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Collated cruise reports with regional maps of distribution and abundance of mesopelagic communities in the North Atlantic focusing on potential fishing areas

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Lead participant:	5-MFRI

Authors		
Name	Organisation	E-mail
Klara Jakobsdóttir	MFRI	klara.jakobsdottir@hafogvatn.is
Paula Álvarez	AZTI	palvarez@azti.es
Guillermo Boyra	AZTI	gboyra@azti.es
Teresa Sofia Giesta da Silva	MFRI	teresa.silva@hafogvatn.is
Thor Klevjer	IMR	thor.klevjer@imr.no
Webjörn Melle	IMR	webjorn.melle@imr.no
Stefan Neuenfeldt	DTU	stn@aqua.dtu.dk
Eduardo Grimaldo	SINTEF	eduardo.grimaldo@sintef.no
Warsha Singh	MFRI	warsha.singh@hafogvatn.is
Alina Wieczorek	MI	alina.Wieczorek@Marine.ie

*corresponding authors

Keywords
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Executive Summary
The deliverable compiles information available from MEESO field campaigns that have been carried out by Month 30 with focus on potential fishing areas. Some of the cruises were carried out before MEESO started, while others were conducted within the project period, but they will all be providing data to MEESO. Altogether, field campaigns carried out by MEESO cover extensive areas in the N-Atlantic. Large area of survey transects have been covered by acoustics and numerous net samples have been collected down to 1000 m on various stations throughout the study area. A range of new methods and technologies have been tested for the quantification of abundance of the mesopelagic fauna at the finest taxonomic scale possible. Also, data on horizontal and vertical distribution of oceanographic parameters, such as temperature, salinity, light penetration, and chlorophyll-a have been collected. All these sampling efforts have been described in various cruise reports and within the project advanced analysis of data is on-going. Cruises carried out prior to 2021 have been reported on in Deliverable 4.1. In this document reports from cruises carried out in year 2021 are collated. Additionally, this document shows assembled regional maps of acoustic abundance (NASC values) of the mesopelagic layers along cruise transect in majority of study areas. Finally, a chapter highlights findings on fish distributions and abundances in four regions i.e. Northeastern Atlantic transect (Cape Verde to Bay of Biscay), Bay of Biscay, Iceland basin and Irminger Sea.

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1. **Overview of cruise activity in support of MEESO by month 30**

Task 4.1 of MEESO performs field campaigns in the whole North Atlantic, from the Labrador Sea in the west to The Norwegian Sea in the east and from around the Azores and west of Africa in the south to the Nordic Seas in the north. In addition to research vessels, the MEESO project also makes use of samples taken by commercial fishing vessels.

In year 2021 Three MEESO field campaigns were realized. The MEESO project is now at the end of cruise activity period and up to date the project has achieved considerable coverage of the sampling area. Few more field campaigns are planned in 2022 i.e. west of British Isles and around the Azores.

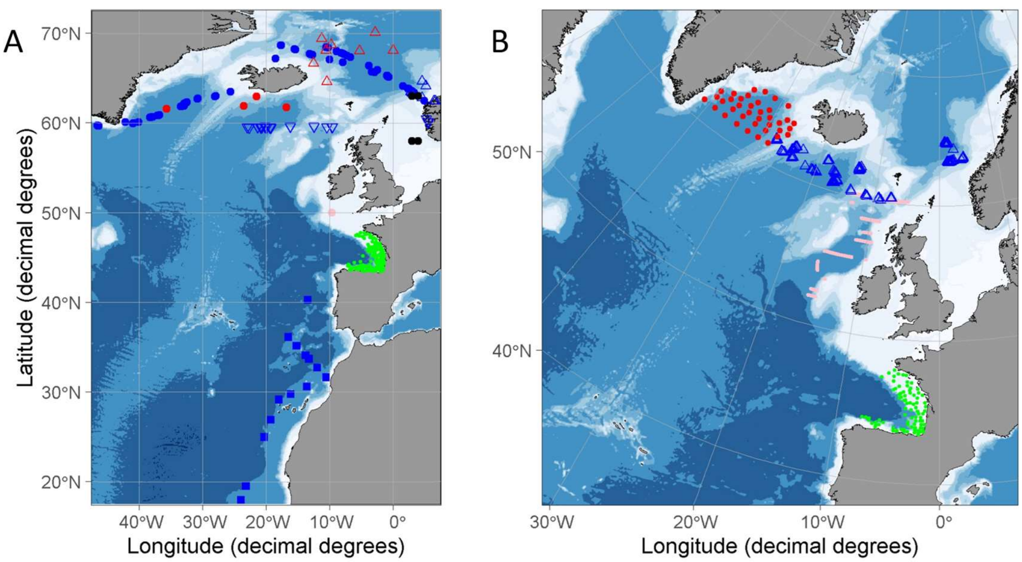

Figure 1. MEESO field campaign. A. The map shows trawling stations of cruises for MEESO that have taken place before 2021. Blue colour represents cruises by IMR red cruises by MFRI, pink by MI and the light green dots cruises undertaken by AZTI. The black dots show the regions where the fishing vessels were operating. B. MEESO field campaign in 2021 and 2015. The map shows MEESO stations by three cruises performed in 2021 and 2015. Blue triangles represent cruises by IMR, red dots historical cruise by MFRI (2015), pink by MI and the green dots cruises undertaken by AZTI.

2. Regional maps of acoustic abundance of the mesopelagic layers.

In this section back scattering values on the mesopelagic layer from various cruises are presented. These are all total value of back scattering of the mesopelagics along various cruise transects in the North Atlantic.

The cruise IMR2013107 was conducted in May June 2013 and followed a transect from Norway, Iceland Sea, Irminger Sea, Labrador sea and back (Figure 2, Cruise report is found in D.4.1). In this cruise the highest NASC values were observed in the Irminger Sea (appr. 15-3000 m^2/nm^2) and the lowest from the Iceland Sea (Figures 2 and 3). The NASC values were highest in the most eastern part of the Irminger (area west off Reykjanes Ridge).

The cruise IMR 2018106 was carried out in June 2018 and followed a transect west of Hebrides working westward and back again (Figure 4, cruise report in D.4.1). Observed average values were 1500-2000 m^2/nm^2 with highest values near the Wyville Thomson Ridge (Figures 4 and 5).

In Cape Verde waters off W-Africa (Cruise IMR 2019703, Figure 6, cruise report in D.4.1) high values were observed (up to 3500 m^2/nm2) in the most southern area of the transect. In this cruise the value maintained high along the African coast but showed a latitudinal decrease (Figures 6 and 7). More detailed analysis of acoustics can be found in (Agersted et al., 2021).

The cruise MFRI A72020 was carried out in June 2020 and followed a transect from Irminger Sea east over the Reykjanes ridge and into the Iceland basin. Higher values are observed to the east of the transect (Figures 8 and 9, see also cruise report in D.4.1 and in this document).

The acoustic abundance map from cruise MFRI 2021105 show high values at the Reykjanes ridge similar to abundance in 2013 and to the MFRI 2020 in the Iceland basin (cruise report in this document).

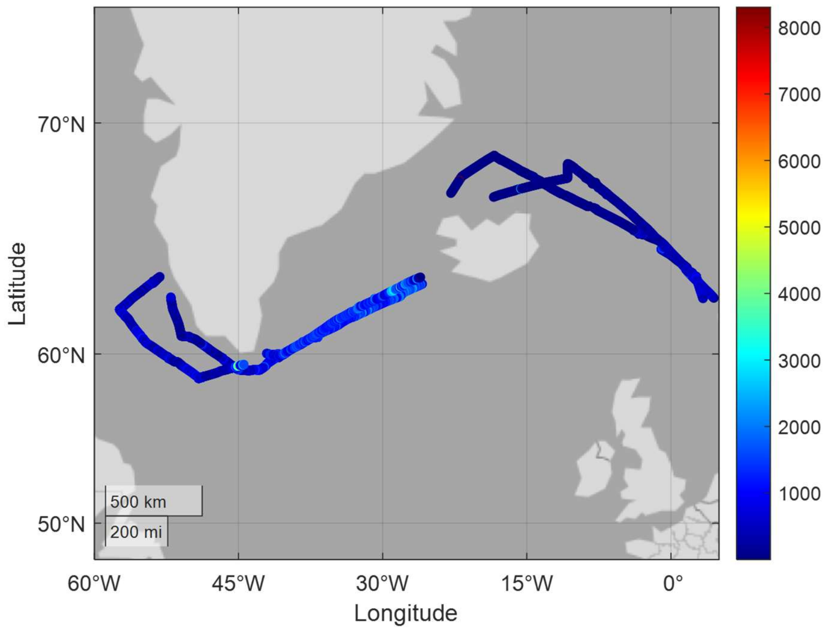

Figure 2. IMR 2013107. Acoustic abundance map of the mesopelagic layer laong the cruise transect (NASC, m^2/nm^2).

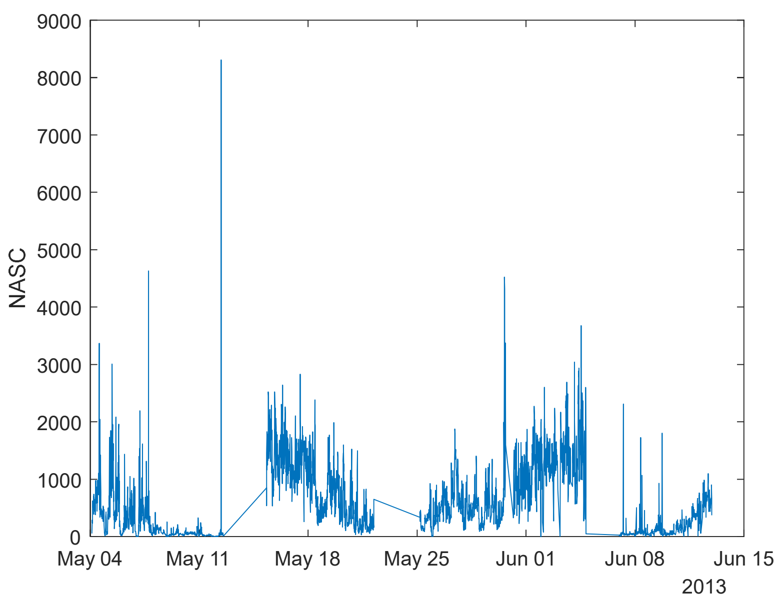

Figure 3. IMR 2013107. Back scattering values (NASC, m^2/nm^2). Time series by date of the cruise. May 04-May 11: Iceland Sea. May 14-May 20: Irminger Sea. May 21-May30: Labrador Sea. May 30-June 04: Irminger Sea. June 06-June 12. Iceland Sea. Unusual high peaks are artefakts.

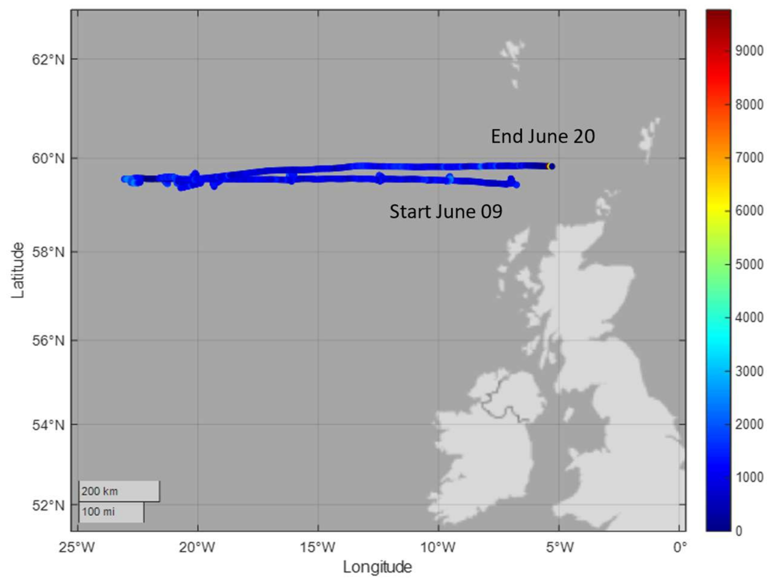

Figure 4. IMR 2018106. Acoustic abundance map of the mesopelagic layer along the cruise transect (NASC, m^2/nm^2).

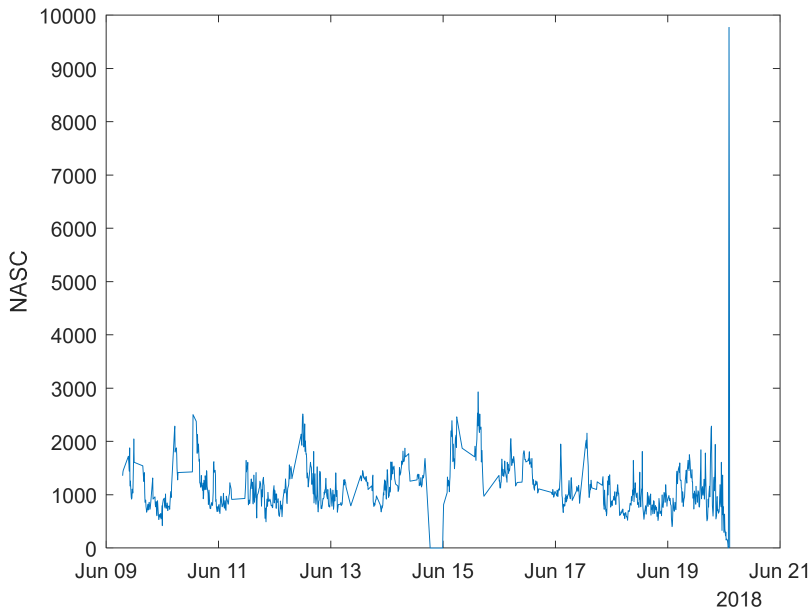

Fig 5: IMR 2018106. Back scattering values (NASC, m^2/nm^2).Time series by date of the cruise.

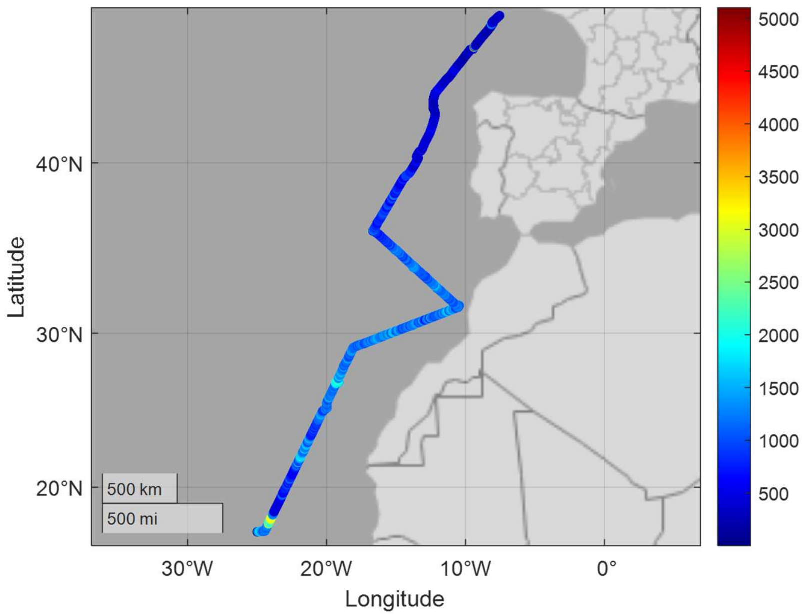

Figure 6. IMR 2019703. Acoustic abundance map of the mesopelagic layer along the cruise transect (NASC, m^2/nm^2).

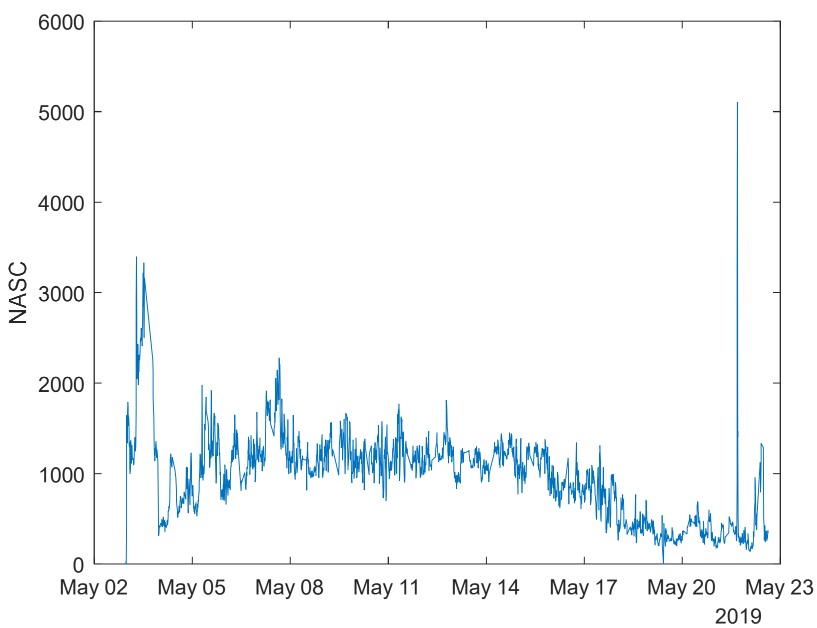

Figure 7. IMR 2019703. Back scattering values (NASC, m^2/nm^2). Time series by date of the cruise Starting off Cape verde in May 02 and ends in Bay of Biscay on May 23.

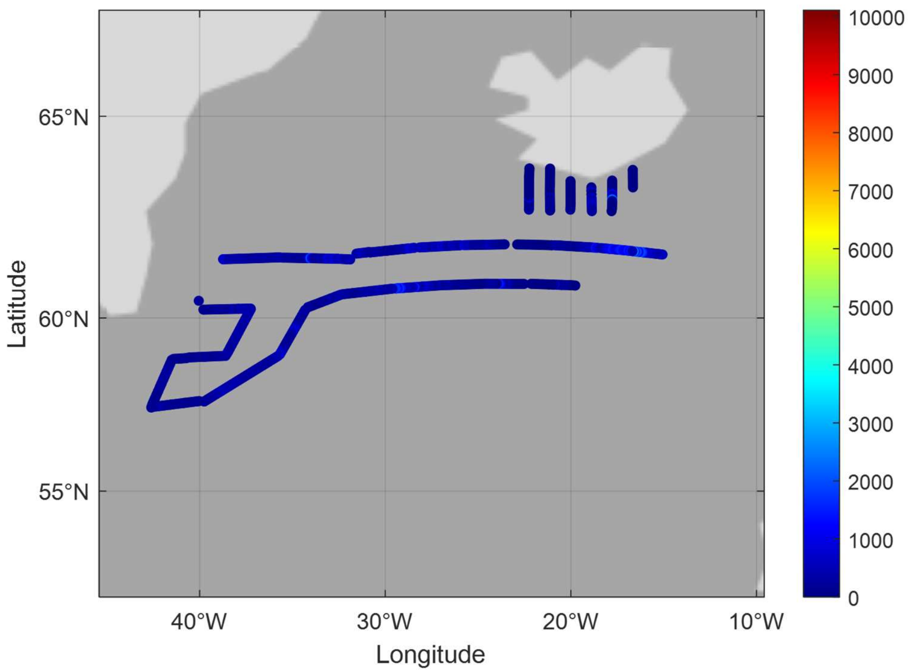

Figure 8. MFRI A72020 (and IESSNS 2020). Acoustic abundance map of the mesopelagic layer along the cruise transect (NASC, m^2/nm^2).

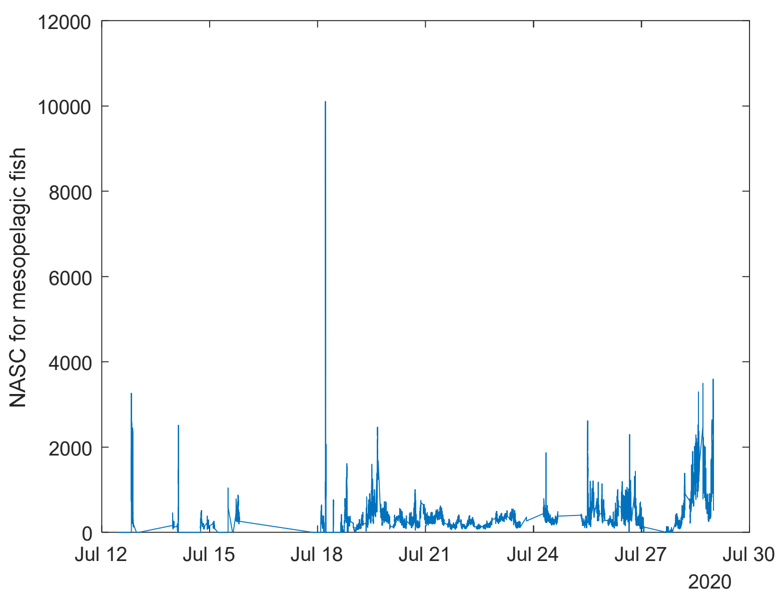

Fig 9. MFRI A72020. Back scattering values (NASC, m^2/nm^2). Time series by date of the cruise Starting in Irminger Sea July 12 and ends off S Iceland in July 30.

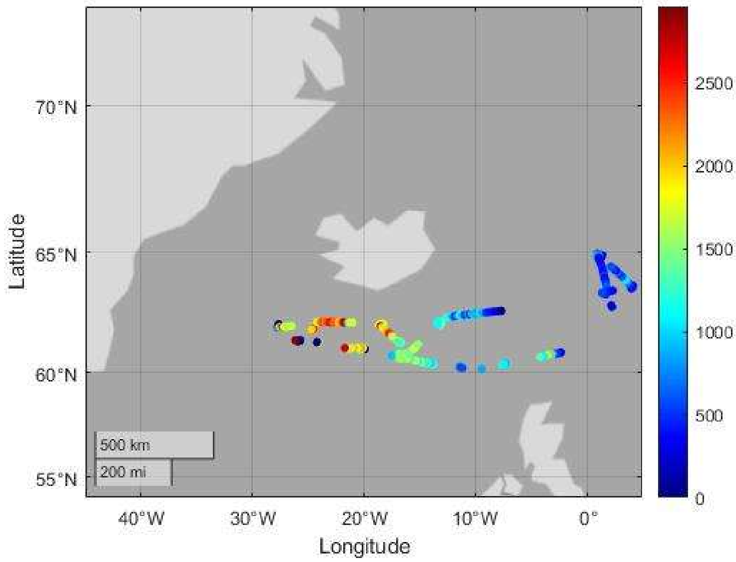

Figure 10. IMR 2021105. Acoustic abundance map of the mesopelagic layer along the cruise transect (NASC, m^2/nm^2).

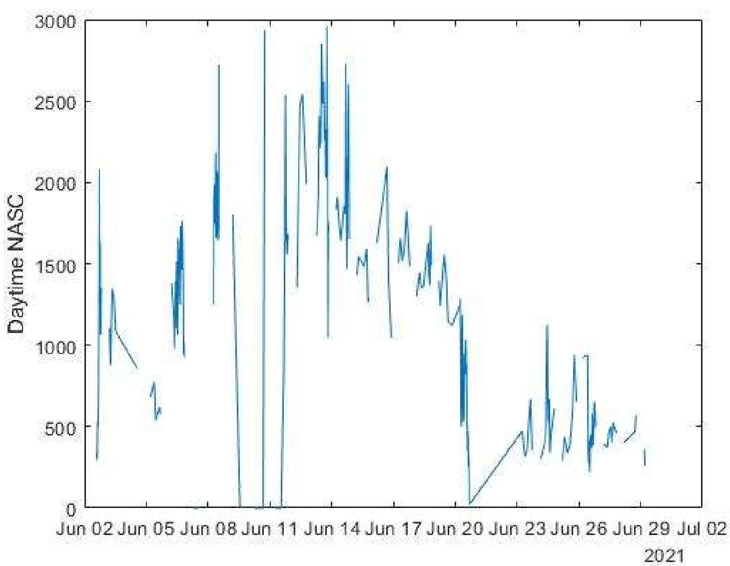

Figure 11. IMR 2021105. Back scattering values (NASC, m^2/nm^2). Time series by date of the cruise Starting at Wyville Thomson Ridge June 02 cruising westward and back eastward near Iceland- Faroe Ridge June 20. Norwegian Sea June 23-June 28.

3. **Focus on potential fishing areas: Highlighting findings in MEESO field campaigns on fish distribution and diversity in the mesopelagic layers**

MEESO field campaigns have obtained information on fish diversity, distribution and abundance throughout the study area both by applying conventional methods such as ground truthing of hull mounted acoustic data by net sampling and deploying different type of trawl gears but also by developing more recent approaches. Deployment of echosounder mounted on towed vehicles, echosounder mounted directly on trawls and visual technics have been developed and applied in order to inform about fish species and/or fish behaviour in the mesopelagic layer. In following chapters regional progress toward quantification of fish biomass within the mesopelagic is described.

3.1. Northeastern Atlantic transect (Cape Verde to the Bay of Biscay)

IMR 2019703

The IMR cruise 2019703 was conducted during transit from Cape Town to Oslo. The main objectives were pelagic ecosystem studies, focusing on mesopelagic organisms. A total of 130 fish taxa were identified. The dominant family in catches was *Gonostomatidae*, with four species (*Cyclothone braueri, Cyclothone microdon, Cyclothone pseudopallida, and Cyclothone pallida*) being responsible of more than 78% of the total density. The most frequent species that appeared to be present throughout the area were *C. braueri and C. pseudopallida*, while *Myctophidae* was the most diverse family. The fish community in the southern stations (25–37°N) was more diverse than in the northern stations (42–48°N). A detailed analysis of distribution and abundance of mesopelagic fish can be found in recent paper by García-Seoane (García-Seoane et al., 2021). Another recent conceptual study based on the data from this cruise highlights the importance of separating the targets into different target groups to obtain correct backscatter information in order to achieve more accurate biomass/abundance estimates. It furthermore demonstrates the use of a towed broadband acoustic platform for fine- scale numerical density estimates as a complementary method to hull-mounted acoustic data to increase knowledge on mesopelagic ecosystem structure. (Agersted et al. 2021).

3.2. Bay of Biscay (Juvena field campaigns)

As part of the project MEESO, AZTI has committed to providing information on the mesopelagic community in the Bay of Biscay from its annual JUVENA acoustic survey. Reports from cruises 2019, 2020 (reports in D. 4.1) and 2021 (in this document) have been delivered and additionally, historical distribution maps have been delivered to the project (reports in D. 4.1). The survey is carried out in September, with the aim of estimating the biomass of juveniles of anchovy. This survey also provides data of acoustic abundance of the mesopelagic species such as pearlside, *Maurolicus muelleri*. For the project, this survey is considered opportunistic, and as no funding has been requested for additional campaigns days, the goals of this sampling are adapted to these restrictions.

The survey in 2021 has a similar coverage as earlier surveys and sampled around 2500 nm that provided a coverage of about 37,500 nm^2 along the continental shelf and shelf break of the Bay of Biscay, from the 7º30' W in the Cantabrian area up to 47º 56' N at the French coast (Figure 1). In 2021 92 hauls were done during the survey to identify the species detected by the acoustic equipment.

Main findings from the JUVENA surveys are that pearlside is the second most abundant specie in the area after anchovy. Most of the acoustic biomass of pearlside was detected in ocean waters (76% in 2021) off and at the outer shelf in both Spanish and French coasts (Figure 12 and Figure 13). Larger individuals seem to be preferentially located on the shelf or closer to the shore, while the younger ones are distributed throughout the area. Pearlside undergoes diel vertical migration i.e. it aggregates to100 and 250 m depth during the day but during the night M. muelleri may ascend to depths of 20-25 m although it is preferentially located around 50 m.

In years from 2013 the biomass has been estimated on average 180 thousand tonnes with a maximum in year 2017 (~268 thousand tonnes) and minimum in year 2016 (~132 thous. tonnes). Estimation for 2021 is around 220, 000 tonnes. In year 2021 *M.punctatum* had a significant presence but the acoustic biomass has not been calculated as its TS is not known (Figure 14)

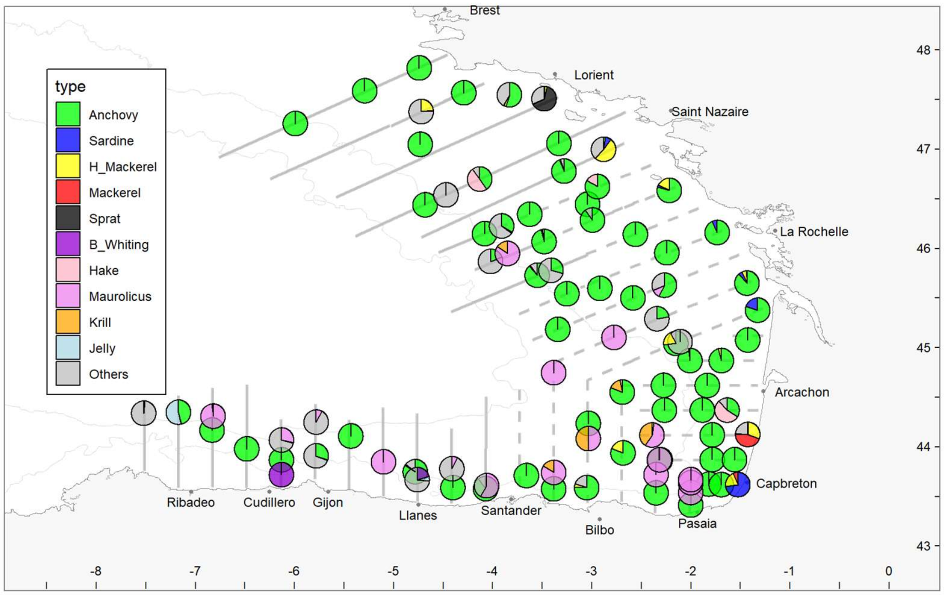

Figure 12. AZTI. JUVENA field campaign 2021. Species distribution.

Figure 13. AZTI. JUVENA field campaign. *M. muelleri* NASC values (report 2021) in this document.

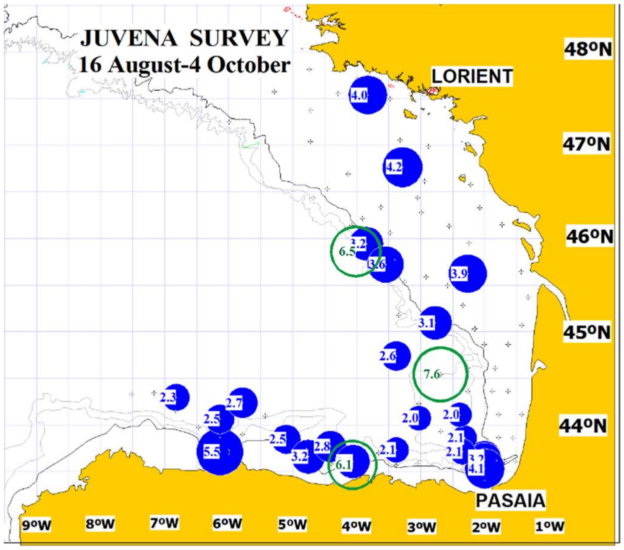

Figure 14. AZTI. JUVENA field campaign 2021. Size of the M. muelleri (blue solid circle) and M.punctatum (green circle) in the positive hauls. The size of the circle is proportional at the mean of the total length of the species.

Maurolicus muelleri is the main component of the mesopelagic in the Bay of Biscay. There is an indication of relatively large quantities are also found west of British Isles but the sampling is experimental and thorough analysis of data is needed. Information on life history of this species has been emerging i.e. within these areas vital rates of Maurolicus muelleri is being assessed bey season and area (Figure 15 and Figure 16).

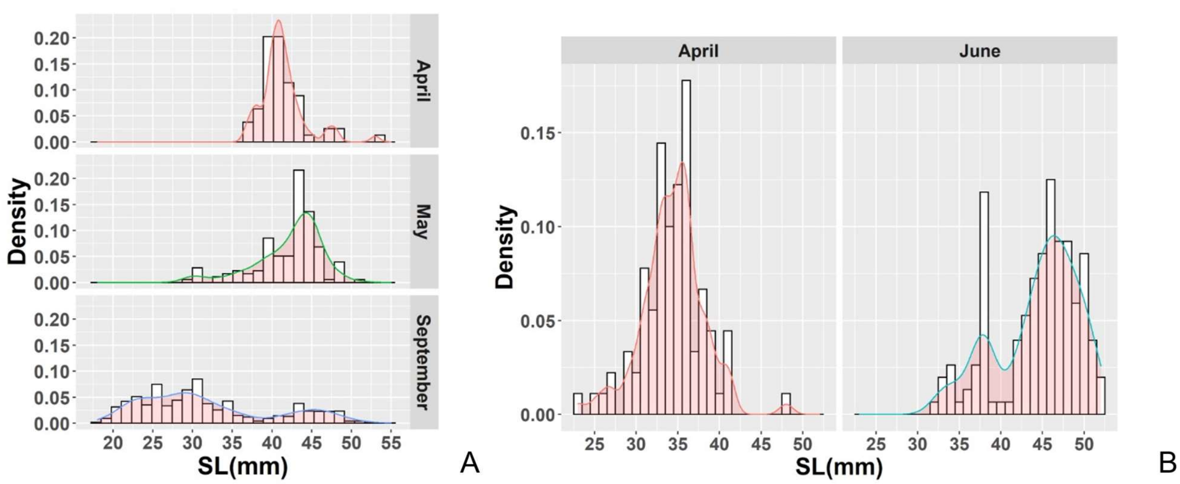

Figure 15. Maurolicus muelleri in Bay of Biscay. Length distributions by season. A. Celtic Sea B. Bay of Biscay.

4.2 . Iceland basin, West of Hebrides and Celtic Sea (IMR 2018106, MFRI A72020, IMR 2021 and IBWSS 2021)

IMR2018106

The cruise IMR 2018106 followed a transect west of the Hebrides measuring abundance and biomass of major mesopelagic stocks using acoustics, optics, and nets. In this cruise acoustic sampling at depths that are not accessible to the higher frequencies of hull-mounted echosounders was explored. An echosounder with a 120 kHz transducer was mounted forward-facing on the headline of a macrozooplankton trawl. Thus, observation of behavior of individuals in front of the trawl was possible and it wass possible to estimate the densities inside and outside the mesopelagic layers in front of the trawl, the vertical profiles of target strengths and the movement of organisms with a forward- facing trawl-mounted echosounder. Detailed analysis and results have been published (Underwood et al., 2020).

