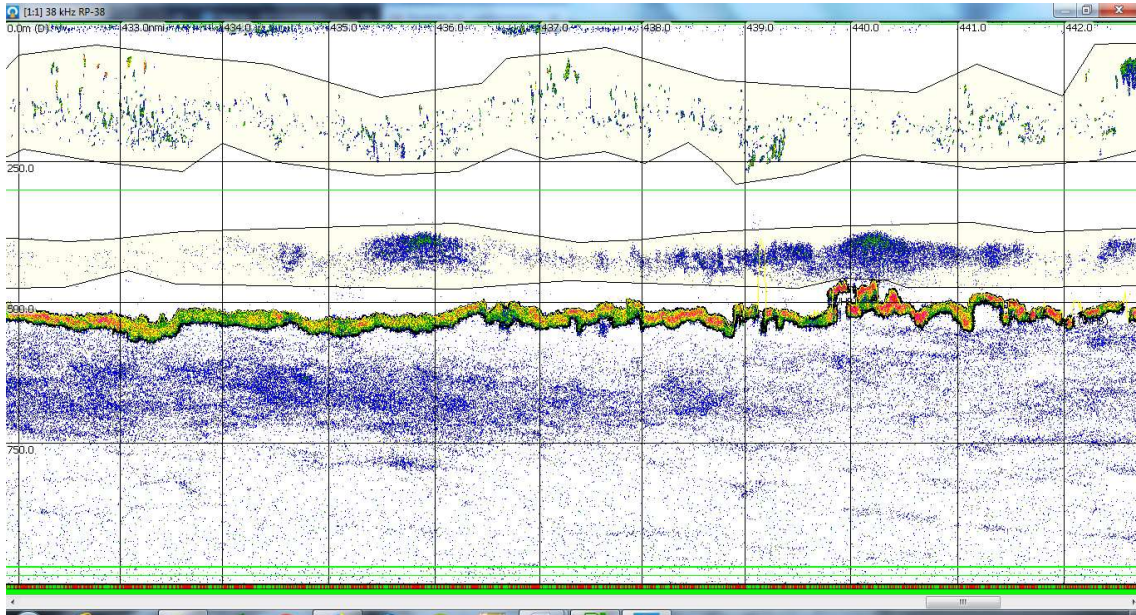


f). High density day time blue whiting layer at 500- 600m recorded by the RV *Miguel Oliver* the Porcupine Sea bight area (stratum 7).

**Figure 8**. Echograms of interest encountered during the IBWSS, March-April 2019. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU), vertical binning at 50 m intervals. All echograms presented at 38 kHz.
