**Working Document to**

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# INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in April - May 2023

Post-cruise meeting on Teams, 13-15 June 2023

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## Introduction

In April-June 2023, four research vessels and one hired commercial vessel participated in the International ecosystem survey in the Nordic Seas (IESNS); R/V Dana, Denmark (joint EU survey by Denmark, Germany, Ireland, The Netherlands and Sweden), R/V Jákup Sverri, Faroe Islands, R/V Árni Friðriksson, Iceland, R/V G.O. Sars, Norway and M/S Resolute, United Kingdom (UK). Like in 2022, the Barents Sea was not surveyed by a Russian research vessel. The aim of the survey was to cover the whole distribution area of the Norwegian Spring-spawning herring with the objective of estimating the total abundance of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 the EU has also participated (except 2002 and 2003) and from 2004 onwards the survey has been more integrated into an ecosystem survey.

This report represents analyses of data from this International survey in 2023 that are stored in the PGNAPES database and the ICES acoustic database and supported by national survey reports from some survey participants (Dana: Cruise Report R/V Dana Cruise 03/2023. International Ecosystem survey in the Nordic Seas (IESNS) in 2023, Árni Friðriksson: A6-2023 Cruise Report, Bjarnason, 2023, Jákup Sverri: Cruise Report 2320).

## Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2023 and by correspondence. Planning of the acoustic transects, hydrographic stations and plankton stations were carried out by using the survey planner function in the r-package Rstox version 1.11 (see https://www.hi.no/en/hi/forskning/projects/stox). The survey planner function generates the survey plan (transect lines) in a cartesian coordinate system and transforms the positions to the geographical coordinate system (longitude, latitude) using the azimuthal equal distance projection, which ensures that distances, and also equal coverage, if the method used is designed with this prerequisite, are preserved in the transformation. Figure 1 shows the planned acoustic transects and hydrographic and plankton stations in each stratum. Only parallel transects were used this year, however, because the transects follow great circles they appear bended in a Mercator projection. The participating vessels together with their effective survey periods are listed in the table below:

| Vessel | Institute | Survey period |
|---|---|---|
| Dana | DTU Aqua - National Institute of Natural Resources, Denmark | 28/04-24/05 |
| G.O. Sars | Institute of Marine Research, Bergen, Norway | 27/04-01/06 |
| Jákup Sverri | Faroe Marine Research Institute, Faroe Islands | 05/05-16/05 |
| Árni Friðriksson | Marine and Freshwater Research Institute, Iceland | 08/05-27/05 |
| Resolute | CEFAS, United Kingdom | 24/04-06/05 |

Figure 2 shows the cruise tracks, Figure 3 the hydrographic and WPII plankton stations and, Figure 4 Macroplankton trawl and Multinet stations and Figure 5 the pelagic trawl stations. Survey effort by each vessel is detailed in Table 1. Daily contacts were maintained between the vessels during the course of the survey, primarily through electronic mail. The temporal progression of the survey is shown in Figure 6.

In general, the weather conditions did not affect the survey even if there were a few days in the northern part at the end of the survey that were not favourable and trawling, WP2 and Multinet sampling at some stations were prevented. The weather conditions in the first part of the survey, when most of the herring was observed, were unusually good. The survey was based on scientific echosounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote *et al.*, 1987) prior to the survey. Salient acoustic settings are summarized in the text table below.

**Acoustic instruments and settings for the primary frequency (boldface).**

| | Dana | G. O. Sars | Arni Friðriksson | Jákup Sverri | Resolute |
|---|---|---|---|---|---|
| Echo sounder | Simrad EK60 | Simrad EK80 | Simrad EK80 | Simrad EK80 | Simrad EK80 |
| Frequency (kHz) | **38** | **38**, 18, 70, 120, 200, 333 | **38**, 18, 70, 120, 200 | 18,**38**, 70, 120, 200, 333 | **38**,200 |
| Primary transducer | ES38BP | ES 38-7 | ES38-7 | ES38-7 | ES38-7 |
| Transducer installation | Towed body | Drop keel | Drop keel | Drop keel | Hull-mounted |
| Transducer depth (m) | 4-6 | 6 | 6.9 | 6-9 | 6 |
| Upper integration limit (m) | 10 | 15 | 12 | 15 | 10 |
| Absorption coeff. (dB/km) | 8.9 | 10.1 | 10.6 | 10.3 | 10.1 |
| Pulse length (ms) | 1.024 | 1.024 | 1.024 | 1.024 | 1.024 |
| Band width (kHz) | 2.425 | 2.43 | 2.425 | 3.06 | 2.425 |
| Transmitter power (W) | 2000 | 2000 | 2000 | 2000 | 2000 |
| Angle sensitivity (dB) | 21.9 | 21.9 | 18 | 21.9 | 18 |
| 2-way beam angle | -20.5 | -20.7 | -20.3 | -20.4 | -20.7 |

| | Dana | G. O. Sars | Arni Friðriksson | Jákup Sverri | Resolute |
|---|---|---|---|---|---|
| (dB) | | | | | |
| Sv Transducer gain (dB) | | | | | |
| Ts Transducer gain (dB) | 25.51 | 26.11 | 27.05 | 26.94 | 26.75 |
| $s_A$ correction (dB) | -0.60 | -0.04 | 0.01 | -0.13 | -0.07 |
| 3 dB beam width (dg) | | | | | |
| alongship: | 6.76 | 6.39 | 6.44 | 6.47 | 6.32 |
| athw. ship: | 6.99 | 6.38 | 6.52 | 6.54 | 6.40 |
| Maximum range (m) | 500 | 500 | 500 | 500 | 500 |
| Post processing software | LSSS | LSSS | LSSS | LSSS | Echoview |

All participants except UK used the same post-processing software (LSSS). The UK data were, however, scrutinized using Echoview. Scrutinization was carried out according to an agreement at the PGNAPES scrutinizing workshop in Bergen in February 2009 (ICES 2009), and “Notes from acoustic Scrutinizing workshop in relation to the IESNS”, Reykjavík 3.-5. March 2015 (Annex 4 in ICES 2015). Generally, acoustic recordings were scrutinized on daily basis and species identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms. Immediately after the 2023 survey an online meeting was held to standardise the scrutiny and to agree on particularly difficult scrutiny situations encountered. All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls, plankton nets and hydrographic equipment are as follows:

| | **Dana** | **G.O. Sars** | **Arni Friðriksson** | **Jákup Sverri** | **Resolute** |
|---|---|---|---|---|---|
| **Trawl dimensions** | | | | | |
| **Circumference (m)** | | **496** | **832** | **832** | **972** |
| **Vertical opening (m)** | **20-30** | **25-30** | **20–35** | **45–55** | **30-50** |
| **Mesh size in codend (mm)** | **18** | **24** | **20** | **45** | **20** |
| **Typical towing speed (kn)** | **3.5-4.5** | **3.0–4.5** | **3.1–5.0** | **3.5–4.5** | **3.5-5** |
| | | | | | |
| **Plankton sampling** | | | | | |
| **Sampling net** | **WP2** | **WP2** | **WP2** | **WP2** | **WP2** |
| **Standard sampling depth (m)** | **200** | **200** | **200** | **200** | **200** |

| | Dana | G.O. Sars | Arni Friðriksson | Jákup Sverri | Resolute |
|---|---|---|---|---|---|
| **<u>Hydrographic sampling</u>** | | | | | |
| **CTD unit** | **SBE911** | **SBE911** | **SBE911** | **SBE911** | **SAIV SD208** |
| **Standard sampling depth (m)** | **1000** | **1000** | **1000** | **1000** | **250** |

Catches from trawl hauls were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. A subsample of herring, blue whiting and mackerel were sexed, aged, and measured for length and weight, and their maturity status was estimated using established methods. An additional sample of fish was measured for length. For the Norwegian, Icelandic and Faroese vessel, a smaller subsample of stomachs was sampled for further analyses on land. As part of ongoing stock identity research, herring genetic samples were collected. Salient biological sampling protocols for trawl catches are listed in the table below.

| | Species | Dana | G.O. Sars | Arni Friðriksson | Jákup Sverri | Resolute |
|---|---|---|---|---|---|---|
| Length measurements | Herring | 200-300 | 100 | 300 | 100-200 | 100 |
| | Blue whiting | 200-300 | 100 | 50 | 100-200 | 100 |
| | Mackerel | 100-200 | 100 | 50 | 100-200 | 100 |
| | Other fish sp. | 50 | 30 | 30 | 100-150 | 30 |
| Weighed, sexed and maturity determination | Herring | 50 | 25-100 | 100 | 50* | 50 |
| | Blue whiting | 50 | 25-100 | 50 | 50* | 50 |
| | Mackerel | 50 | 25-100 | 50 | 50* | 50 |
| | Other fish sp. | 0 | 0 | 0 | 0* | 0 |
| Otoliths/scales collected | Herring | 50 | 25-30 | 100 | 25-50 | 50 |
| | Blue whiting | 50 | 25-30 | 50 | 25-50 | 50 |
| | Mackerel | 0 | 25-30 | 50 | 25-50 | 50 |
| | Other fish sp. | 0 | 0 | 0 | 0 | 0 |
| Stomach sampling | Herring | 0 | 10 | 10 | 5 | 0 |
| | Blue whiting | 0 | 10 | 10 | 5 | 0 |
| | Mackerel | 0 | 10 | 10 | 5 | 0 |
| | Other fish sp. | 0 | 0 | 0 | 0 | 0 |
| Genetic samples | Herring | 50 | | 0 | 30 | 50 |

* If the catch is sufficiently large 100 individuals are always weighed.

Acoustic data were analysed using the StoX software package (version 3.6.1) which has been used for many years now for WGIPS coordinated surveys. A description of StoX can be found in Johnsen et al. (2019) and here: https://www.hi.no/en/hi/forskning/projects/stox. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). This method requires pre-defined strata, and the survey area was therefore split into 5 strata with pre-defined acoustic transects (this year only 4 strata, as the Barents Sea was not surveyed).

Within each stratum, parallel transects with equal distances were used. The distance between transects was based on available survey time, and the starting point of the first transect in each stratum was randomized. This approach allows for robust statistical analyses of uncertainty of the acoustic estimates. The strata and transects used in StoX are shown in Figure 2. Generally, and in accordance with most WGIPS coordinated surveys, all trawl stations within a given stratum with catches of the target species (either blue whiting or herring) were assigned to all transects within the stratum, and the length distributions were weighted equally within the stratum.

The following target strength (TS)-to-fish length (L) relationships were used:

Blue whiting: TS = 20.0 log(L) – 65.2 dB (ICES 2012)

Herring: TS = 20.0 log(L) – 71.9 dB (Foote et al. 1987)

The target strength for herring is the traditionally one used while this target strength for blue whiting was first applied in 2012 (ICES 2012).

The hydrographical and plankton stations by survey are shown in Figure 3. Most vessels collected hydrographical data using a SBE 911 CTD. Maximum sampling depth was 1000 m.

Zooplankton was sampled by WP2 nets on all vessels, according to the standard procedure for the surveys. Mesh sizes were 180 or 200 µm. The net was hauled vertically from 200 m to the surface or from the bottom whenever bottom depth was less than 200 m. All samples were split in two and one half was preserved in formalin while the other half was dried and weighed. The samples for dry weight were size fractionated before drying by sieving the samples through 2000 µm and 1000 µm sieves, giving the size fractions 180/200 – 1000 µm, 1000 – 2000 µm, and > 2000 µm. Data are presented as total mg dry weight per m2. For the zooplankton distribution map, all stations are presented. Interpolation was carried out using Bratseth’s Successive Correction Method (Bratsheth, 1986). This method was designed specifically for marine data, and it uses bottom depth to calculate the similarity among the interpolation points. More specifically, it uses objective analysis with a Gaussian correlation function where the effective distance between the observations and the nodes of the interpolation grids is defined based on the difference in bottom depths, as follows:

$$r^2 = r_x^2 + r_y^2 + \left(\lambda \frac{H_a - H_o}{H_a + H_o}\right)^2$$

where rx and ry is the geographic distance in the zonal and meridional directions, and Ha and Ho are the bottom depths at the analysis and observation points, respectively (Skagseth and Mork, 2012). The analysis was done using an R script based on a MATLAB routine developed by Kjell Arne Mork (Mork et al. 2014). For the time series, stations in the Norwegian Sea delimited to east of 14°W and west of 20°E have been included. Estimates of the statistical distribution of the zooplankton biomass indices is done by simple bootstrapping by re-sampling with replacement.