Two sizes of trawls (6x6 and 60x60 m opening) were tested on stations along the transect. The relative length distribution for the main fish species was plotted and indicating higher catch of larger specimens by the larger trawl (Figure 16). Diversity was higher in the larger trawl compared with the smaller, 6 x 6 m, trawl. *Benthosema glaciale* was caught in all trawl stations with relatively high abundance. *Maurolicus muelleri* was mainly caught in stations to the east and few species were caught mainly in the stations west on the transect i.e. *Bathylagur euryops, Cyclothone spp., Lampanyctus macdonaldi and Scopelogadus beanii* (Figure 17).

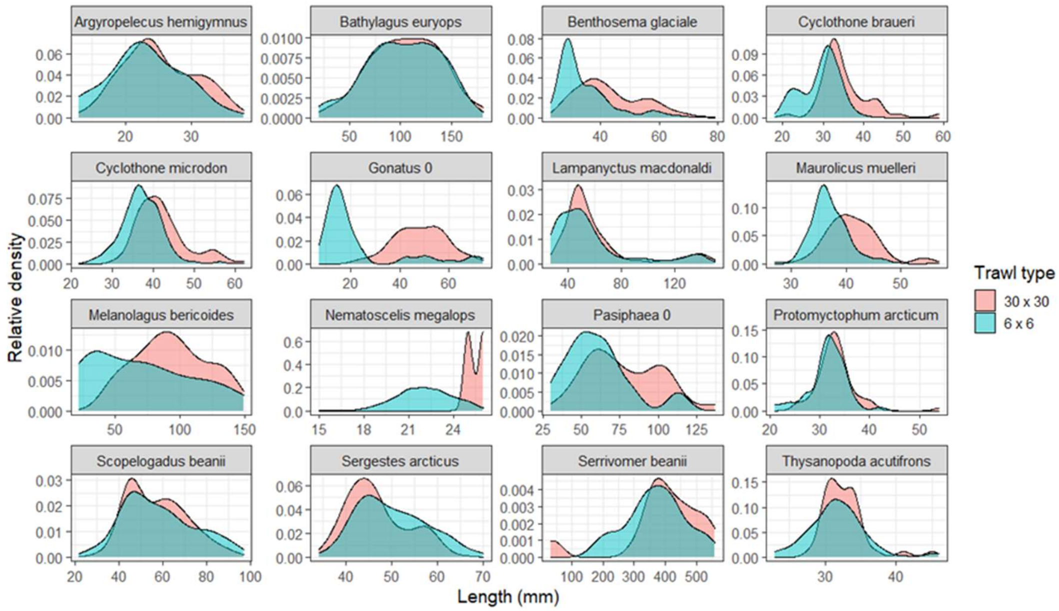

Figure 16 . IMR 2018106. Relative length distribution for some common species divided by trawl Type (i.e. 6x6 m opening or 30x30 m opening).

Figure 17. IMR 2018106. Upper panel. Map showing locations of trawl stations taken with a small fine meshed trawl, 6 x 6 m. Lower panel. Logarithmic density of species/groups for the 6x6 oblique trawl stations (0-1000m) with measured volume. Color represents different phylum (Cruise report IMR2018106, D.4.1).

MFRI A72020

The cruise MFRI A72020 took place as a part of another cruise which is designed to study pelagic ecosystems of the Nordic Seas during summer (IESSNS) in July 2020. The focus was on a longitudinal transect along ~61°50'N, from ~38°49'W to ~16°05'W, from the Irminger Sea and into the Iceland Basin and including a station in Grindavík basin (Figure 18).

Within this cruise net samples were taken at four locations. Three of those are located off south Iceland East of the Reykjanes Ridge (Figure 18). Net samples were taken with pelagic midwater trawl, 'macrozooplankton trawl'. Two types of tows were performed at each station. Integrated tows: The trawl was lowered slowly to 1000 m depth and then hived slowly up again while the ship cruises at slow speed (ca. 1.5-2 knots). Target tows: The trawl was towed horizontally through two layers of dense acoustic backscattering registrations.

Acoustic layers were scrutinized to groups/species level based on each species frequency response and catch composition of the pelagic trawl. Acoustic backscatter was identified to the following categories: Jellies, Red fish, Herring, Krill, Plankton, Squid, Mesopelagic fish & crustaceans, Mesopelagic fish and Other. The defined categories and total backscatter at all frequencies was stored as Nautical Area Scattering Coefficient Values (NASC, S_A, m^2 nmi^{-2}) with -82 dB lower threshold in 0.1 nmi resolution. Macrozooplankton and nekton were collected at two main DSML evident in the 18 kHz and 38 kHz echograms. It was clear during the survey that one mesopelagic layer with stronger backscatter at 18 kHz was composed mainly of mesopelagic fish (Figure 19) that would conduct a vertical migration at night and maintain a depth of ~300-400 m during the day. Another layer with minimal diel vertical movement was with stronger backscatter at 38 kHz between 500-700 m was mainly composed of mesopelagic fish and crustaceans (Figure 19). NASC values lines of both categories, i.e. mesopelagic fish and mesopelagic fish and crustaceans, are shown in Figures 20 and 21. Respective frequency response use for differentiation of those two categories are presented in Figure 22. Vertical profile of proportional NASC values along the cruise transect is show that mesopelagic fish and crustaceans make up the majority of backscattering values of the layer. The proportion of mesopelagic fish along the transect seems to be variable but increases to the east. Near the 25°W mesopelagic fish is the main component of the measurable layer. After that there is an area with now apparent fish. Around 20°W it increases again with less patchiness than in the western part of the transect. A notable proportion of squid is found in the most western part of the transect but absent in the eastern part (Figure 23).

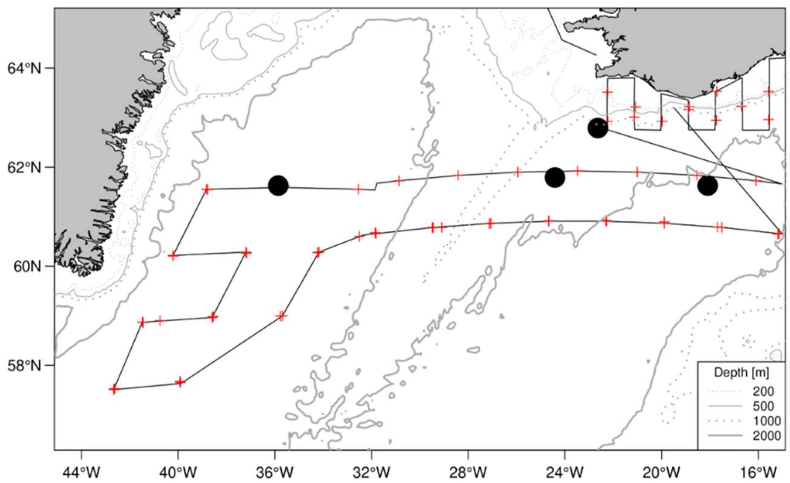

Figure 18. MFRI A7-2020. Map showing the cruise track (black line), IESSNS stations (red crosses) and the position of the MEESO stations (black dots).

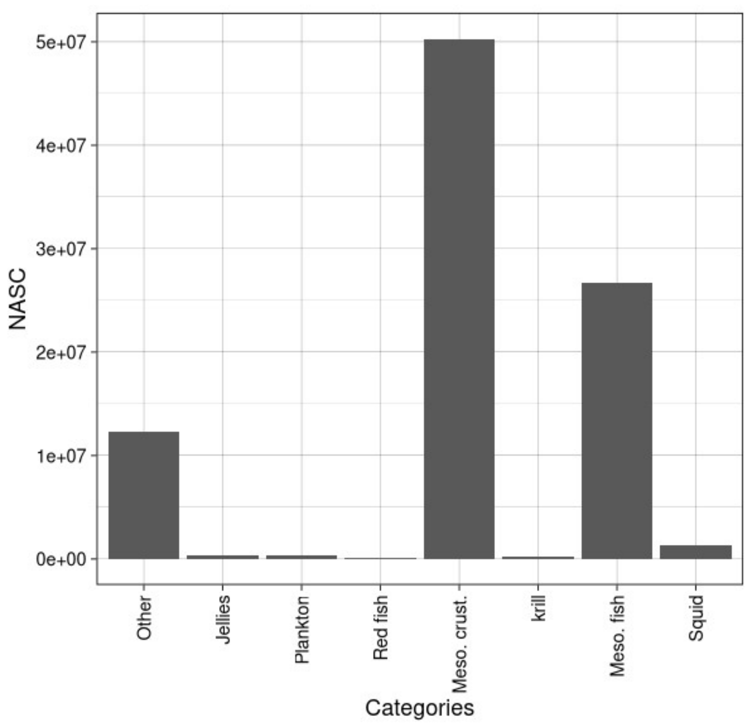

Figure 19. Total acoustic backscatter (SA values m^2/nm^2) at 38kHz for each category scrutinized along the uppermost transect ca. 61°50‘N. Categories are Jellies, Red fish, Krill, Plankton, Squid, Mesopelagic fish and crustaceans (Meso.crust.), Mesopelagic fish (Meso.fish) and other organisms (Other).

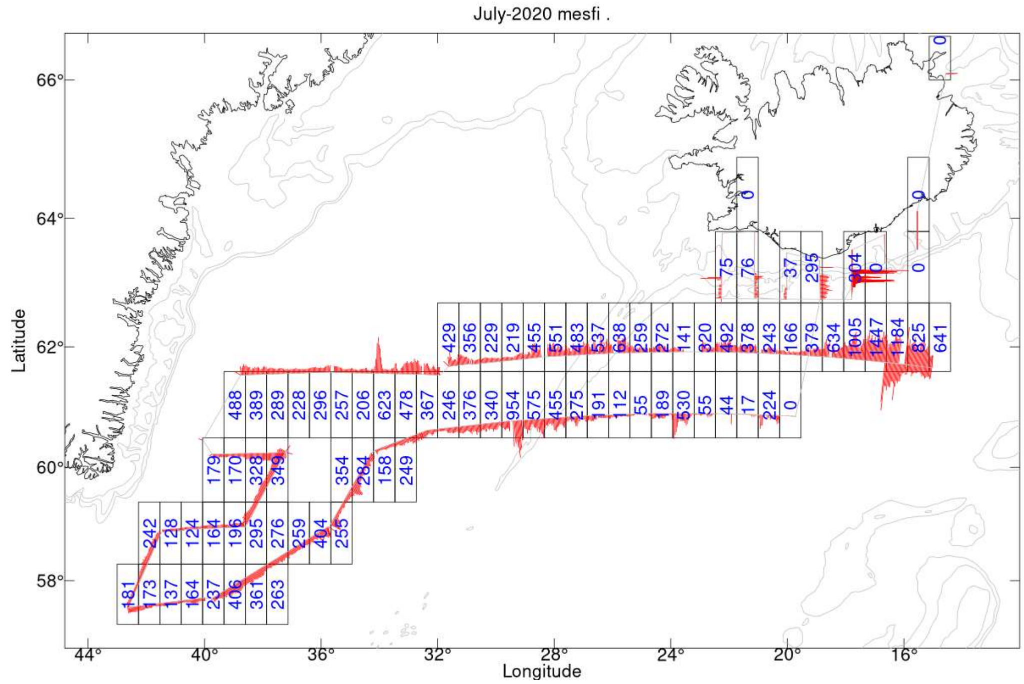

Figure 20. MFRI A7-2020 (and IESSNS 2020) Acoustic abundance map of the upper mesopelagic layer. Back scattering values (NASC, m^2/nm^2 at 38kHz) along the cruise transect (MEESO and the IESSNS). Blue digits annotate average NASC value within each square

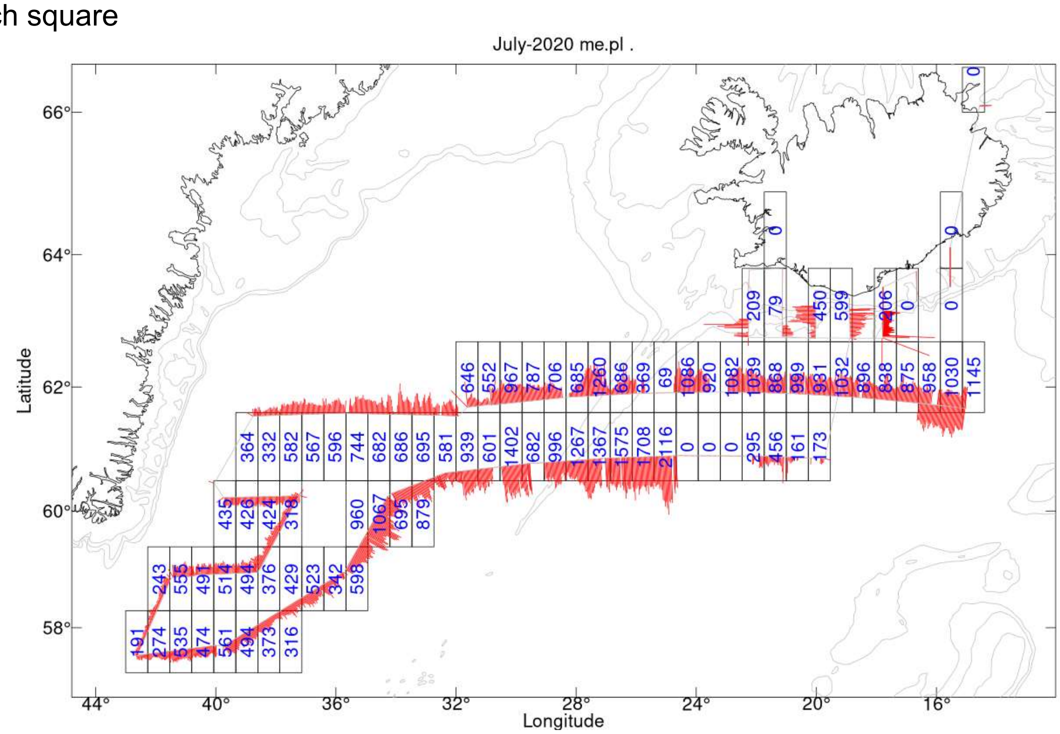

Figure 21. MFRI A7-2020 (and IESSNS 2020) Acoustic abundance map of the lower (deeper) mesopelagic layer. Back scattering values (NASC, m^2/nm^2 at 38kHz) along the cruise transect (MEESO and the IESSNS). Blue digits annotate average NASC value within each square

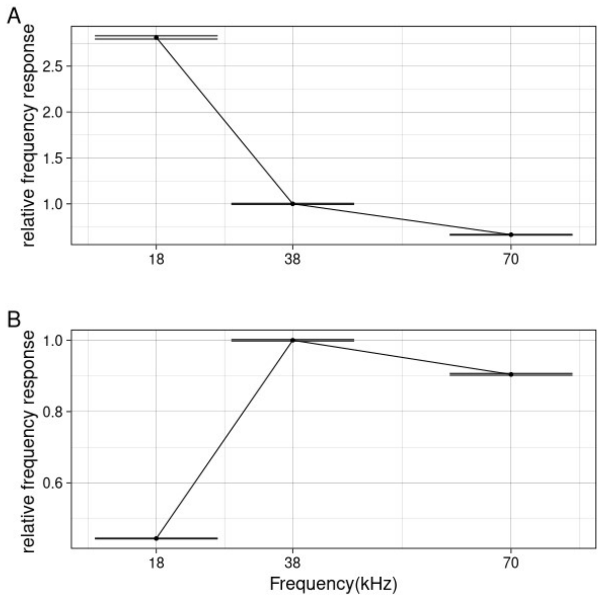

Figure 22. MFRI A72020. Frequency response of categories "mesopelagic fish" (A) and the category "mesopelagic fish & crustaceans" (B) observed in the hull-mounted acoustics.

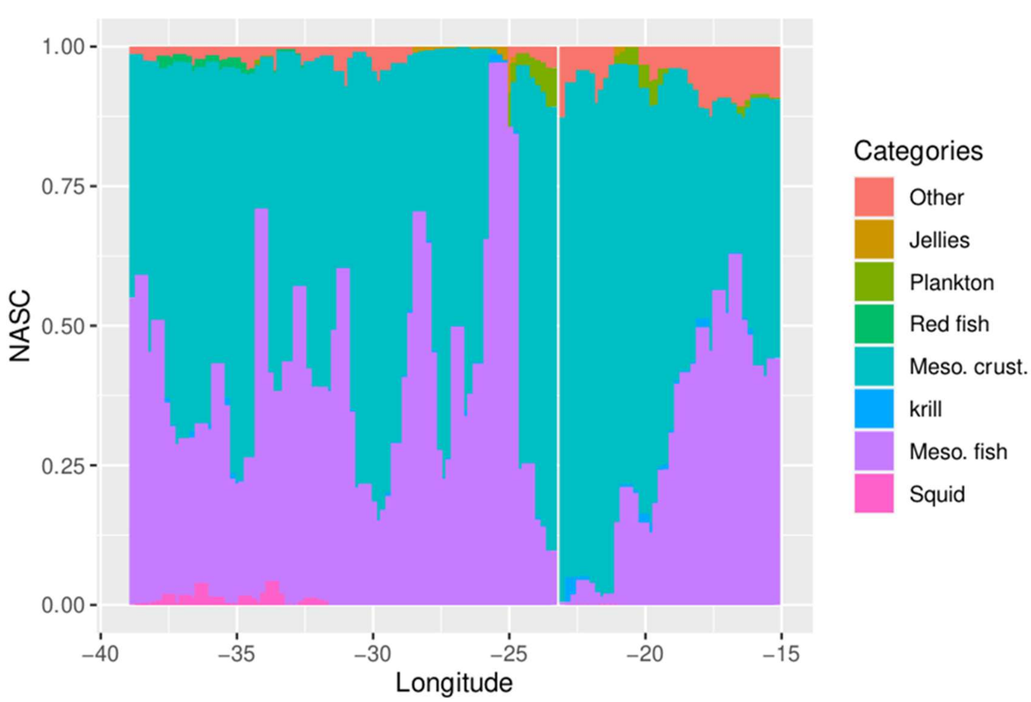

Figure 23. A72020. Vertical profile of proportional NASC values along the cruise transect.

The most abundant species both in number and weight was the lanternfish *Benthosema glaciale.* Main species besides BGH were *Bathylagus euryops*, bristlemouths such as *Cyclothone*, *Serrivomer beani*, *Lampanyctus macdonaldi* and *Protomyctophum arcticum*. Catch composition of and the average biomass of each tow is shown in Figures 24, 25 and 26. Benthosema glaciale dominated the catch of tows taken near Reykjanes ridge. Lampanyctus and Protomyctophum were mainly caught in the Irminger Sea. Lampanyctus was caught only in an intergrated tow but Protomyctophum was frequent in all tows in that area. Bathylagus and Serrivomer were mainly caught in intergrated tows.

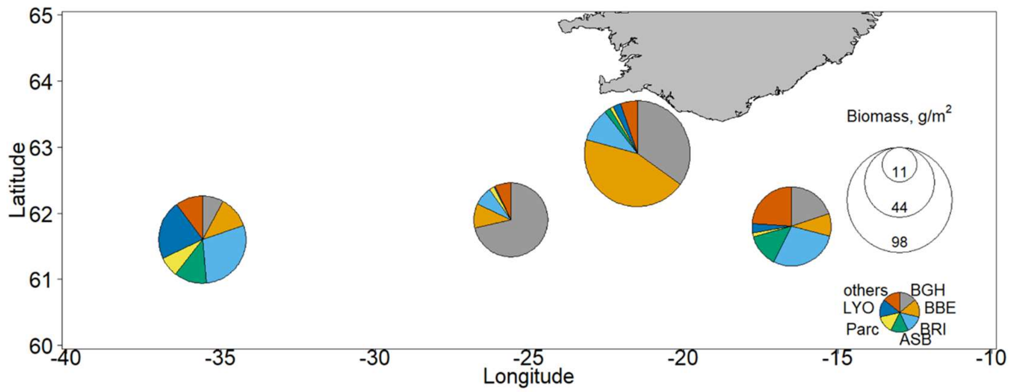

Figure 24. MFRI A72020. Integrated trawls (0-1000m). Average biomass of mesopelagic fish (0-1000 m) from trawl catches. Areas of circles are proportional to biomass densities in g WWm^{-2}. Main species in catch: BGH=Benthosema, BBE=Bathylagus, BRI=Bristlemouths, ASB=Serrivomer, Parc=Protomyctophum, LYO=Lampanyctus.

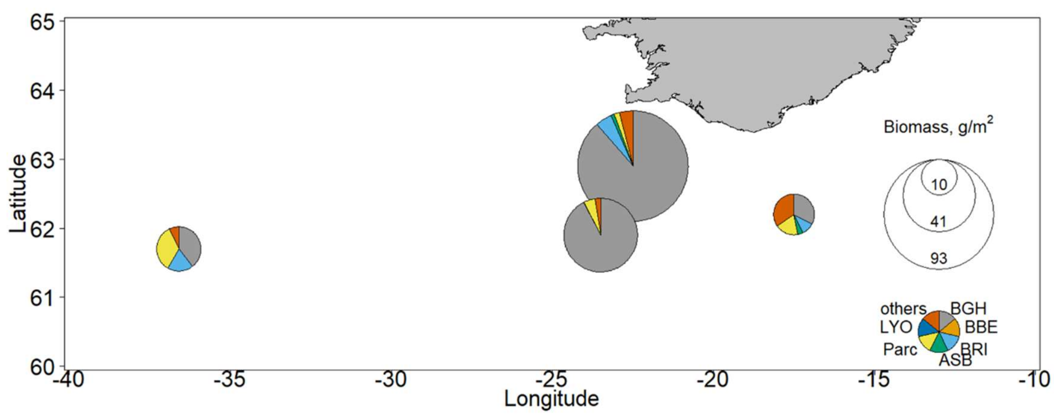

Figure 25. MFRI A72020. Average biomass of mesopelagic fish in target tows in upper acoustic layer (250-325 m). Areas of circles are proportional to biomass densities in gWWm^{-2}. Main species in catch: BGH=Benthosema, BBE=Bathylagus, BRI=Bristlemouths, ASB=Serrivomer, Parc=Protomyctophum, LYO=Lampanyctus, BGH=Benthosema, BBE=Bathylagus, BRI=Bristlemouths, ASB=Serrivomer, Parc=Protomyctophum, LYO=Lampanyctus.

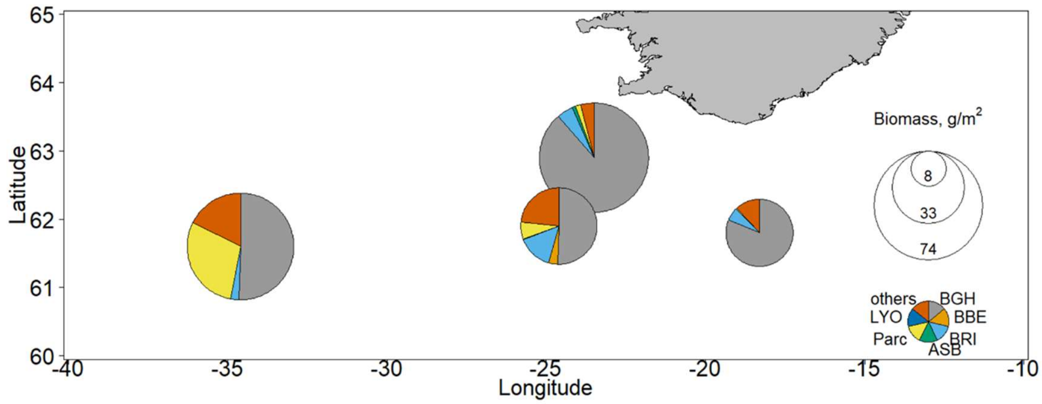

Figure 26. MFRI A72020. Average biomass of mesopelagic fish in target tows in lower acoustic layer (400-570 m). Areas of circles are proportional to biomass densities in gWWm^{-2}. Main species in catch: BGH=Benthosema, BBE=Bathylagus, BRI=Bristlemouths, ASB=Serrivomer, Parc=Protomyctophum, LYO=Lampanyctus, BGH=Benthosema, BBE=Bathylagus, BRI=Bristlemouths, ASB=Serrivomer, Parc=Protomyctophum, LYO=Lampanyctus.

IMR 2021105

This cruise IMR 2021105 was conducted in the Iceland Basin and the Norwegian Sea from 1-30 June, starting and ending in Bergen, Norway. The main objectives were related to the mesopelagic ecosystem, but also the epipelagic ecosystem was observed to assess potential drivers of the mesopelagic biomass. Acoustic Backscattering values indicate relatively high production in several places over the Iceland basin (Figure 27). Trawl samples taken with pelagic trawl indicate five dominating families in this area (Figure 28).

More detailed analysis is ongoing but these preliminary results from both surveys (A72020 and IMR 2021105) indicate that densities of mesopelagic layers in this area could be considerable.

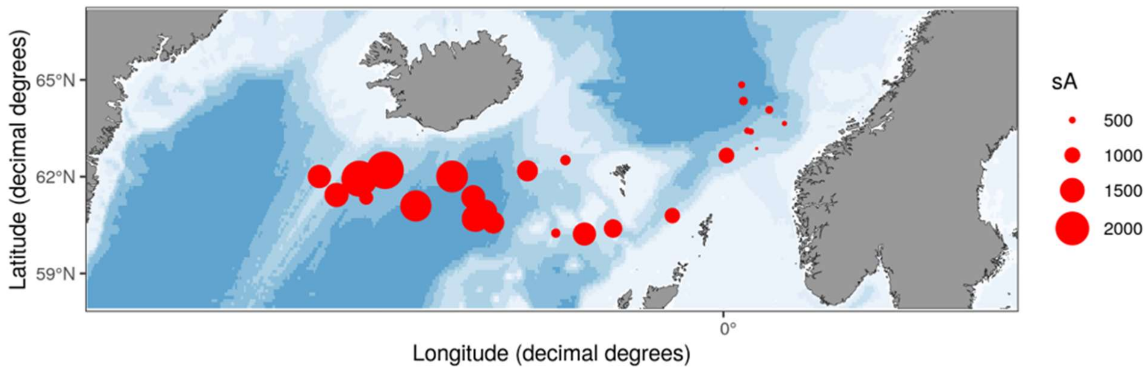

Figure 27. IMR 2021105. Acoustic abundance map. Preliminary results. Daytime average 38 kHz mesopelagic (200-1000 m) backscatter along the cruisetrack. Point radius is proportional to average daytime backscattering levels 200 – 1000 m.

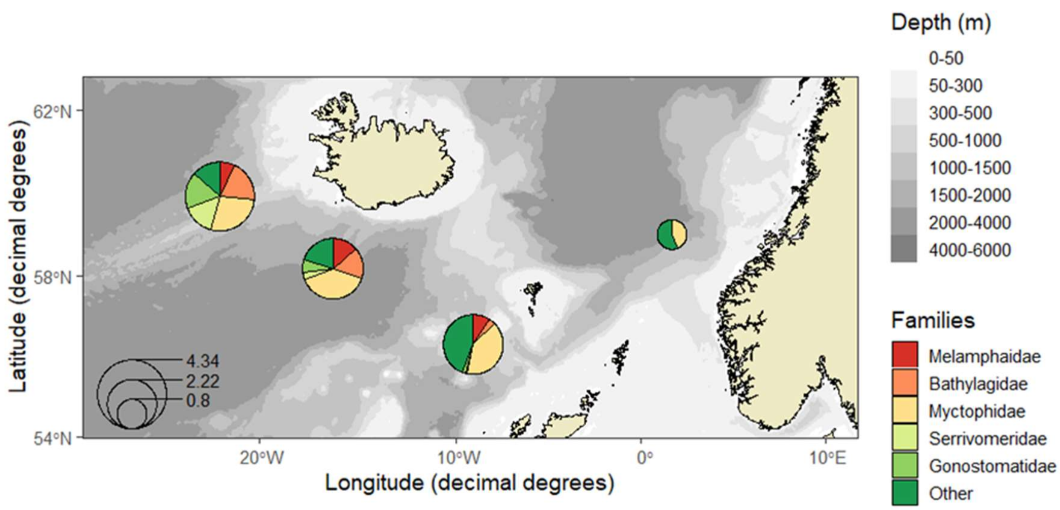

Figure 28. IMR 2021105. Preliminary results. Average biomass of mesopelagic fish (0-1000 m) across the surveyed areas of the North Atlantic, from trawl catches. Areas of circles are proportional to biomass densities in g WW m^{-2}. The 5 dominating families of fish colour coded in the pies, with all remaining (39) families grouped in “Other”. (Melle et al., unpublished material).

IBWSS survey 2021

The survey is carried out in spring with the main objective of estimating Blue whiting spawning stock. Echogram scrutinization for mesopelagic fish species was conducted by participants during the survey and included in uploads to the ICES database. However, due to the complexities involved and issues regarding representative trawl catches these data are considered as experimental and outputs reported to the ICES database should be treated as such. A distributional map of pearlside (Maurolicus muelleri) off W-British isles was provided to the MEESO and shows relatively high density of pearlside at several stations within this area (Figure 24) .

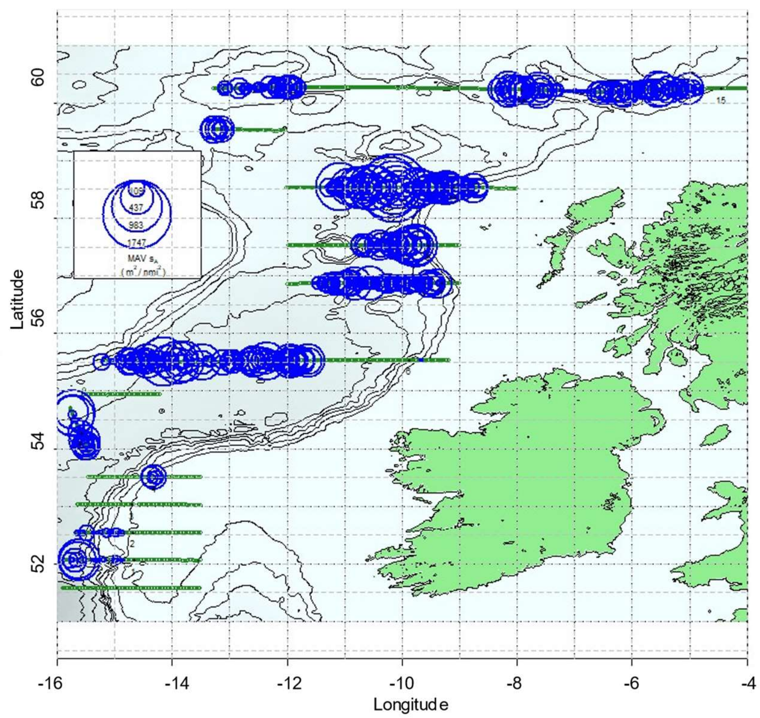

Figure 29. IBWSS spring 2021. Preliminary regional acoustic abundance map for pearlside (*Maurolicus muelleri*).

4.3. Irminger Sea (IMR2013, MFRI2015)

IMR 2013107

This cruise was a conducted as a Trans Atlantic cruise and an integral part of the EURO-BASIN project's field campaign but MEESO project has provided opportunity for extended and advanced analyses of vast information collected in this cruise. Altogether 22 different taxa were caught using the MULTPELT trawl. In the Irminger sea, a fairly rich community of mesopelagic fishes caught at relatively high biomasses. In addition to the trawl catches, the multi-frequency acoustics data supported the difference between the ecosystems with regards to lack of pelagic fish and gave no indications of missed occurrences of pelagic fish in these ecosystems.

This transatlantic cruise has showed that mesopelagic layers are highly variable in quantity as well in diversity throughout the study area. One of the surveys that is reported on within MEESO found that among four sub-polar basins in the North Atlantic (Labrador Sea, Irminger Sea, Iceland Sea, Norwegian Sea), the biomass of epipelagic, larger nektonic species (>20 cm length) was highest in the Norwegian Sea and Iceland Sea basins, while mesopelagic non-gelatinous micronekton biomass peaked in the Irminger Sea and Labrador Sea basins (Klevjer et al., 2020; Melle et al., 2020). Distinct mesopelagic scattering layers were found in all basins, but the daytime depth of the layers varied between basins (T. Klevjer et al., 2020)). Melle et al. (Melle, Klevjer, Drinkwater, et al., 2020) reviewed the trophic functioning of the four sub-polar ocean basins, the Labrador, Irminger, Iceland and Norwegian seas. Their analyses suggest that these ecosystems were similar in many ways. However, the biomass of mesopelagic micronekton was about one order of magnitude higher in the western basins and peaked in the Irminger Sea.

MFRI 2015

As part of the project MEESO, MFRI has committed to providing information on the mesopelagic communities explored during historical surveys for redfish in the Irminger sea. The MFRI redfish survey in the Irminger sea was carried out in June 2015, with the objective of estimating the biomass of pelagic redfish in the area (Figure 30). This cruise is a part of a larger survey in that area organized by the ICES Working Group on International Deep Pelagic Ecosystem Surveys (WGIDEEPS). This cruise follows a transect for acousic registration and 38 trawl stations were taken evenly throughout the study area. For trawl samples the net used was a Gloria type #1024, with a vertical opening of 45-50 m. The codend of the pelagic trawls were equipped with multi-sampler, which consists of 3 codends (Engås et al., 1997). Thus, trawl catch can be sampled at three different depths in one haul.This equipment allows for more intensive sampling and better vertical resolution. MEESO project provides an opportunity for an analyses of mesopelagic data collected in this cruise.

Total NASC values of this area is highly variable throughout the area (480-4100 m^2/nm2 , Figure 31). The highest values are observed in the southernmost transect. On the other hand NASC values of the main mesopelagic layer is relatively stable (600-1100 m^2/nm2 , Figure 32).