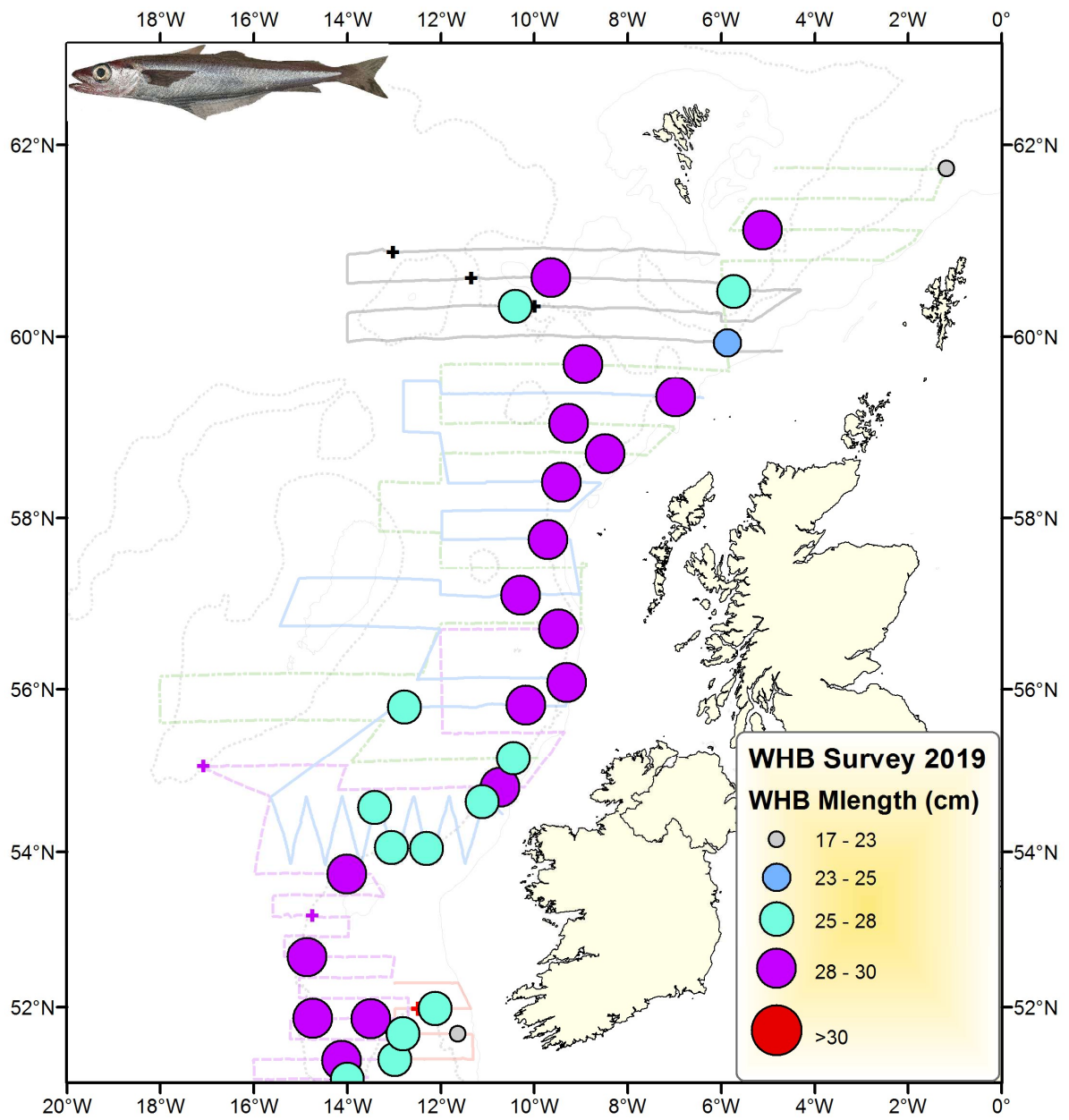
**Figure 9**. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2019. Crosses indicate hauls with zero blue whiting catches.
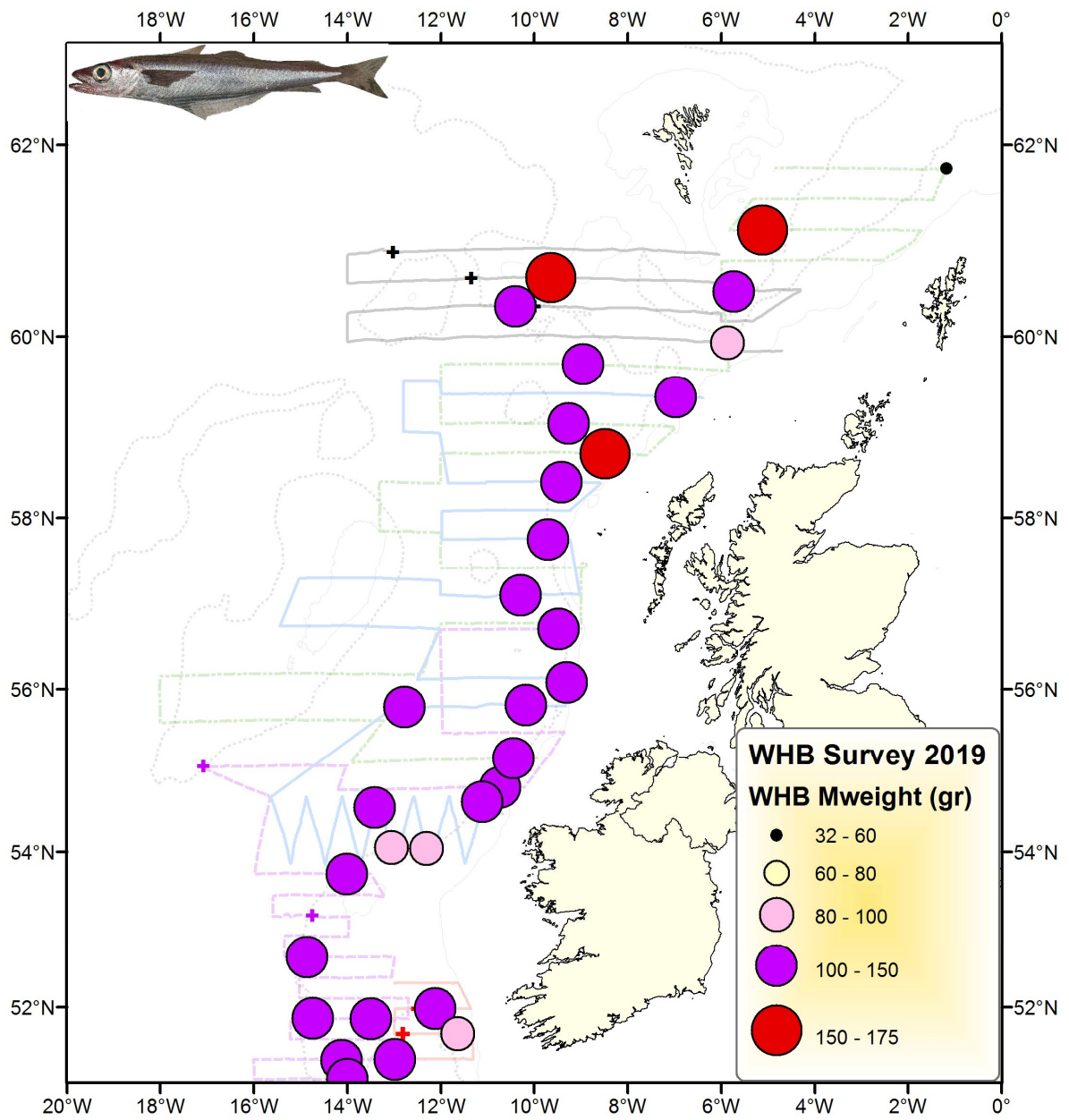
**Figure 10**. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2019. Crosses indicate hauls with zero blue whiting catches.