## Results and Discussion

### Hydrography

The temperature distributions in the ocean, averaged over selected depth intervals; 0-50 m, 50-200 m, and 200-500 m, are shown in Figures 7a-c. The temperatures in the surface layer (0-50 m) ranged from below 0°C in the Greenland Sea to 9-10°C in the southern part of the Norwegian Sea (Figure 7a). The Arctic front was encountered south of 65°N east of Iceland extending eastwards towards about 2°W where it turned north-eastwards to 65°N and then almost straight northwards. The front sharpened and had a more eastern location with depths. Further to west at about 8°W, another front runs northward to Jan Mayen, the Jan Mayen Front, that was most distinct in the upper 200 m. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures about 5 °C to the Bear Island at 74.5°N in the surface layer.

Relative to the long-term mean, from 1995 to 2021, the temperatures at 0-50 m were below the mean at the western and eastern parts of Norwegian Sea while in the central areas, the temperatures were mostly above the mean (Figure 7a). At 50-200 m depth, the patterns were also fragmented, but the Norwegian Sea was, in general, colder than the long-term mean in the western part and in the Lofoten Basin (Figure 7b). At 200-500 m depth, the patterns were less fragmented and nearly the whole Norwegian Sea was colder than the long-term mean (Figure 7c). The negative anomalies North of the Faroese derive likely from increased influenced of the East Iceland Current compared to the long-term mean.

Two main features of the circulation in the Norwegian Sea, where the herring stock is grazing, are the Norwegian Atlantic Current (NWAC) and the East Icelandic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the southwestern Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is in the last four decades a similar layer has been observed all over the Norwegian Sea. Also, in periods this layer has been less well-defined.

This circulation pattern creates a water mass structure with warm Atlantic Water in the eastern part of the area and more Arctic conditions in the western part. The NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward. The western branch of the NWAC reaches the area of Jan Mayen at about 71°N. Further northward in the Lofoten Basin the lateral extent of the Atlantic water gradually narrows again, apparently under topographic influence of the mid-ocean ridge. It has been shown that atmospheric forcing largely controls the distribution of the water masses in the Nordic Seas. Hence, the lateral extent of the NWAC, and consequently the position of the Arctic Front, that separates the warm North Atlantic waters from the cold Arctic waters, is correlated with the large-scale distribution of the atmospheric sea level pressure. The local air-sea heat flux in addition influence the upper layer and it is found that it can explain about half of the year-to-year variability of the ocean heat content in the Norwegian Sea.

## Zooplankton

The zooplankton biomass (mg dry weight $m^{-2}$) distribution in the upper 200 m in 2023 is shown in Figure 8b). Sampling stations were evenly spread over the area, covering Atlantic water, Arctic water, and the Arctic frontal zone. The highest zooplankton biomasses were found in the Iceland Sea, northeast of Iceland. This was also reflected in the time series. A smaller area with high biomass was also found outside the Norwegian continental shelf, at 66°N. In the rest of the investigated area there was a relatively even distribution of zooplankton biomass. This was different from the distribution in 2022, where the highest zooplankton biomasses were found in the eastern and southeastern parts.

Figure 9b) shows the zooplankton time series indices for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional biomass differences, the area was divided into 4 sub-areas 1) East of Iceland, 2) the Jan Mayen Arctic front, 3) the Lofoten Basin (covering the northern Norwegian Sea, and 4) the Norwegian Basin (covering the southern Norwegian Sea), figure 10 a). The zooplankton biomass index for 2023 was respectively: 13394, 8009, 8484 and 9688 mg dry weight $m^{-2}$. There was an increase in zooplankton biomass in Icelandic water, where the biomass was almost three times higher in 2023 compared to 2022. For the other sub-areas minor changes were observed from last year. The zooplankton biomass indices for the Norwegian Sea in May have been estimated since 1995. All sub-areas had a high biomass period until mid-2000, and a lower period thereafter. The long-term decrease has been most pronounced in the Iceland Sea. In the Lofoten- and Norwegian Basins there has been an increasing trend during the low-biomass period.

The reasons for the changes in zooplankton biomass are not obvious. It is worth noting that the period with lower zooplankton biomass coincides with higher-than-average heat content in the Norwegian Sea (ICES, 2020) and reduced inflow of Arctic water into the southwestern Norwegian Sea (Kristiansen et al., 2019; Skagseth et al., 2022). Timing effects, such as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. The high biomass of pelagic fish feeding on zooplankton has been suggested to be one of the main causes for the reduction in zooplankton biomass. However, carnivorous zooplankton and not pelagic fish may be the main predators of zooplankton in the Norwegian Sea (Skjoldal et al., 2004), and we do not have good data on the development of the carnivorous zooplankton stocks.

### Norwegian spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2023. The zero-line was believed to be reached for adult NSS herring in most of the areas. It is recommended that the results from IESNS 2023 can be used for assessment purpose. The herring was primarily distributed in the western and northwestern area this year (Figure 10). The 2016-year-class was by far the most abundant year class in the areas where most of the herring biomass was found. It is a commonly observed pattern that the older fish are distributed in the southwest while the younger fish are found closer to the nursery areas in the Barents Sea (Figure 11).

Seven-year-old herring (2016-year class) dominated both in terms of number and biomass (both around 57%) on basis of the StoX bootstrap estimates for the Norwegian Sea (Table 2). The point estimate of abundance of the 2016 year-class decreased by 2% compared to last year's estimate which is much less than the decline between 2021 and 2022 (Figure 12). However, the 2015-2013 year classes decrease with 47-66% compared to last year's estimates. This indicates that the mortality of older herring has been higher than that of the 2016 year class. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 13 and Table 2. The relative standard error (CV) is 23% for the total biomass and 22% for the total numbers estimate, and the relative standard errors for the dominating age groups is around 24-32% (Figure 13).

The total estimate of herring in the Norwegian Sea from the 2023 survey was 16.5 billion in number and the biomass was 4.1 million tonnes. The biomass estimate is about 8% lower than the 2022 survey estimate and the estimated number is about 17% lower than in 2022. The biomass estimate decreased significantly from 2009 to 2012 and has since then been rather stable at 4.1 to 5.9 million tonnes with similar confidence interval (Figure 14), with the lowest abundance occurring in 2023.

Since 2015 an increased awareness has been raised around the age reading of herring. It appeared that the age distributions from the different participants some years showed differences and also the older specimens appear to have uncertain ages. An age-reading workshop was held in Bergen 17.-19. April 2023 (WKARNSSH2). This workshop was based on otoliths and scales collected in 2021 and subsequently exchanged between the participating countries. At the publication of this survey report the concluding report from WKARNSSH2 is not yet available, but it will be for next year's survey report.

With respect to age-reading, the comparison between the nations, in this year's survey, show that there were some differences within strata (Figure 15). Particularly, in stratum 2 there were differences between the EU vessel (3-year-olds dominating) and the Norwegian vessel (7-year-olds dominating). This could at least partly be explained by spatial differences in sampling between vessels; the EU vessel have all their samples in the northern part of stratum 2 while the Norwegian vessel have samples both from the northern and the southern part of the stratum. It is well known that mean age of herring in the IESNS generally decreases with increasing latitude.

Recently, concerns have been raised by the survey groups for the International ecosystem surveys in the Nordic Seas (IESNS and IESSNS) on mixing issues between Norwegian spring-spawning herring and other herring stocks (e.g. Icelandic summer-spawning, Faroese autumn-spawning, Norwegian summer-spawning and North Sea type autumn-spawning herring) occurring in some of the fringe regions in the Norwegian Sea. Until now, fixed cut lines have been used by the survey group to exclude herring of presumed other types than NSS herring, however this simple procedure is thought to introduce some contamination of the stock indices of the target NSS herring. WGIPS noted in their 2019 report that the separation of different herring stock components is an issue in several of the surveys coordinated in WGIPS and the needs for development of standardized stock splitting methods was also noted in the WKSIDAC (ICES 2017).

### Blue whiting

Boostrap estimates of abundance, biomass, mean length and mean weight of blue whiting during IESNS 2023 are shown in Table 3. The estimated biomass was 961 thousand tons (CV=0.14) which is a 36% decrease from last year’s estimate, and slightly below the average from the period 2008-2022. The estimated total abundance was 12.8 billion (CV=0.15) which is a 57% decrease from last year’s estimate. The stock is dominated by 1-3 years old blue whiting. Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 18 and Table 3.

The spatial distribution of blue whiting in 2023 is shown in Figure 16. As usual, most of the fish was registered in the eastern part of the Norwegian Sea. The largest fish was found in the northwestern part of the of the survey area (Figure 17). Comparison of the size and age distributions of blue whiting by stratum and country are shown in Figure 19 and 20, and they seem to be in fairly good agreement.

### Mackerel

Trawl catches of mackerel are shown in Figure 21. Mackerel was present in the southern and eastern part of the Norwegian Sea in the beginning of May. The spatial distribution of catches in 2023 were similar to 2022, i.e. a lower northward extent than in the period 2008-2021. No further quantitative information can be drawn from these data as this survey is not designed to monitor mackerel.

## General recommendations and comments

| Recommendation | Addressed to |
|---|---|
| 1. Continue the methodological research in distinguishing between herring and blue whiting in the interpretation of echograms. | WGIPS |
| 2. Implement logging of sonar data to measure the amount of herring in the surface blind zone | WGIPS |

## Next year's post-cruise meeting

We will aim for next meeting in 16-18 June 2024. The final decision will be made at the next WGIPS meeting.

## Concluding remarks

- The sea temperature in 2023 was generally below the long-term mean (1995-2021) in the Norwegian Sea.
- The 2023 indices of meso-zooplankton biomass in the Norwegian Sea and adjoining waters were fairly similar to last year's estimates for all areas except the Icelandic area where the index is much higher compared to the most recent years.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 4.1 million tonnes, which is an 8% decrease from the 2022 survey estimate. The estimate of total number of NSSH was 16.5 billion, which is 17% lower than in the 2022 survey. The survey followed the pre-planned protocol and the survey group recommends using the abundance estimates in the analytical assessment.
- The 2016 year class of NSSH dominated in the survey indices both in numbers and biomass (both 57%). The abundance of the 2016 year-class decreased by 2% compared to last year's estimate.
- The biomass of blue whiting measured in the 2022 survey decreased by 36% from last year's survey and 57% in terms of numbers. The stock is dominated by the 2020 to 2022 year classes.

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# Tables

**Table 1**. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2023.

| Vessel | Effective survey period | Effective acoustic cruise track (nm) | Trawl stations | Ctd stations | Aged fish (HER) | Length fish (HER) | Plankton stations |
|---|---|---|---|---|---|---|---|
| Dana | 28/4-19/5 | 2218 | 31 | 38 | 154 | 335 | 37 |
| Jákup Sverri | 6/5-14/5 | 1297 | 17 | 22 | 569 | 1849 | 22 |
| Árni Fridriksson | 10/5-24/5 | 2700 | 19 | 31 | 1424 | 4608 | 29 |
| G.O. Sars | 27/4-01/6 | 3858 | 36 | 78 | 226 | 557 | 67 |
| Resolute | 24/4-06/5 | 1345 | 13 | 19 | 145 | 244 | 19 |

**Table 2**. IESNS 2023 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring. The estimates are mean of 1000 bootstrap replicates in Stox.