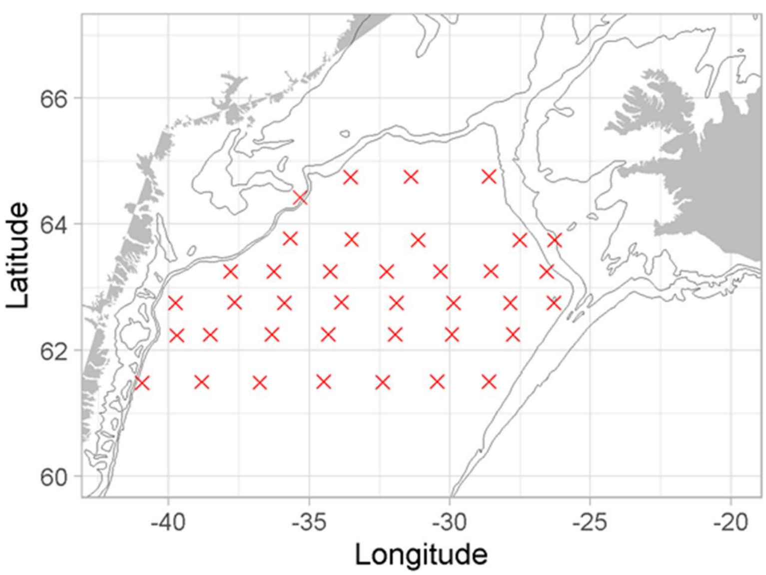

Figure 30. MFRI A62015. Irminger Sea Trawl sampling stations (Pelagic redfish trawl equipped with multisampler).

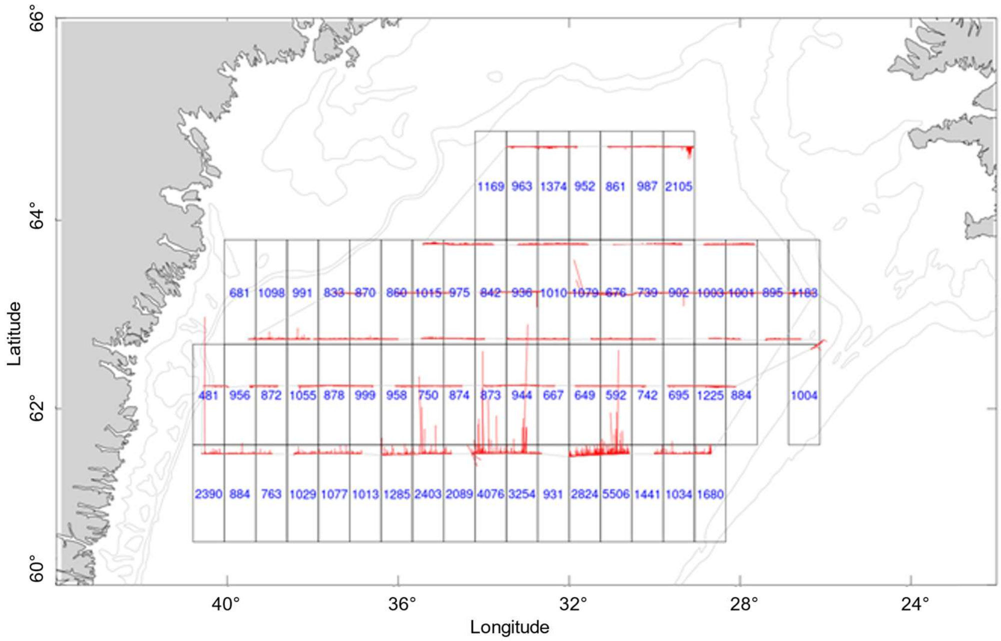

Figure 31. MFRI A6-2015. Irminger Sea. Acoustic abundance map. Total NASC values (m^2/nm^2, 38kHz) along the cruise transect. Blue digits annotate average NASC value within each square.

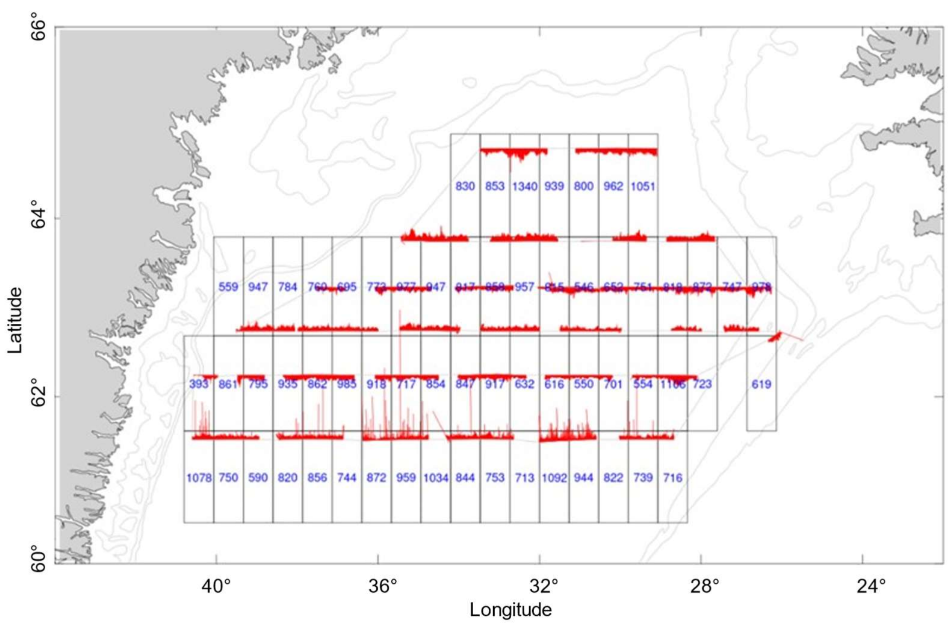

Figure 32. MFRI A6-2015. Irminger Sea. Acoustic abundance map of the main mesopelagic layer (NASC values,m^2/nm^2, 38kHz) along the cruise transect. Blue digits annotate average NASC value within each square.

Lanternfishes (myctophids) are by far the largest group of fish caught in this survey. The main species of myctophids are *Benthosema glaciale*, unclassified lanternfishes *Myctophidae*, *Notoscopelus kroeyeri* and *Lampanyctus macdonaldi*. Species from other fish groups such as *Bathylagus euryops* & *Serrivomer beanie* are also relatively abundant (Figure 33). In this survey Benthosema was by far the most abundant mesopelagic fish in the area (Figure 34). Benthosema was caught in all layers but mainly at medium and shallow depths. Lampanyctus was also caught at all depths but mainly deeper. Similar to Benthosema, Notoscopelus was mainly distributed at medium and shallow depths. Advanced analysis of this data is ongoing.

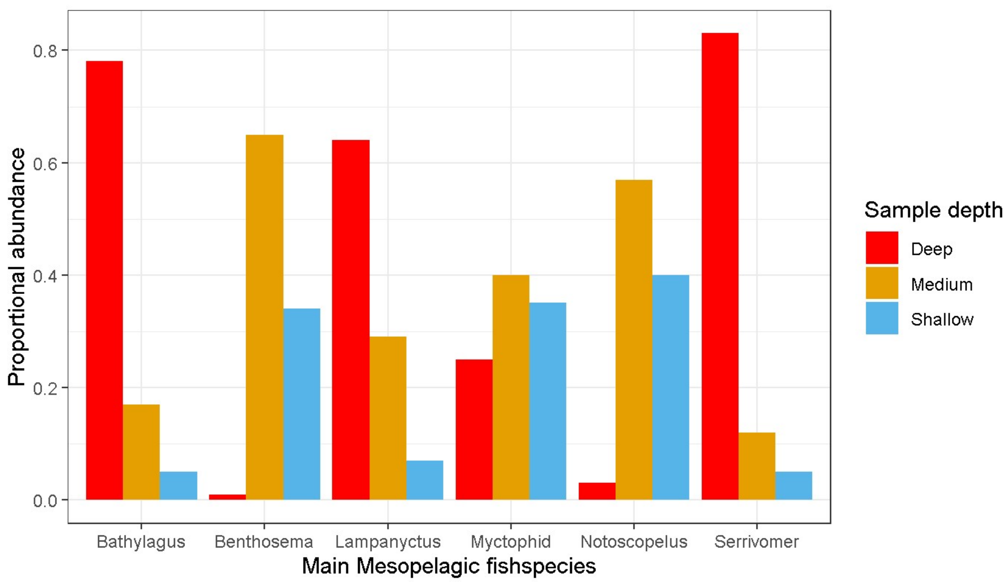

Figure 33. MFRI A62015. Proportional abundance of the main mesopelagic species in Irminger Sea. Collected with multisampler trawl. Shallow depth: 300-450 m, Medium 550 m and Deep 700-850 m.

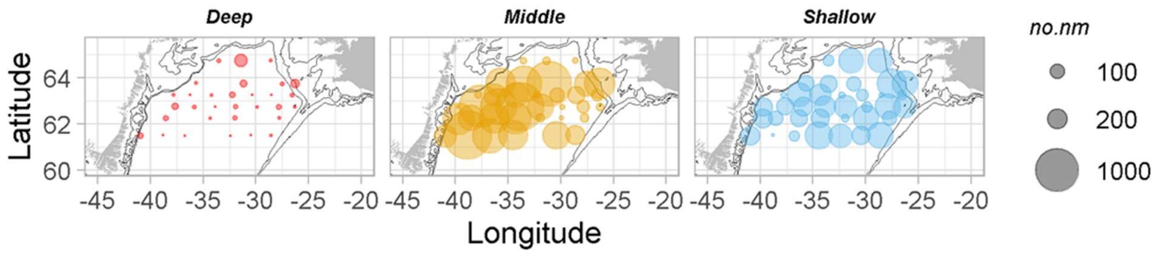

Figure 34. MFRI A62015. *Benthosema glaciale*. Tows with multisampler. Distribution in shallow (300-450 m), medium (550 m) and deep (700-850 m) depths.

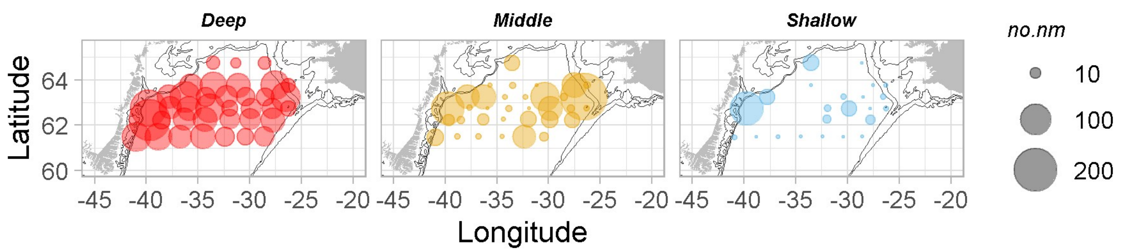

Figure 35. MFRI A62015. *Lampanyctus macdonaldi*. Distribution in shallow (300-450 m), medium (550 m) and deep (700-850 m) depths.

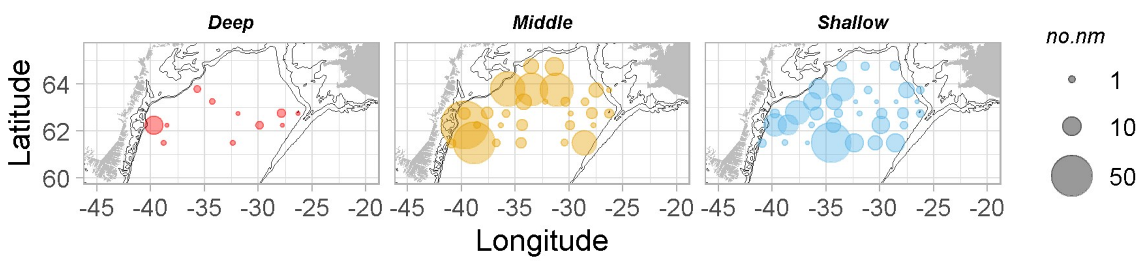

Figure 36. MFRI A62015. *Notoscopelus kroyeri.* Tows with multisampler. Distribution in shallow (300-450 m), medium (550 m) and deep (700-850 m) depths

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Working Document

Working Group on International Pelagic Surveys
January 2022

Working Group on Widely Distributed Stocks

August 2021

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2021

Jan Arge Jacobsen[4*], Leon Smith[4*], Jens Arni Thomassen[4], Mourits M. Joensen[4]
Jákup Sverri

Bram Couperus[1*], Dirk Burggraaf[1], Serdar Sakinan[1], Thomas Smith[1], Tom Bangma[1], Thomas Pasterkamp[1],
R/V Tridens

Michael O'Malley[5*], Graham Johnston[5], Eugene Mullins[5], Ciaran O'Donnell[5*]
R/V Celtic Explorer

Åge Høines[2^*], Ørjan Sørensen[2], Frøydis Tousgaard Rist[2], Susanne Tonheim[2], Christine Djønne[2], Sindre Vatnehol[2*], Valantine Anthonypillai[2*]
M/S Vendla

Urbano Autón[*9], Pablo Carrera[9]
R/V Vizconde de Eza

1 Wageningen Marine Research, IJmuiden, The Netherlands
2 Institute of Marine Research, Bergen, Norway
3 PINRO, Murmansk, Russia
4 Faroe Marine Research Institute, Tórshavn, Faroe Islands
5 Marine Institute, Galway, Ireland
8 Danish Institute for Fisheries Research, Denmark
9 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 2021 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	21/3 – 04/4
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	29/3 – 05/4
Tridens	Wageningen Marine Research, the Netherlands	18/3 – 03/4
Vendla	Institute of Marine Research, Norway	25/3 – 05/4
Vizconde de Eza	Spanish Institute of Oceanography, Spain	18/3 – 23/3

The survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Weather conditions were regarded as exceptionally poor and all vessels experienced multiple days of downtime, with the exception of the Spanish vessel working in the Porcupine Seabight. This considered, the stock was covered comprehensively and contained within the survey area. The entire survey was completed in 19 days, below 21-day target threshold (Figure 4).

Vessel 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. 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 Spanish vessel where the maximum depth was 520 m. 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 RV *Jákup Sverri* (FO) to a depth of 200 m (Table 3). WP2 casts were also carried out by FV *Vendla*, 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 differed among the vessels;

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 post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside (surface down to 250 m), mesopelagics/krill and blue whiting. Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms. The pearlside layer typically migrated above the transducer depth during night and reappeared on the echogram early in the morning.

On RV *Tridens*, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.10.1) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On FV *Vendla*, the acoustic recordings were scrutinized using LSSS (V. 2.10.1) 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.

Echogram scrutinisation for mesopelagic fish species was conducted by participants using guidelines developed at WGIPS 2021 (ICES 2021, Annex 22). This process is ongoing and requires further development in terms of categorisation and trawl sampling equipment. Progress updates will be reported through WGIPS.

Due to the bad weather conditions acoustic recording of all vessels suffered from transmission loss and spikes caused by wave impact on the ship's hull (Figure 8e). Scientists onboard RV *Tridens* analysed data collected during the survey to investigate the effects of bias. A case study showed that there was no significant bias and therefore no need to apply filtering or a correction factor. Further details are provided in Annex 1.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V3.0.5) and R-StoX packages software package (RStoX Framework 3.0.12, RStoX Base 1.3.8 and RStoX Data 1.1.3). A description of StoX software package is provided by Johnsen et. al. (2019). 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 2021 (Figure 1). Area stratification and transect design 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 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 2021 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

Distribution of blue whiting

In total 7,794 nmi (nautical miles) of survey transects were completed across seven strata, relating to an overall geographical coverage of 118,169 nmi² and is comparable to survey effort in 2019 (Figure 1, Tables 3 & 7). Effort in the Porcupine Seabight area was extended in 2021 and included as a new stratum area. 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 2021 was located within the three strata that cover the shelf edge area (Strata 1-3 inclusive) accounting for 84% of total biomass observed (Table 4). The Rockall Trough, strata 3, contained less biomass than observed in 2019 (41% and 61 % of TSB respectively). Distribution in the Porcupine Bank (stratum 1) decreased by 69% compared to 2019. However, it should be noted that this stratum was subdivided into what is now stratum 7 (Porcupine Seabight). The three strata outside the core shelf edge area (stratum 4, 5, and 6) collectively increased from around 5% in 2019 to 10% in 2021 (Table 4). The new Porcupine Seabight area (stratum 7) contributed around 6% of the overall biomass of blue whiting in 2021.

The two northernmost strata South Faroes (stratum 4) and Shetland Channel (stratum 6) accounted for 3.2% of the biomass (Table 4).

Overall, the distribution of blue whiting was found to be highly compressed against the shelf edge from south to north, with the main body of the stock located in the mid-latitudes to the north of the Porcupine Bank (strata 2-3).

The highest s_A value (73,312 m²/nmi² - per 1 nmi EDSU) observed in the survey in 2021 was recorded by *Celtic Explorer* on the slope in the southern part of stratum 3 (Figure 8c). The second highest density value for the combined survey was also found in the same area in the eastern part of the northern slope of Porcupine Bank (stratum 2). Example echograms are provided in Figures 8a, 8b, 8g, showing high density layers of blue whiting extending onto the shelf area on the Porcupine Bank. Juvenile blue whiting, observed as weak scattering layers were found in the northern stratum of South Faroes and Faroe – Shetland Channel (Figure 8d).

The vertical distribution of blue whiting observed in 2021 did not extend deeper than 750 m as observed in 2018 and so were considered vertically contained in the insonified layer.

Stock size

The estimated total stock biomass of blue whiting for the 2021 international survey was 2.4 million tonnes, representing an abundance of 36.9×10^9 individuals (Table 4). Spawning stock was estimated at 2.3 million tonnes and 18.1×10^9 individuals (Table 5).

Stock composition

Survey samples show the age range of 1 to 13 years were observed during the survey.

The main contribution to the spawning stock biomass was composed of the age groups 5, 7 and 6 years representing 63% of the total. Five year olds (2016 year-class) being most abundant (20%), followed by the 7-year-olds (17%) and lastly the 6-year-olds (16%) (Table 5).

The highest mean lengths of blue whiting were caught in Stratum 1 and 7 (Figure 9). High mean weights were also found in this area but two samples in the northern part (Stratum 3 and 4) also had large blue whiting in relation to weight (Figure 10). Highest mean weight in 2021 was in Stratum 7 (Porcupine Seabight) representing 136g.

This year different age groups dominated in different strata (Figure 12). The oldest and largest fish were found in the southern part of the survey area. In the western and southern part of the Porcupine area (Strata 1 and 7) six-year olds (2015 year-class) dominated. On the northern slope of Porcupine (Stratum 2) two-year olds were the second most important age group, but still five-year olds were dominant. In the northern part of the survey area (Strata 4 and 6) the youngest fish were present, and the 2020 year-class dominated. In the core area (Stratum 3) three, five and seven-year olds were approx. at the same level with 15-16% of the estimate each. (Figure 12). The proportion of the different age groups in the total estimate in 2021 were considered evenly distributed and well represented from 1-7 years (Figure 13).

An uncertainty estimate at age based on a comparison of the abundance estimates was calculated for IBWSS for years 2018, 2019 and 2021 using StoX (Figure 11). By comparing the estimates from 2018 to 2021 it appears that good cohort tracking is achieved in the survey for some year classes. For example, the relative abundance of four year olds in 2018 (2014-year class) was high; the strong abundance of this cohort is also seen in 2019 as five year olds, and to some extent in 2021 as seven year olds. Similarly, the 2015 year-class were picked up as three-year olds in 2018, and subsequently the four and six year olds in 2019 and 2021 respectively are relatively strong. The CV of the abundant age groups 3 to 7 was below 0.25 in 2019 (Figure 11).

The CV of the total estimate of both biomass and abundance were 0.14, which is lower than the years before (0.16 - 0.17)

The survey time series (2004-2021) of TSN and TSB are presented in Figures 14 and 15 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 16-19 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). 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.

Mesopelagic fish

Echogram scrutinisation for mesopelagic fish species was conducted by participants during the survey and included in uploads to the ICES database. However, due to the complexities involved and issues 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 exceptionally poor and all vessels experienced multiple days of downtime, except for the Spanish vessel working in the Porcupine Seabight. This considered, the stock was regarded as suitably contained within the survey area.
- The total area surveyed and acoustic sampling effort (miles) was the same as 2019.
- Overall, biological sampling saw an increased number of both measured and aged individuals compared to 2019.
- The International Blue Whiting Spawning Stock Survey 2021 shows a 44% decrease in total stock biomass and a corresponding 46% decrease in total abundance when compared to the 2019 estimate.
- The survey was carried out over 19 days, below the 21-day time window target. With core areas covered well by multiple vessels.
- Estimated uncertainty around the total stock biomass was lower than in 2019, CV=0.14 compared to 0.17.
- The stock biomass within the survey area was dominated by 5, 6 and 7-year-old fish contributing 61% of total stock biomass.
- There was no evidence of blue whiting below 750 m
- Immature fish (mainly 1-year-old) represent 3.6% of the TSB and 10% of TSN.
- The harmonisation of reporting of mesopelagic fish began in earnest and will be developed within the IBWSS survey over the coming years to report abundance and biomass of identified target groups.

Interpretation of the results

- The group considers the 2021 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.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and the Hebrides.
- The Northern migratory stock and the Porcupine Seabight; Spatio-temporal survey data and biological data from trawl hauls (RV *Vizconde de Eza*) 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 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 3.2) are standardised and developed by WGIPS for wider use.
- Through WGIPS, agreement needs to be reached on the synchronisation of reporting blue whiting maturity by participants and how this is handled within the ICES database.
- It is recommended that the effective timing of the survey point is maintained to begin around the 20th March in 2022.

Achievements

- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable to 2019.
- All survey data were uploaded to the ICES trawl-acoustic database in advance of the post cruise meeting.
- Mesopelagic fish scrutinisation was carried out by all participants using the guidelines developed during WGIPS.
- Directed trawling on mesopelagic layers was carried out using a range of sampling nets (MiK and Macrozooplankton). Although still experimental, this is a further step towards reporting.

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Table 1. Country and vessel specific details, IBWSS March-April 2021.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Trawl dimensions					
Circumference (m)	768	852	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)	3.5-4.0	3.0-4.0	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	1000	1000	1000	520

Table 2. Acoustic instruments and settings for the primary acoustic sampling frequency, IBWSS March-April 2021.

	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	7.5
Upper integration limit (m)	20	15	15	15	15
Absorption coeff. (dB/km)	9.8	10.7	9.5	9.5	9.2
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	3.06	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.6	-20.4	-20.6	-20.7	-20.6
Sv Transducer gain (dB)			27.28		
Ts Transducer gain (dB)	25.65	26.96	27.27	25.18	24.68
s_A correction (dB)	-0.64	-0.16	-0.01	-0.66	-0.54
3 dB beam width (dg)					
alongship:	6.97	6.55	6.86	7.01	6.90
athw. ship:	7.06	6.45	6.89	6.90	7.10
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 2021. Directed mesopelagic sampling 150-350 m depth layer) was carried out by the RV *Celtic Explorer* and RV *Tridens* using macrozooplankton and Mik net trawls respectively.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Mesopelagic sampling	Aged fish	Length-measured fish
Celtic Explorer	21/3-04/4	2123	15	19	3	550	6571
Jákup Sverri	25/3-5/4	1100	3	19	-	300	668
Vendla	25/3- 5/4	2100	9	19	-	239	800
Tridens	18/3-3/4	1574	13	31	5	1000	2836
Vizconde de Eza	18/3-23/3	897	5	14	-	-	1144
Total	28/3-11/4	7794	45	102	8	2089	12019

Table 4. Abundance and biomass estimates of blue whiting by strata in 2019 and 2018. IBWSS March-April 2021.

		2021				2019				Difference 2021-2019	
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	270	2 232	11.4	11.1	870	8 350	20.7	22.6	-69 %	-73 %
2	N Porcupine Bank	746	6 500	31.6	32.3	572	5 692	13.6	15.4	30 %	14 %
3	Rockall Trough	977	8 094	41.4	40.2	2 555	21 116	60.9	57.2	-62 %	-62 %
4	South Faroes	154	1 413	6.5	7.0	125	1 039	3.0	2.8	24 %	36 %
5	Rockall Bank	41	300	1.7	1.5	29	272	0.7	0.7	43 %	10 %
6	Faroe/Shetland Ch.	34	595	1.5	3.0	47	448	1.1	1.2	-27 %	33 %
7	Porcupine Seabight	139	984	5.9	4.9	0	0				
	Total	2 361	20 119	100	100	4 198	36 918	100	100	-44 %	-46 %

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2021.

Length	Age in years (year class)										Number	Biomass	Mean	Prop
	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012		(10^6)	(10^6 kg)	(g)	
14-15										0	0	0	0.0	0
15-16	24										24	1	21.7	84
16-17	386										386	9	24.0	12
17-18	476										476	13	27.7	6
18-19	403	9									412	13	32.2	2
19-20	228										228	9	39.0	0
20-21	177										177	8	45.1	3
21-22	155										155	8	52.4	0
22-23	67	1	17								85	5	62.0	21
23-24	34	167	41								242	17	68.1	86
24-25		498	327	22	18						865	66	76.5	97
25-26		746	585	154	83	6					1 574	134	85.0	95
26-27		468	685	545	713	9	1	0			2 421	225	92.8	97
27-28		139	483	568	686	160	52	4			2 092	223	106.5	99
28-29		62	255	539	808	573	223	19	1		2 479	294	119.0	100
29-30			38	187	454	681	799	5	1		2 165	287	132.4	100
30-31		6	86	82	586	621	806	40	76		2 302	326	142.1	100
31-32			28	127	286	581	606	25	35	22	1 712	267	155.5	100
32-33				41	225	245	514	21			1 047	176	168.3	100
33-34				4	16	158	238	105			521	98	188.8	100
34-35				2	28	82	69	136	5	21	343	71	206.9	100
35-36				2	9	27	38	55	10	40	181	41	227.4	100
36-37				2		49	12	19	13	1	94	25	254.4	100
37-38						5	7	12	32		57	17	280.3	100
38-39						1		21		8	31	9	296.5	100
39-40							4			8	12	4	345.3	100
40-41									15		15	6	386.3	100
41-42							4				4	1	329.0	100
42-43										6	6	3	432.0	100
43-44										6	6	0	556.0	100
44-45							6				6	3	448.7	100
TSN(mill)	1 948	2 095	2 545	2 275	3 914	3 197	3 379	463	189	114	20 119			
TSB(1000 t)	68.8	179.3	243.9	265.0	470.0	469.0	504.1	98.5	35.2	20.9	2 357.3			
Mean length(cm)	18.1	25.0	26.1	27.5	28.3	30.0	30.5	33.3	33.0					
Mean weight(g)	35	84	98	111	122	144	152	199	206					
% Mature	6	96	95	100	100	100	100	100	100	100				
SSB (1000kg)	3.9	172.0	232.3	264.8	469.5	469.0	504.1	98.5	35.2	20.9	2 270.1			
SSN (mill)	109.1	2010.0	2423.6	2273.4	3910.1	3197.2	3379.0	462.6	189.1	113.7	18 067.7			

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(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

*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

* End of Russian participation.

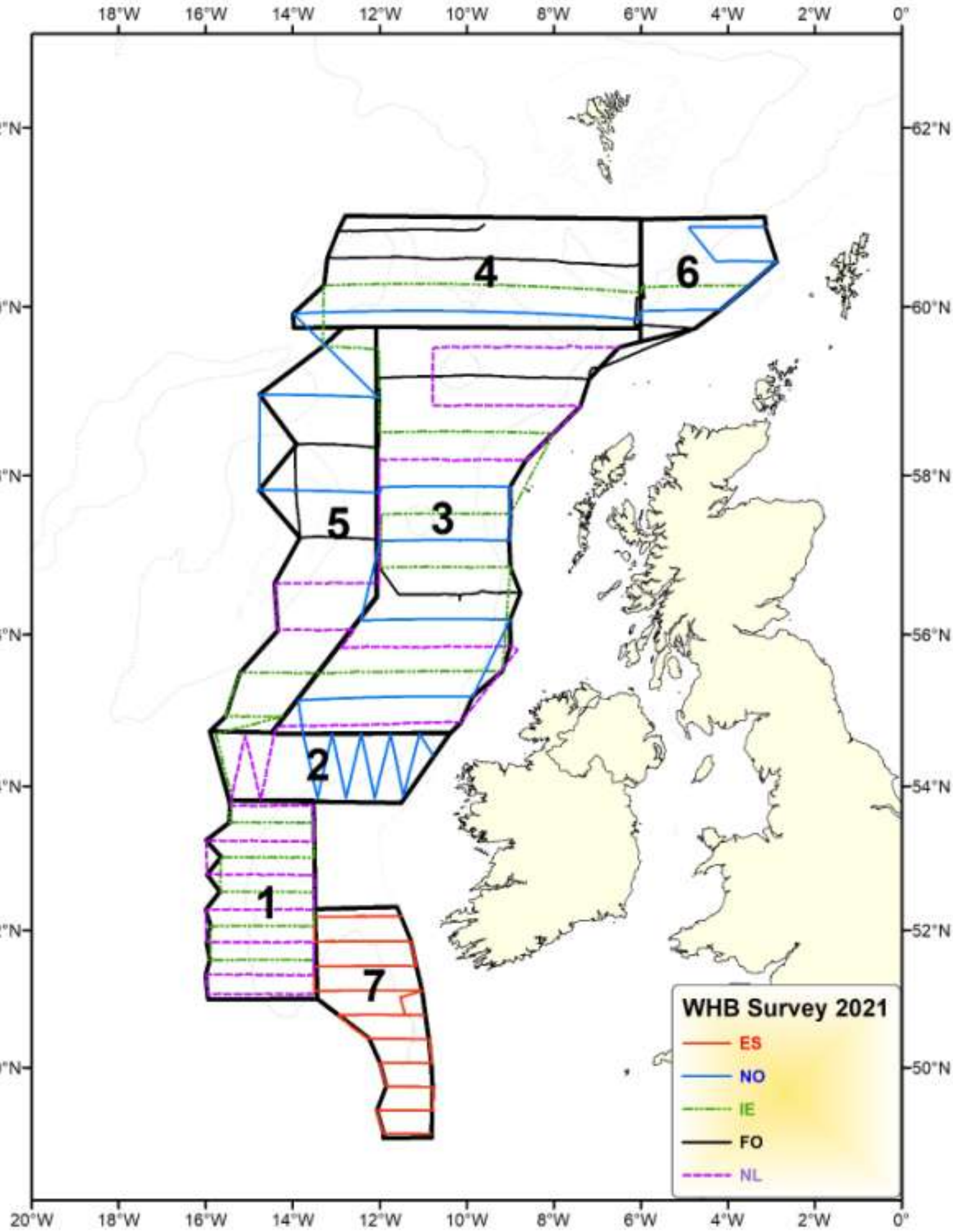


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

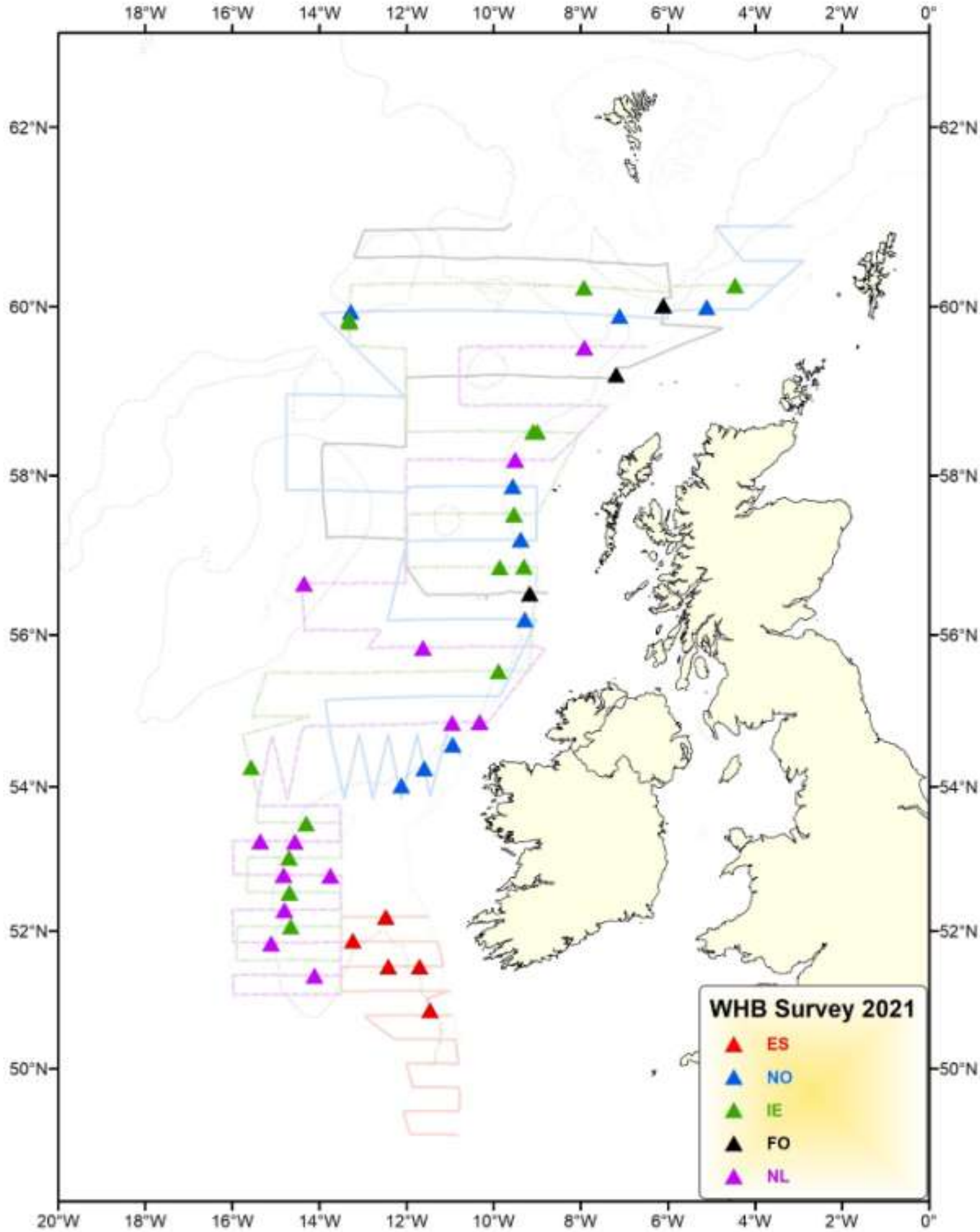


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021. ES: Spain (RV *Vizconde de Eza*); FO: Faroe Islands (RV *Jakúp Sverrí*); IE: Ireland (RV *Celtic Explorer*); NL: Netherlands (RV *Tridens)*; NO: Norway (FV *Vendla*).