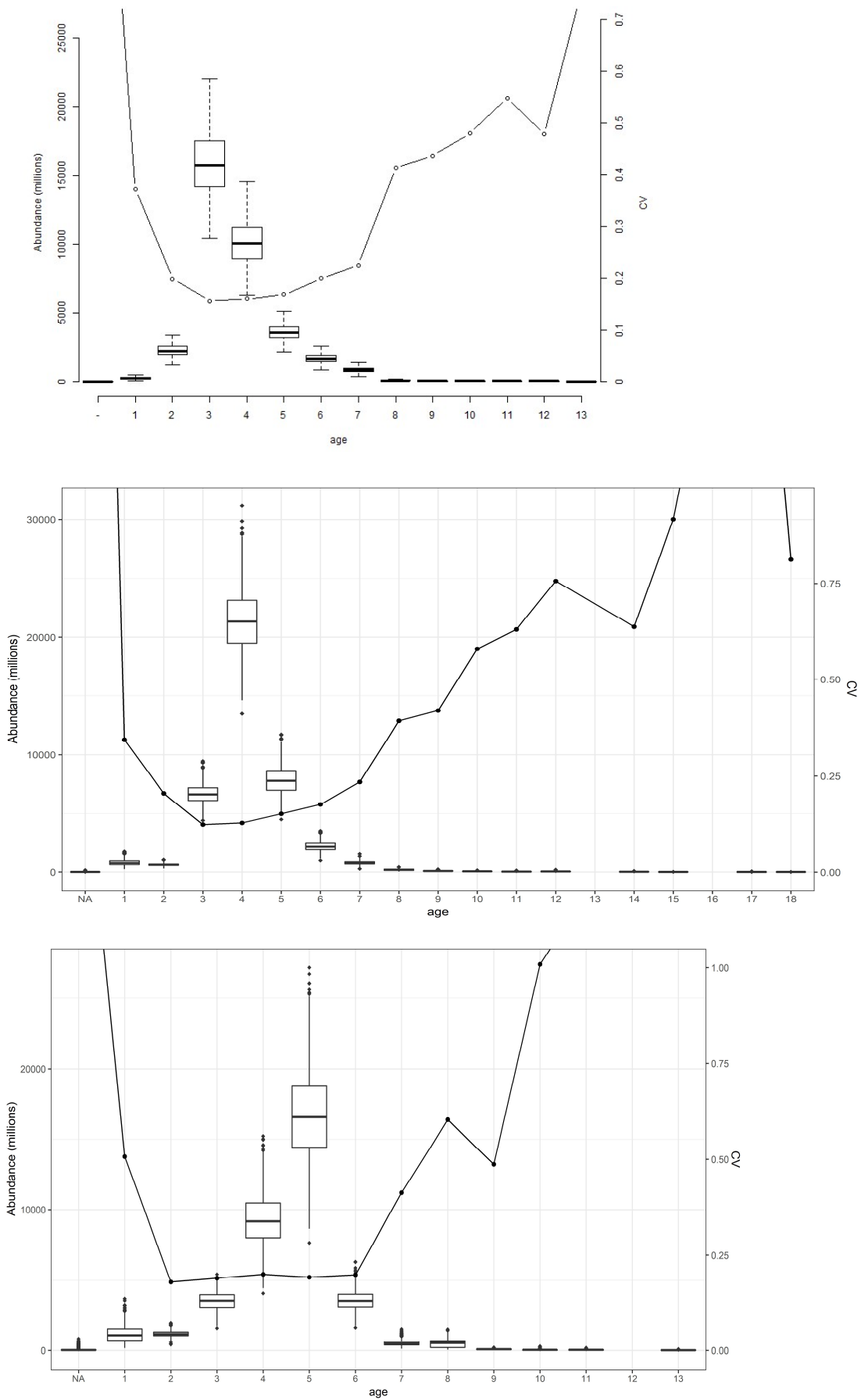
**Figure 11**. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2017 (top panel), 2018 (middle panel) and 2019 (lower panel). From StoX.