| | Age in years (year class) | | | | | | | | | | | | | | | | | | | Number | Biomass | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | Unknown | | | weight |
| (cm) | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | | (10^6) | (10^6 kg) | (g) |
| 11-12 | | | | | | | | | | | | | | | | | | | 1.1 | 1.1 | 0.0 | 10.0 |
| 12-13 | 3.2 | | | | | | | | | | | | | | | | | | 0.2 | 3.4 | 0.0 | 13.6 |
| 13-14 | 22.6 | | | | | | | | | | | | | | | | | | 0.0 | 26.2 | 0.4 | 15.5 |
| 14-15 | 20.4 | | | | | | | | | | | | | | | | | | 0.2 | 20.5 | 0.4 | 18.7 |
| 15-16 | 4.7 | | | | | | | | | | | | | | | | | | 0.2 | 6.7 | 0.2 | 23.1 |
| 16-17 | 5.7 | | | | | | | | | | | | | | | | | | 0.1 | 5.7 | 0.2 | 34.3 |
| 17-18 | | 4.9 | | | | | | | | | | | | | | | | | 0.8 | 5.7 | 0.2 | 38.5 |
| 18-19 | | 12.4 | | | | | | | | | | | | | | | | | | 12.4 | 0.6 | 48.3 |
| 19-20 | | 16.0 | | | | | | | | | | | | | | | | | | 16.0 | 0.9 | 56.7 |
| 20-21 | | 30.9 | 5.7 | | | | | | | | | | | | | | | | | 36.7 | 2.3 | 61.6 |
| 21-22 | | 74.5 | 30.3 | | | | | | | | | | | | | | | | | 104.8 | 7.8 | 74.8 |
| 22-23 | | 20.4 | 53.3 | | | | | | | | | | | | | | | | | 73.6 | 6.2 | 84.9 |
| 23-24 | | 22.4 | 38.1 | 6.5 | | | | | | | | | | | | | | | | 67.1 | 6.4 | 94.2 |
| 24-25 | | 1.9 | 53.8 | 6.1 | | | | | | | | | | | | | | | | 61.8 | 6.7 | 109.0 |
| 25-26 | | | 67.4 | 17.9 | | | | | | | | | | | | | | | 0.0 | 85.3 | 10.6 | 121.1 |
| 26-27 | | | 97.8 | 3.4 | 8.4 | | | | | | | | | | | | | | | 109.6 | 14.6 | 134.1 |
| 27-28 | | | 68.1 | 47.7 | 3.4 | | 7.3 | | | | | | | | | | | | | 126.5 | 19.3 | 153.6 |
| 28-29 | | | 95.4 | 37.6 | 37.0 | 102.8 | 14.9 | 10.8 | | | | | | | | | | | | 298.5 | 49.2 | 164.9 |
| 29-30 | | | 43.0 | 83.0 | 285.5 | 75.7 | 35.6 | 4.7 | 5.0 | 4.7 | | | | | | | | | | 537.2 | 99.0 | 183.3 |
| 30-31 | | | 24.8 | 53.9 | 246.2 | 65.4 | 146.4 | 15.4 | 10.4 | 10.2 | | | | 4.7 | | | | | | 577.4 | 116.0 | 201.0 |
| 31-32 | | | | 57.4 | 255.1 | 390.1 | 861.8 | 27.8 | 5.7 | | | | | | | | | | | 1 597.9 | 352.7 | 219.8 |
| 32-33 | | | 2.8 | 27.2 | 142.0 | 411.4 | 3076.3 | 40.0 | | 11.1 | | | | | | | | | | 3 710.8 | 878.2 | 236.1 |
| 33-34 | | | | | 18.9 | 144.0 | 3616.7 | 108.6 | 91.3 | 115.6 | | | | | | | | | | 4 095.1 | 1030.3 | 251.3 |
| 34-35 | | | | | | 28.2 | 1463.1 | 141.7 | 171.7 | 316.1 | 25.2 | | | 5.2 | | | | | | 2 151.2 | 582.6 | 270.2 |
| 35-36 | | | | | | | 209.3 | 73.4 | 220.9 | 370.4 | 83.7 | 47.7 | 13.8 | | 6.0 | 6.9 | | | | 1 032.1 | 302.7 | 292.7 |
| 36-37 | | | | | | | 20.9 | 36.4 | 42.3 | 257.2 | 136.3 | 108.8 | 96.9 | 90.4 | 74.0 | 30.5 | 13.6 | 18.4 | | 925.7 | 296.1 | 318.6 |
| 37-38 | | | | | | | 7.0 | 3.6 | 11.1 | 24.3 | 37.3 | 39.1 | 80.4 | 108.7 | 72.8 | 85.0 | 18.7 | 12.3 | | 500.4 | 168.0 | 335.8 |
| 38-39 | | | | | | | | | | | 21.4 | 18.0 | 26.9 | 28.6 | 27.6 | 34.8 | 46.4 | 20.6 | | 224.3 | 78.7 | 351.3 |
| 39-40 | | | | | | | | | | | | | | 18.5 | 18.1 | | 17.3 | 3.0 | 0.1 | 57.0 | 21.6 | 379.0 |
| 40-41 | | | | | | | | | | | | | | | 1.3 | 2.0 | 2.6 | 2.3 | | 8.2 | 3.2 | 392.0 |
| TSN(mill) | 56.6 | 185.2 | 584.0 | 340.7 | 996.4 | 1217.7 | 9459.2 | 462.4 | 558.4 | 1109.7 | 303.8 | 213.5 | 218.1 | 256.2 | 199.9 | 159.2 | 98.7 | 56.6 | | 16 478.8 | | |
| cv (TSN) | 0.86 | 0.52 | 0.34 | 0.31 | 0.29 | 0.25 | 0.24 | 0.29 | 0.27 | 0.27 | 0.33 | 0.34 | 0.31 | 0.35 | 0.39 | 0.40 | 0.46 | 0.61 | | 0.22 | | |
| TSB(1000 t) | 1.1 | 13.0 | 77.1 | 62.2 | 200.2 | 270.0 | 2 329.9 | 123.3 | 156.3 | 324.3 | 95.9 | 70.2 | 72.2 | 85.4 | 67.8 | 53.1 | 33.9 | 19.3 | | 4 055.3 | | |
| cv (TSB) | 0.80 | 0.54 | 0.35 | 0.31 | 0.29 | 0.25 | 0.24 | 0.29 | 0.28 | 0.27 | 0.33 | 0.34 | 0.31 | 0.35 | 0.40 | 0.41 | 0.46 | 0.60 | | 0.23 | | |
| Mean length(cm) | 13.8 | 20.1 | 25.0 | 29.1 | 30.4 | 31.4 | 32.7 | 33.6 | 34.4 | 34.8 | 35.9 | 36.2 | 36.7 | 36.9 | 37.1 | 37.1 | 37.9 | 37.7 | | | | |
| Mean weight(g) | 19.8 | 65.5 | 125.5 | 185.2 | 203.3 | 224.5 | 247.7 | 270.2 | 281.8 | 293.1 | 317.0 | 328.6 | 333.2 | 334.9 | 342.8 | 335.1 | 345.6 | 345.7 | | | | |

**Table 3**. IESNS 2023 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting. The estimates are mean of 1000 bootstrap replicates in Stox.

| | Age in years (year class) | | | | | | | | | | | | Number | Biomass | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | Unknown | | | weight |
| (cm) | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2008 | | (10^6) | (10^6 kg) | (g) |
| 16-17 | | | | | | | | | | | | 9.4 | 9.4 | 0.2 | 18.0 |
| 17-18 | 102.2 | | | | | | | | | | | | 102.2 | 2.9 | 28.5 |
| 18-19 | 813.8 | 19.9 | | | | | | | | | | 0.1 | 833.8 | 28.5 | 34.5 |
| 19-20 | 1439.5 | | | | | | | | | | | | 1 439.5 | 55.4 | 38.8 |
| 20-21 | 1192.6 | 129.1 | 154.6 | | | | | | | | | | 1 476.4 | 68.2 | 47.0 |
| 21-22 | 316.1 | 396.1 | 45.7 | | | | | | | | | | 758.0 | 40.6 | 55.1 |
| 22-23 | 1.4 | 1198.6 | 125.6 | | | | | | | | | | 1 325.5 | 85.9 | 66.2 |
| 23-24 | 7.5 | 1550.3 | 426.9 | | | | | | | | | | 1 984.8 | 146.3 | 74.8 |
| 24-25 | | 1183.2 | 652.0 | 28.9 | 1.6 | | | | | | | | 1 865.7 | 155.0 | 83.6 |
| 25-26 | | 247.7 | 768.0 | 70.5 | 1.1 | 13.0 | | | | | | | 1 100.4 | 104.2 | 95.4 |
| 26-27 | | 62.9 | 530.0 | 73.4 | 3.1 | | | | | | | | 669.4 | 71.3 | 107.0 |
| 27-28 | | 3.9 | 213.1 | 114.0 | 8.4 | | 17.3 | | | | | | 356.7 | 42.6 | 119.8 |
| 28-29 | | | 64.2 | 61.3 | 41.4 | 29.3 | | 28.0 | | | | | 224.2 | 32.3 | 139.4 |
| 29-30 | | | 11.7 | 32.1 | 17.2 | 34.6 | 36.0 | 19.7 | | | | | 151.3 | 25.3 | 161.5 |
| 30-31 | | | | 15.7 | 43.3 | 22.2 | 41.6 | | | | 3.9 | | 126.6 | 22.2 | 171.4 |
| 31-32 | | | | 18.0 | 27.7 | 26.4 | 24.4 | 36.5 | 2.6 | 4.1 | | | 139.5 | 26.9 | 191.8 |
| 32-33 | | | | | 22.7 | 32.1 | 20.2 | 17.8 | 8.7 | | | | 101.4 | 22.5 | 209.1 |
| 33-34 | | | | 13.1 | 14.5 | 10.9 | 15.4 | | | | | | 53.9 | 13.1 | 240.0 |
| 34-35 | | | | | 4.5 | | 23.5 | 3.8 | | | | 0.0 | 31.9 | 8.2 | 254.5 |
| 35-36 | | | | | | | | | | | | | | | |
| 36-37 | | | | | | | | | | | | 2.3 | 2.3 | | |
| 37-38 | | | | | 13.9 | | | | | | | 0.6 | 14.5 | 4.8 | 348.0 |
| 38-39 | | | | | | | 12.9 | | | | | | 12.9 | 5.0 | 388.0 |
| TSN(mill) | 3873 | 4792 | 2992 | 427 | 199 | 168 | 191 | 106 | 11 | 4 | 4 | | 12 780.1 | | |
| cv (TSN) | 0.36 | 0.19 | 0.17 | 0.28 | 0.48 | 0.54 | 0.59 | 0.59 | 0.89 | 0.99 | 1.35 | | 0.15 | | |
| TSB(1000 t) | 157.4 | 348.5 | 269.3 | 54.2 | 37.9 | 29.9 | 40.1 | 19.8 | 2.5 | 0.8 | 0.6 | | 961.3 | | |
| cv (TSB) | 0.33 | 0.18 | 0.17 | 0.29 | 0.49 | 0.56 | 0.59 | 0.60 | 0.90 | 0.99 | 1.40 | | 0.14 | | |
| Mean length(cm | 19.4 | 23.1 | 24.9 | 27.1 | 29.9 | 30.0 | 30.8 | 30.2 | 31.6 | 32.0 | 30.0 | | | | |
| Mean weight(g) | 42 | 76 | 95 | 126 | 174 | 177 | 198 | 186 | 213 | 200 | 154 | | | | |

# Figures

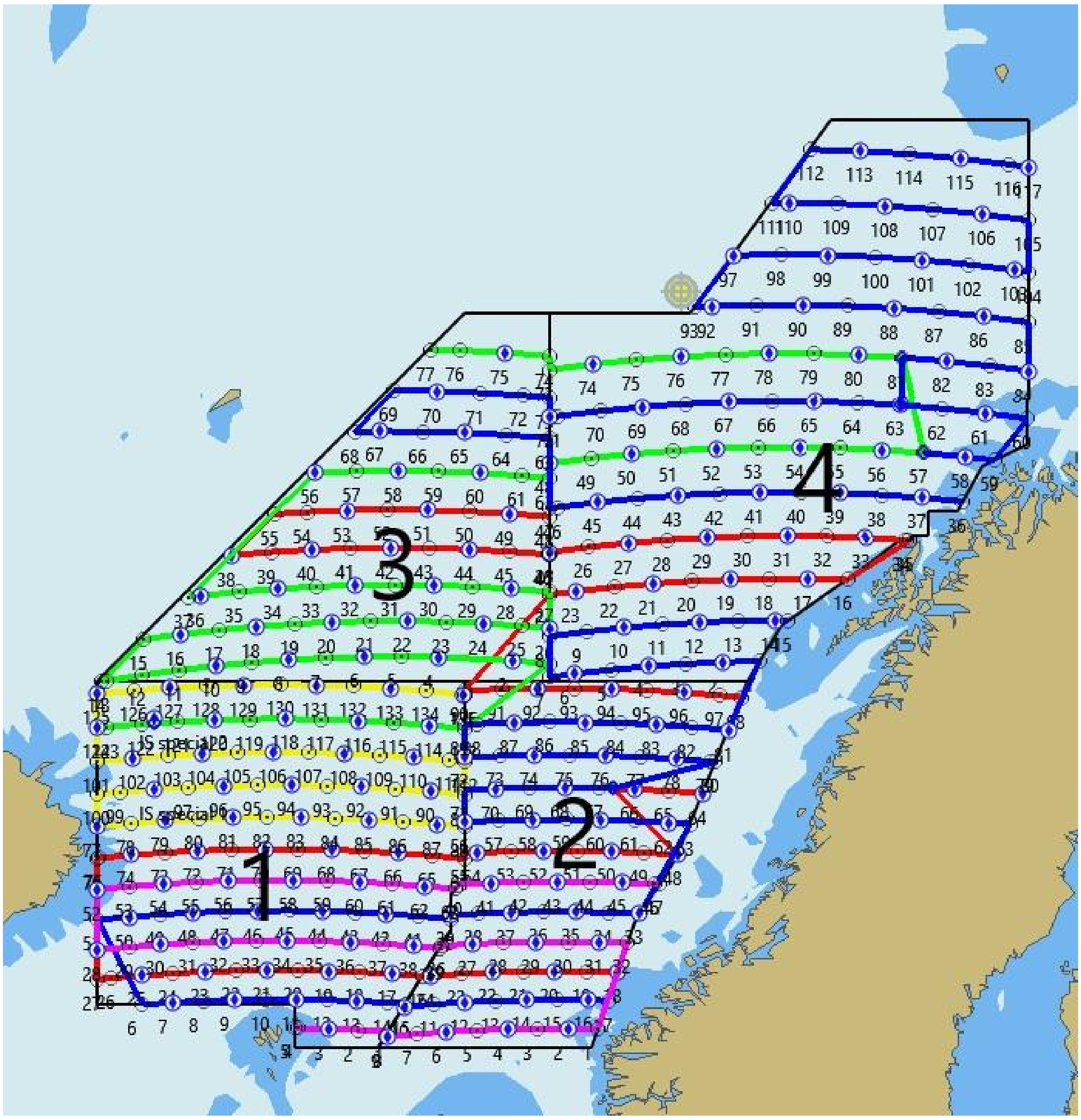



**Figure 1.** The pre-planned strata and transects for the IESNS survey in 2023 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: UK, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends**.**