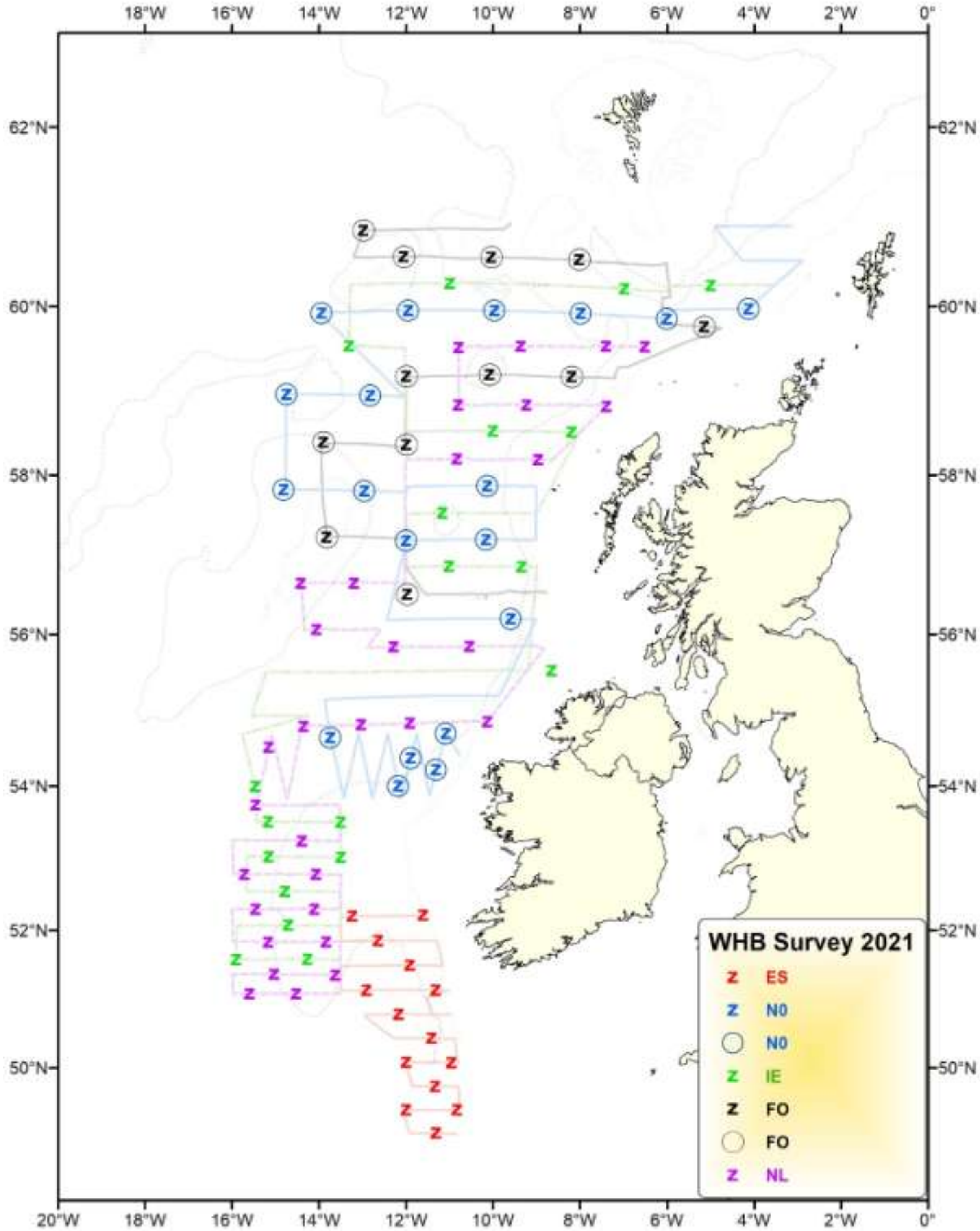


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021. Colour coded by vessel.

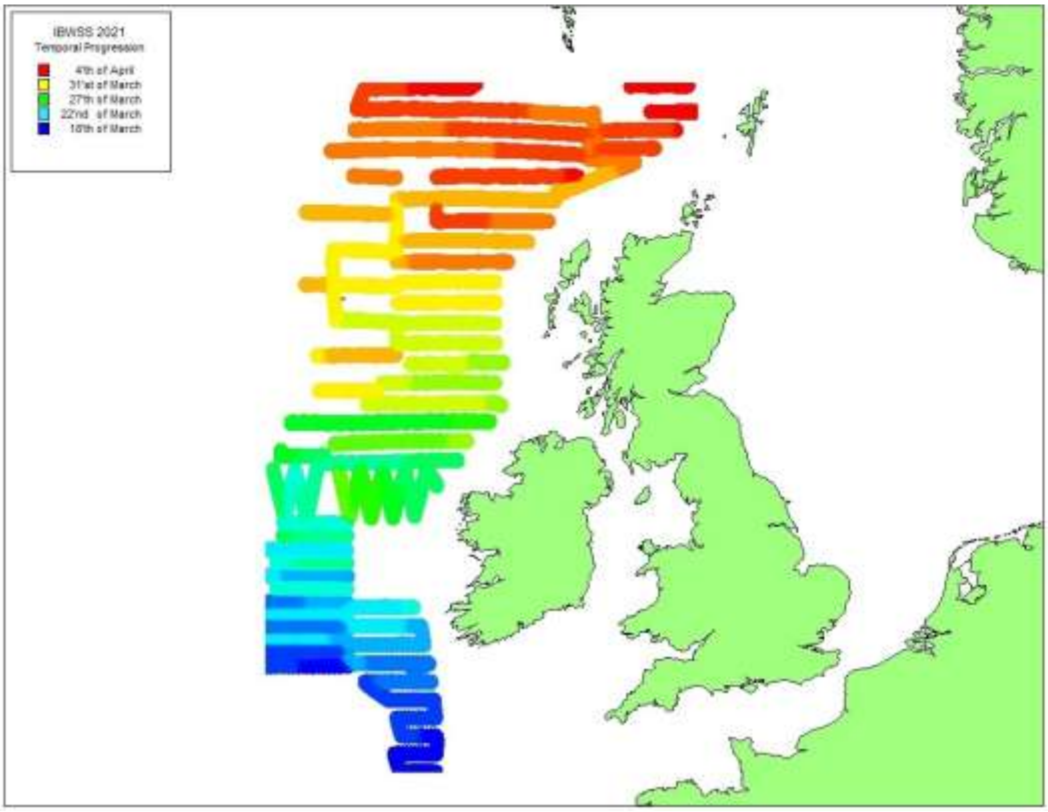


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

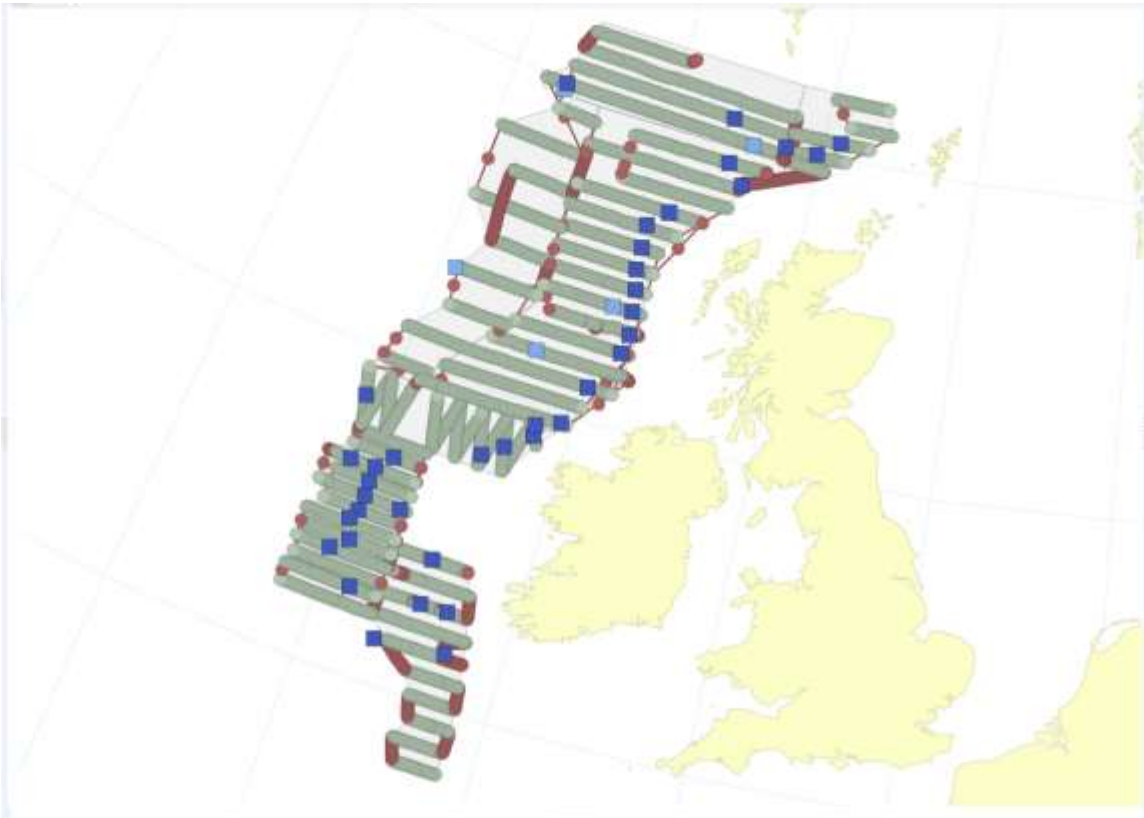


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (dark blue squares) used in the StoX abundance estimation. IBWSS March-April 2021.

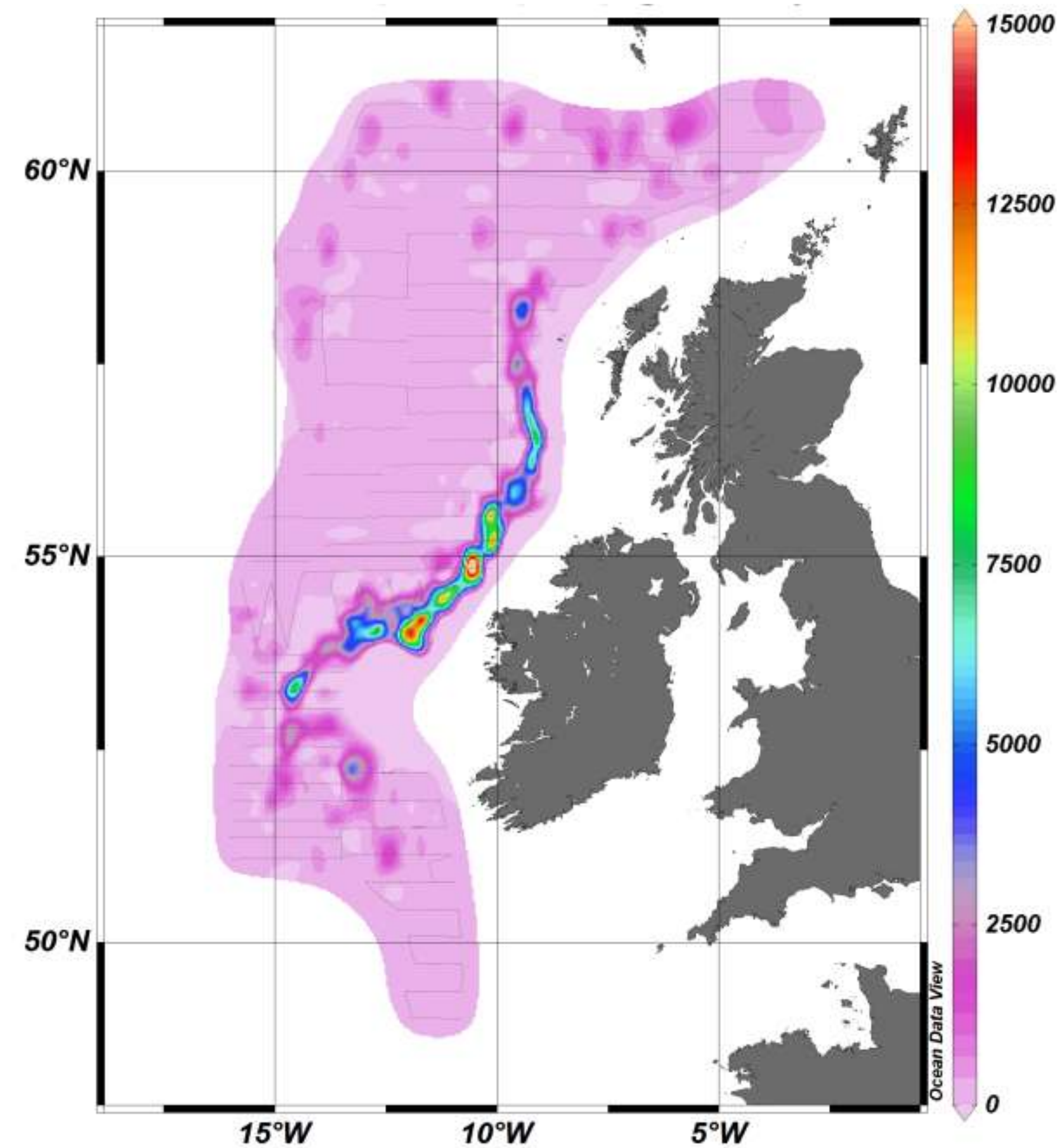


Figure 6. Acoustic density heat map (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

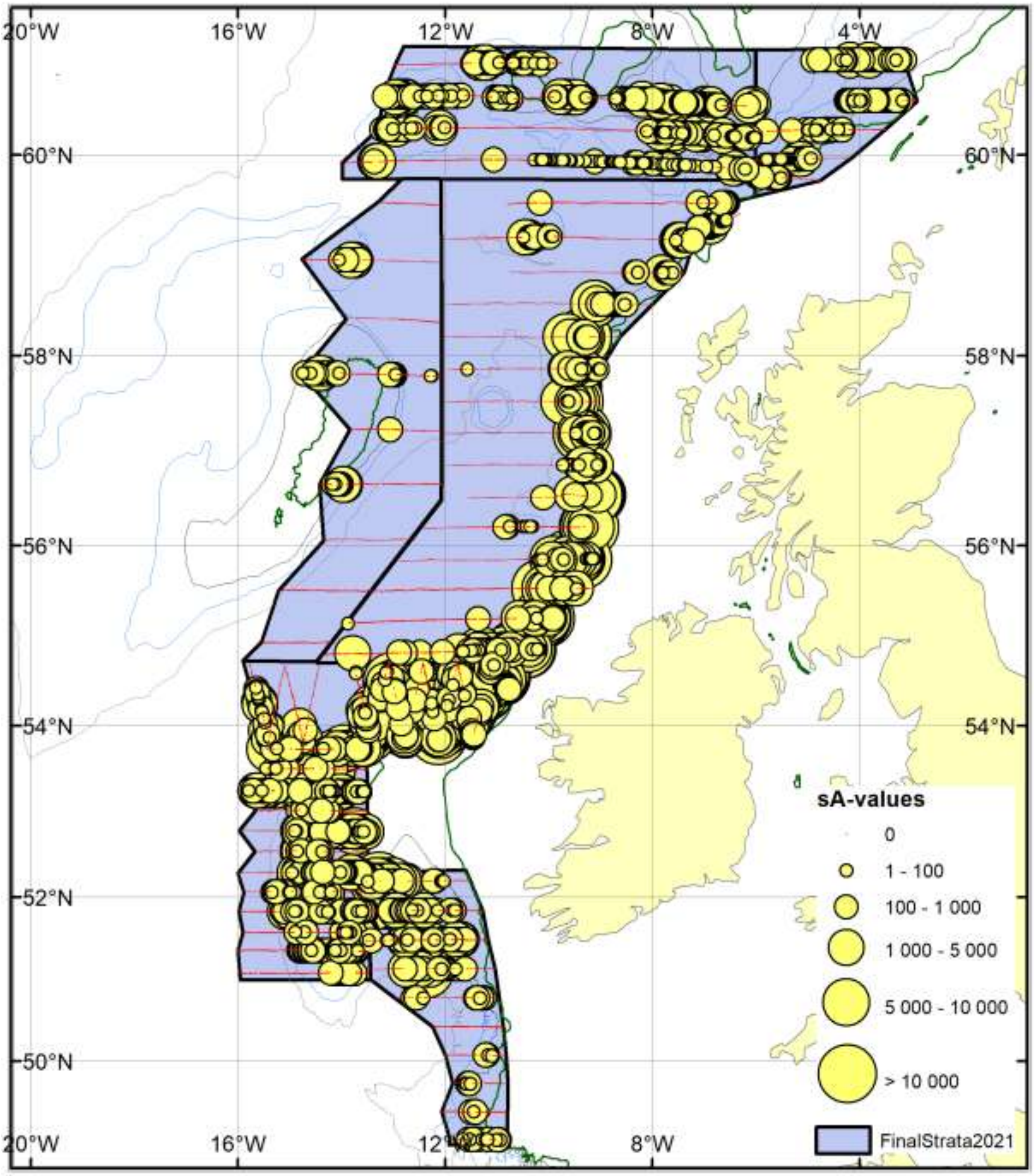
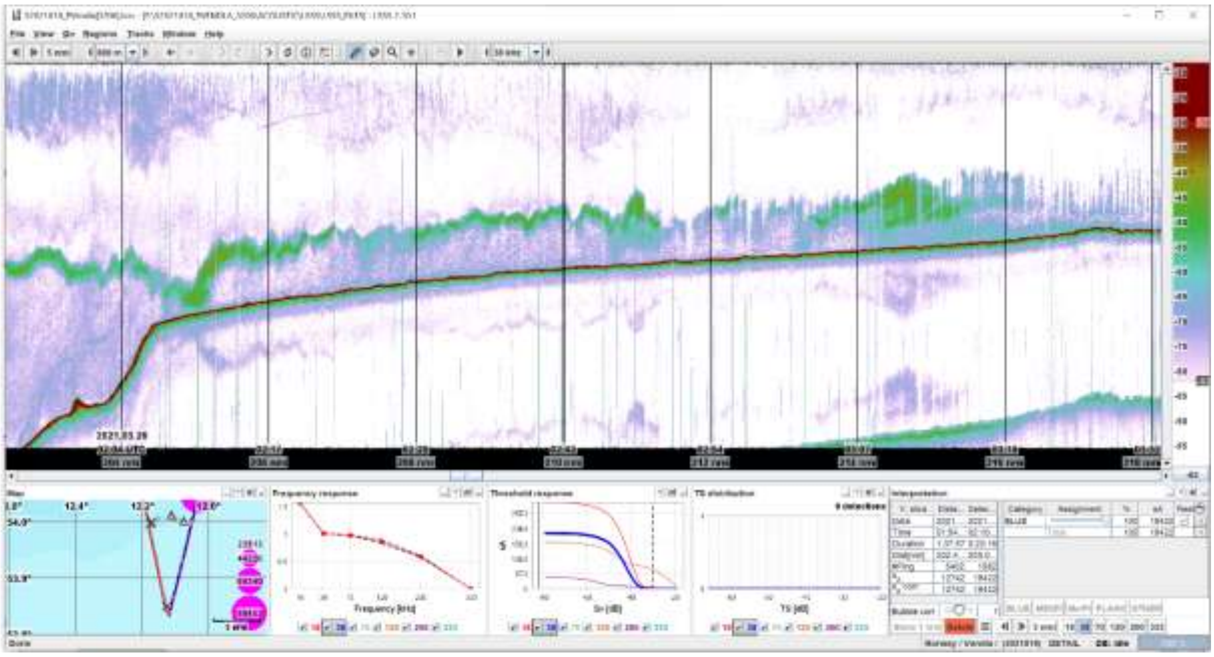
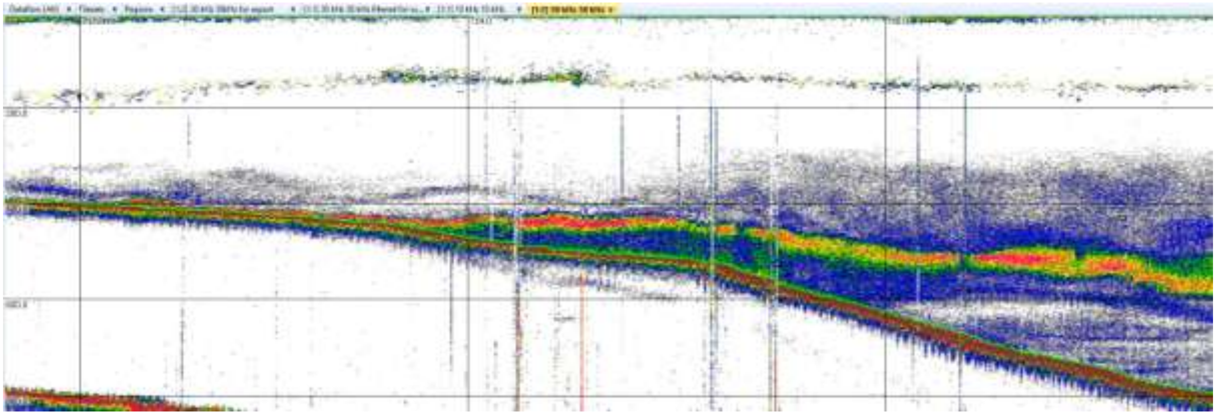


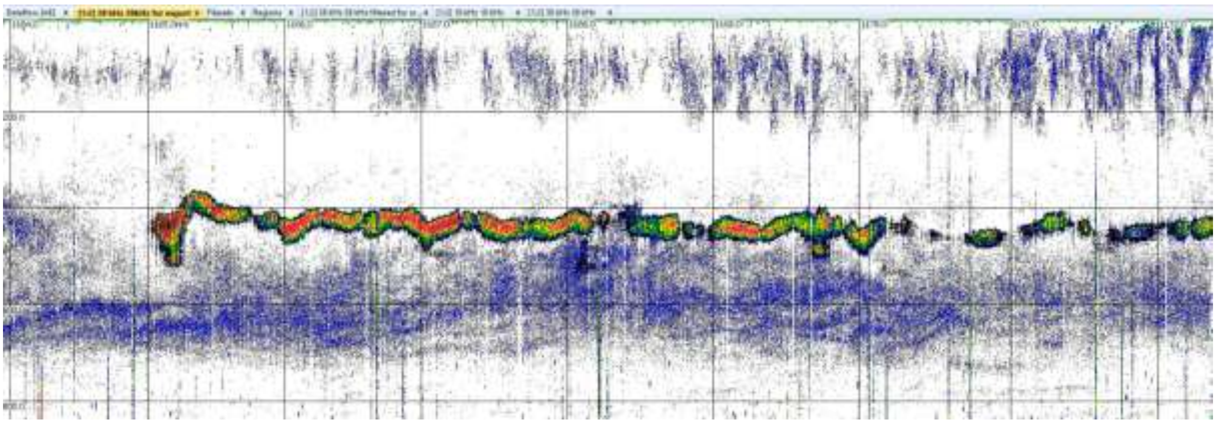
Figure 7. Map of proportional acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi sampling unit. IBWSS March-April 2021.



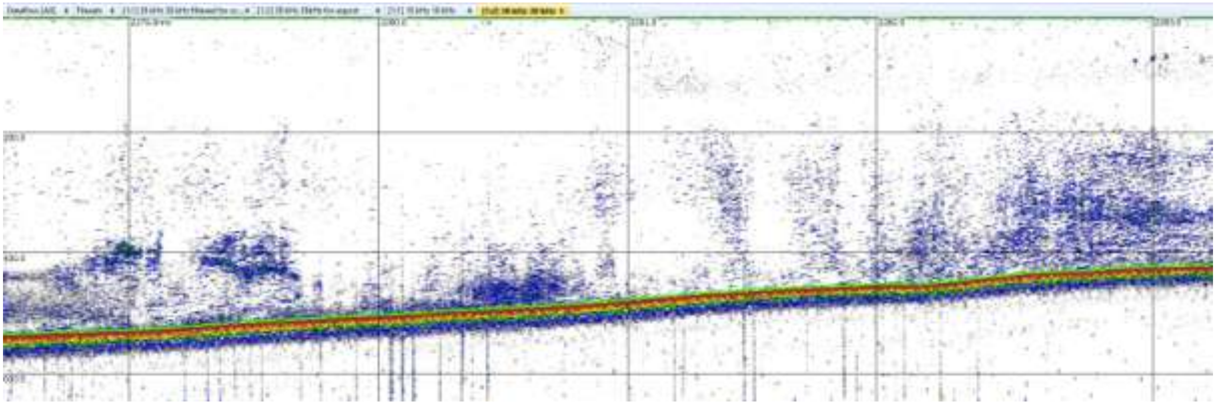
a) High density blue whiting per 1nmi log interval recorded on the northern slope of the Porcupine Bank area (Stratum 2) FV *Vendla*, Norway.



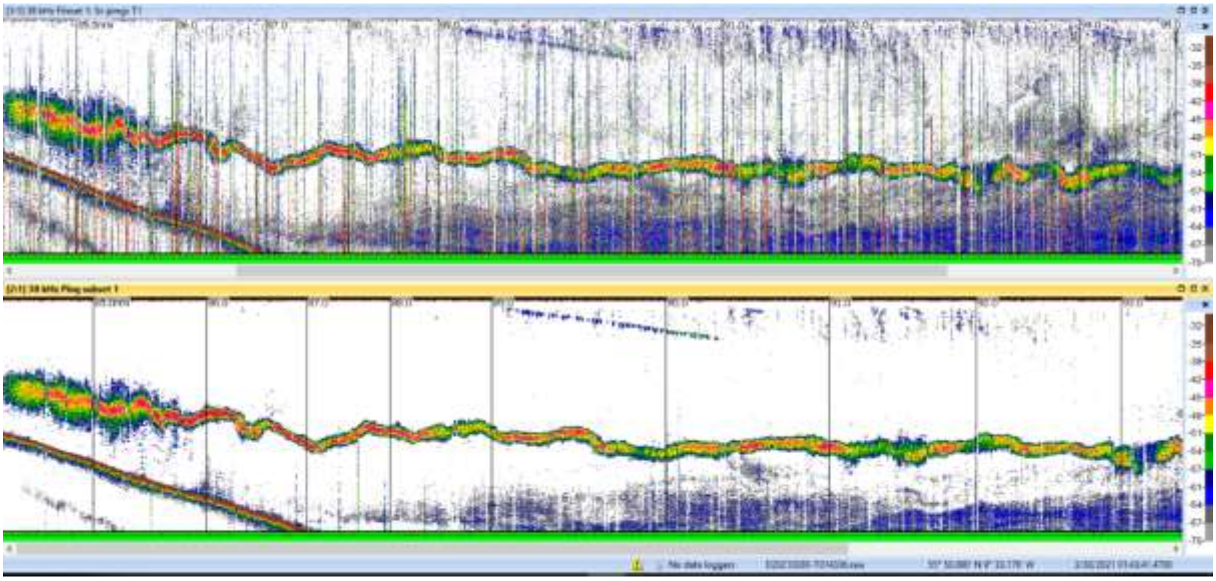
b) High density blue whiting layer per 1nmi log interval at 400- 600m recorded by the RV *Celtic Explorer* in the western Porcupine Bank area (strata 1).



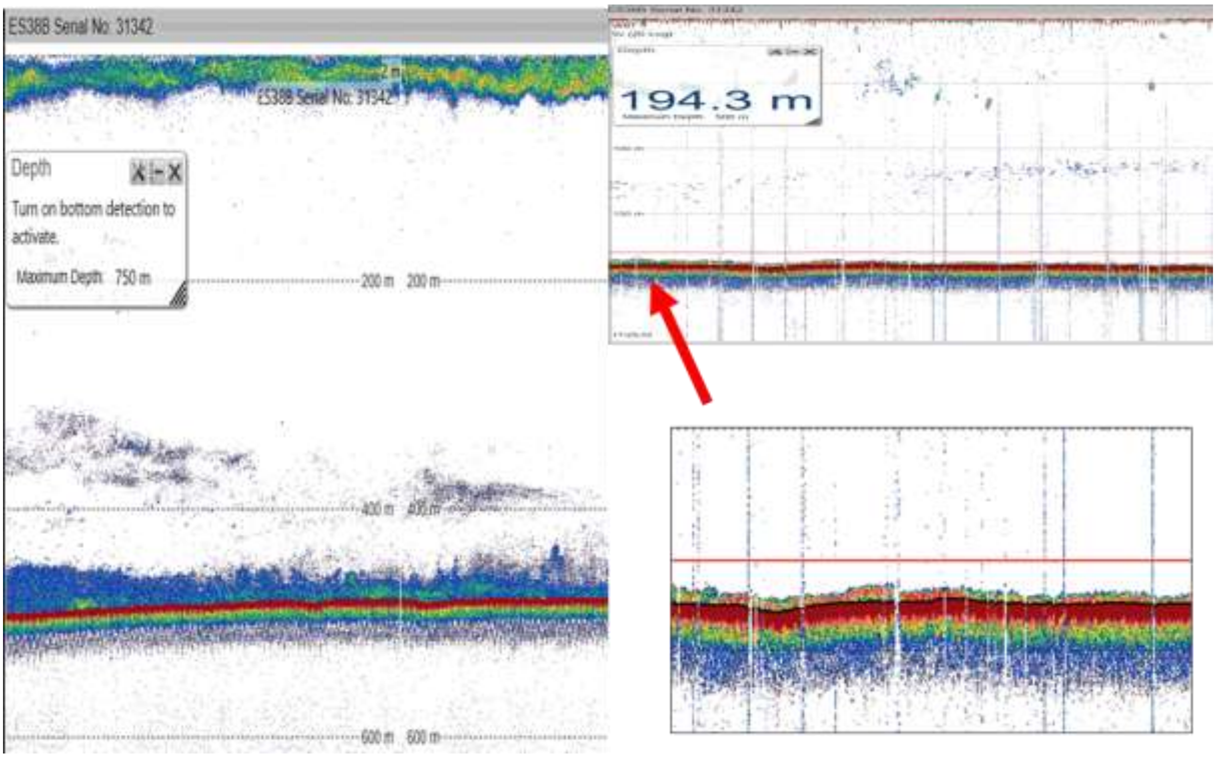
c) Single highest density blue whiting layer per 1nmi log interval (s_A value (73,312 m²/nmi²) observed during the survey recorded by the Celtic Explorer in the Rockall Trough area (Stratum 3) in 400 – 500 m.



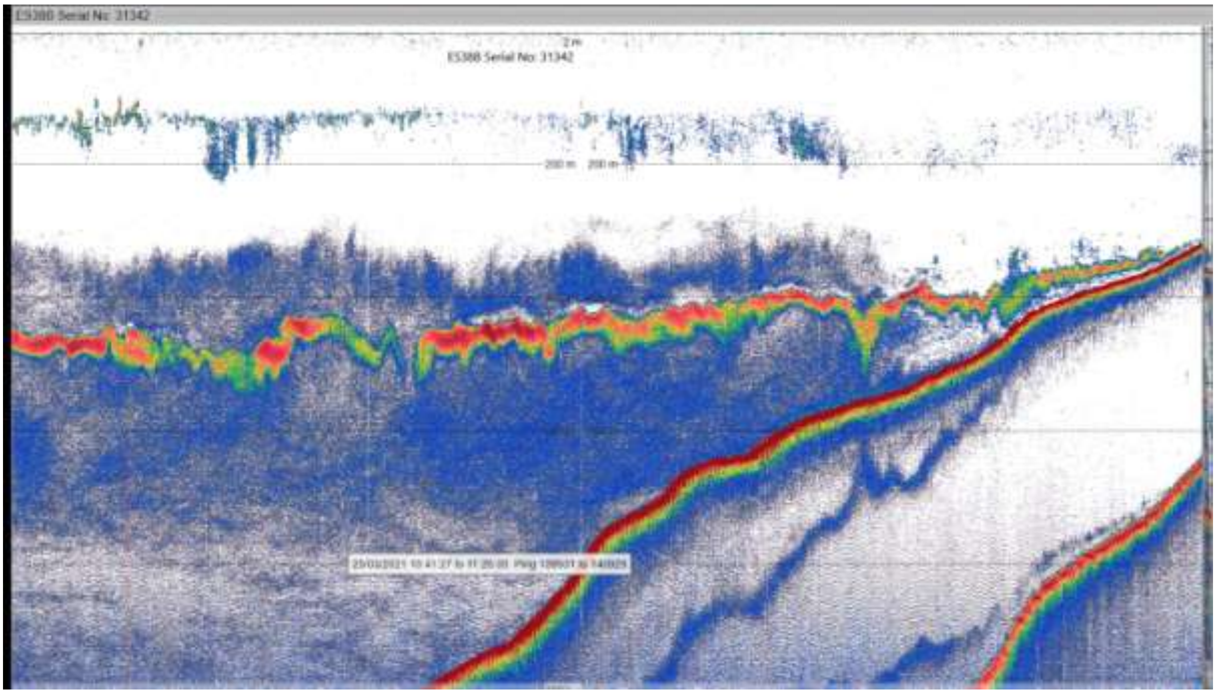
d) Weak scattering of predominantly juvenile blue whiting per 1 nmi log interval along the 400-500 m contour depth. This was an area that some of the fleet were fishing during the survey. Recorded by the RV *Celtic Explorer* in the Faroe – Shetland channel area (Stratum 6).



e) Blue whiting aggregations as observed by Tridens at the shelf edge (55.51N-9.00W). Above: without spike filtering. Below: after spike filtering. Test with spike filtering and removal of transmission loss, showed that there was no significant difference in NASC assigned to blue whiting before and after filtering (See annex 1). The weather conditions did not allow fishing.



f) Left: layer of blue whiting on Rockall Bank (*Tridens* – 19 March, haul1). Right: layer of grey gurnard on Rockall Bank (*Tridens* – 31 March, haul 11).



g) Blue whiting aggregations observed by *Tridens* at the edge of the continental shelf at 54.51N – 10.19W (25 March, haul 9).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2021. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU). All echograms presented at 38 kHz.