25
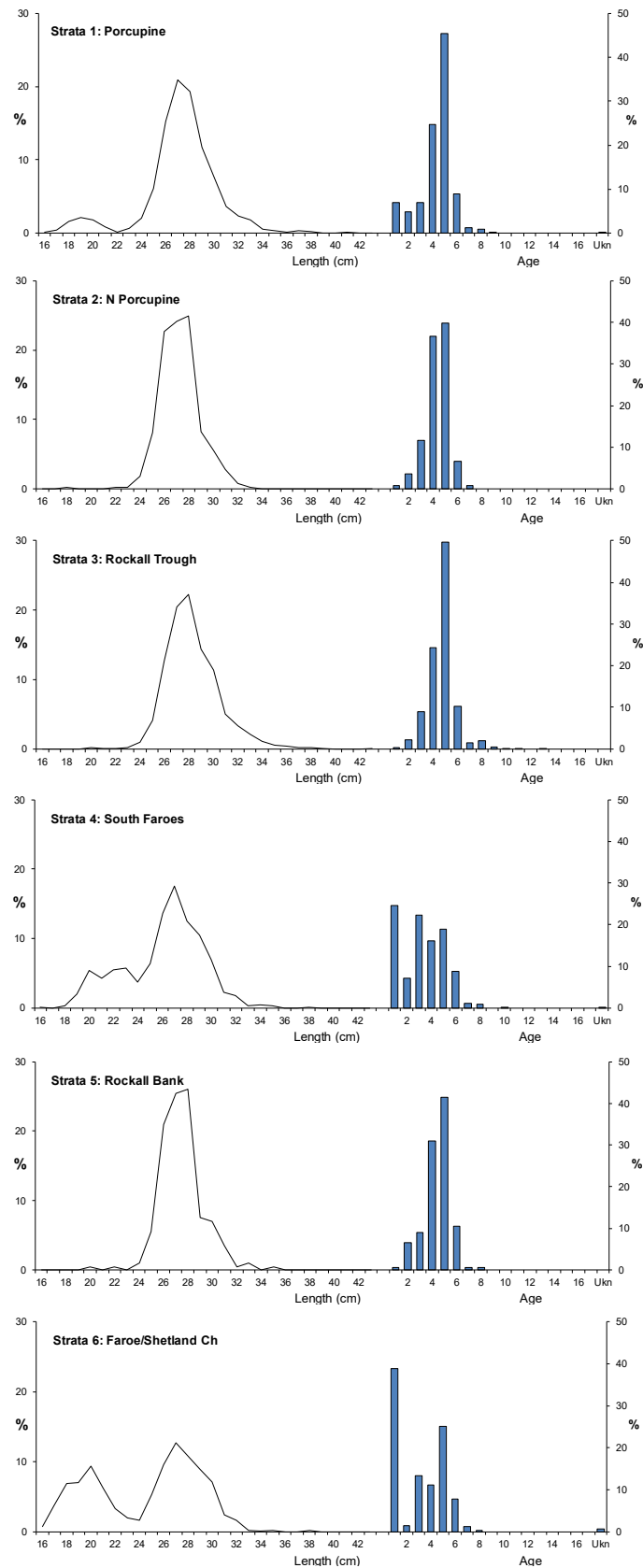
**Figure 12**. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2019.
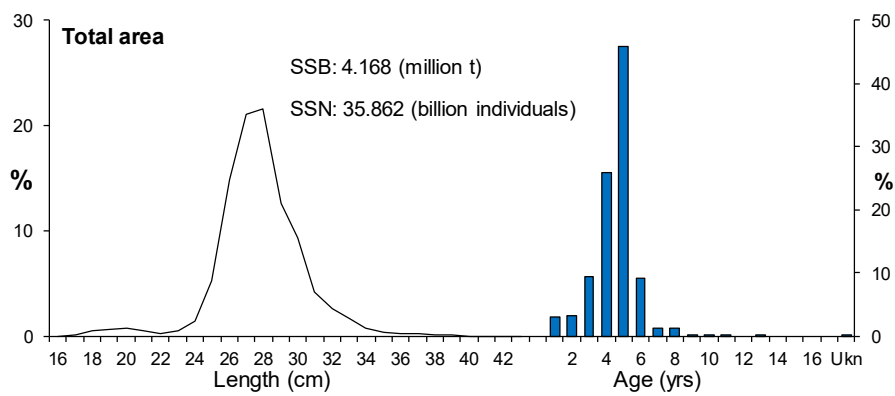
**Figure 13**. Length and age distribution (numbers) of total