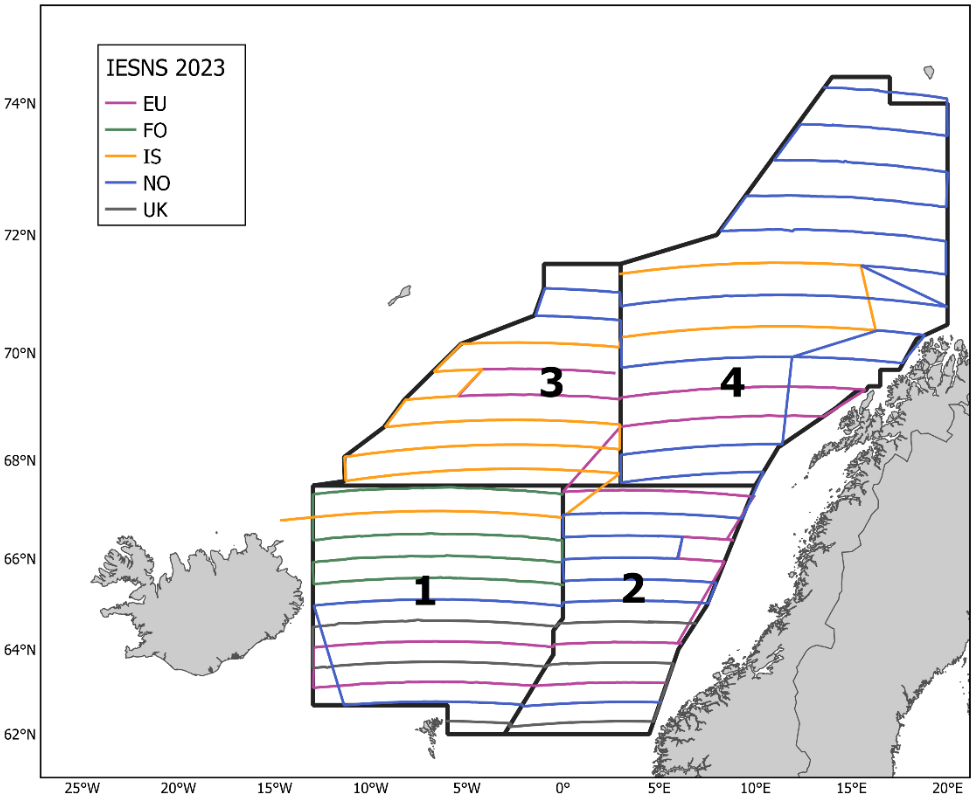



**Figure 2**. Cruise tracks and strata (with numbers) for the IESNS survey in May 2023.

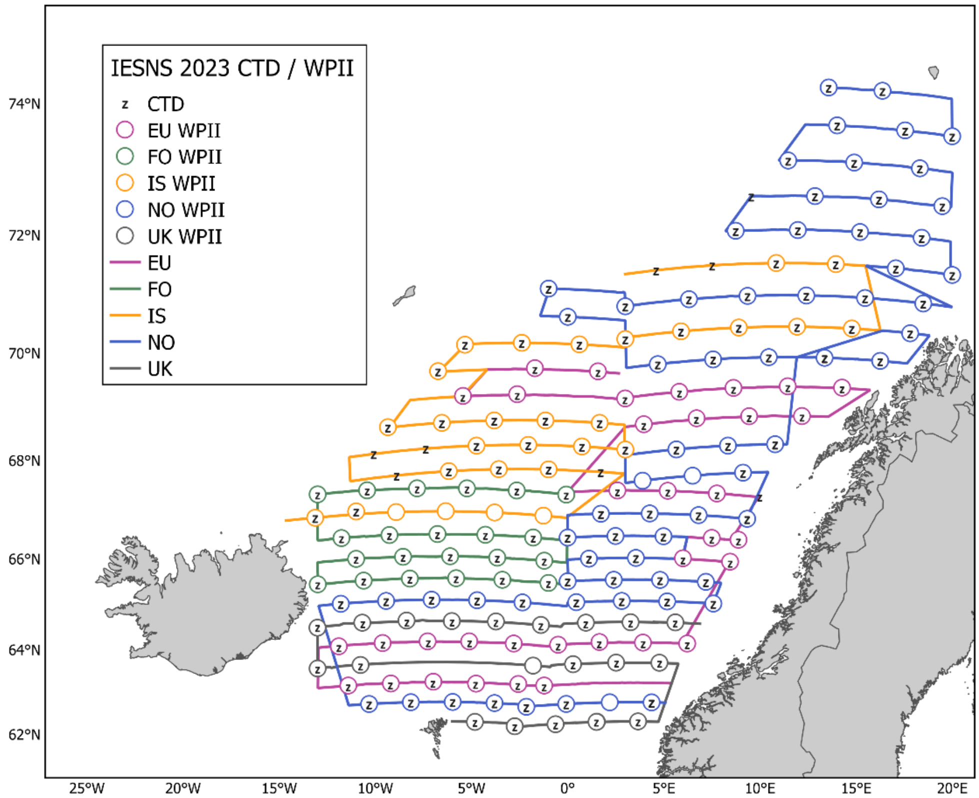



**Figure 3.** IESNS survey in May 2023: location of hydrographic and WPII plankton stations.

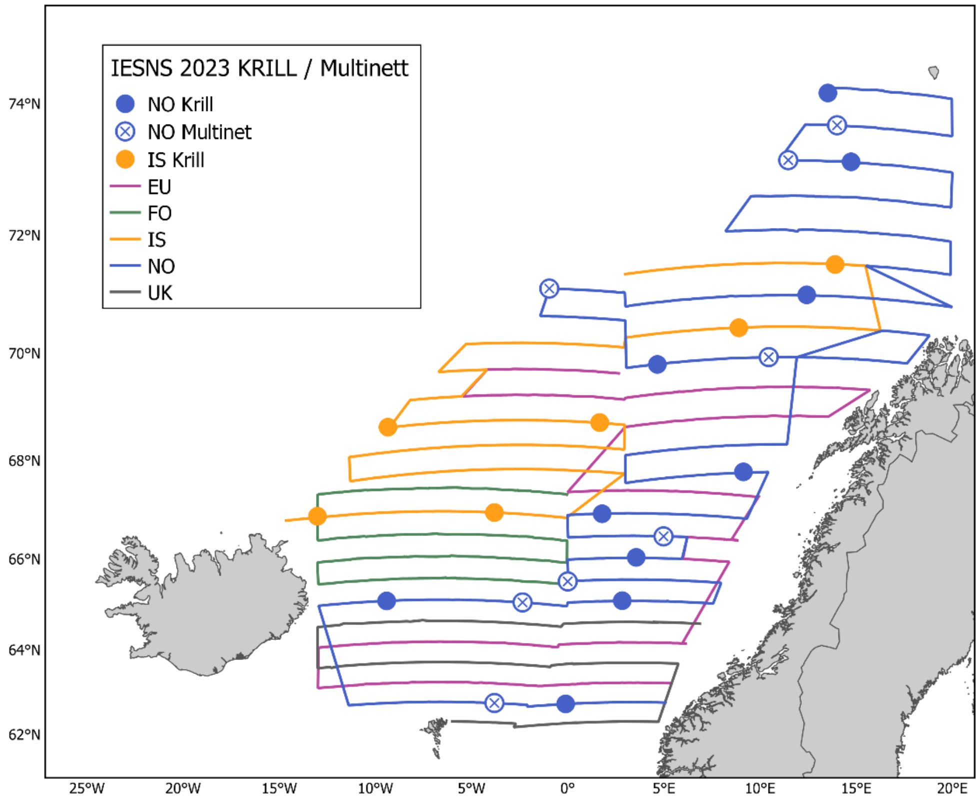



**Figure 4**. IESNS survey in May 2023: location of Macroplankton/Krill trawl and Multinet stations.

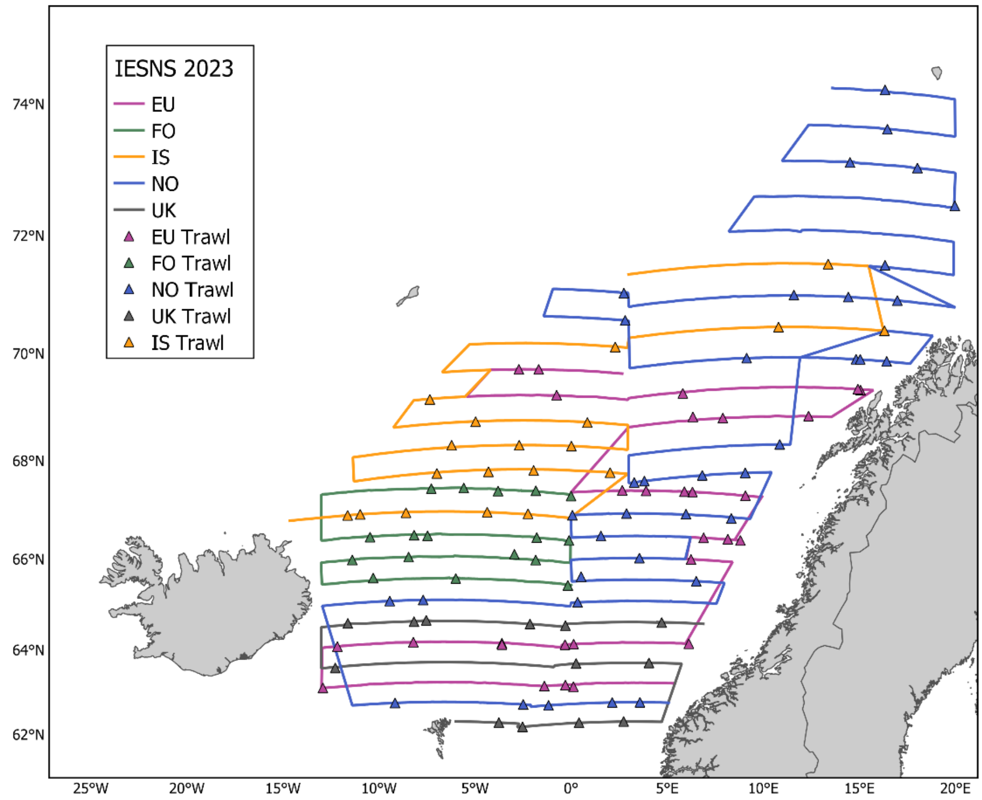



**Figure 5**. IESNS survey in May 2023: cruise tracks and location of pelagic trawl stations.

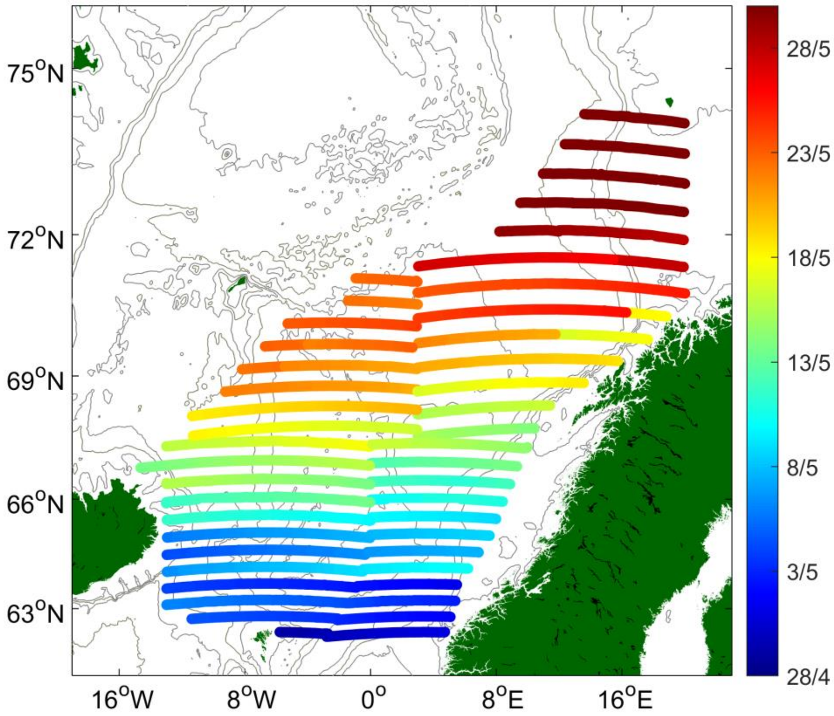