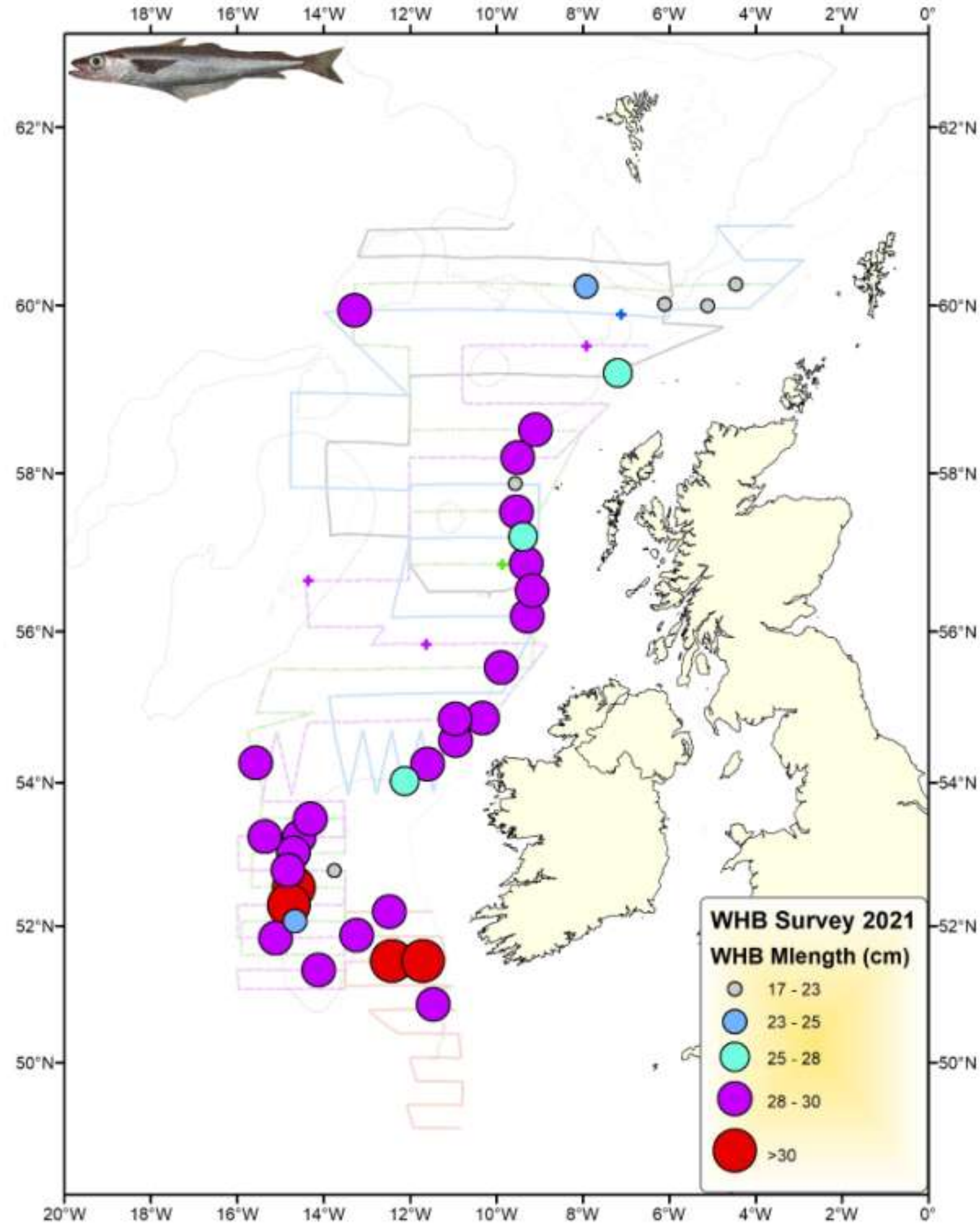


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2021. Crosses indicate hauls with zero blue whiting catches.

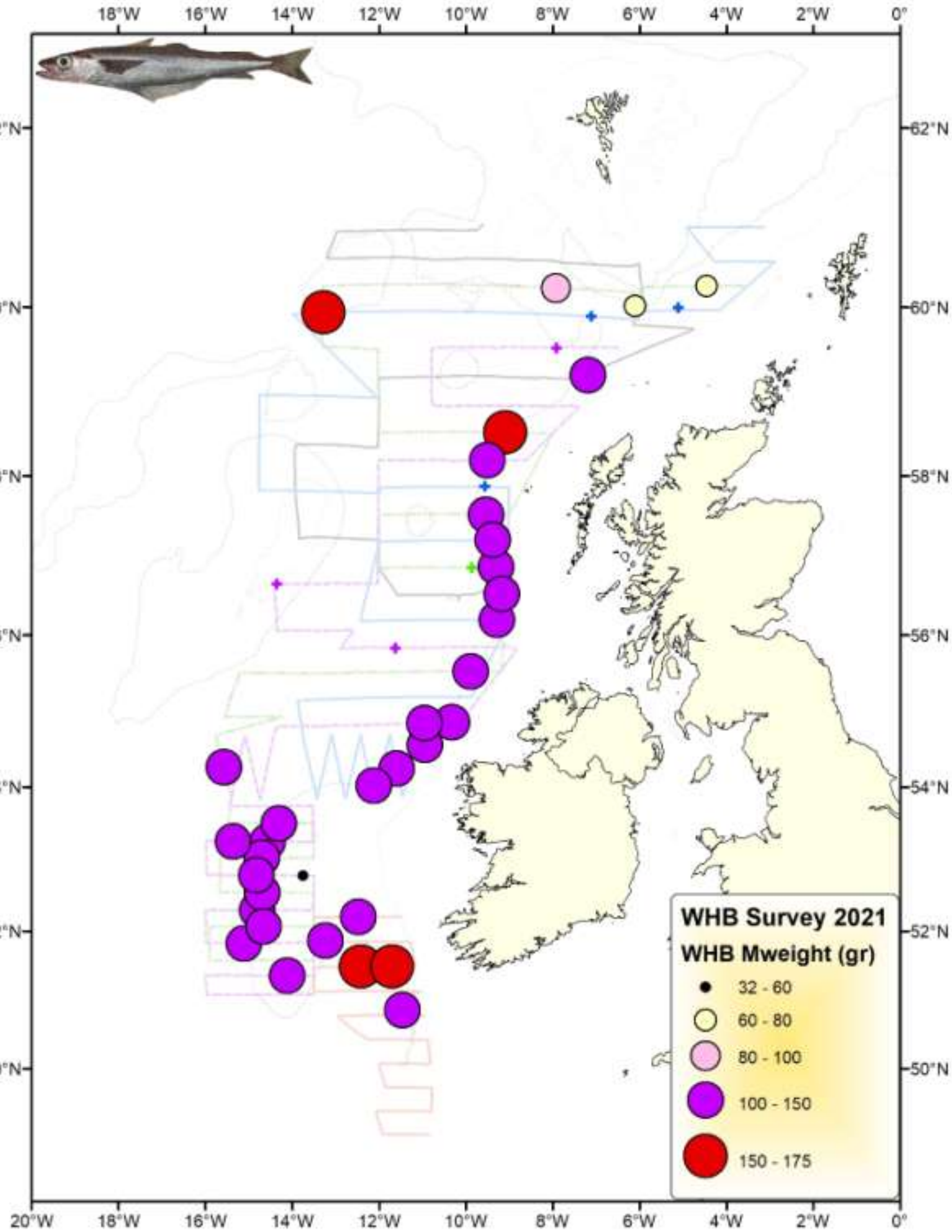


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2021. Crosses indicate hauls with zero blue whiting catches.

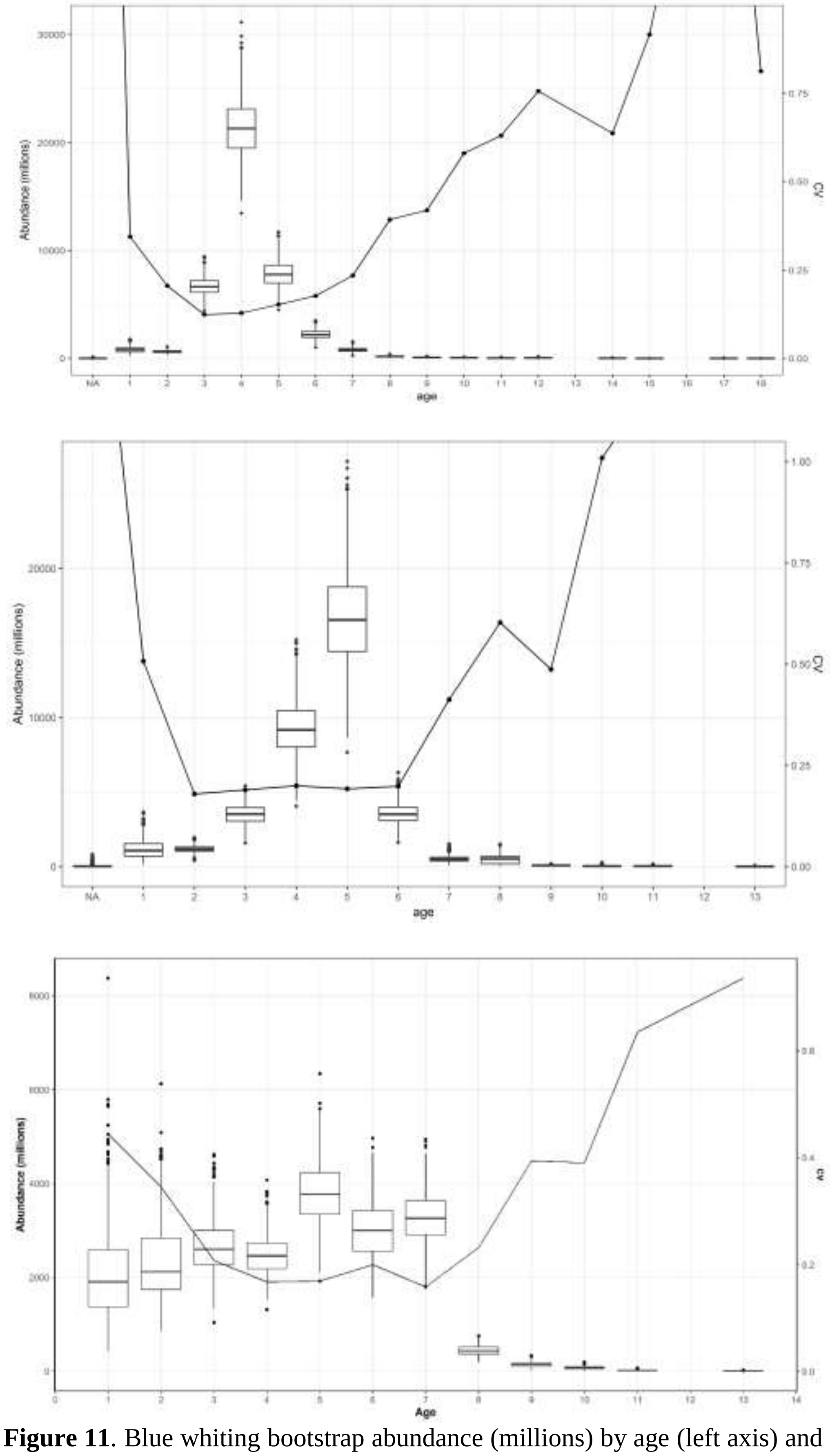


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2018 (top panel), 2019 (middle panel) and 2021 (lower panel). From StoX.

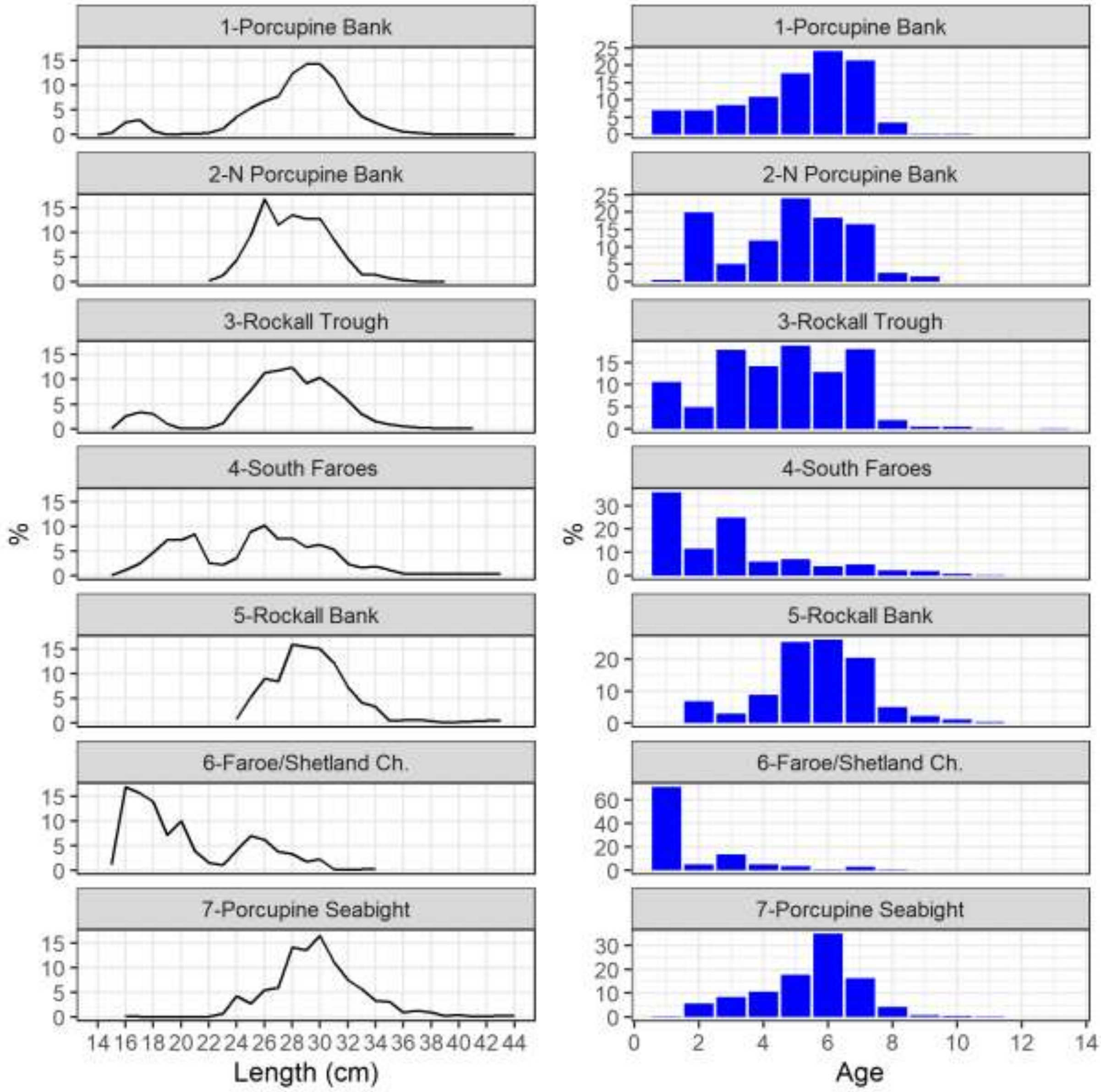


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2021.

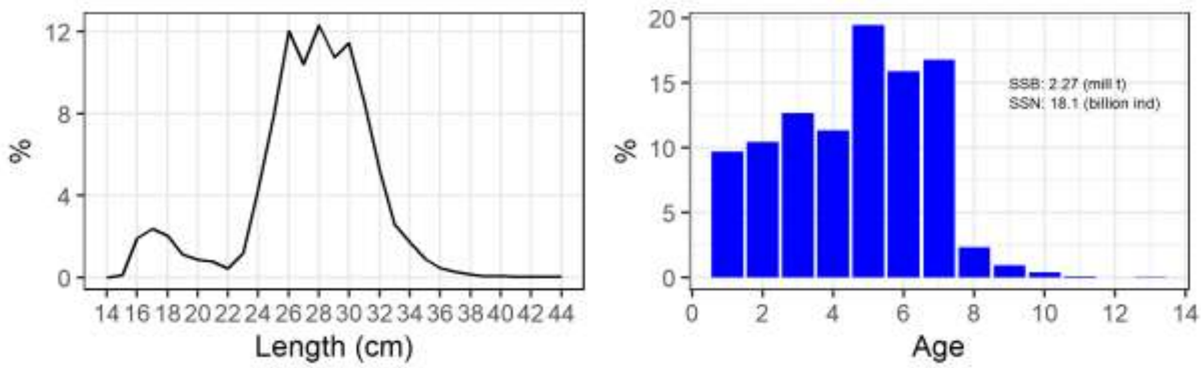


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2021.

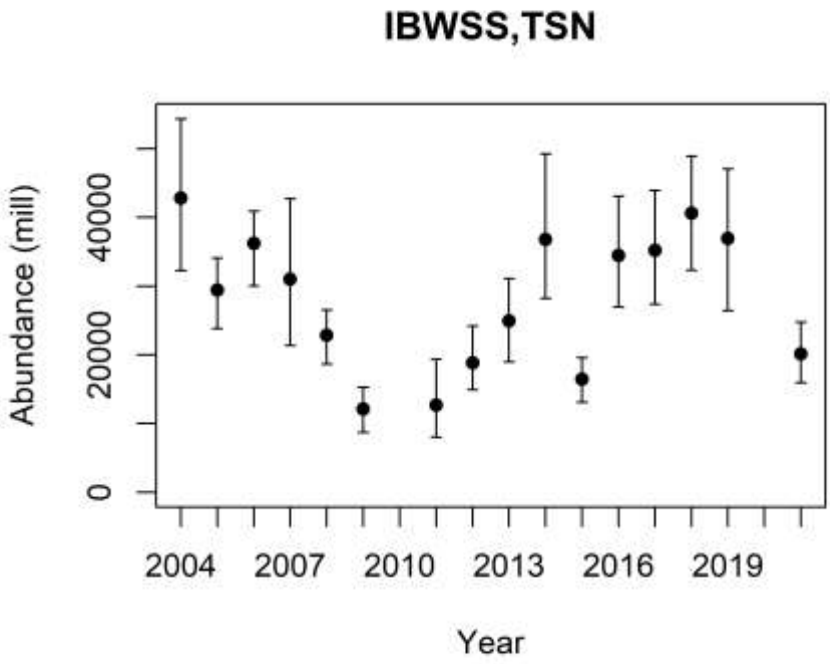


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2021, excluding 2010.

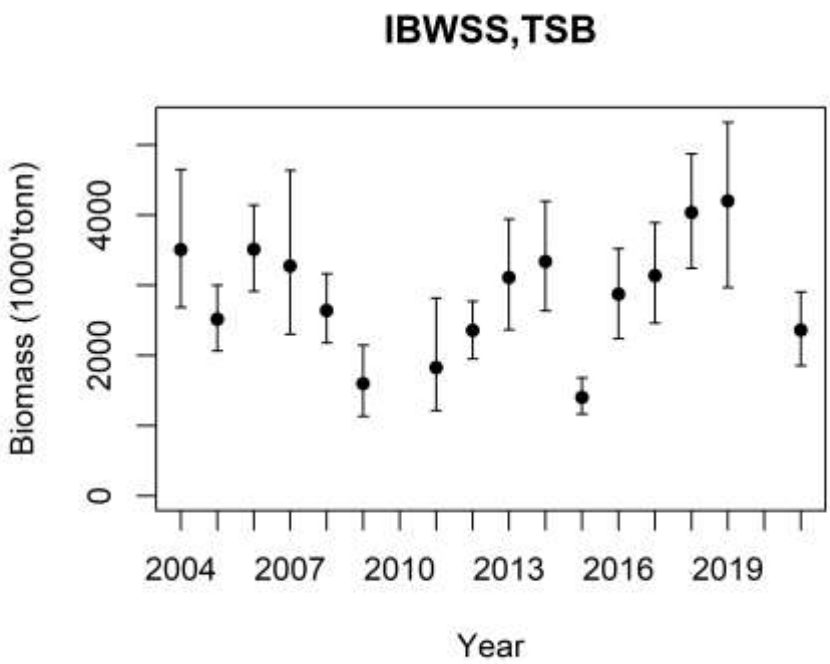


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2021, excluding 2010.

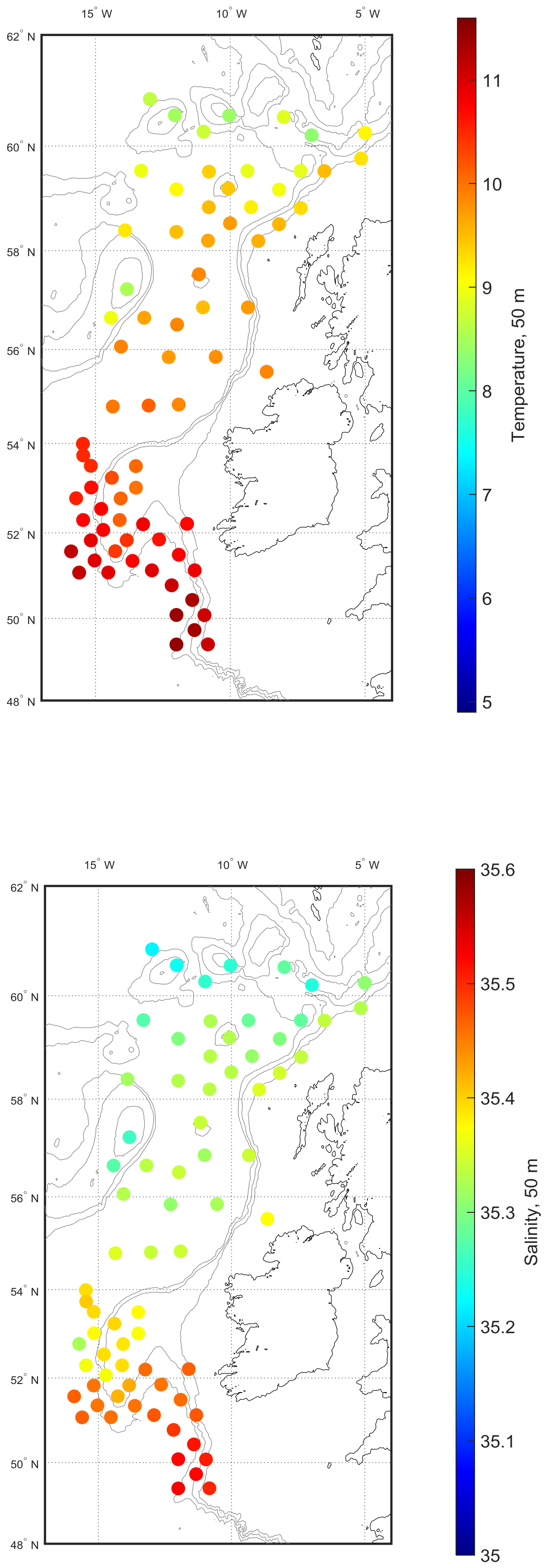


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

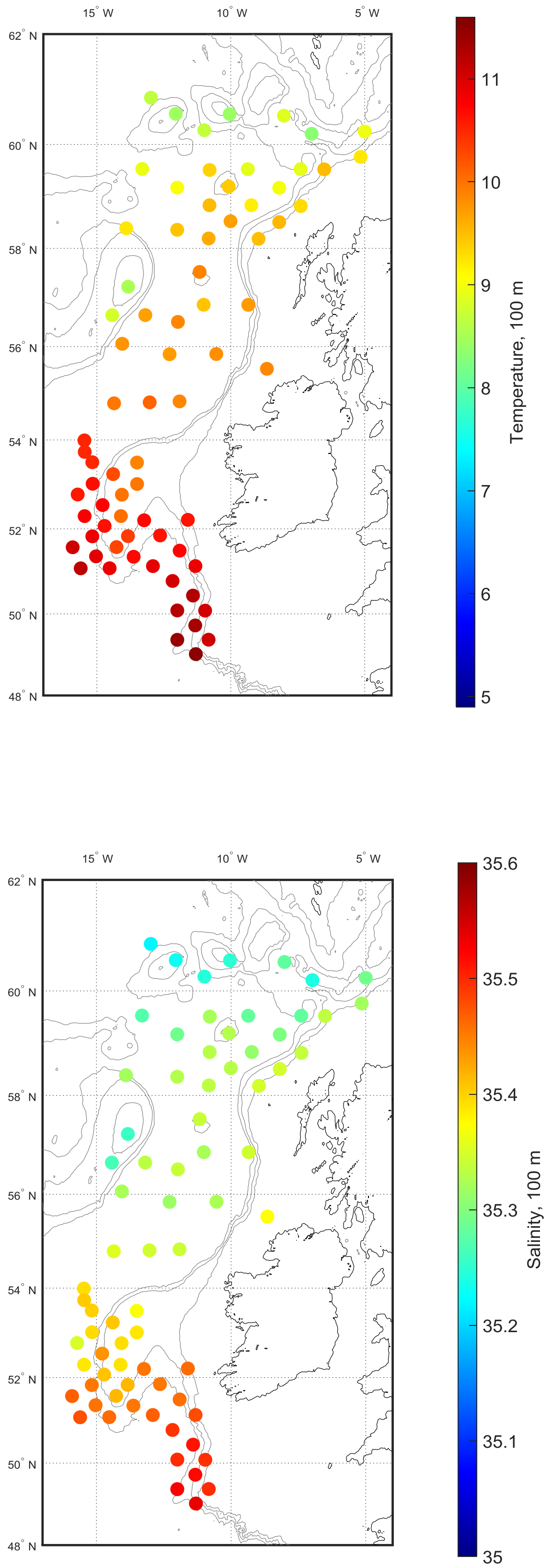


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

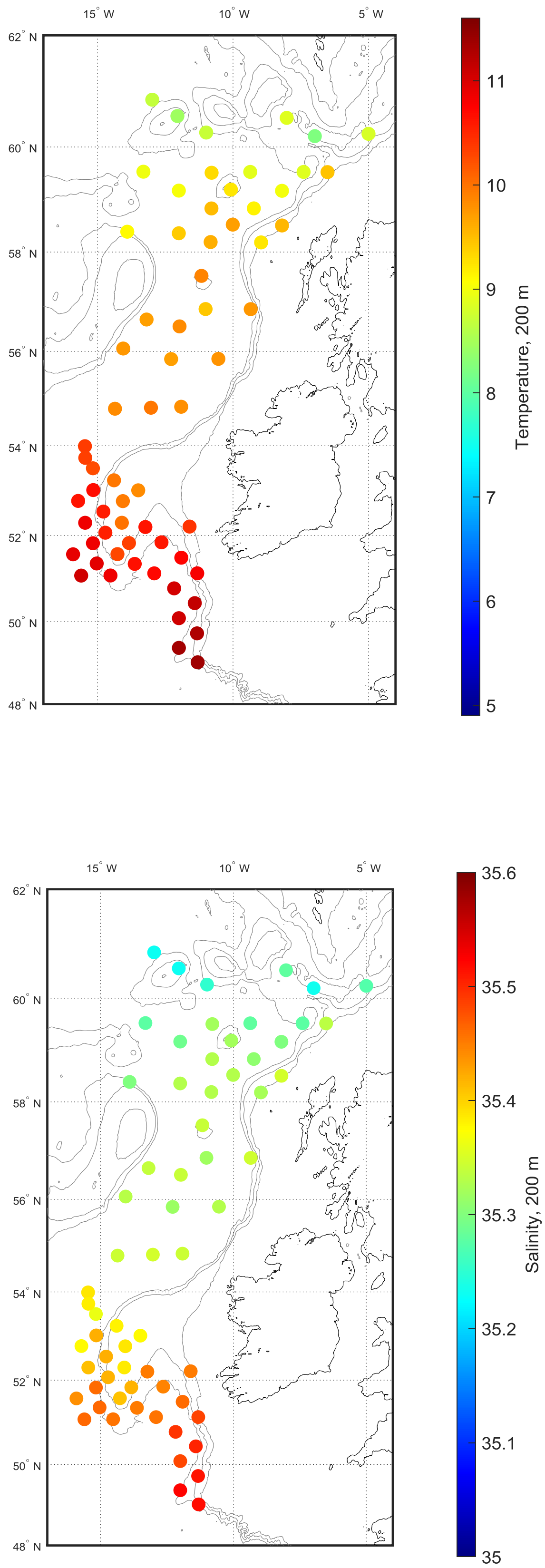


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

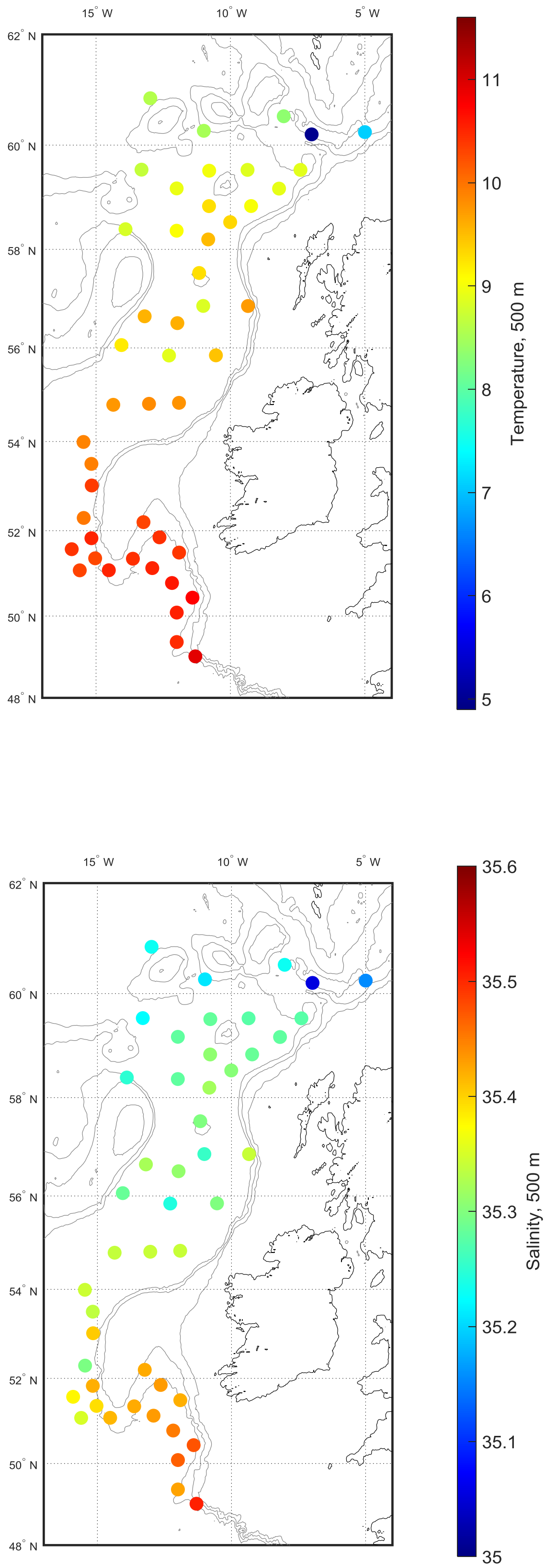


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

Annex 1 – Bad data treatment on board RV Tridens

Part of this year's survey had to be conducted during adverse weather conditions where data quality deteriorated due to vessel motion, increased bubble entrainment and increased noise levels. These factors caused the signal degradation in the form of attenuations, spikes or dropouts. Concerns were especially raised in areas where dense and large aggregations of blue whiting were observed when the weather condition was adverse. Typically, Echoview and LSSS software have generic tools to address these issues, such as noise removal tools (Dunford correction, transient or impulse noise filter) or spike filters. However, such manipulations can come with a cost of data loss or possible additional bias. To understand the effects of this adverse weather condition, a data processing exercise was carried out on board Tridens during the Survey.

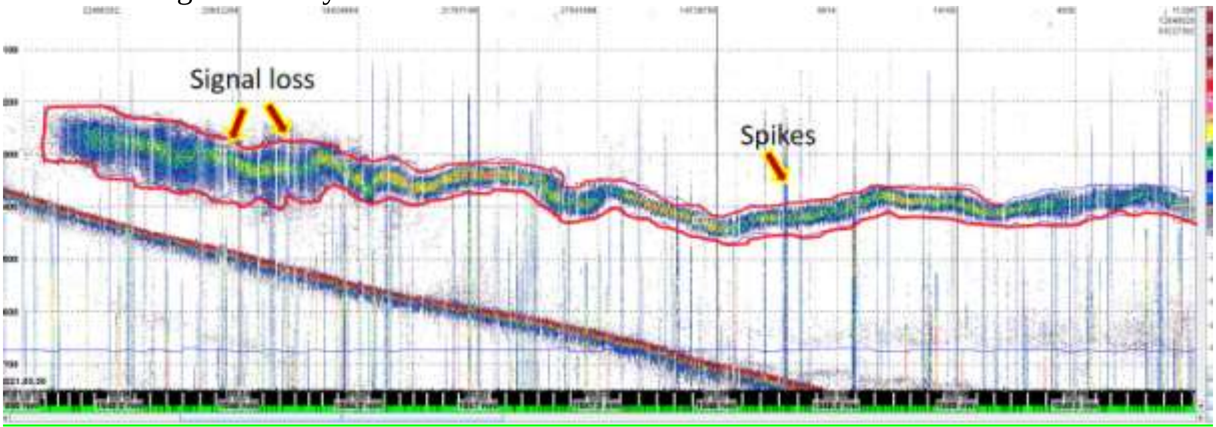


Figure 1 Dense-large aggregation of blue whiting encountered during a period of bad weather (2021 -03-30 early morning). Data contains both spike noise and transmission loss due to abrupt motion of the ship as well as bubble entrainment as a result of bad weather.

The exercise focused on a particular data set where the wind force was 7-8 Beaufort and swell height was greater than 2 m (March 30, 2021). During this time a large and dense aggregation was encountered along the transect where the acoustic recordings were subjected to signal degradation.