stock of blue whiting. March-April 2019.

## IBWSS,TSN
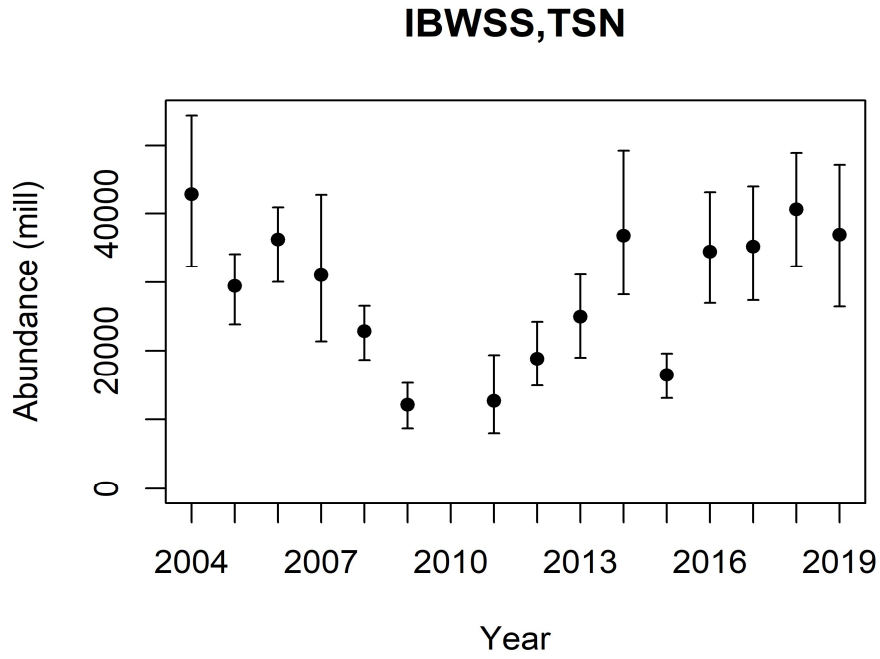


**Figure 14.** Time series of StoX survey indices of blue whiting abundance, 2004-2019, excluding 2010 due to data problems.