**Figure 6**. Temporal progression IESNS in April-May 2023.

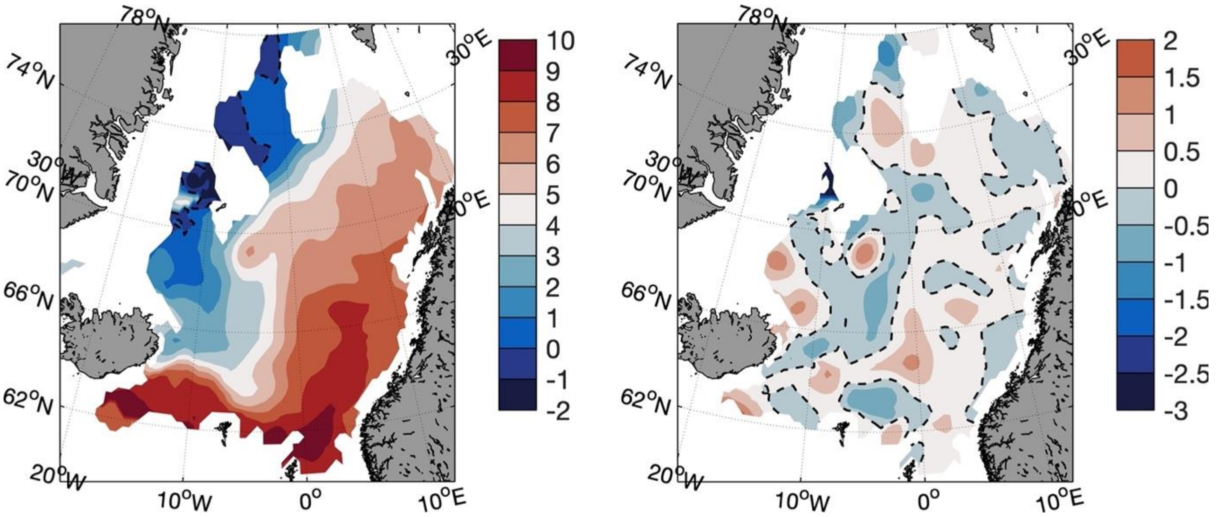



**Figure 7a**. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2023. Anomaly is relative to the 1995-2021 mean.

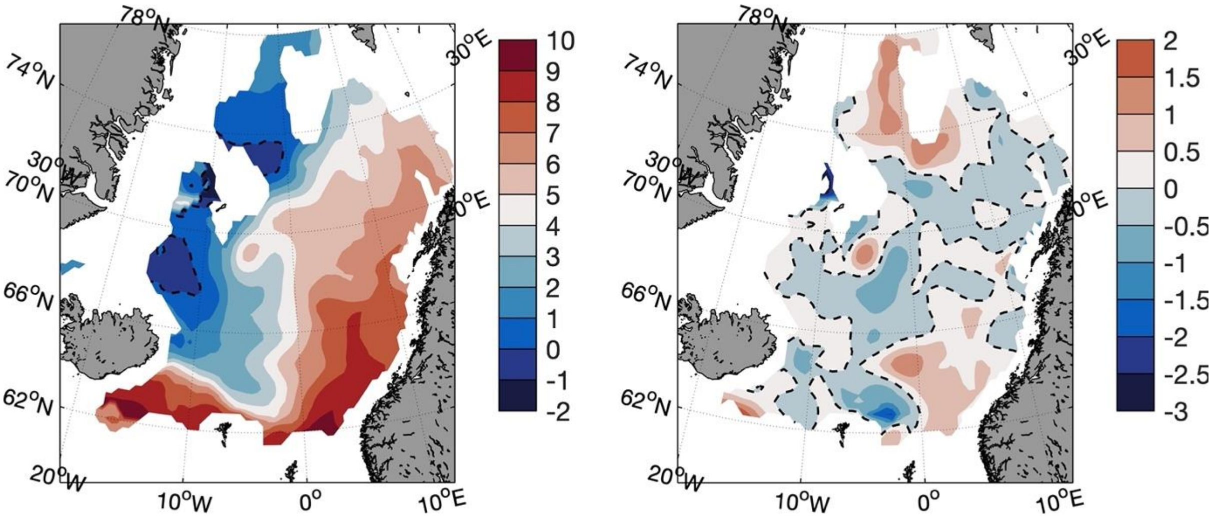



**Figure 7b**. Same as above but averaged over 50-200 m depth.

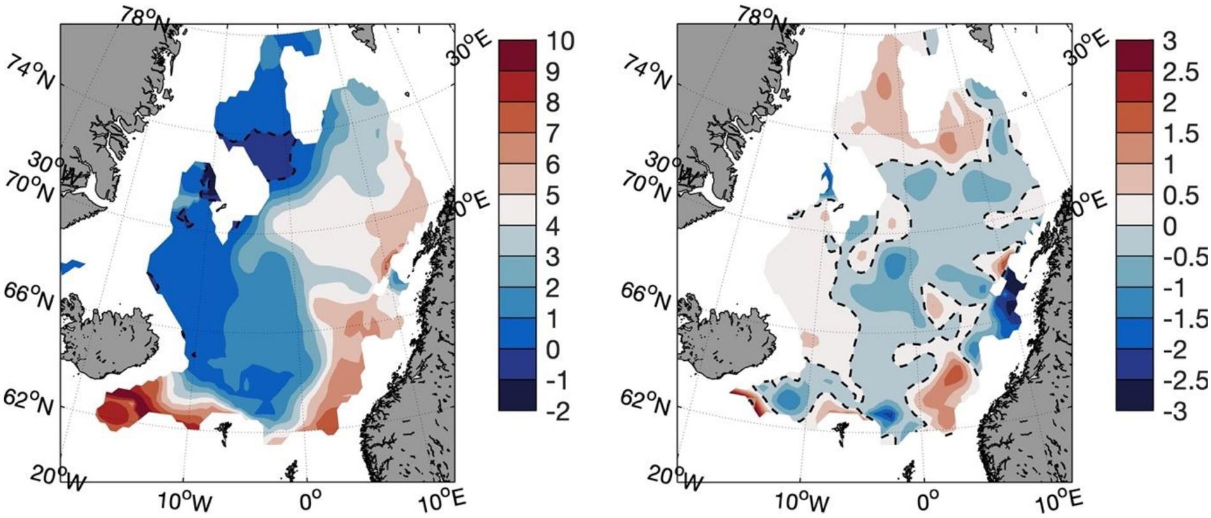



**Figure 7c**. Same as above but averaged over 200-500 m depth.

a) b)

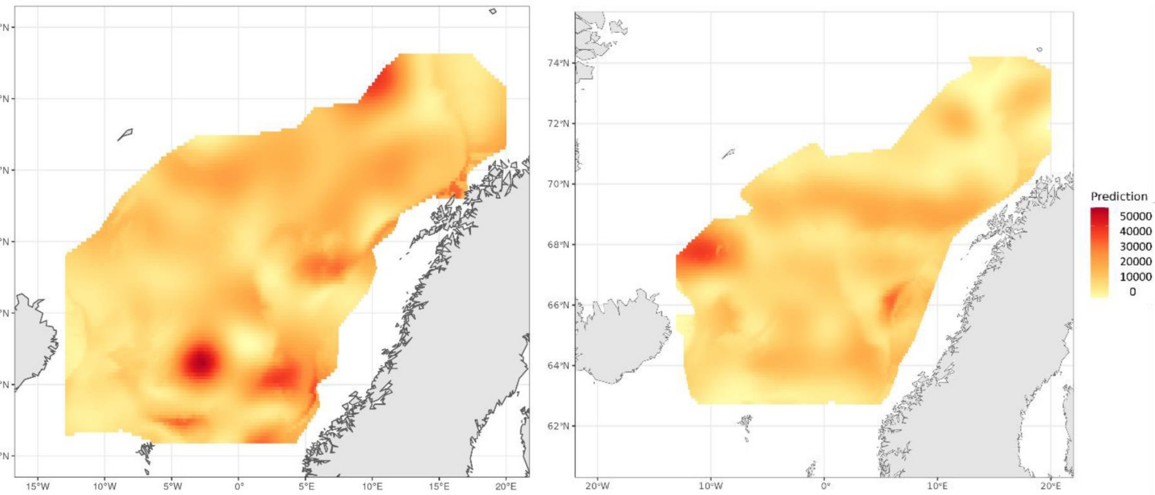
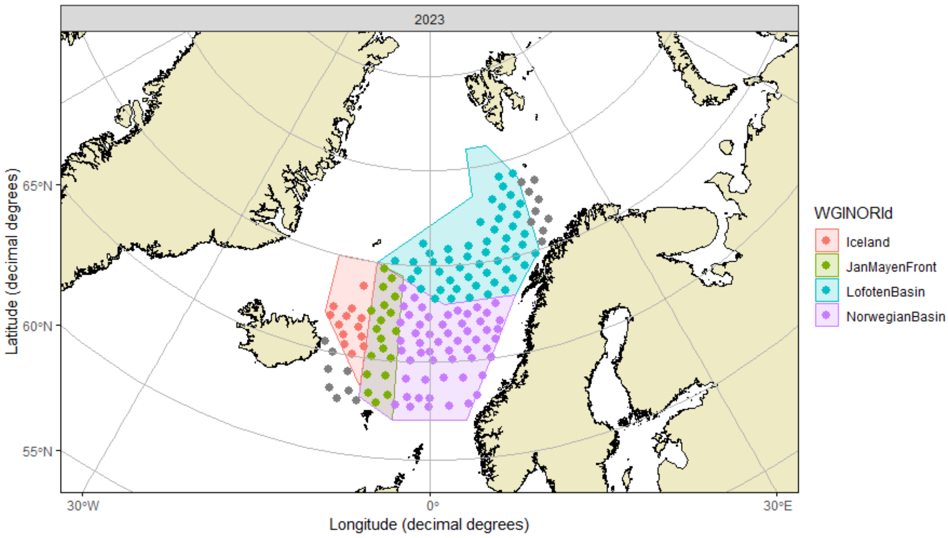



Figure 8. Distribution of zooplankton biomass (mg dry weight $m^{-2}$) in the upper 200 m in May a) IESNS 2022 and b) IESNS 2023.

a)




b)