The effect of such signal degradation was investigated by using various methods including custom-written R-codes and postprocessing software: LSSS and Echoview. The main objective was to classify the recorded signals as "good pings" and "bad pings".

The stepwise processing procedure was as follows;

1- The aggregation was isolated by drawing a line around it.
2- Center of mass (CofMass) of the aggregation was determined per each ping (a function of Echoview that averages the sample depths weighted by sample Sv).
3- A horizontal line connecting the CofMass of each ping was created and a median smoothing filter (moving window of 21 pings) was applied.
4- A region from 5 meter above and below (10 meters in total) of this smoothed CofMass line was integrated per ping.
5- The integrated output values were grouped by 1000 consecutive pings.
6- For each of these 1000 pings a LOESS (local regression smoothing) curve was fitted based on mean Sv values. Using this fitted curve, expected values per each ping were calculated.
7- Standard deviation (SD) per each 1000 ping group was calculated.

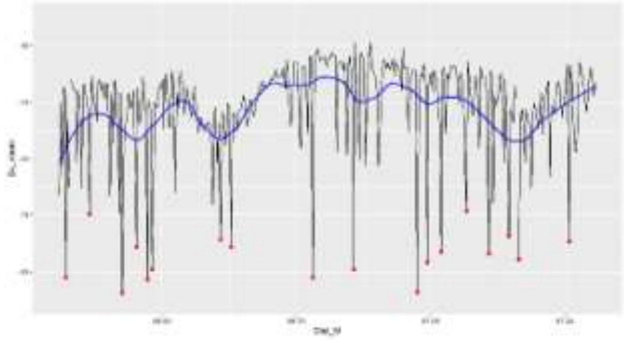
8- The predicted values were subtracted from the observed Sv values per each 1000 ping group and compared against the SD for detection of the outliers (“bad pings”).

9- For outlier-detection a stepwise approach was applied such that,

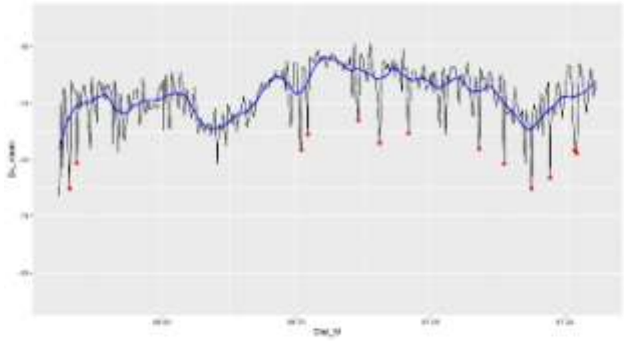
   a. 2*SD was used as a threshold. Values below -2*SD and above +2*SD standard deviations were identified as bad pings and removed from the data.

   b. After removal of bad pings, a new LOESS curve was fitted over the retained values. Again, a new standard deviation was calculated from these retained values and used as threshold for bad pings again.

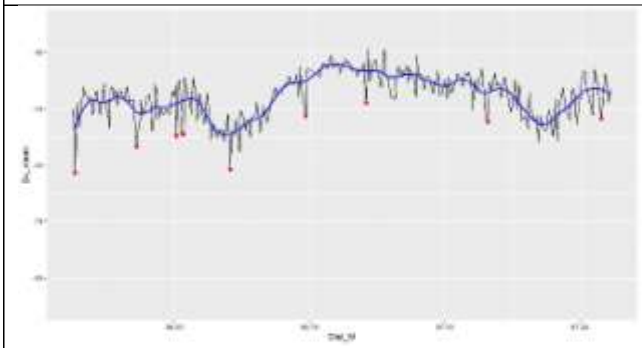
   c. Same procedure repeated over the same 1000 ping group until no more bad pings were detectable. Then the same procedure was applied to the next ping group.



Step 1



Step 3



Step 5

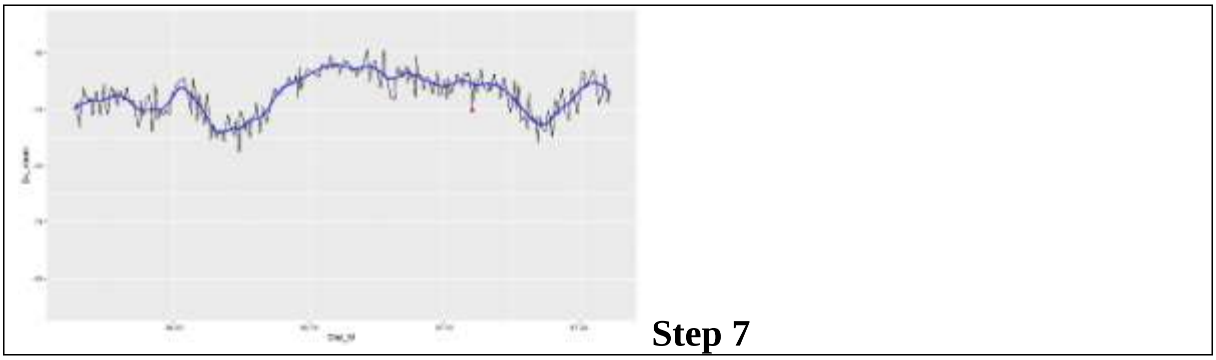


Figure 2 An example of bad ping detection for a group of 1000 pings. For this group, the procedure was finalized in 7 repetitive steps. The red dots indicate the bad pings (beyond SD threshold), the blue line is the fitted LOESS curve. The x axis is the time and the y axis is the mean Sv.

The identified bad-pings were handled in different ways by:

1- Removing all the bad pings
2- Assign bad pings with 0 values
3- Use of the mean value of the surrounding pings

In addition to this custom processing, both Echoview and LSSS has built-in spike filtering algorithms. These algorithms were also used to process separately as well. Results from these different methods were compared with non-cleaned values. The solution where all bad pings were removed resulted in a slightly higher mean Sv. And those where bad pings were assigned to “0” resulted in slightly lower values. However overall variation was less than 5% relative to the uncleaned echograms. Consequently, non-cleaned data was used for the survey calculations.

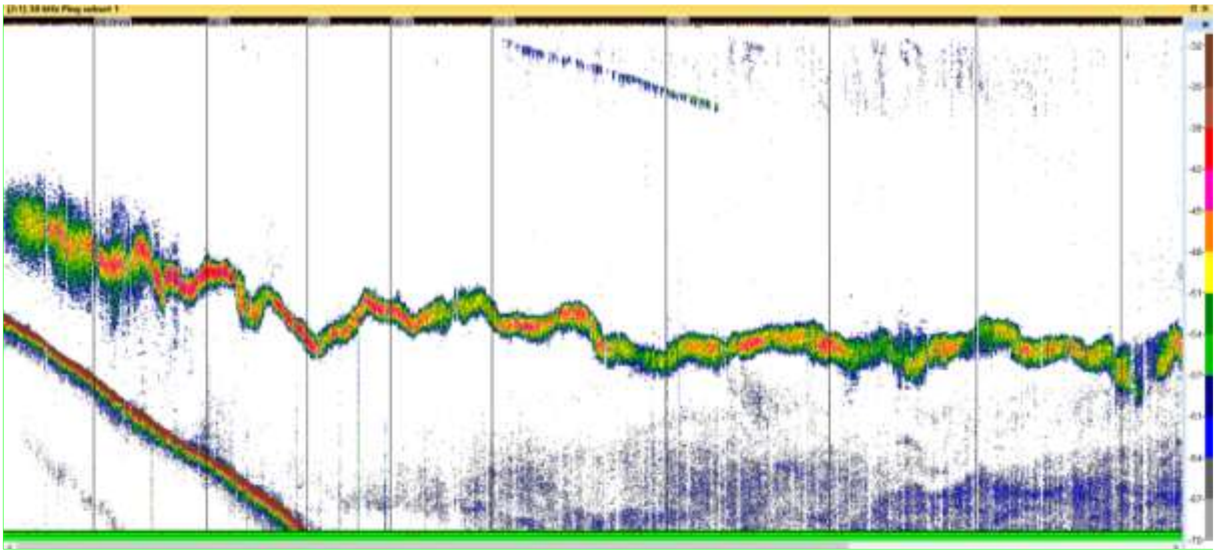


Figure 3 One of the processing solutions where all the identified bad pings were removed using the ping-subset function of Echoview. The resulting echogram looks similar to recordings in good weather.

Cruise report, RV “G.O. Sars”

Cruise no. 2021105

Mesopelagic biomass estimation and ecosystem studies, 1-30 June 2021

Institute of Marine Research, Bergen, Norway

University of Bergen, Norway

Table of Contents

1. Introduction

The cruise with R/V «G.O. Sars» started 1 June in Bergen, Norway, and ended there, 30 June. The scientific crew counted 12 scientists and 2 technical engineers (see Table 1). The cruise leader was Webjørn Melle, IMR.

The mesopelagic ecosystem is contained within the water depths between 200 and 1000 m. Mesopelagic fish resources have been assessed at 1 billion tonnes (Gjøsæter and Kawaguchi 1980) and more recently at 2-50 billion tonnes (Irigoien et al. 2014). The recent upgrade of potential biomass in the mesopelagic ecosystem has provoked interest from scientist as well as fishing companies and marine fish feed producers. The present cruise was conducted in the Iceland Basin and the Norwegian Sea from 1-30 June, starting and ending in Bergen, Norway. The main objectives were related to the mesopelagic ecosystem, but also the epipelagic ecosystem was observed to assess potential drivers of the mesopelagic biomass. Primary productivity and transport of energy to mesopelagic depths are hypothesized to be main drivers for the mesopelagic biomass, its biodiversity and vertical structure. This cruise was part of the MEESO field campaign.

During the cruise we used submersible broadband acoustics and optical sensors on the towed platform, MESSOR, to quantify abundance and biomass of mesopelagic organisms down to 1000 m. In combination with non-graded trawls with Deep Vision (cod-end camera system) and new developments in the use of acoustic models, we will improve our knowledge of mesopelagic stock's biomass and their ecological role.

The University of Bergen (Cristian Tiedemann) was responsible for the underwater light characterization. This characterization was based on *in situ* measurements of the epipelagic and a proxy method similar to that used in Aksnes et al. (2017) for the mesopelagic.

The University of Bergen, PI: Tatiana Tsagaraki, also contributed with measurements of particulate nutrients and their distribution between depths and productivity gradients. Their focus were on nutrients within the lower trophic food web, that are utilised by both autotrophic and heterotrophic plankton. This information is important both for estimating energy transfer to higher trophic levels and as a proxy of export potential. Specifically, they measured the concentration and ratios of particulate Carbon, Nitrogen, Phosphorus, Iron, Calcium, Silicon, Sulphur, Magnesium, Zinc and Manganese. Calcium and Silicon can additionally be used as proxies for calcifying (e.g. coccolithophores) and silicifying organisms (e.g. diatoms). For many of these nutrients, very little is known about their concentration in different areas and water masses.

UoB in cooperation with IMR explored the vertical carbon transport. From the surface mixed layer sinking particles are impacted by physical and biological factors, leading to fractionation, aggregation and recycling (amongst other processes) and thus modulating carbon export to the deep ocean. If diel vertically migrating fishes and zooplankton eat more of their food in the epipelagic than in the mesopelagic, they will likely contribute, via active carbon flux, to increased vertical carbon flux and sequestration. This is because the carbon ingested as food in the epipelagic is rapidly transported by swimming to mesopelagic depths.

Here, parts of this carbon are respired as CO2, excreted as DOC, defecated as POC, and consumed by stationary mesopelagic piscivores. To investigate this potentially important link to carbon sequestration, and thus climate change, we collect water samples above and below the deep scattering layers with large (100 L) Nisken bottles, called Marine Snow Catchers (MSC). The MSC, in combination with Flowcams, allows us to estimate sinking velocity and size distribution of organic particles, including marine snow and faecal pallets. We analyse these particles for their carbon content, other major elements, as well as bacterial abundances and diversity. This will allow us to get a better understanding of remineralisation rates. From vertical profiles, 0-1000 m, with Video Plankton Recorder (VPR) on MESSOR, images of marine snow were extracted and quantified and measured. In combination with sinking speeds measured with the MSCs, the total particle sinking rates were estimated.

During the cruise we collect mesopelagic species to investigate the levels of contaminants including heavy metals and persistent organic contaminants as well as nutrients such as fatty acid and amino acid profile, vitamins and minerals and bulk nutrients. Using existing regulations and recommendations, the safety of different mesopelagic species will be evaluated as food or feed and how they can contribute into nutrition security.

We also study the transfer and magnification of the measured nutrients and contaminants in the mesopelagic food webs of the North Atlantic.

The scientific personnel attending the cruise is listed in Tab. 1.

The cruise track with position of sampling stations are shown in Fig.1 and sampling stations and gears are listed in Tab. 2.

The main scientific objectives of the cruise were:

To measure abundance, biomass and diversity of the ecosystems and how it vary among ocean regions. Identify drivers of biomass.

Assess microbial loop functionality and nutrient cycling within the different water masses and depth layers

Established particulate macro and micro nutrient concentrations

Describe vertical distribution, DVM and the main drivers

Study the main flow of energy in the system (diet)

Measure active and passive carbon flux, the role of mesopelagics in active flux.

Map the hydrography, PP (chlorophyll), nutrients and oxygen distributions of the ocean

Table 1. Scientific personnel.

Name	Affiliation

Atabak Azad	Institute of Marine Research
Mette Agersted	Institute of Marine Research
Babak Khodabandeloo	Institute of Marine Research
Thor Klevjer	Institute of Marine Research
Chris Lindemann	University of Bergen
Monica Martinussen	Institute of Marine Research
Webjørn Melle (cruise leader)	Institute of Marine Research
Jon Rønning	Institute of Marine Research
Espen Strand	Institute of Marine Research
Tatiana Tsagaraki	University of Bergen
Mel Underwood	Institute of Marine Research
Rupert Wienerroither	Institute of Marine Research

2. Sampling and cruise track

A total of 67 trawl stations, 18 MESSOR tows, 14 Multinet Mammoth and 18 CTD stations were conducted. In addition we measured light (multi-spectral) and did a vertical algae net haul from 30 m to the surface at all CTD stations. At CTD stations we also collected water with Snow Catchers from several depths.

Table 2. Overview of sampling program. Details are in IMR database structures.

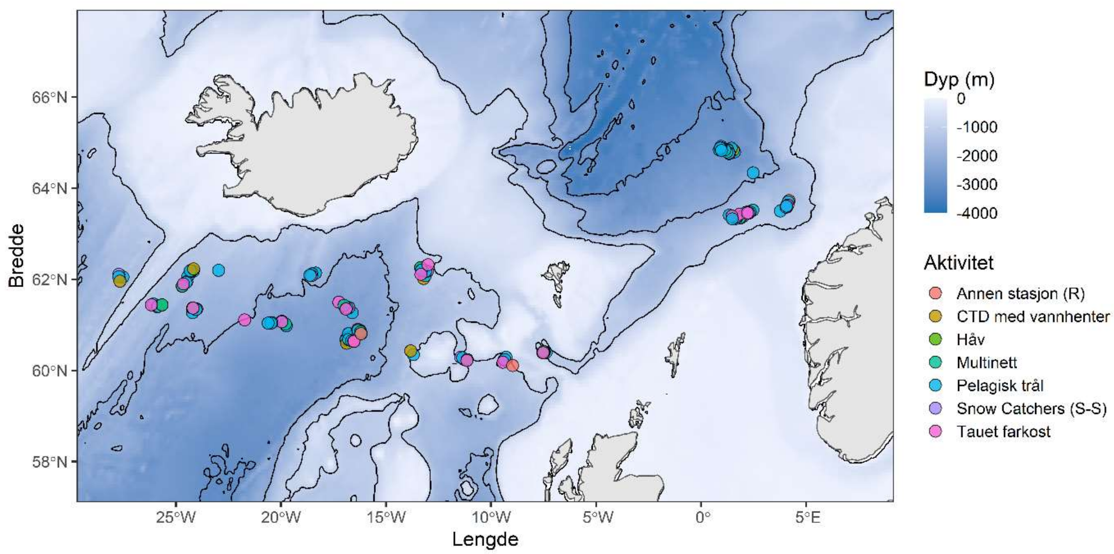
Gear	Station	Time	Latitude	Longitude
Pelagisk trål	53	03.06.2021 09:41	60.40	-7.38
Pelagisk trål	54	03.06.2021 13:36	60.39	-7.54
Annen stasjon (S-S)	163	03.06.2021 16:42	60.41	-7.46
CTD med vannhenter	163	03.06.2021 17:03	60.41	-7.47
Håv	163	03.06.2021 17:47	60.41	-7.49
Multinett	163	03.06.2021 18:21	60.42	-7.51
Tauet farkost	163	03.06.2021 20:33	60.39	-7.52
Pelagisk trål	55	04.06.2021 06:22	60.29	-9.29
Multinett	164	04.06.2021 09:59	60.23	-9.39
CTD med vannhenter	164	04.06.2021 11:17	60.23	-9.34
Annen stasjon (S-S)	164	04.06.2021 12:27	60.23	-9.34
Pelagisk trål	56	04.06.2021 13:37	60.24	-9.35
Tauet farkost	164	04.06.2021 16:16	60.18	-9.43
Annen stasjon (R)	164	04.06.2021 21:11	60.11	-8.98
Pelagisk trål	57	05.06.2021 05:48	60.24	-11.27

Annen stasjon (S-S)	165	05.06.2021 08:46	60.29	-11.45
Pelagisk trål	58	05.06.2021 11:40	60.28	-11.36
Annen stasjon (S-S)	165	05.06.2021 14:59	60.24	-11.14
CTD med vannhenter	165	05.06.2021 15:04	60.24	-11.14
Håv	165	05.06.2021 15:57	60.24	-11.14
Multinett	165	05.06.2021 16:22	60.24	-11.14
Tauet farkost	165	05.06.2021 18:14	60.22	-11.15
Pelagisk trål	59	06.06.2021 05:37	60.35	-13.70
CTD med vannhenter	166	06.06.2021 09:05	60.43	-13.83
Pelagisk trål	60	07.06.2021 05:39	60.98	-19.75
Annen stasjon (S-S)	167	07.06.2021 09:11	61.08	-19.96
CTD med vannhenter	167	07.06.2021 12:05	61.08	-19.96
Håv	166	07.06.2021 13:00	61.08	-19.96
Annen stasjon (S-S)	167	07.06.2021 13:12	61.08	-19.96
Pelagisk trål	61	07.06.2021 13:52	61.07	-19.94
Multinett	167	07.06.2021 16:43	61.02	-19.79
Tauet farkost	167	07.06.2021 19:43	61.07	-19.97
Pelagisk trål	62	08.06.2021 01:16	61.05	-20.44
Pelagisk trål	63	08.06.2021 02:39	61.04	-20.48
Pelagisk trål	64	08.06.2021 05:08	61.04	-20.62
Tauet farkost	168	08.06.2021 14:47	61.11	-21.74
Pelagisk trål	65	09.06.2021 05:19	61.27	-24.22
CTD med vannhenter	168	09.06.2021 09:11	61.35	-24.02
Annen stasjon (S-S)	168	09.06.2021 10:26	61.35	-24.02
Pelagisk trål	66	09.06.2021 12:50	61.34	-24.06
Annen stasjon (S-S)	168	09.06.2021 15:45	61.37	-24.22
Håv	168	09.06.2021 15:49	61.37	-24.22
Multinett	168	09.06.2021 16:09	61.37	-24.21
Tauet farkost	169	09.06.2021 18:08	61.37	-24.19
Pelagisk trål	67	10.06.2021 06:32	61.46	-26.08
Annen stasjon (R)	169	10.06.2021 09:42	61.40	-25.90
Pelagisk trål	68	10.06.2021 12:27	61.41	-25.86
CTD med vannhenter	169	10.06.2021 14:58	61.44	-25.67
Annen stasjon (S-S)	169	10.06.2021 16:01	61.44	-25.67
Håv	169	10.06.2021 16:13	61.44	-25.67
Multinett	169	10.06.2021 16:32	61.44	-25.67
Tauet farkost	170	10.06.2021 20:21	61.44	-26.18
Pelagisk trål	69	11.06.2021 06:32	62.05	-27.53
Annen stasjon (S-S)	170	11.06.2021 09:50	62.11	-27.73
Pelagisk trål	70	11.06.2021 12:35	62.06	-27.73
CTD med vannhenter	170	11.06.2021 16:47	61.96	-27.68
Pelagisk trål	71	12.06.2021 07:23	62.07	-24.44
Annen stasjon (S-S)	171	12.06.2021 11:24	61.95	-24.49
Pelagisk trål	72	12.06.2021 14:22	61.93	-24.53
CTD med vannhenter	171	12.06.2021 17:14	61.85	-24.71
Håv	171	12.06.2021 18:14	61.85	-24.71

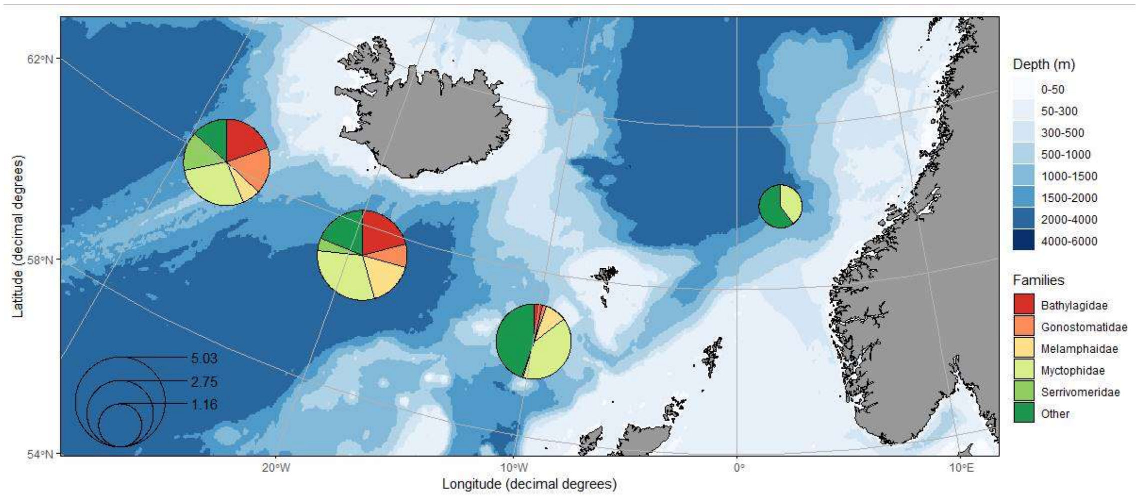
Annen stasjon (S-S)	171	12.06.2021 18:28	61.85	-24.71
Multinett	171	12.06.2021 18:54	61.85	-24.70
Tauet farkost	171	12.06.2021 20:41	61.90	-24.66
Pelagisk trål	73	13.06.2021 02:45	62.18	-24.18
Pelagisk trål	74	13.06.2021 03:38	62.18	-24.27
Pelagisk trål	75	13.06.2021 07:01	62.19	-24.33
CTD med vannhenter	172	13.06.2021 09:30	62.23	-24.17
Pelagisk trål	76	13.06.2021 14:21	62.20	-22.98
Pelagisk trål	77	14.06.2021 07:33	62.14	-18.36
Pelagisk trål	78	14.06.2021 10:15	62.14	-18.36
Pelagisk trål	79	14.06.2021 12:32	62.12	-18.53
CTD med vannhenter	173	14.06.2021 14:18	62.08	-18.56
Håv	172	14.06.2021 15:14	62.08	-18.56
Annen stasjon (S-S)	173	14.06.2021 15:31	62.08	-18.56
Pelagisk trål	80	14.06.2021 16:34	62.09	-18.63
Tauet farkost	172	14.06.2021 23:25	61.50	-17.25
Pelagisk trål	81	15.06.2021 06:44	61.27	-16.61
Annen stasjon (S-S)	174	15.06.2021 10:08	61.38	-16.77
CTD med vannhenter	174	15.06.2021 12:37	61.38	-16.77
Annen stasjon (S-S)	174	15.06.2021 13:46	61.38	-16.77
Pelagisk trål	82	15.06.2021 14:45	61.38	-16.86
Multinett	174	15.06.2021 17:46	61.43	-17.01
Tauet farkost	174	15.06.2021 20:34	61.35	-16.91
Pelagisk trål	83	16.06.2021 08:35	60.75	-16.65
Pelagisk trål	84	16.06.2021 10:13	60.73	-16.78
Annen stasjon (S-S)	175	16.06.2021 12:11	60.69	-16.90
Pelagisk trål	85	16.06.2021 14:53	60.67	-16.91
CTD med vannhenter	175	16.06.2021 17:25	60.60	-16.88
Pelagisk trål	86	17.06.2021 08:39	60.81	-16.79
Pelagisk trål	87	17.06.2021 13:30	60.68	-16.79
Pelagisk trål	88	17.06.2021 16:08	60.65	-16.64
Annen stasjon (R)	175	17.06.2021 18:06	60.64	-16.54
Tauet farkost	175	17.06.2021 20:41	60.64	-16.53
Pelagisk trål	89	18.06.2021 01:48	60.88	-16.24
Pelagisk trål	90	18.06.2021 08:25	60.81	-16.19
Annen stasjon (R)	176	18.06.2021 11:32	60.90	-16.35
Pelagisk trål	91	18.06.2021 13:09	60.88	-16.34
Multinett	175	18.06.2021 16:19	60.85	-16.21
Annen stasjon (R)	176	18.06.2021 18:24	60.81	-16.19
CTD med vannhenter	176	19.06.2021 05:04	62.02	-13.21
Pelagisk trål	92	19.06.2021 07:05	62.08	-13.14
Annen stasjon (S-S)	176	19.06.2021 10:17	62.18	-13.03
Pelagisk trål	93	19.06.2021 13:40	62.18	-13.11
Pelagisk trål	94	19.06.2021 16:12	62.23	-13.28
Annen stasjon (R)	176	19.06.2021 18:02	62.26	-13.36
Håv	176	19.06.2021 18:13	62.26	-13.36

Multinett	176	19.06.2021 18:29	62.26	-13.36
Pelagisk trål	95	19.06.2021 20:21	62.20	-13.32
Tauet farkost	176	19.06.2021 23:26	62.11	-13.34
Tauet farkost	177	20.06.2021 03:53	62.32	-13.01
CTD med vannhenter	177	23.06.2021 04:38	63.59	4.04
Pelagisk trål	96	23.06.2021 06:24	63.63	4.09
Annen stasjon (R)	177	23.06.2021 09:17	63.73	4.19
Pelagisk trål	97	23.06.2021 11:32	63.70	4.15
Håv	177	23.06.2021 15:04	63.61	4.09
Annen stasjon (S-S)	177	23.06.2021 15:30	63.61	4.09
Multinett	177	23.06.2021 15:52	63.61	4.09
Pelagisk trål	98	23.06.2021 17:42	63.59	4.08
Tauet farkost	178	23.06.2021 20:40	63.63	4.13
Pelagisk trål	99	24.06.2021 01:13	63.50	3.78
Annen stasjon (S-S)	178	24.06.2021 05:54	63.59	4.04
Pelagisk trål	100	24.06.2021 09:21	63.61	4.07
Pelagisk trål	101	24.06.2021 17:32	64.34	2.48
Pelagisk trål	102	25.06.2021 00:40	64.80	1.59
CTD med vannhenter	178	25.06.2021 04:32	64.84	1.53
Pelagisk trål	103	25.06.2021 06:24	64.88	1.44
Annen stasjon (S-S)	178	25.06.2021 09:54	64.85	1.26
Pelagisk trål	104	25.06.2021 11:36	64.83	1.28
Håv	178	25.06.2021 14:05	64.76	1.34
Annen stasjon (S-S)	178	25.06.2021 14:18	64.76	1.34
Pelagisk trål	105	25.06.2021 15:07	64.78	1.32
Multinett	178	25.06.2021 16:35	64.80	1.23
Pelagisk trål	106	25.06.2021 18:44	64.84	1.13
Pelagisk trål	107	26.06.2021 01:00	64.92	0.95
Pelagisk trål	108	26.06.2021 04:56	64.84	0.87
Annen stasjon (S-S)	178	26.06.2021 06:32	64.89	0.94
Pelagisk trål	109	26.06.2021 09:11	64.88	0.92
Pelagisk trål	110	26.06.2021 11:13	64.83	0.97
Pelagisk trål	111	26.06.2021 22:29	63.38	1.93
Pelagisk trål	112	27.06.2021 01:00	63.40	2.05
CTD med vannhenter	179	27.06.2021 03:49	63.35	1.88
Pelagisk trål	113	27.06.2021 05:01	63.35	1.83
Annen stasjon (S-S)	179	27.06.2021 08:01	63.34	1.64
Pelagisk trål	114	27.06.2021 09:36	63.34	1.68
Pelagisk trål	115	27.06.2021 11:41	63.34	1.67
Håv	179	27.06.2021 13:07	63.37	1.60
Annen stasjon (S-S)	179	27.06.2021 13:21	63.37	1.60
Tauet farkost	179	27.06.2021 14:10	63.37	1.66
Annen stasjon (S-S)	179	27.06.2021 18:13	63.48	2.20
Pelagisk trål	116	27.06.2021 19:19	63.47	2.14
Tauet farkost	179	27.06.2021 23:00	63.43	1.83
Pelagisk trål	117	28.06.2021 04:52	63.52	2.47

Multinett	179	28.06.2021 06:58	63.48	2.34
Annen stasjon (S-S)	180	28.06.2021 08:42	63.46	2.27
CTD med vannhenter	180	28.06.2021 10:12	63.46	2.27
Annen stasjon (S-S)	180	28.06.2021 11:00	63.46	2.27
Annen stasjon (S-S)	180	28.06.2021 11:33	63.46	2.27
Tauet farkost	180	28.06.2021 12:46	63.46	2.21
Pelagisk trål	118	28.06.2021 19:15	63.41	1.34
Multinett	180	28.06.2021 20:59	63.39	1.47
Tauet farkost	180	28.06.2021 23:24	63.39	1.47
Pelagisk trål	119	29.06.2021 01:06	63.33	1.49

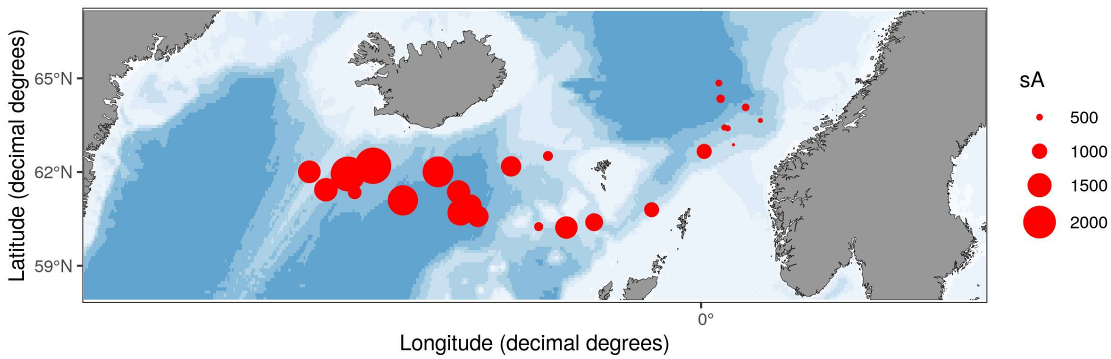


Cruise map.



Preliminary results, average biomass of mesopelagic fish (0-1000 m) across the surveyed areas of the North Atlantic, from trawl catches. Areas of circles are proportional to biomass densities in g WW m⁻

[2]. The 5 dominating families of fish colour coded in the pies, with all remaining (39) families grouped in "Other". (Melle et al., upublisert).



Preliminary results: Daytime average 38 kHz mesopelagic (200-1000 m) backscatter along the cruisetrack. Point radius is proportional to average daytime backscattering levels 200 – 1000 m.

Date	Lon	Lat	Day_sA	Nite_sA
02/06/2021	−4.23	60.72	979	1063
03/06/2021	−7.34	60.40	1144	1254
04/06/2021	−9.38	60.23	1408	1859
05/06/2021	−11.19	60.24	636	498
06/06/2021	−15.56	60.57	1345	1150
07/06/2021	−19.28	60.94	NA	NA
08/06/2021	−20.68	61.08	1858	2026
09/06/2021	−24.12	61.30	901	1955
10/06/2021	−26.40	61.55	1468	NA
11/06/2021	−26.96	61.99	1422	1187
12/06/2021	−24.69	62.00	2123	1769
13/06/2021	−22.85	62.19	2211	1909

14/06/2021	−18.32	61.96	1893	1552
15/06/2021	−16.81	61.34	1456	1177
16/06/2021	−16.82	60.72	1397	1216
17/06/2021	−16.75	60.80	1633	1147
18/06/2021	−15.83	60.99	1447	1215
19/06/2021	−13.30	62.11	1288	1336
20/06/2021	−9.13	62.56	692	915
21/06/2021	−0.72	62.67	987	647
22/06/2021	NA	NA	NA	NA
23/06/2021	4.03	63.61	406	590
24/06/2021	2.95	64.12	557	414
25/06/2021	1.23	64.87	509	475
26/06/2021	1.37	64.28	602	673
27/06/2021	1.87	63.40	463	533
28/06/2021	1.96	63.45	471	478
29/06/2021	1.88	63.17	299	428

Table 2: Preliminary results: Daily average mesopelagic (200-1000 m) nautical area scattering values along the cruise.

3. References

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Acoustic surveying of Maurolicus muelleri in the Bay of Biscay:

JUVENA 2021 Survey Report

By

AZTI, Instituto Tecnológico Pesquero y Alimentario, Pasaia, SPAIN.