## IBWSS,TSB
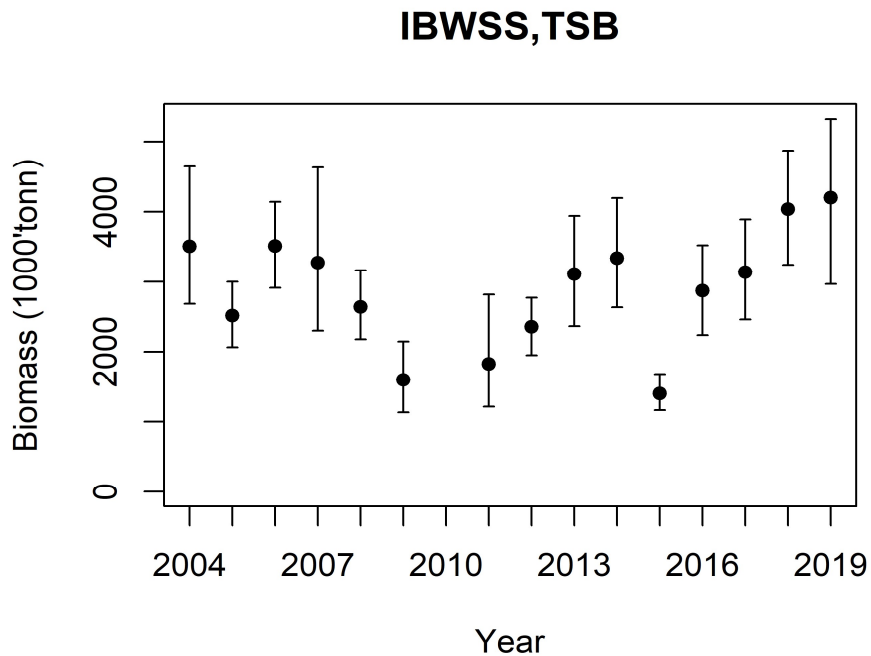


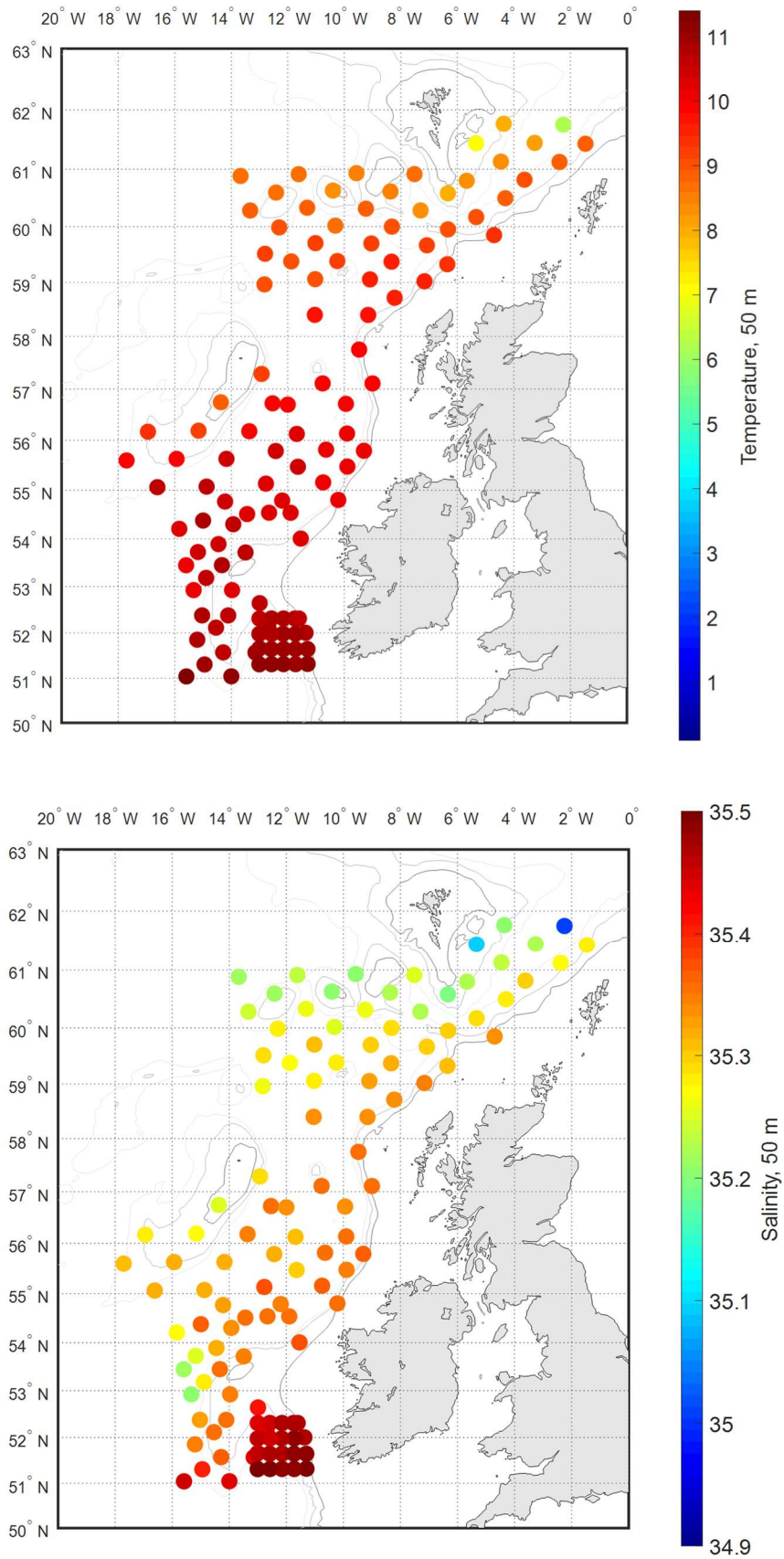**Figure 15.** Time series of StoX survey indices of blue whiting biomass, 2004-2019, excluding 2010 due to data problems.