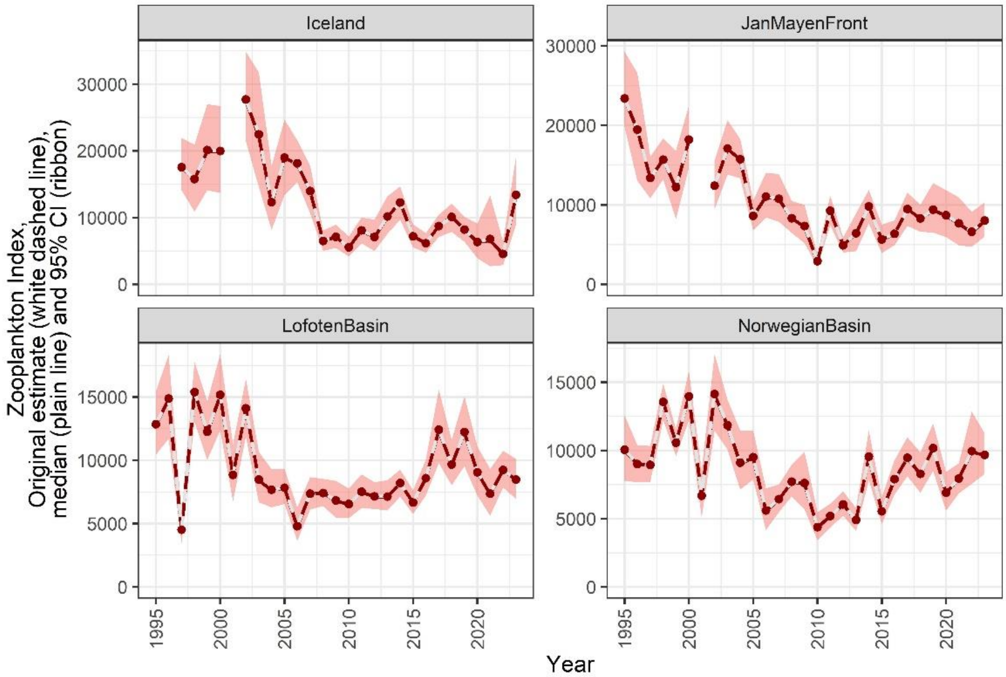
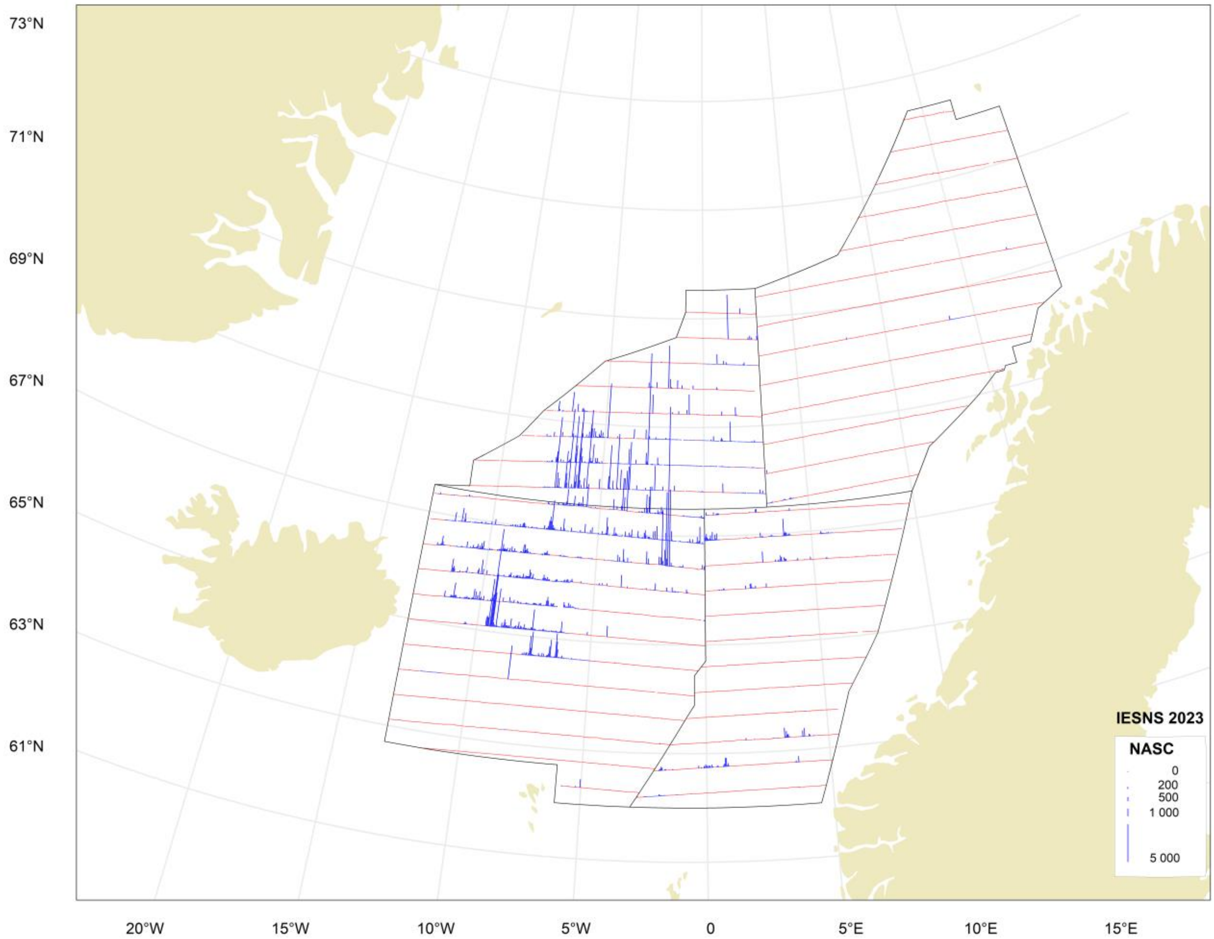



Figure 9 a) shows the sub-areas, and b) the indices of zooplankton biomass (mg dry weight $m^{-2}$) sampled by WP2 in May from 1995-2023.

**(a)**


73°N
71°N
69°N
67°N
65°N
63°N
61°N
20°W
15°W
10°W
5°W
0
5°E
10°E
15°E
IESNS 2023
NASC
0
200
500
1 000
5 000

**(b)**

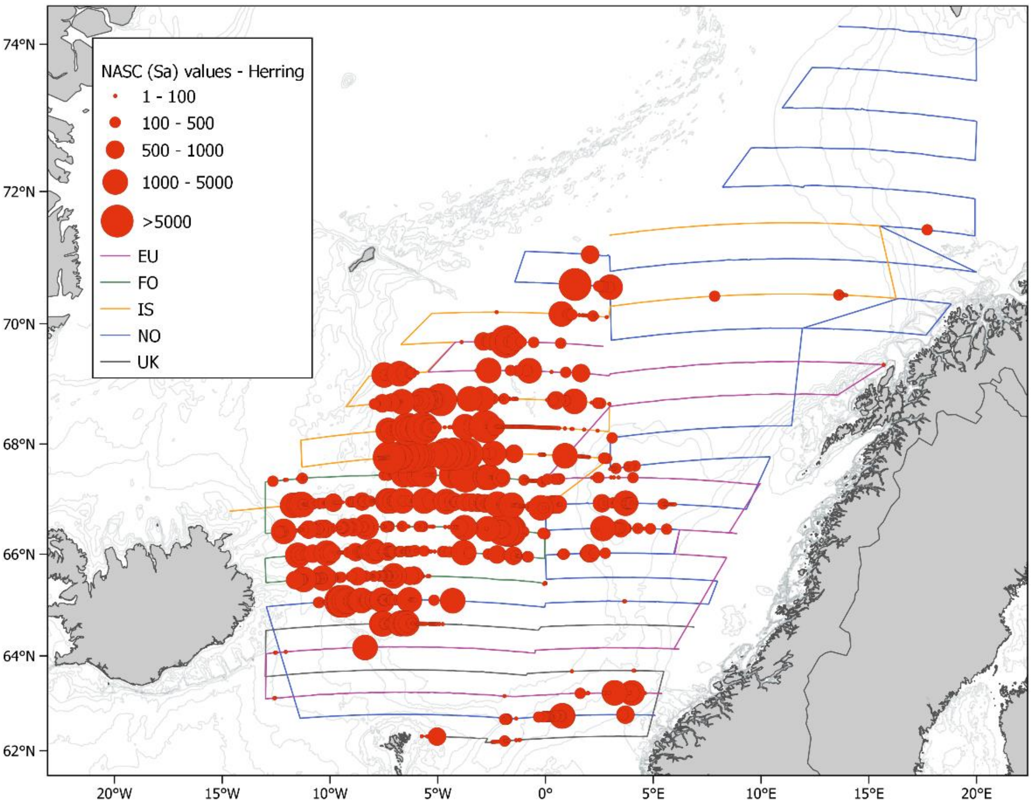



**Figure 10**. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2023 in terms of NASC values ($m^2/nm^2$) averaged for every 1 nautical mile. The NASC values are represented as both bars (a) and bubbles (b).

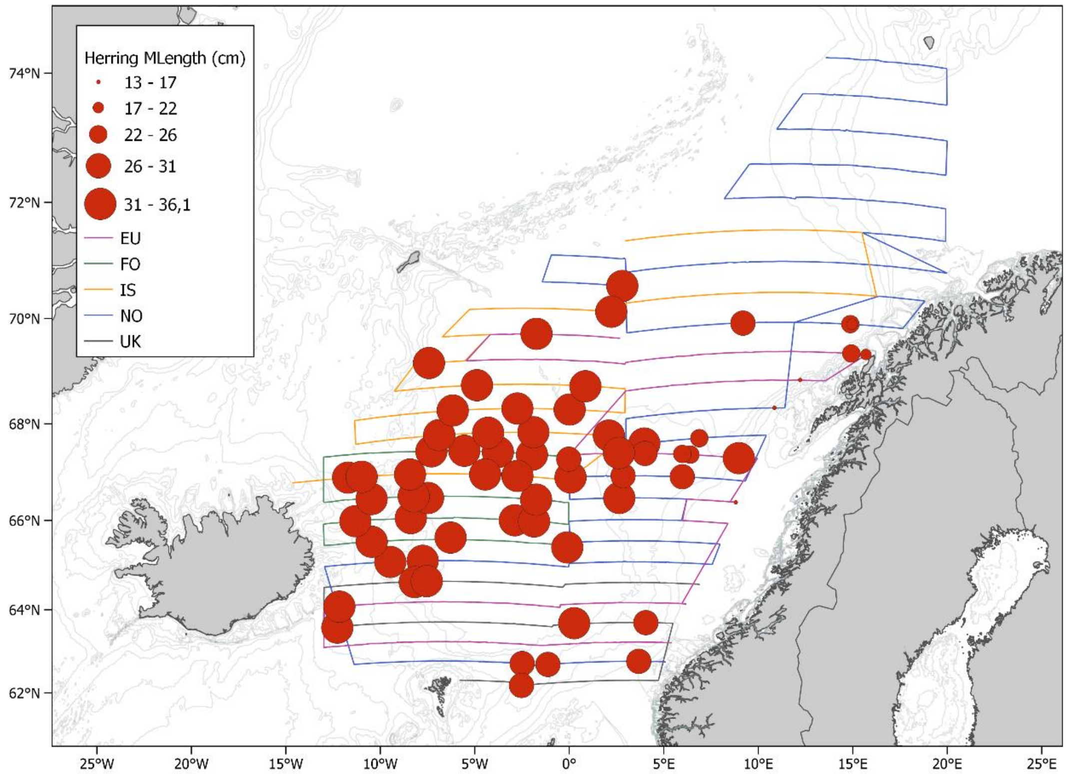



**Figure 11**. Mean length of Norwegian spring-spawning herring in all hauls in IESNS 2023.

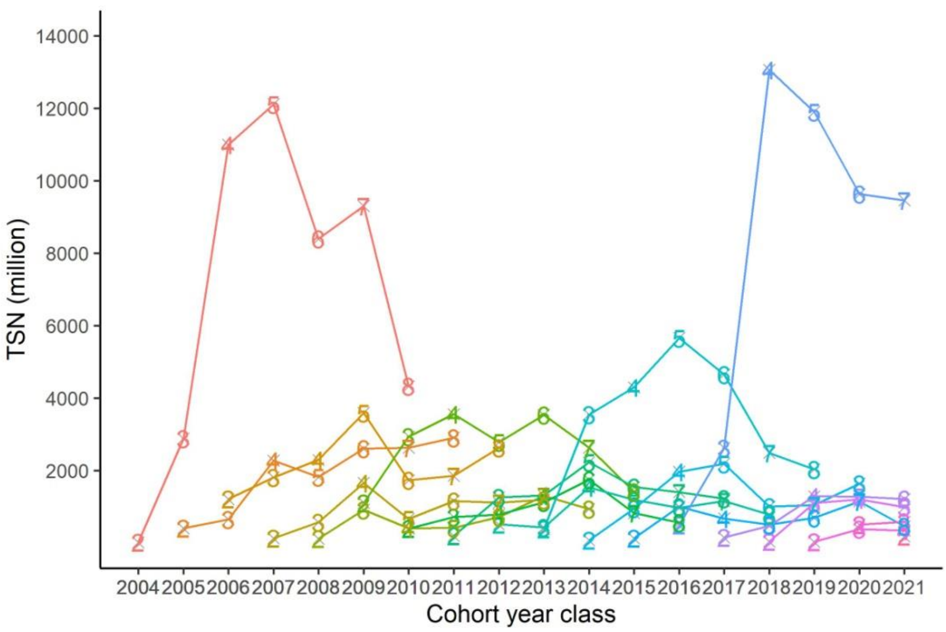



**Figure 12.** Tracking of the Total Stock Number at age (TSN, in billions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 8. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