1. Abstract

The survey JUVENA aims at estimating the abundance of the pelagic community, with emphasis on anchovy juvenile population as an early estimator of recruitment, with trawl-acoustic methodology in the Bay of Biscay at the end of the summer every year. This survey also provides data of acoustic abundance of the mesopelagic species such as *Maurolicus muelleri*. The survey took place in two research vessels: the Angeles Alvariño and the Emma Bardán. It took place between the 2021-08-16 and the 2021-10-04 (see Table 2). The survey sampled around 2500 n.mi. that provided a coverage of about 37,500 n.mi.^{2} along the continental shelf and shelf break of the Bay of Biscay, from the 7º30' W in the Cantabrian area up to 47º 56' N at the French coast (Figure 1). 92 hauls were done during the survey to identify the species detected by the acoustic equipment. Regarding mesopelagic species, 23 hauls were positive for pearlside and 3 for glacier lantern fish (*Benthosema glaciale*) (Figure 2, Tables 3, 4, 5 and 6). Some specimens of the latter have been occasionally collected in the area in previous year, but compared to 2021 their presence has been insignificant. Mean total length of pearlside was 2.68 (±0.711) cm, ranged from 1.99 cm to 5.51 cm and the total weight varied from 0.069 g to 1.36 g. Mean total length for glacier lantern fish was 7.18 (±1.16) cm, with a minimum of 3.20 cm and a maximum of 9.75 cm and the total weight varied from 0.28 g to 12 g. Pearlside is the second most abundant specie in the area. The biomass estimated for 2021 is around 220, 000 tonnes, which represents a medium estimation in the series. Most of the acoustic biomass of pearlside was detected in

ocean waters (76%), while shelf account for only 14% of total. The acoustic biomass of glacier lantern fish has not been calculated as its echoes in the echogram are not known.

2. Materials and Methods

2.1 Data acquisition

The survey JUVENA 2021 took place onboard the chartered R/V Angeles Alvariño and the R/V Emma Bardán, both equipped with scientific echosounders. The acoustic equipment included three split beam echo sounders Simrad EK60/80 (Kongsberg Simrad AS, Kongsberg, Norway; Table 1) calibrated using Standard procedures (Foote *et al.* 1987). In the Angeles Alvariño, the 18, 38, 70, 120 and 200 kHz transducers were installed looking vertically downwards, 6.5 m deep, at the drop keel, and the 333 kHz was installed in a lateral perch, vertically oriented. At the R/V Emma Bardan the 38, 120 and 200 kHz transducers were installed at the hull (3 m depth), plus a 120 and 200 kHz transducer horizontally oriented. For acoustic data processing the Echoview software was used.

The water column was sampled to depths of 400 m. Acoustic back-scattered energy by surface unit (S_A, MacLennan *et al.* 2002) was recorded for each geo-referenced ESDU (Echointegration Sampling Distance Unit) of 0.1 nautical mile (185.2 m). Fish identity and population size structure was obtained from fishing hauls and echotrace characteristic using a pelagic trawl (Table 1). Acoustic data, thresholded to -60 dB, was processed using Echoview for biomass estimation and the processed data was represented in maps using R. Hydrographic recording was made with CTD casts.

Sampling strategy

The sampling area covered the waters of the Bay of Biscay (being 7º30' W and 47º56' N the limits, Figure 1). Sampling started from at Southern part of the sampling area, the Cantabrian Sea, moving gradually to the North to cover the waters in front of the French Coast. The acoustic sampling was preferably performed during the daytime.

The vessels followed parallel transects, spaced 15 n.mi., perpendicular to the coast along the sampling area, taking into account the expected spatial distribution of anchovy juveniles for these dates, that is, crossing the continental shelf in their way to the coast from offshore waters (Uriarte et al. 2001; Boyra et al., 2016).

Details of the sampling design and data analysis can be found in Boyra et al., 2013 and Boyra, 2016.

Data analysis

Biological processing

Each fishing haul was classified to species and a random sample of no more than 100 specimens for each species was measured to produce size frequencies of the communities under study. In those positive hauls for mesopelagic fish a sub-sample 100 individuals maximum were taken, and stored to be analysed in the laboratory at AZTI.

Acoustic data processing

Acoustic data processing was performed by layer echo-integration by 0.1 nautical mile (s_A) of the first 65 m of the water column with Movies+ software, after noise filtering and bottom correction, increasing or decreasing this range when the vertical distribution of juveniles made it necessary.

The hauls were grouped by strata of homogeneous species and size composition. Inside each of these homogeneous strata, the echo-integrated acoustic energy s_A was assigned to species according to the composition of the hauls. Afterwards, the energy corresponding to each specie-size was converted to biomass using their corresponding conversion factor.

Each fish species has a different acoustic response, defined by its scattering cross section that measures the amount of the acoustic energy incident to the target that is scattered backwards. This scattering cross section depends upon specie *i* and the size of the target *j*, according to:

$$\sigma_{ij} = 10^{TS_j/10} = 10^{\{(a_i + b_i \log L_j)/10\}}$$

Here, L_j represents the size class, and the constants a_i and b_i are determined empirically for each species.

For pearlside and glacier lantern fish, we have used the following TS to length relationship (Yoon et al 1999):

$$TS_i = -71.4 + 20 \log L_i$$

The composition by size and species of each homogeneous stratum is obtained by averaging the composition of the individual hauls contained in the stratum, being the contribution of each haul weighted to the acoustic energy found in its vicinity (2 nm of diameter). Thus, given a homogeneous stratum with M hauls, if E_k is the mean acoustic energy in the vicinity of the haul k, w_i, the proportion of species i in the total capture of the stratum, is calculated as follows:

$$w_i = \sum_j w_{ij} = \sum_j \left(\frac{\sum_{k=1}^{M} \left(q_{ijk} \cdot E_k \big/ Q_k \right)}{\sum_{k=1}^{M} E_k} \right).$$

Being q_{ijk} the quantity (in mass) of species i and length j in the haul k; and Q_k, the total quantity of any species and size in the haul k.

Inside each homogeneous stratum, we calculated a mean scattering cross section for each species, by means of the size distribution of such specie obtained in the hauls of the stratum:

$$\langle \sigma_i \rangle = \frac{\sum_j w_{ij} \sigma_{ij}}{w_i}.$$

Let s_A be the calibration-corrected, echo-integrated energy by ESDU (0.1 nautical mile). The mean energy in each homogeneous stratum, $E_m =< s_A >$, is divided in terms of the size-species composition of the haul of the stratum. Thus, the energy for each species, E_i, is calculated as:

$$E_i = \frac{w_i \langle \sigma_i \rangle E_m}{\left(\sum_i w_i \langle \sigma_i \rangle \right)}$$

Here, the term inside the parenthesis sums over all the species in the stratum. Finally, the number of individuals F_i of each species is calculated as:

$$F_i = H \cdot l \frac{E_i}{\langle \sigma_i \rangle}$$

Where *l* is the length of the transect or semi-transect under the influence of the stratum and *H* is the distance between transect (about 15 n.mi.). To convert the number to biomass, the size-length ratio obtained in each stratum is applied to obtain the average weight of the juveniles in the stratum:

$$< W_i >= a \cdot < L_i >^b$$

Thus, the biomass is obtained by multiplying F_i times $< W_i >$.

The mean weight for pearlside and glacier lantern fish was obtained from the length at weight relationship established by: Rasmussen and Giske, 1994 (W [g] = $9 \cdot 10^{-3}$ *$L^{3.03}$ [cm]) and AZTI, 2020 (W [g] = $5.7 \cdot 10^{-3}$ *$L^{3.36}$ [cm]) respectively
.

3. Results and discussion

3.1 Checking and calibrations

Calibration of the EB was performed in Pasaia during the first days of the survey following the sphere method (Foote et al. 1987). The calibration of the AA was done also at the beginning of the survey inside the ria de Pontevedra, in Galicia. The intercalibration between vessels was done on September 18th along 40 n.mi. The result showed similar acoustic values for both vessels.

3.2 Sampling coverage

The survey JUVENA 2021 took place between the 2021-08-19 and the 2021-10-04 (see Table 2). The survey sampled around 2500 n.mi. that provided a coverage of about 37,500 n.mi.2 along the continental shelf and shelf break of the Bay of Biscay, from the 7º30' W in the Cantabrian area up to 47º 56' N at the French coast (Figure 1). 92 hauls were done during the survey to identify the species detected by the acoustic equipment, 23 of which were positive for mesopelagic species (Figure 2, Tables 3, 4).

The survey was covered by both vessels in coordination, in the Spanish region both vessels followed alternate transects, while in the French part they concentrated the sampling effort of each vessel in the most appropriate areas according to their efficiency: this is, oceanic and slope waters for the AA and continental shelf for the smaller pelagic trawler EB (Figure 1).

Species size frequency distribution of mesopelagic species

The total length of 1903 pearlsides and 202 glacier lantern fishes were recorded from 23 and 3 positives haul stations repectively. Measures were taken by half-cm. The mean total length of pearlside was 2.68 (±0.711) cm, ranged from 1.99 cm to 5.51 cm (Figure 3) and the total weight varied from 0.069 g to 1.36 g. For glacier lantern fish the mean total weight was 7.18 (±1.16) cm, with a minimum at 3.20 cm and a maximum at 9.75 cm (Figure 3). Size frequency distributions by haul for both species are presented in Figures 4 and 5 respectively. For *M. muelleri* most of samples consisted of small specimens with unimodal distributions at a TL of 3 cm or lower, except for samples 9006 and 9204 with modes above this value. Only at station 9202 a two-modal distribution was observed. The dominance of juveniles of pearlside in September in the Bay of

Biscay has been observed regularly since 2016, although their abundance can vary annually depending on annual changes in natural mortality rates in these early stages (eggs, larvae and juveniles).

Size distribution of glacier lantern fish was clearly unimodal with the mode at 6 cm TL. According to length at age growth curves estimated from data collected in northern areas (personal communic.) all individual captured in the survey were adults ranged from 3 to 6 years old.

3.3 Spational distributrion of biomass

Spatial distribution of pearlside (*Maurolicus muelleri*) and other species.

As usual, pearlside was distributed off and at the outer shelf in both the Spanish and French coasts (Figure 7).The biomass was over 220,000 tones (Table 5) the second most abundant species after anchovy (Table 6), most of them located in ocean waters (75.6% of the total including the cap-breton area) or shelf break (10.5%) (Figures 7 and 10). This value represents a medium estimation in the series (Figure 8). Regarding the spatial distribution of the mean size per fishing haul (Figure 6), the larger individuals seem to be preferentially located on the shelf or closer to the shore, while the younger ones are distributed throughout the area.

The mean length and weight seem to be in the lower end of the typical observed range (Figure 9). This difference with respect to other years can be interpreted in two ways; the first hypothesis is that most of the individuals born at the "peak" of the spawning of the species did not survive and the juveniles that have survived in September come from a late spawning (July, for instance) and have not yet had time to grow more. Alternatively, it could also be that these surviving September juveniles were indeed born at the "peak" of the spawning in May, but their growth rates were so low that they reached September with these very reduced sizes. The former hypothesis appears to be the most likely, as natural mortality rates of low-growing individuals have been found to be higher due to their greater accessibility as prey for a wider range of other fish (as faster as better recruitment theory).

As for the glacier lantern fish, its presence in the BoB was reduced to 3 positive hauls located in ocean waters (Figure 6). This species it known to have a deeper and outer distribution compared to that of the pearlside. In the JUVENA surveys the presence of this species is rare, likely because the survey coverage is strongly constrained to the presence of juveniles anchovy, which is characterized by a shelf and inshore distribution. Additionally, the sampling depth of the net in the water column hardly extent beyond 400 m depth, whereas the vertical distribution of *B. glaciale* is usually deeper.

Anchovy juvenile was located off-the-shelf or in the outer part of the shelf in the first layers of the water column (Figure 10). The area of distribution this year was among the highest in the temporal series, but with small size and low density.

Sardine was distributed all along the French shelf (Figure 10) increasing its spatial distribution area with respect to the previous years.

Horse mackerel was found in very small quantities and small sizes along with juvenile anchovy in surface aggregations in the inner shelf of the coast of Landes (Figure 10).

Mackerel was found in very small quantities and sizes of ~23 cm along the French coast (Figure 10).

Spratt was poorly observed this year. The mean length and weight seem to have decreased slightly since last year following a long-term decreasing trend (Figure 10).

3.4 Environmental conditions

The observed oceanographic conditions showed different regional patterns for surface salinity and temperature (Figure 11). Surface salinity had values below 35 in the center of the Bay of Biscay around Cap Ferret, increasing towards the north and west. The surface temperature showed a combination of two patterns, a warming gradient from coast to ocean plus a cooling gradient with increasing latitude. The SE of the Bay had higher (~ 22ºC) temperature and lower (~ 34-34.5) salinity, while at the north and west of the Bay the temperature decreased 4ºC and salinity increased in one unit.
The geostrophic velocity described a well-defined high-velocity front of about 12 cm/s along the Cantabrian shelf, while the French coast presented velocities below 8 cm/s. Right in the centre of the Bay of Biscay, in oceanic waters, a peak of high velocities was described (12 cm/s).

4. Conclusions

- Good general performance of the equipment and different acoustic configurations for different tasks-scenarios.
- The survey maintains or even increases its recently acquired multi-species and ecological scope
- The biomass estimates of this year (~220, 000 tones) is a medium abundance respect to the JUVENA series, slightly above the mean of the series.
- This year juvenile pearlside covered a great area of the Bay of Biscay, but preferentially in ocean waters
- For the first time, the captures of glacier lantern fish were significant in the area, and were located in ocean waters. They all seem to be 3 to 6 year old adults.
- The juvenile abundance value foresees a medium recruitment level for next year.

5. Acknowledgements

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7. Figures

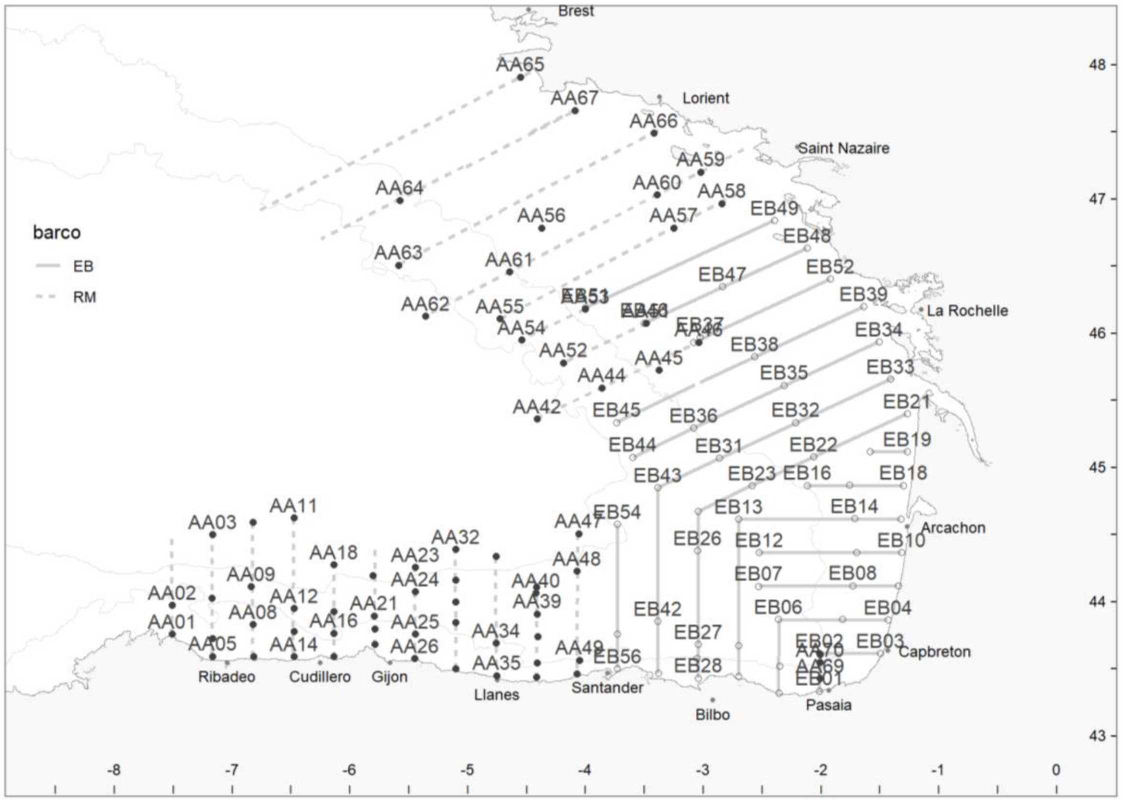

Figure 1. Visited transects and stations of hydrography/plankton. Hauls performed by Angeles Alvariño are indicated by AA are the transects are marked with dashed lines; hauls performed in the Emma Bardan are indicated by EB and the transects are marked with solid lines.

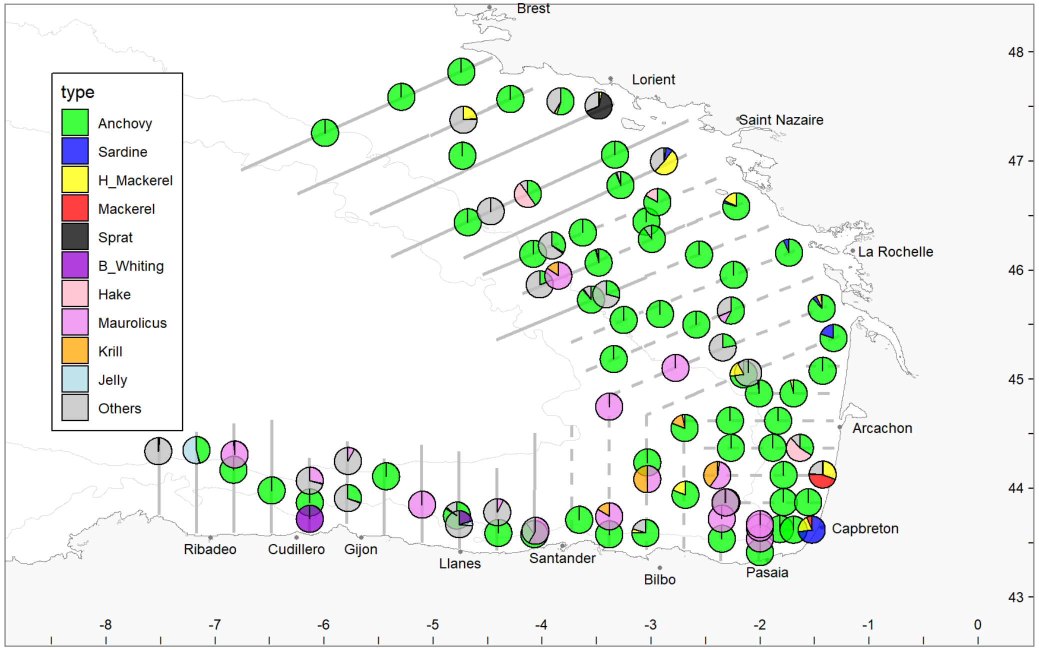

Figure 2. Composition of hauls. The pie charts show the percentage of species in the fishing hauls.

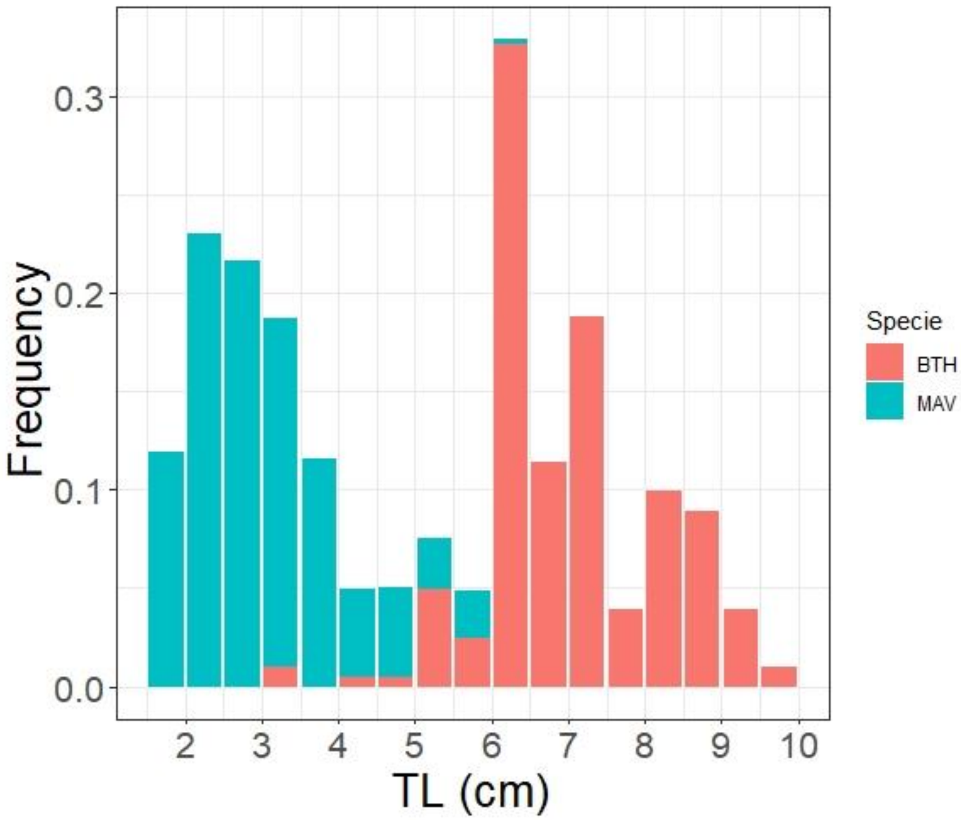

Figure 3: Length frequency distribution (expressed in time one) of *M. muelleri* (MAV) and *B. glacile* (BTH) in Agust-Septembre 2021.

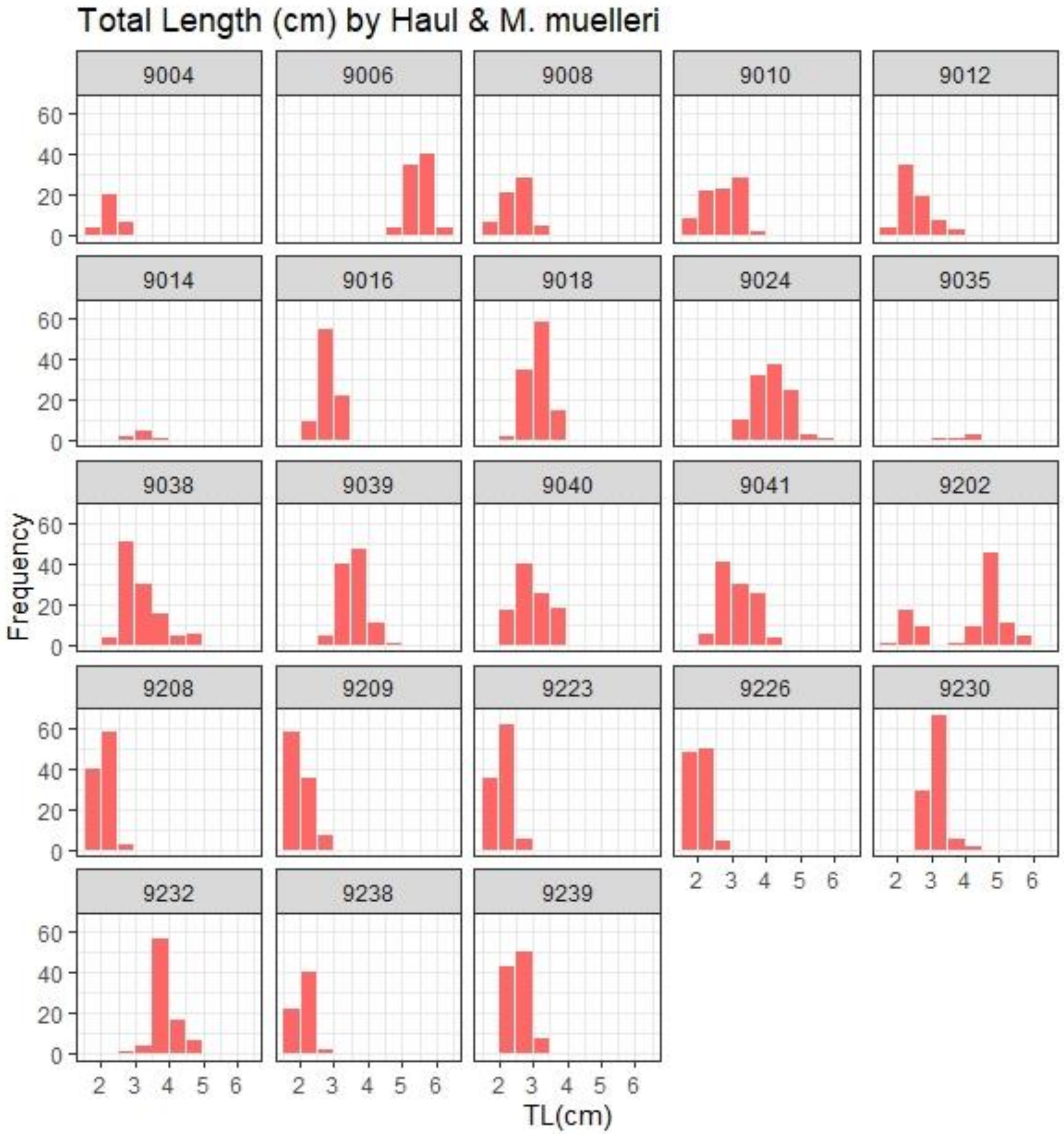
Total Length (cm) by Haul & M. muelleri
9004
9006
9008
9010
9012
9014
9016
9018
9024
9035
9038
9039
9040
9041
9202
9208
9209
9223
9226
9230
9232
9238
9239
Frequency
0
20
40
60
2
3
4
5
6
TL(cm)

Figure 4: Length frequency distribution of pearlside by fishing haul.

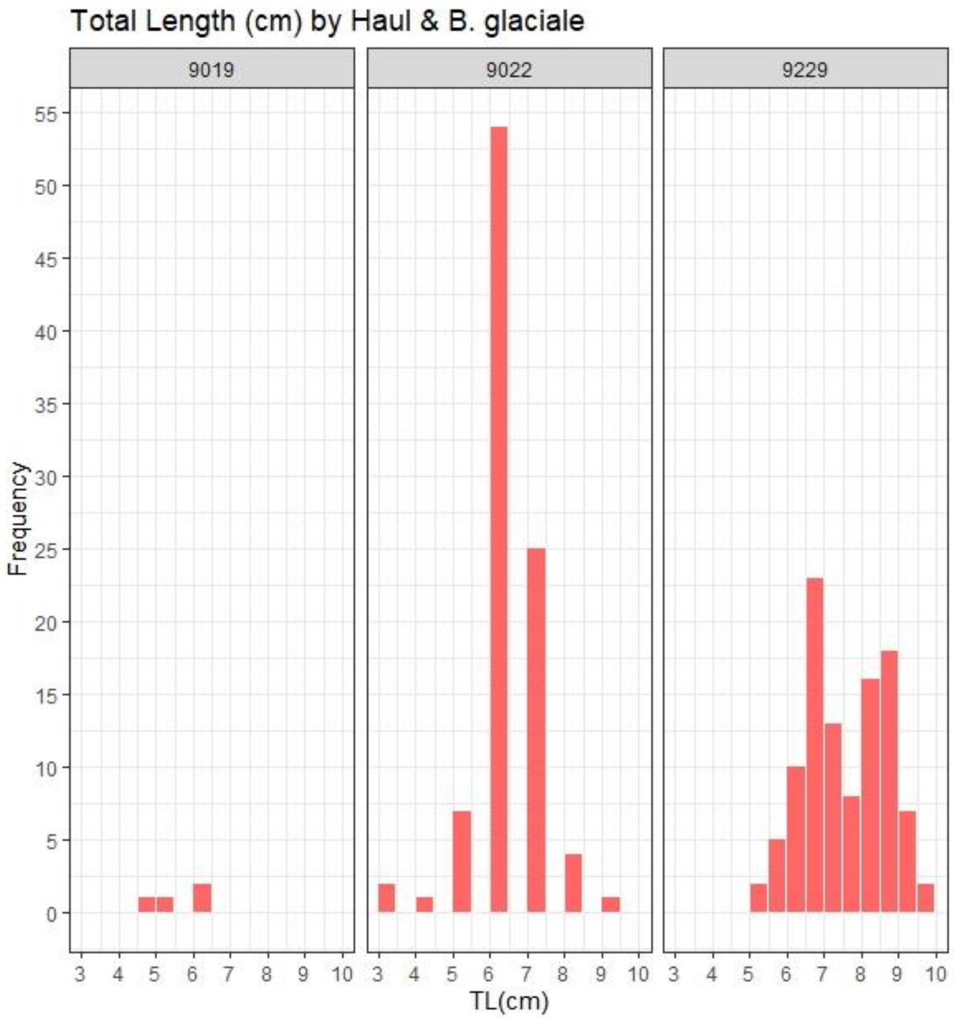

Figure 5: Length frequency distribution of glacier lantern fish by fishing haul.

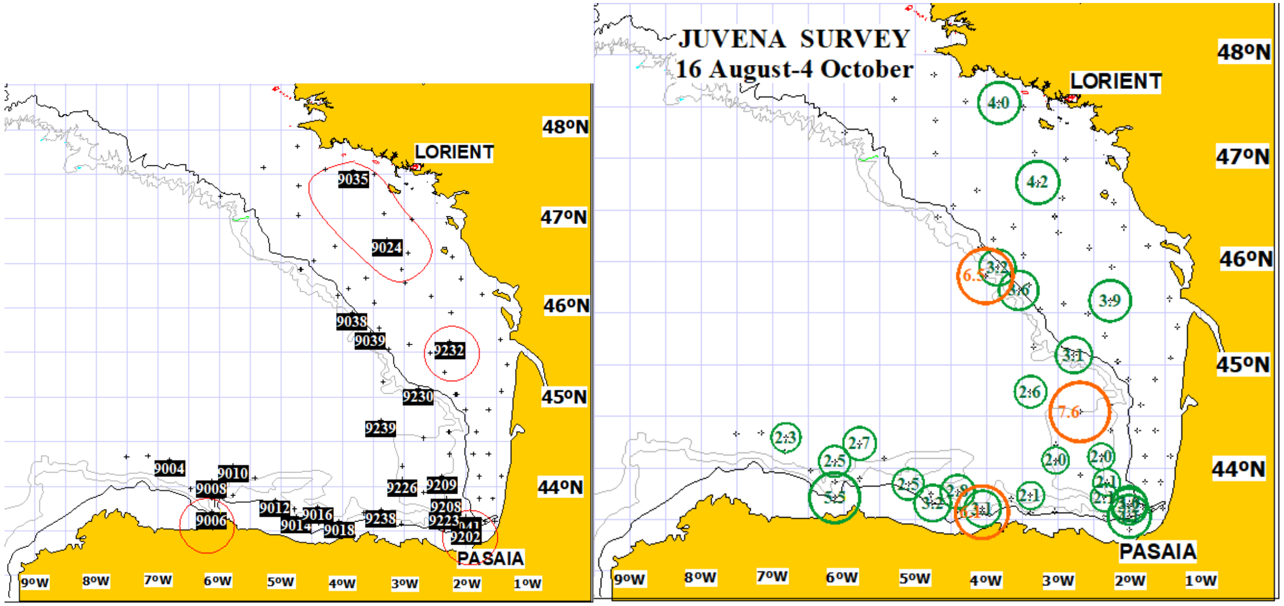

Figure 6. (Left) Position of the positive fishing stations for M. muelleri. Hauls performed by AA are numbered from 9001 to 9034 and hauls performed in the EB are numbered from 9201 to 9244. In red are marked the stations with the highest mean sizes for this species. (Right) Size of the M. muelleri (green circle) and B. glaciale (red circle) in the positive hauls. The size of the circle is proportional at the mean of the total length of the species.

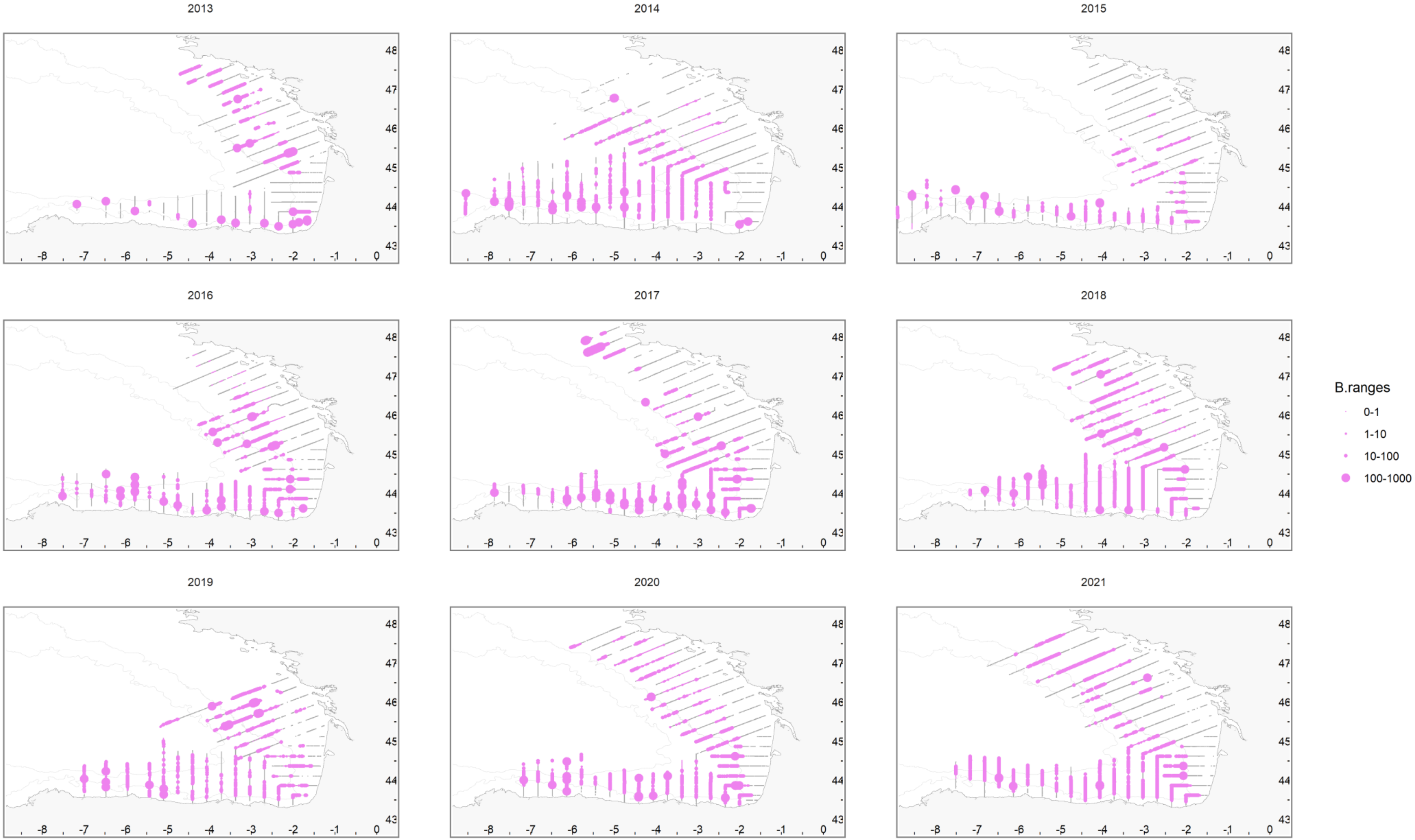

Figure 7: Spatial distribution and acoustic NASC energy of pearlside in the Bay of Biscay according to the JUVENA survey.