**Figure 16**. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.
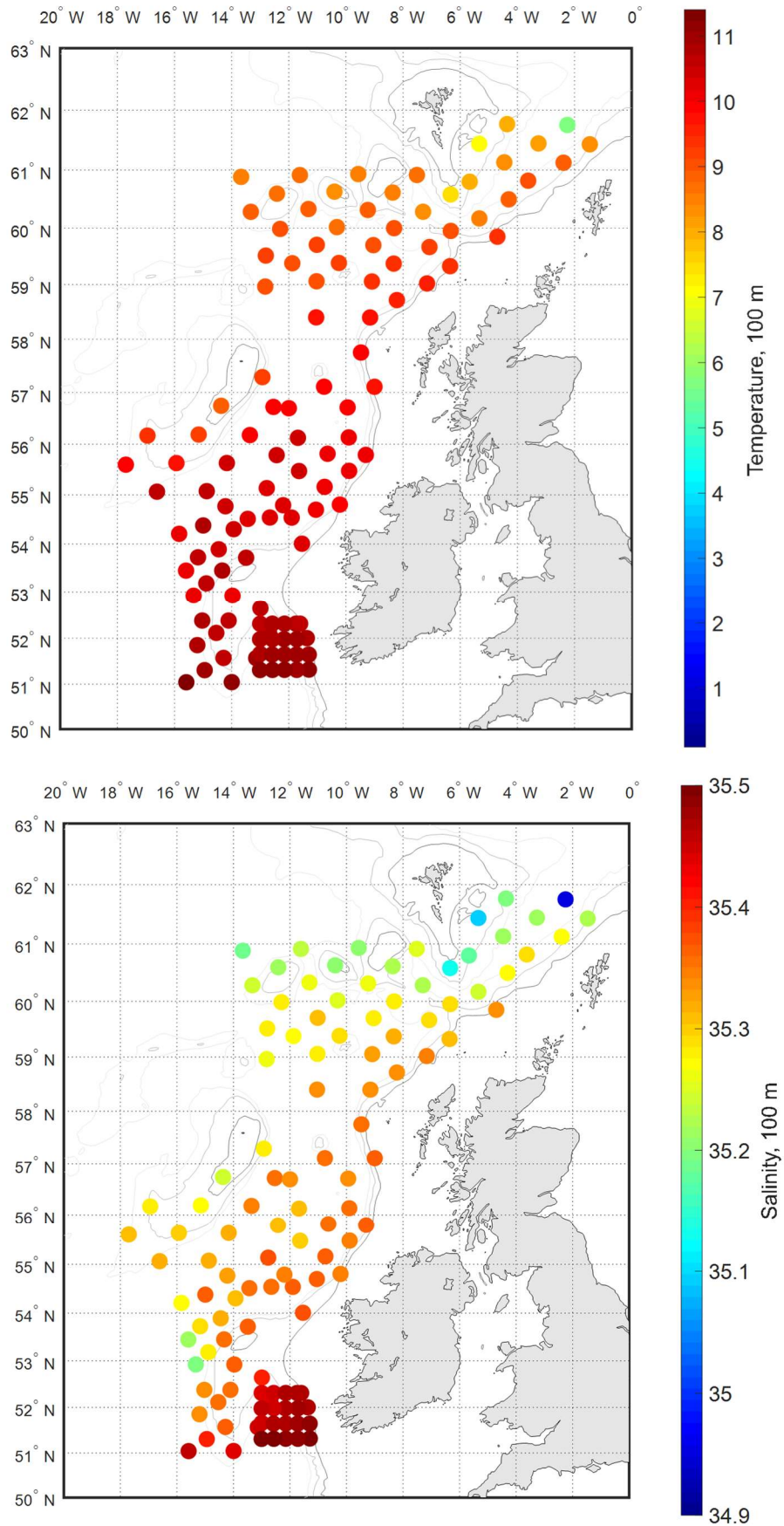
**Figure 17**. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.
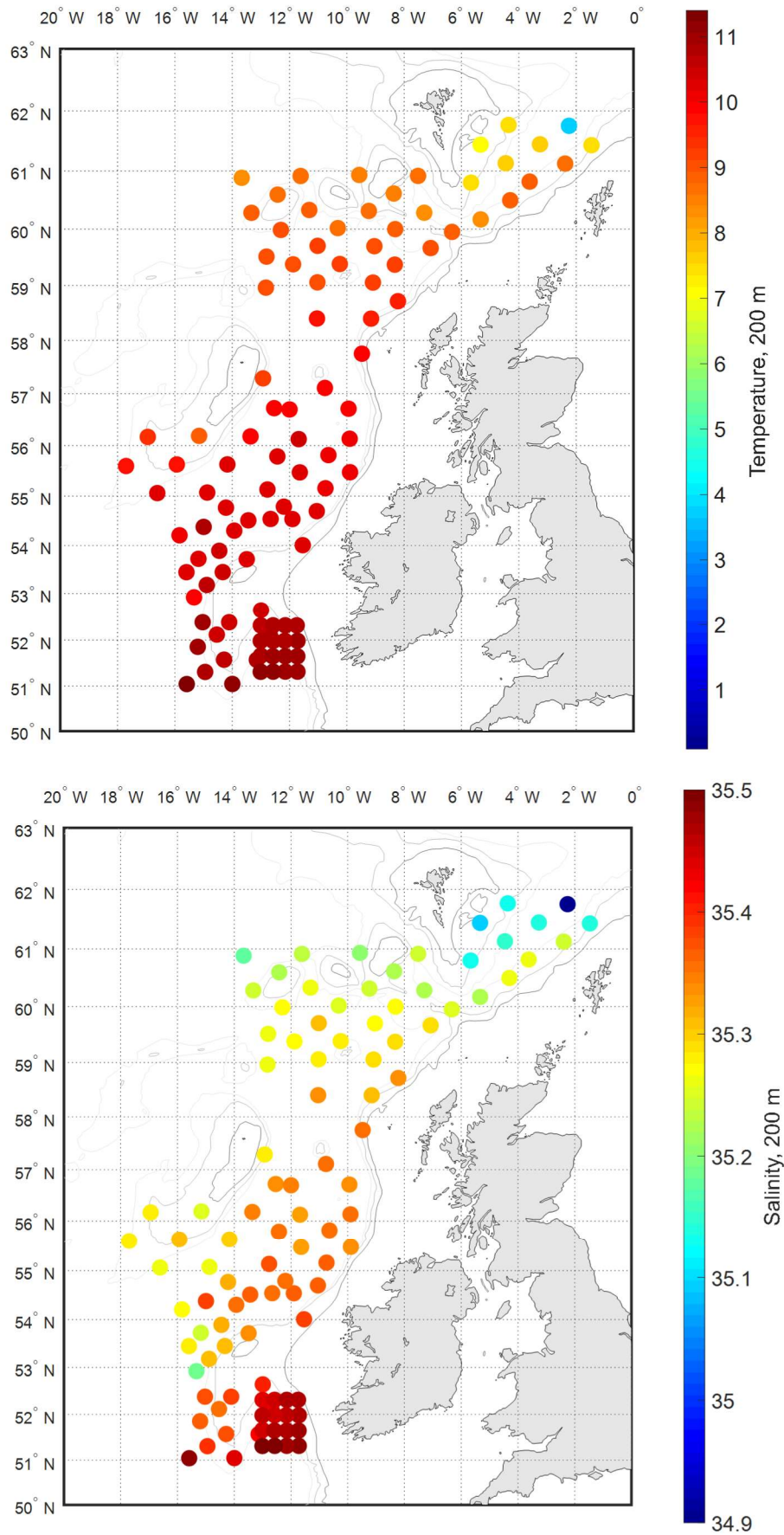