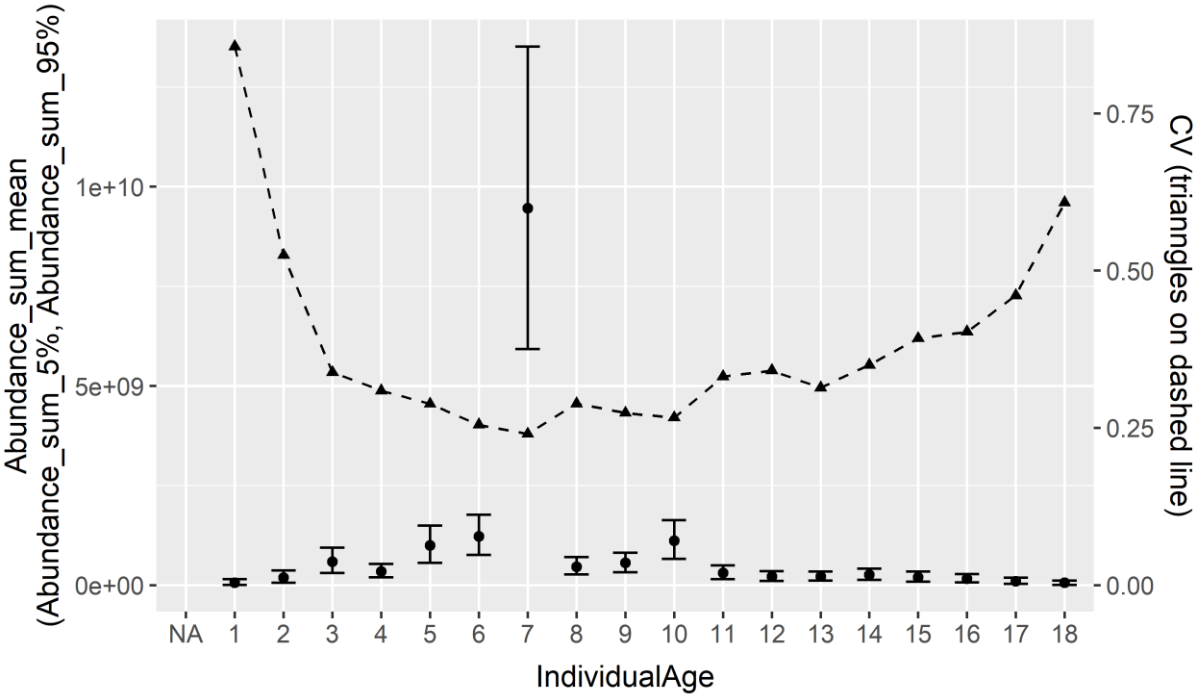



**Figure 13**. IESNS 2023. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

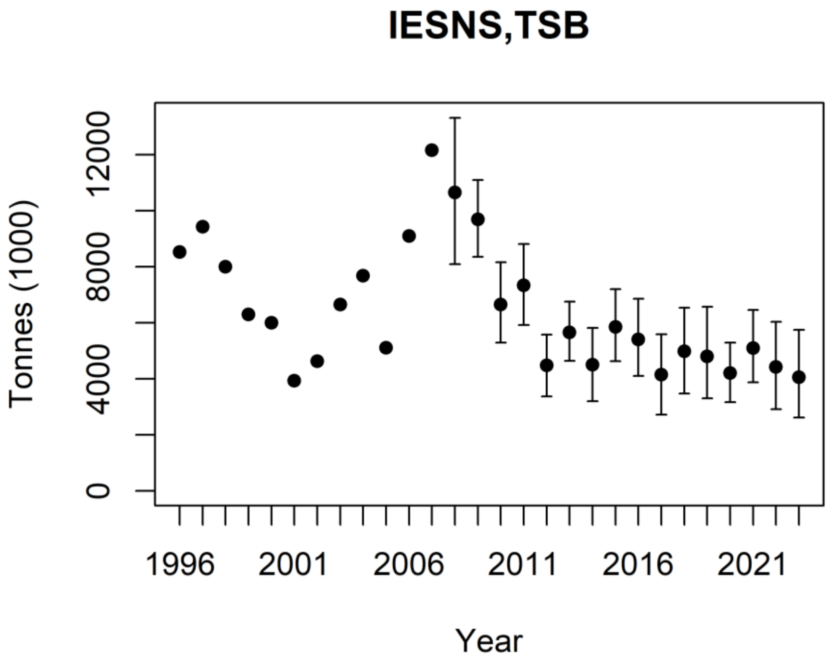



**Figure 14.** Biomass estimates of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2023 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2023; bootstrap means with 90% confidence interval; calculated on basis of standard stratified transect design).

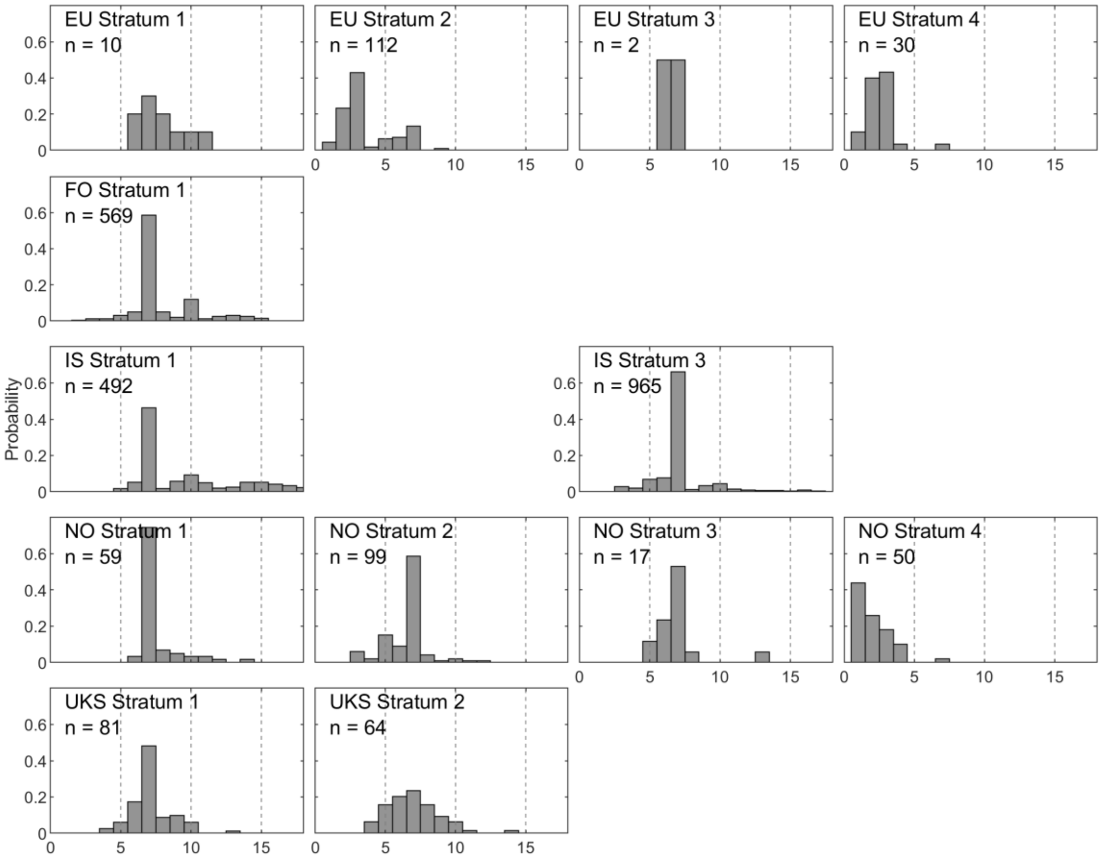
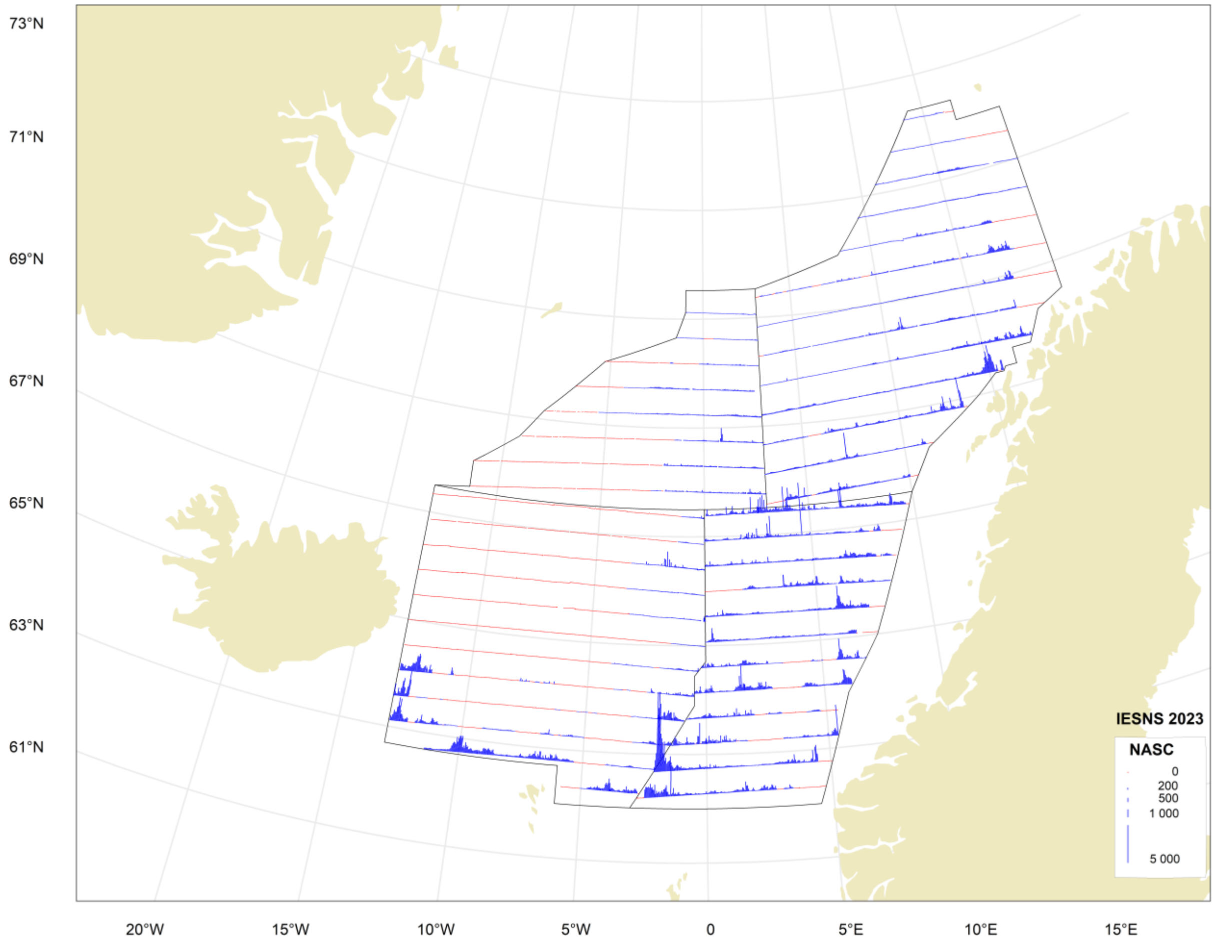



**Figure 15**. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2023. The strata are shown in Figure 3.

**(a)**


73°N
71°N
69°N
67°N
65°N
63°N
61°N
20°W
15°W
10°W
5°W
0
5°E
10°E
15°E
IESNS 2023
NASC
0
200
500
1 000
5 000

**(b)**

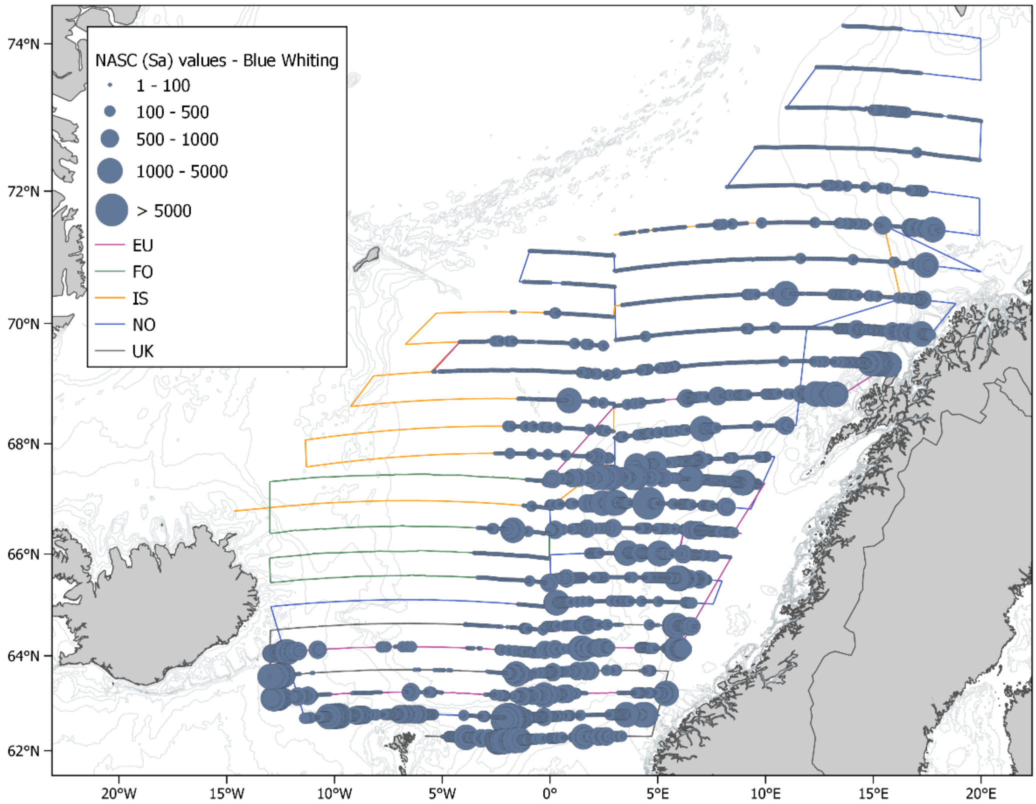



**Figure 16**. Distribution of blue whiting as measured during the IESNS survey in May 2023 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile. The NASC values are represented as both bars (a) and bubbles (b).