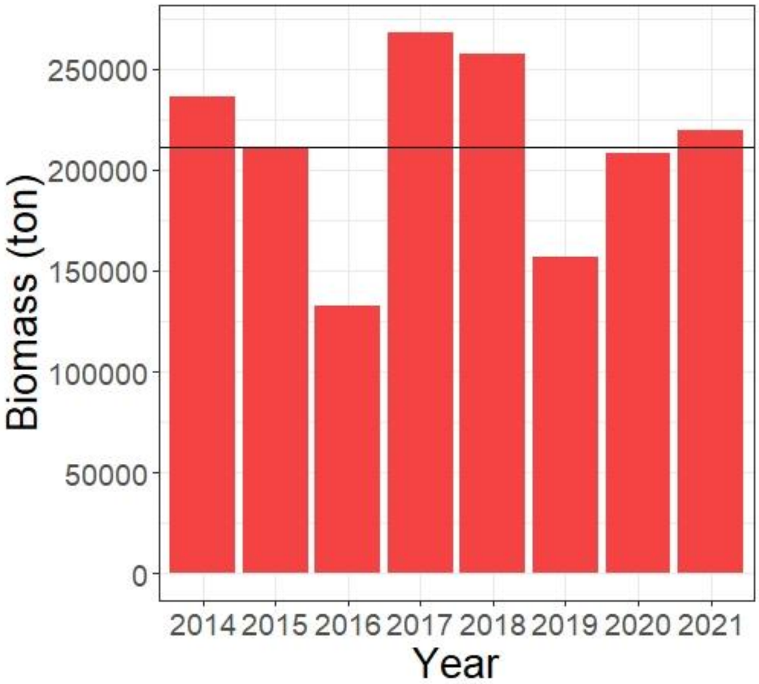

Figure 8: Temporal series of the estimated abundances of pearlside. Horizontal black line shows the mean biomass of the time series.

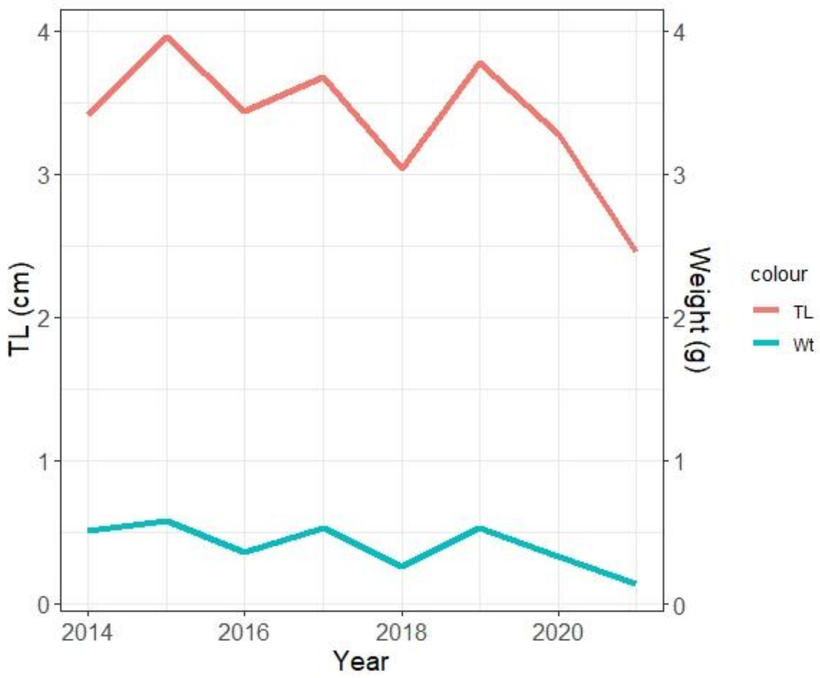

Figure 9: Temporal series of length (cm, red line) and weight (g, blue line) of pearlside.

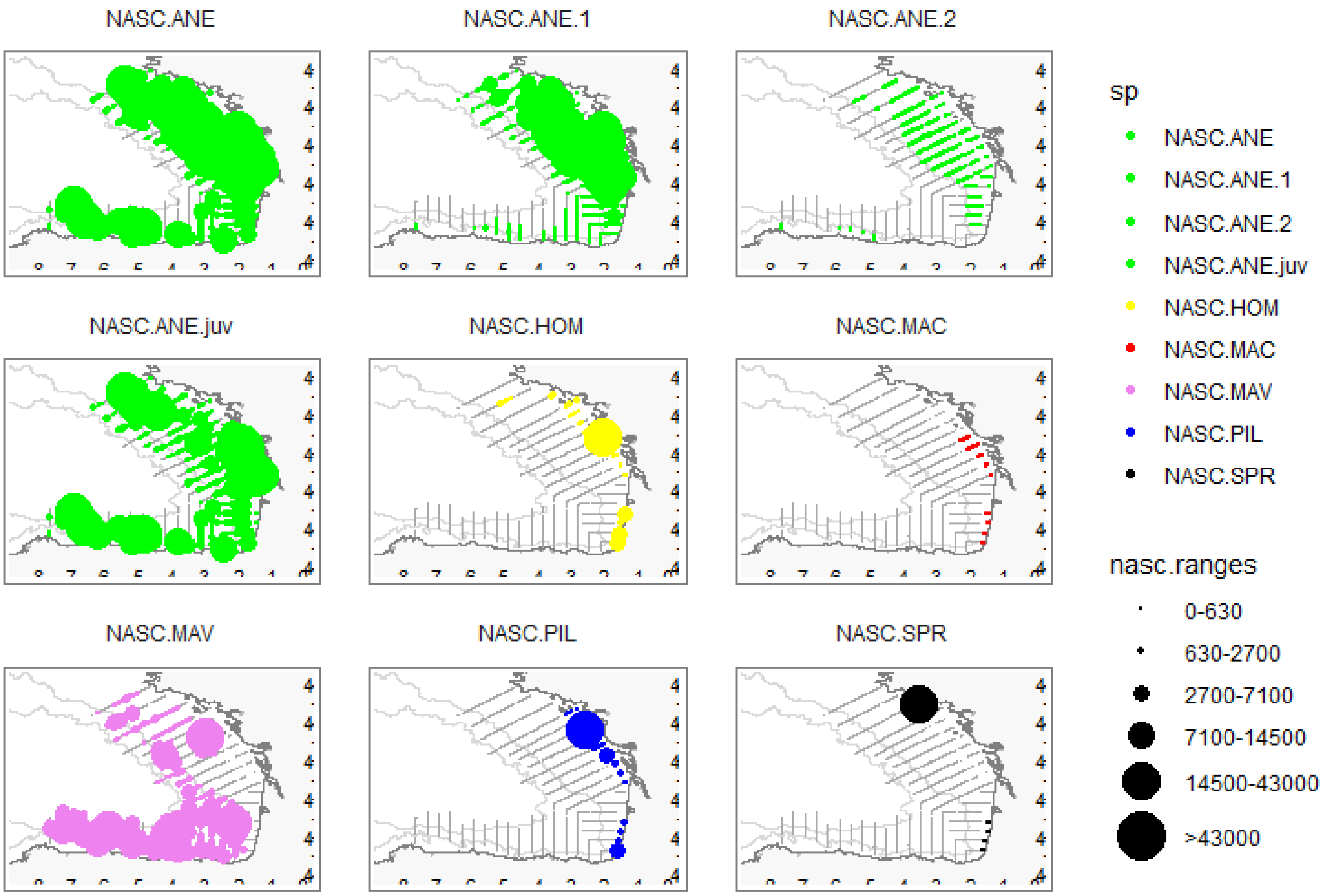

Figure 10 : Spatial distribution and acoustic NASC energy of fish species in the Bay of Biscay according to the JUVENA survey.

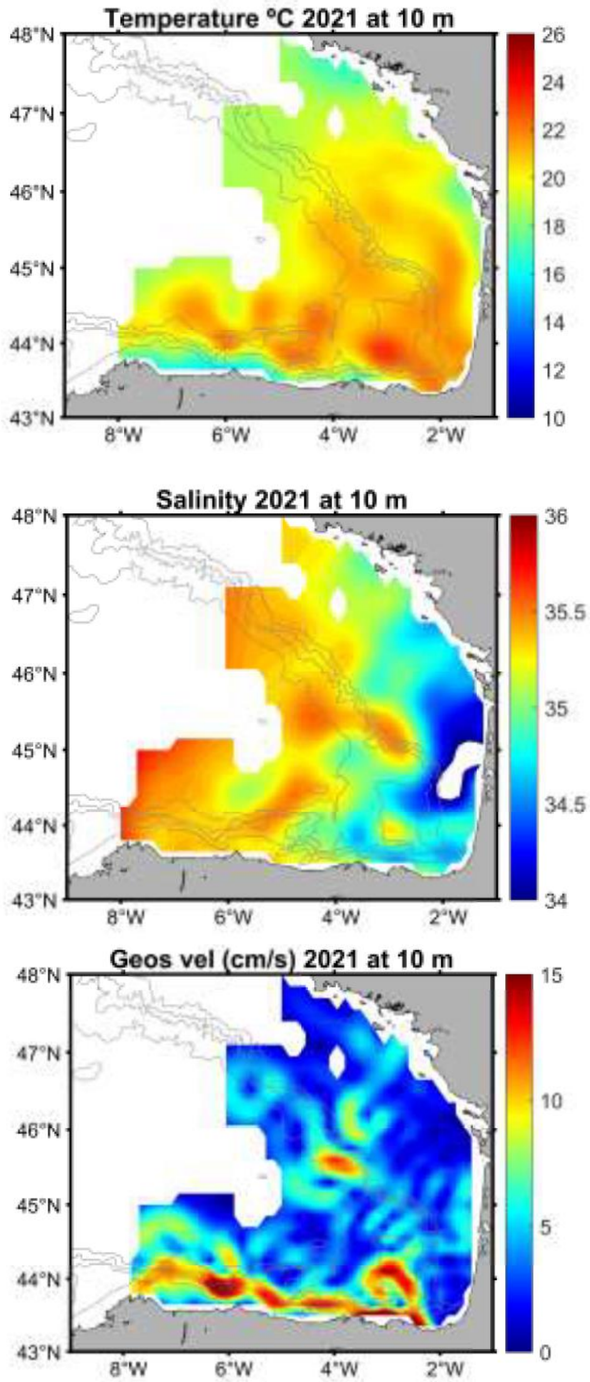

Figura 11: Maps of SST (top), SSS (middle) and geostrophic velocity (bottom) obtained by geostatistical interpolation of data from CTD casts.

8. Tables

Table 1:
Dimensions of the two vessels and installed equipment onboard

	R/V Angeles Alvariño	R/VEmma Bardán
Echosounder	Simrad EK60, 38, 70, 120, 200 y 333 kHz	Simrad EK60, 38, 120 y 200 kHz
Multibeam Echosounder	Simrad ME70	No
Fishing gear	pelagic (15 m vertical opening) doors Polyice Apollo mesh: 8 mm bar length	pelagic (15 m vertical opening) doors Polyice Apollo mesh: 4 mm bar length
Fishing gear Echosounder	Simrad FS70	Marport Trawl Eye
Gear geometry	Depth sensor Scanmar	Simrad ITI: depth/temp and door opening sensors
Hidrography	**CTD-Roseta** CTD SeaBird SBE25 with fluorimeter Turner Scufa, Roseta SeaBird SBE32 with 12 Niskin-type bottels (SBE) de 5l. **WP2 net**: Double ring net, 35 cm diameter each, 200 µm mesh size **Bongo net:** Double ring net, 60 cm diameter each, 500 µm mesh size. Flux control by fluorometer GO. Real time depth monitoring by acoustic sensor (Scanmar). Salinity temperture and fluorescence recording during the trawl with CTD RBR XR-420. **Bongo-Mik net**: Net combining 35 cm 333 µm Bongo, inside a square Mik-type net of 120 cm side, 1000 µm mesh size. Net monitoring same as withe the Bongo (above). **Termosalingraph-Fluorimeter:** Continuous sampler of superficial water for salinity, temperature and fluorescence.	**CTD SeaBird SBE25** with fluorimeter , oxímeter y pH-meter **WP2 net**: double ring net, of 35 cm diameter each, 200 µm mesh size

Table 2:
Schedule of the survey

Activity	**Harbor**	**Date**	**Notes**
Setup EB	Pasaia	16/08/2021	Calibration / Gear testing.
Instalation AA	Vigo	02/09/2021	
Setup AA	Vigo	04/09/2021	Equipment testing. Calibration.
Start survey AA		05/09/2021	
Start survey EB		19/08/2021	
Escale AA	Pasaia	17/09/2021	
Escale EB	Pasaia	23,30/08/2021; 06/09/2021	
End of survey AA	Pasaia	04/10/2021	
End of survey EB	Pasaia	14/09/2021	

Table 3:
Relation of fishing catches performed by Angeles Alvariño (90xx) and Emma Bardan (92xx).

Haul	Date (ddmmyy)	Local Time Time	Lat (cent)	Long (cent)	Prof. haul (m)	Depth (m)	Catch (kg)
9001	05092021	21:55	44,33	-7,52	2	1000	15,668
9002	06092021	9:27	44,34	-7,17	1,8	3400	0,379
9003	07092021	12:59	44,16	-6,83	1,5	800	1,7
9004	07092021	17:10	44,30	-6,82	75	4950	0,3
9005	08092021	12:53	43,97	-6,48	2,5	1000	17,3
9006	09092021	9:35	43,71	-6,13	150	250	84,186
9007	09092021	13:12	43,86	-6,13	4	800	85,05
9008	09092021	18:07	44,06	-6,13	81,6	2500	0,45
9009	10092021	10:08	43,90	-5,78	2	1000	1,05
9010	10092021	16:59	44,24	-5,78	92	4500	0,168
9011	11092021	10:24	44,10	-5,43	3		15,8
9012	12092021	9:38	43,84	-5,10	55	650	1,35
9013	13092021	13:47	43,74	-4,78	6	200	1,75
9014	13092021	17:03	43,66	-4,76	116	301	0,1789
9015	14092021	9:31	43,58	-4,40	5		20,501
9016	14092021	12:44	43,77	-4,41	91	1100	4,231
9017	15092021	16:37	45,77	-3,41	127	145	47,8
9018	16092021	15:05	43,60	-4,06	132	1000	0,2182
9019	16092021	20:42	43,57	-4,07	1,2		24,5
9020	18092021	17:20	43,62	-1,82	3	850	750
9021	19092021	14:52	46,06	-3,48	120	145	14,75
9022	19092021	22:07	45,86	-4,02	6,4		0,65
9023	20092021	10:02	46,14	-4,08	3	180	8,7
9024	21092021	13:58	46,77	-3,28	96	110	500
9025	21092021	21:08	46,99	-2,88	5,2	140	23,1
9026	22092021	13:16	47,05	-3,33	86	95	100
9027	22092021	20:10	46,69	-4,13	120	140	16,75
9028	23092021	9:54	46,53	-4,47	140	150	70
9029	23092021	13:37	46,43	-4,68	3,7	250	21,05
9030	24092021	13:51	47,04	-4,73	58	140	30
9031	25092021	8:22	47,25	-5,99		150	3,25
9032	25092021	13:26	47,58	-5,29	23	132	50
9033	25092021	21:11	47,81	-4,74	3,8	85	400
9034	26092021	18:20	47,50	-3,48	58	68	60
9035	29092021	13:48	47,54	-3,83	77	90	50
9036	29092021	18:27	47,56	-4,29	88	103	45
9037	29092021	22:03	47,37	-4,72		116	9
9038	30092021	12:14	45,94	-3,85	185	350	4,55
9039	30092021	16:37	45,72	-3,55	196	360	150

Haul	Date (ddmmyy)	Local Time Time	Lat (cent)	Long (cent)	Prof. haul (m)	Depth (m)	Catch (kg)
9040	01102021	14:52	43,66	-2,00		700	
9041	02102021	14:07	43,63	-2,00	130	600	
9201	21082021	10:30	43,40	-2,00	7	105	11,4
9202	21082021	14:25	43,53	-2,00	155	550	2,5
9203	21082021	17:12	43,61	-1,69	6	150	3,5
9204	21082021	21:57	43,61	-1,53	22	40	13,14
9205	22082021	8:30	43,86	-1,56	11	74	12,3
9206	22082021	10:58	43,86	-1,78	109	125	60
9207	22082021	15:33	43,86	-2,31	6	500	7,5
9208	22082021	17:12	43,86	-2,32	90	500	0,7
9209	24082021	9:16	44,11	-2,39	50	1000	1,74
9210	24082021	14:45	44,11	-1,78	7	124	42
9211	24082021	22:35	44,12	-1,43	8	40	2,1
9212	25082021	11:34	44,36	-1,63	88	104	2,66
9213	25082021	14:24	44,36	-1,88	6	130	11,9
9214	25082021	18:01	44,36	-2,27	12	500	8,7
9215	26082021	10:43	44,61	-2,28	10	1000	6,5
9216	26082021	21:36	44,61	-1,83	10	130	90
9217	27082021	9:45	44,86	-2,01	118	134	43
9218	27082021	14:27	44,86	-1,63	3	75	1,9
9219	27082021	22:38	45,07	-1,43	15	48	29,6
9220	28082021	9:18	45,37	-1,33	9	35	500
9221	28082021	15:45	45,03	-2,17	90	117	5,4
9222	28082021	22:25	45,03	-2,15	15	117	24,4
9223	29082021	9:23	43,71	-2,35	80	1000	1,5
9224	29082021	13:40	43,53	-2,35	9	250	8,3
9225	31082021	10:05	44,23	-3,03	7	1000	20,34
9226	31082021	13:51	44,07	-3,03	140	1000	1,4
9227	31082021	22:34	43,58	-3,05	6	150	3,5
9228	01092021	13:05	43,93	-2,68	14	1000	0,42
9229	01092021	21:44	44,54	-2,69	5	1000	49,5
9230	02092021	9:30	45,09	-2,78	170	500	4,2
9231	02092021	22:13	45,64	-1,43	2	30	350
9232	03092021	13:18	45,62	-2,27	92	105	4,7
9233	03092021	22:20	45,49	-2,58	6	125	35
9234	04092021	9:25	45,59	-2,92	115	130	120
9235	04092021	18:56	46,15	-1,73	22	35	225
9236	04092021	22:10	45,95	-2,24	20	78	41
9237	08092021	9:55	43,57	-3,38	9	200	18,5
9238	08092021	13:55	43,73	-3,38	125	3000	4,78
9239	09092021	9:11	44,74	-3,38	145	1000	4,75
9240	09092021	22:00	45,28	-2,34	11	118	109,2
9241	10092021	10:25	45,18	-3,34	5	1000	17,5
9242	10092021	21:58	45,53	-3,25	12	156	25,6

Haul	Date (ddmmyy)	Local Time Time	Lat (cent)	Long (cent)	Prof. haul (m)	Depth (m)	Catch (kg)
9243	11092021	13:08	46,28	-2,99	101	118	117
9244	11092021	22:00	46,58	-2,22	14	45	35,2
9245	12092021	11:45	46,61	-2,94	85	100	42
9246	12092021	17:30	46,34	-3,63	123	140	27,1
9247	12092021	22:12	46,22	-3,91	6	152	5,82
9248	13092021	13:27	46,33	-2,08	25	38	
9249	13092021	17:00	46,13	-2,56	83	100	240
9250	13092021	20:36	46,44	-3,04	7	124	35
9251	14092021	21:00	43,70	-3,66	7	500	90

Table 4:

Species composition of the fishing performed by Angeles Alvariño (90xx) and Emma Bardán (92xx).

Haul	Catch (kg)	Catch/species (kg)	Species	FAO	Mean length (cm)
9001	15,668	0,6	Engraulis encrasicholus	ANE	6,09
		15,1	Others	OT	
9002	3,379	1,6	Engraulis encrasicholus	ANE	4,60
		0,0	Trachurus trachurus	HOM	3,50
		1,8	Others	OT	
9003	1,7	1,7	Engraulis encrasicholus	ANE	4,82
9004	0,305	0,3	Maurolicus muelleri	MAV	2,28
		0,0	Euphasiacea	KRX	
9005	17,3	17,3	Engraulis encrasicholus	ANE	5,80
9006	84,1855	0,0	Trachurus trachurus	HOM	5,50
		84,1	Micromesistius poutassou	WHB	14,37
		0,1	Maurolicus muelleri	MAV	5,52
		0,0	Others	OT	
9007	85,05	85,0	Engraulis encrasicholus	ANE	6,24
		0,1	Scomber scombrus	MAC	11,90
9008	0,45	0,0	Capros aper	BOC	2,50
		0,1	Maurolicus muelleri	MAV	2,52
		0,0	Euphasiacea	KRX	
		0,3	Others	OT	
9009	1,05	0,3	Engraulis encrasicholus	ANE	4,81
		0,0	Trachurus trachurus	HOM	5,50
		0,0	Rhopilema spp	JEL	
		0,7	Others	OT	
9010	0,163	0,0	Maurolicus muelleri	MAV	2,71
		0,2	Others	OT	
9011	15,8	15,8	Engraulis encrasicholus	ANE	5,59
9012	1,35	1,4	Maurolicus muelleri	MAV	2,53
9013	1,75	1,5	Engraulis encrasicholus	ANE	3,99
		0,0	Trachurus trachurus	HOM	6,50
		0,0	Rhopilema spp	JEL	
		0,3	Others	OT	
9014	0,1789	0,1	Micromesistius poutassou	WHB	4,30
		0,0	Maurolicus muelleri	MAV	3,18
		0,1	Others	OT	
9015	20,501	20,4	Engraulis encrasicholus	ANE	5,65
		0,0	Trachurus trachurus	HOM	6,00
		0,1	Others	OT	

Haul	Catch (kg)	Catch/species (kg)	Species	FAO	Mean length (cm)
9016	4,231	4,2	Maurolicus muelleri	MAV	2,83
9017	47,8	14,0	Engraulis encrasicholus	ANE	3,65
		0,0	Trachurus trachurus	HOM	5,50
		0,2	Loligo vulgaris	SQR	
		33,3	Capros aper	BOC	7,59
		0,3	Others	OT	
9018	0,2182	0,1	Maurolicus muelleri	MAV	3,14
		0,1	Others	OT	
9019	24,5	23,0	Engraulis encrasicholus	ANE	7,48
		0,1	Myctophidae	LXX	6,13
		1,4	Others	OT	
9020	750	746,3	Engraulis encrasicholus	ANE	9,83
		2,7	Trachurus trachurus	HOM	9,50
		0,5	Scomber scombrus	MAC	11,50
		0,5	Others	OT	
9021	14,75	14,2	Engraulis encrasicholus	ANE	13,78
		0,1	Trachurus trachurus	HOM	4,29
		0,1	Capros aper	BOC	5,13
		0,3	Others	OT	
9022	0,65	0,1	Engraulis encrasicholus	ANE	4,49
		0,3	Myctophidae	LXX	6,47
		0,2	Others	OT	
9023	8,7	8,7	Engraulis encrasicholus	ANE	6,59
9024	500	468,6	Engraulis encrasicholus	ANE	13,75
		7,6	Maurolicus muelleri	MAV	4,16
		23,7	Others	OT	
9025	23,1	0,4	Engraulis encrasicholus	ANE	14,65
		1,9	Sardina pilchardus	PIL	14,92
		12,1	Trachurus trachurus	HOM	6,41
		8,7	Others	OT	
9026	100	100,0	Engraulis encrasicholus	ANE	13,55
9027	16,75	13,3	Engraulis encrasicholus	ANE	14,63
		3,5	Capros aper	BOC	6,63
9028	70	70,0	Capros aper	BOC	6,87
9029	21,05	21,1	Engraulis encrasicholus	ANE	4,81
9030	30	30,0	Engraulis encrasicholus	ANE	4,86
9031	3,25	3,3	Engraulis encrasicholus	ANE	4,04
9032	50	50,0	Engraulis encrasicholus	ANE	5,22
9033	400	399,2	Engraulis encrasicholus	ANE	9,13
		0,2	Trachurus trachurus	HOM	6,17
		0,6	Others	OT	
9034	60	0,3	Engraulis encrasicholus	ANE	12,32

Haul	Catch (kg)	Catch/species (kg)	Species	FAO	Mean length (cm)
		2,0	Trachurus trachurus	HOM	7,20
		38,4	Sprattus spratus	SPR	8,30
		0,1	Merluccius merluccius	HKE	12,50
		19,3	Others	OT	
9035	50	27,4	Engraulis encrasicholus	ANE	13,21
		1,5	Trachurus trachurus	HOM	6,24
		0,1	Sprattus spratus	SPR	8,63
		0,0	Maurolicus muelleri	MAV	3,95
		21,0	Others	OT	
9036	45	45,0	Engraulis encrasicholus	ANE	13,93
9037	9	0,0	Engraulis encrasicholus	ANE	0,00
		2,1	Trachurus trachurus	HOM	16,64
		0,1	Merluccius merluccius	HKE	6,85
		6,8	Capros aper	BOC	6,68
		0,0	Others	OT	
9038	4,55	3,9	Maurolicus muelleri	MAV	3,16
		0,7	Euphasiacea	KRX	
9039	150	132,7	Engraulis encrasicholus	ANE	13,56
		15,0	Capros aper	BOC	8,64
		2,4	Maurolicus muelleri	MAV	3,58
9040	3	3,0	Maurolicus muelleri	MAV	2,97
9041	9,15	9,2	Maurolicus muelleri	MAV	3,15
9201	11,4	11,4	Engraulis encrasicholus	ANE	4,25
9202	2,5	2,5	Maurolicus muelleri	MAV	4,14
9203	3,5	3,5	Engraulis encrasicholus	ANE	4,75
9204	23,14	16,9	Sardina pilchardus	PIL	18,99
		4,9	Trachurus trachurus	HOM	17,55
		1,4	Scomber scombrus	MAC	30,21
9205	12,3	12,3	Engraulis encrasicholus	ANE	5,83
9206	60	60,0	Engraulis encrasicholus	ANE	11,27
9207	7,5	7,5	Engraulis encrasicholus	ANE	4,30
9208	0,7	0,7	Maurolicus muelleri	MAV	2,06
9209	1,74	0,0	Trachurus trachurus	HOM	5,71
		1,0	Maurolicus muelleri	MAV	2,00
		0,7	Euphasiacea	KRX	
9210	42	42,0	Engraulis encrasicholus	ANE	4,95
9211	2,1	0,0	Engraulis encrasicholus	ANE	9,82
		0,6	Trachurus trachurus	HOM	10,98
		0,9	Scomber scombrus	MAC	23,94
		0,0	Sprattus spratus	SPR	5,90
		0,5	Loligo vulgaris	SQR	
9212	2,66	0,9	Engraulis encrasicholus	ANE	12,44

Haul	Catch (kg)	Catch/species (kg)	Species	FAO	Mean length (cm)
		0,3	Loligo vulgaris	SQR	
		1,4	Merluccius merluccius	HKE	47,50
9213	11,9	11,9	Engraulis encrasicholus	ANE	5,01
9214	8,4	8,4	Engraulis encrasicholus	ANE	3,89
9215	6,5	6,5	Engraulis encrasicholus	ANE	4,19
9216	90	90,0	Engraulis encrasicholus	ANE	7,10
9217	43	42,0	Engraulis encrasicholus	ANE	12,00
		1,0	Loligo vulgaris	SQR	
9218	1,9	1,8	Engraulis encrasicholus	ANE	4,76
		0,1	Trachurus trachurus	HOM	5,86
9219	29,6	29,6	Engraulis encrasicholus	ANE	12,93
9220	500	398,4	Engraulis encrasicholus	ANE	10,68
		98,7	Sardina pilchardus	PIL	13,26
		2,9	Scomber scombrus	MAC	11,70
9221	5,4	5,4	Loligo vulgaris	SQR	
9222	24,4	17,8	Engraulis encrasicholus	ANE	7,24
		4,7	Trachurus trachurus	HOM	5,67
		2,0	Loligo vulgaris	SQR	
9223	1,5	1,5	Maurolicus muelleri	MAV	2,10
9224	8,3	8,3	Engraulis encrasicholus	ANE	4,25
9225	20,34	20,3	Engraulis encrasicholus	ANE	5,18
9226	1,4	0,7	Maurolicus muelleri	MAV	2,03
		0,7	Euphasiacea	KRX	
9227	3,5	2,6	Engraulis encrasicholus	ANE	5,08
		0,2	Trachurus trachurus	HOM	4,42
		0,7	Others	OT	
9228	0,42	0,3	Engraulis encrasicholus	ANE	4,36
		0,1	Trachurus trachurus	HOM	5,57
9229	49,5	40,0	Engraulis encrasicholus	ANE	5,37
		1,5	Myctophidae	LXX	7,57
		8,0	Euphasiacea	KRX	
9230	4,2	4,2	Maurolicus muelleri	MAV	3,14
9231	350	307,7	Engraulis encrasicholus	ANE	10,28
		17,2	Sardina pilchardus	PIL	11,61
		20,7	Trachurus trachurus	HOM	10,26
		2,2	Scomber scombrus	MAC	11,72
		2,2	sarda sarda	BON	19,25
9232	4,7	2,7	Engraulis encrasicholus	ANE	12,24
		1,5	Loligo vulgaris	SQR	
		0,5	Maurolicus muelleri	MAV	3,90
9233	35	35,0	Engraulis encrasicholus	ANE	10,01
9234	120	120,0	Engraulis encrasicholus	ANE	13,65

Haul	Catch (kg)	Catch/species (kg)	Species	FAO	Mean length (cm)
9235	225	209,4	Engraulis encrasicholus	ANE	11,82
		15,3	Sardina pilchardus	PIL	14,69
		0,3	Scomber scombrus	MAC	16,83
9236	41	41,0	Engraulis encrasicholus	ANE	12,81
9237	18,5	18,5	Engraulis encrasicholus	ANE	4,67
9238	4,78	4,0	Maurolicus muelleri	MAV	2,09
		0,8	Euphasiacea	KRX	
9239	4,75	4,8	Maurolicus muelleri	MAV	2,58
9240	24,2	24,2	Engraulis encrasicholus	ANE	12,43
9241	17,5	17,5	Engraulis encrasicholus	ANE	5,74
9242	25,6	25,6	Engraulis encrasicholus	ANE	10,04
9243	117	105,0	Engraulis encrasicholus	ANE	13,04
		12,0	Others	OT	
9244	35,2	28,1	Engraulis encrasicholus	ANE	12,51
		0,9	Sardina pilchardus	PIL	14,70
		6,2	Trachurus trachurus	HOM	12,56
9245	42	35,3	Engraulis encrasicholus	ANE	12,52
9246	27,1	27,1	Engraulis encrasicholus	ANE	13,90
9247	5,82	1,9	Engraulis encrasicholus	ANE	7,55
		0,1	Trachurus trachurus	HOM	4,52
		3,8	Loligo vulgaris	SQR	
9248	9,62	0,1	Trachurus trachurus	HOM	6,72
		0,2	Scomber scombrus	MAC	28,00
		9,4	Loligo vulgaris	SQR	
9249	240	240,0	Engraulis encrasicholus	ANE	12,50
9250	35	35,0	Engraulis encrasicholus	ANE	10,27
9251	90	90,0	Engraulis encrasicholus	ANE	5,22

Table 5:
Estimation of abundance (acoustic index of biomass) of pearlside per years.

Year	Specie	sA	Area (n.mi.2)	Mean weight (gr)	Mean TL (cm)	N indiv. ($x10^{11}$)	Biomass (ton)
2014	*M. muelleri*	309.3	21,073	0.51	3.42	4.6	236,063
2015	*M. muelleri*	630.79	8,663	0.58	3.96	3.6	211,510
2016	*M. muelleri*	348.96	7,189	0.36	3.44	3.7	132,410
2017	*M. muelleri*	511.30	13,313	0.53	3.68	5.0	268,377
2018	*M. muelleri*	485.21	21,765	0.26	3.04	9.8	257,725
2019	*M. muelleri*	257.00	16,481	0.53	3.78	3.0	157,042
2020	*M. muelleri*	617.09	18,768	0.33	3.28	6.3	208,403
2021	*M. muelleri*	528.00	20,409	0.14	2.46	15.4	219,260

Table 6:

Biomass estimation for the rest of fish species of the small pelagic community assessed during JUVENA.

Species (scientific name)	Common name	sA	Area (n.mi.2)	N indiv.	Biomass (ton)
Engraulis encrasicolus	Anchovy	270	26722	200,057,359,552.87	471,272
Sardina pilchardus	Sardine	544	1279	561,875,055.39	18,163
Sprattus spratus	Spratt	2879	184	2,627,449,064.36	9,111
Trachurus trachurus	Horse mackerel	812	1537	1,361,876,494.06	20,425
Scomber scombrus	Mackerel	322	821	221,096,152.67	22,482
Maurolicus muelleri	**Pearlside**	**528**	**20409**	**1,542,037,297,224.46**	**219,260.09**
Euphasiacea	Krill	338	7609	76.591.328.778,32	16,489.55
Capros aper	Boarfish	1137	3640	9,823,043,365.91	70,215
Micromesistius poutassou	Blue whiting	828	149	451.550.697,95	5,924.69