**Figure 18**. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.
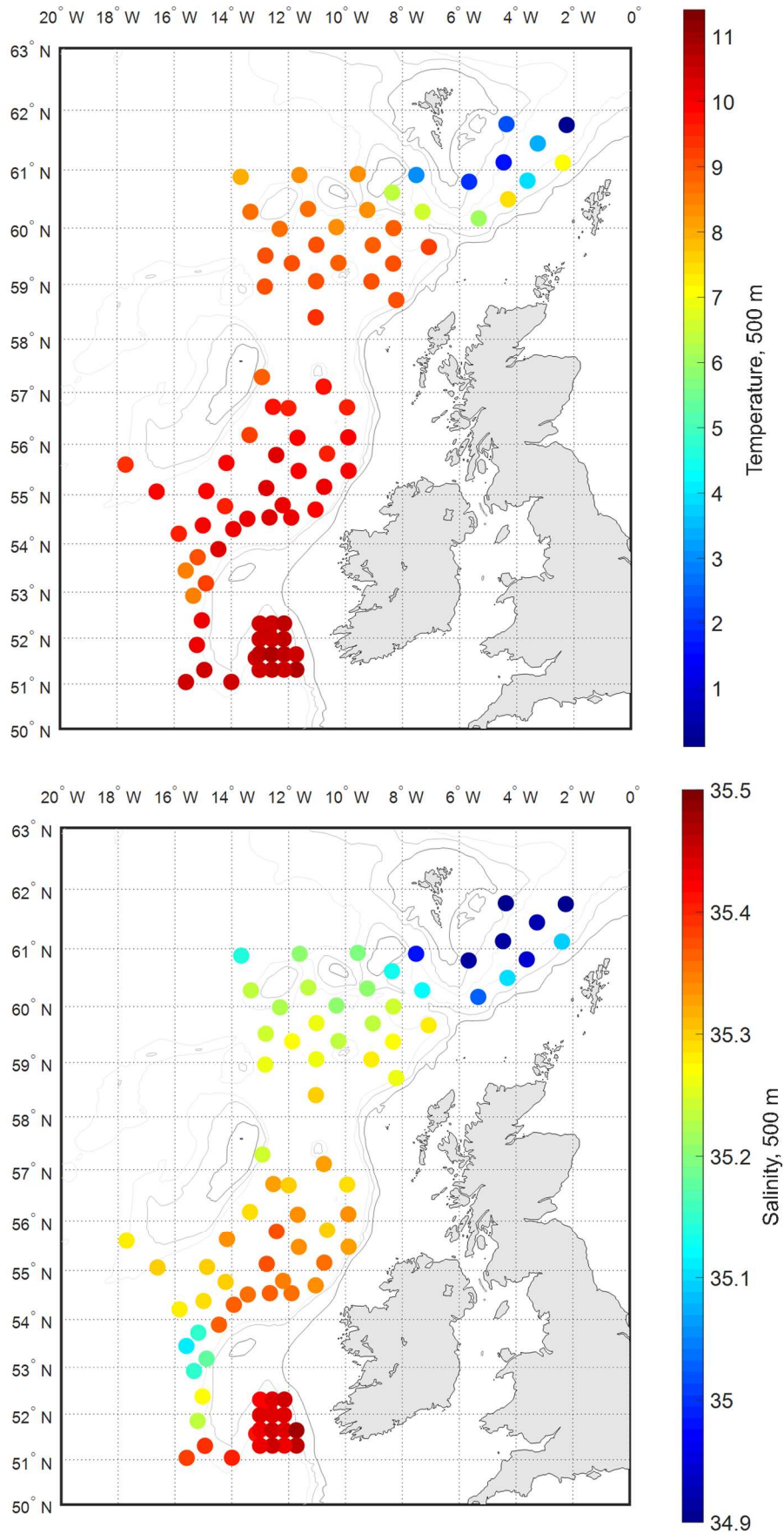
**Figure 19**. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2019.