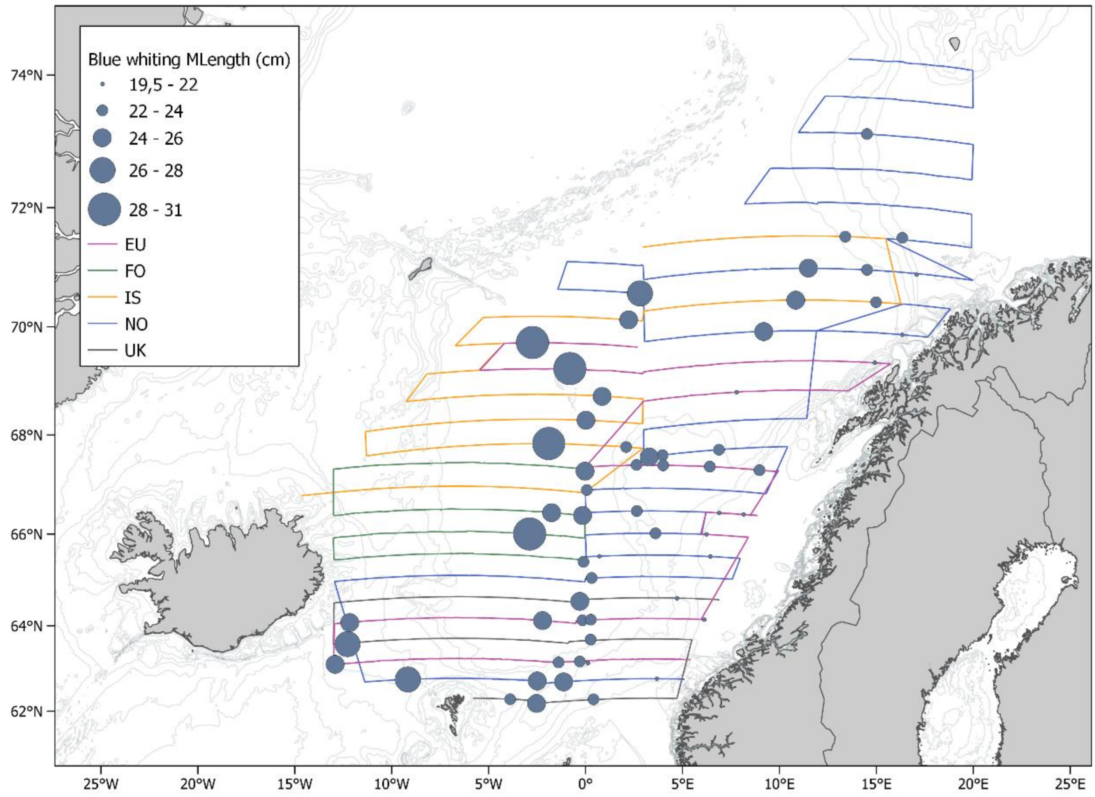



**Figure 17**. Mean length of blue whiting in all hauls in IESNS 2023. The strata are shown.

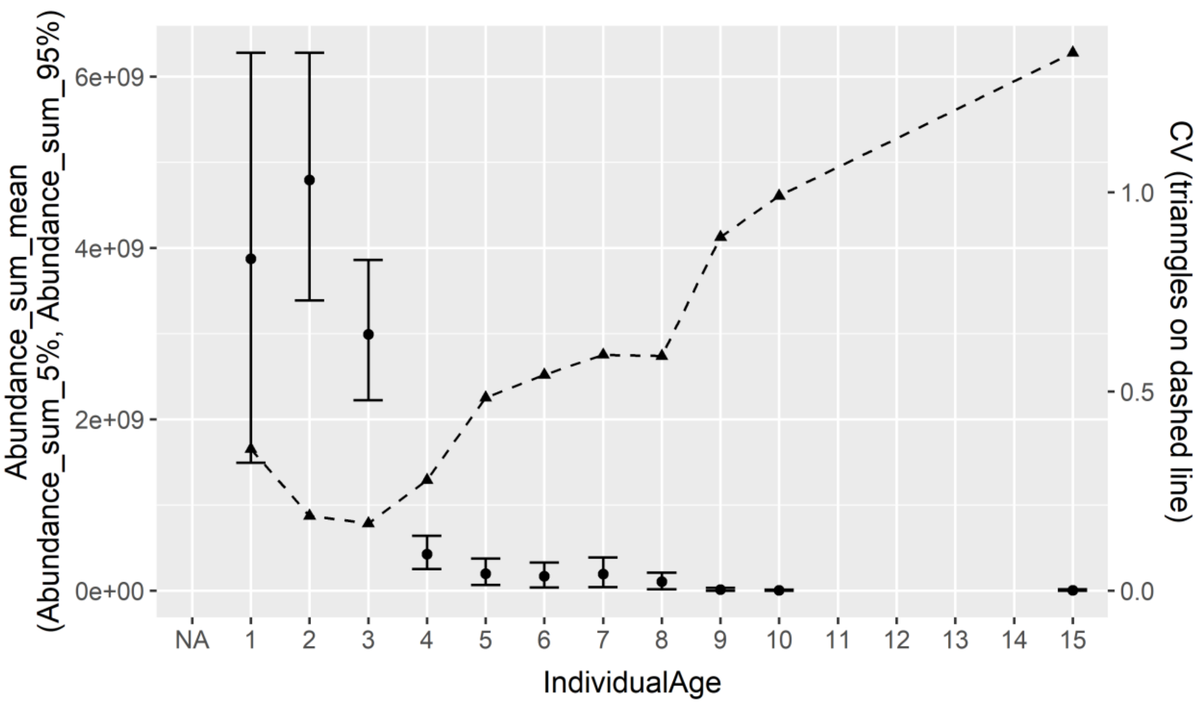



**Figure 18**. IESNS 2023. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

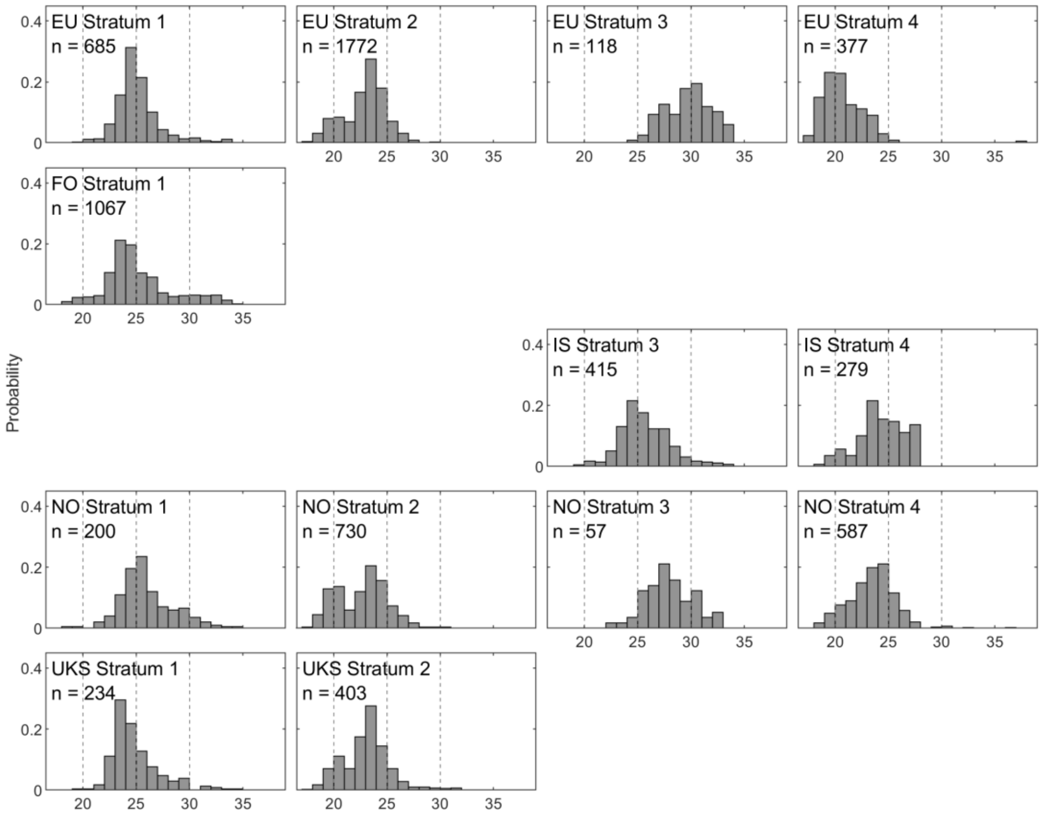



**Figure 19**. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2023. The strata are shown in Figure 3.

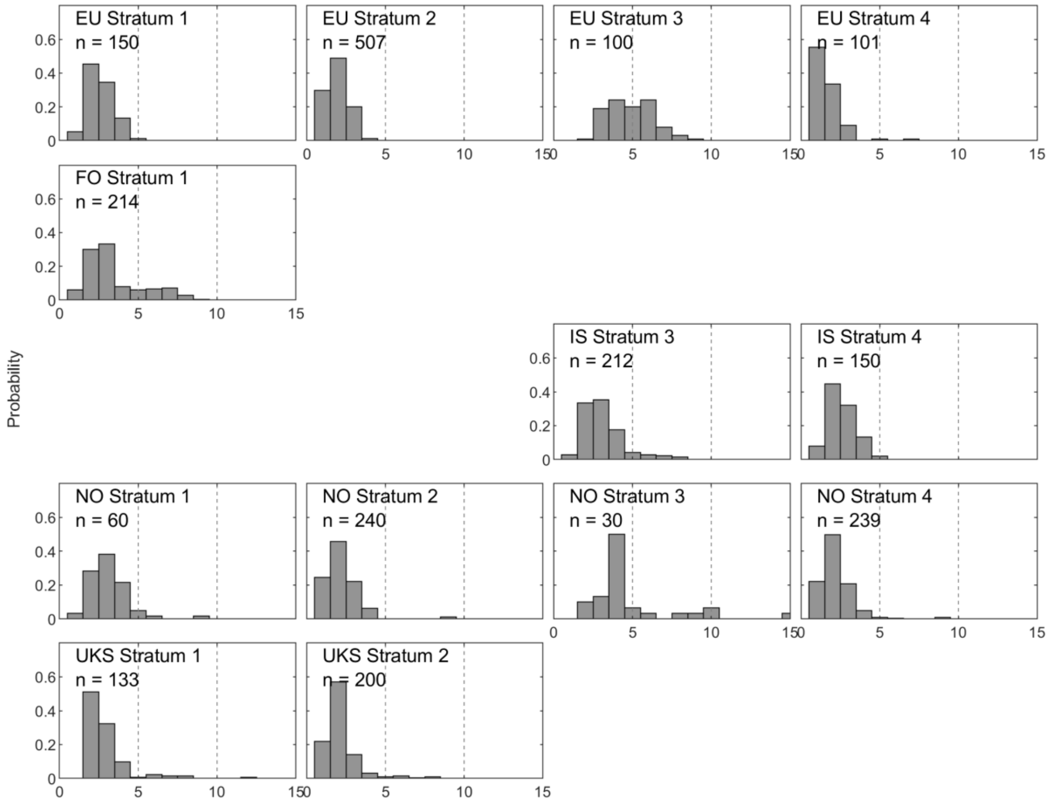



**Figure 20**. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2023. The strata are shown in Figure 3.

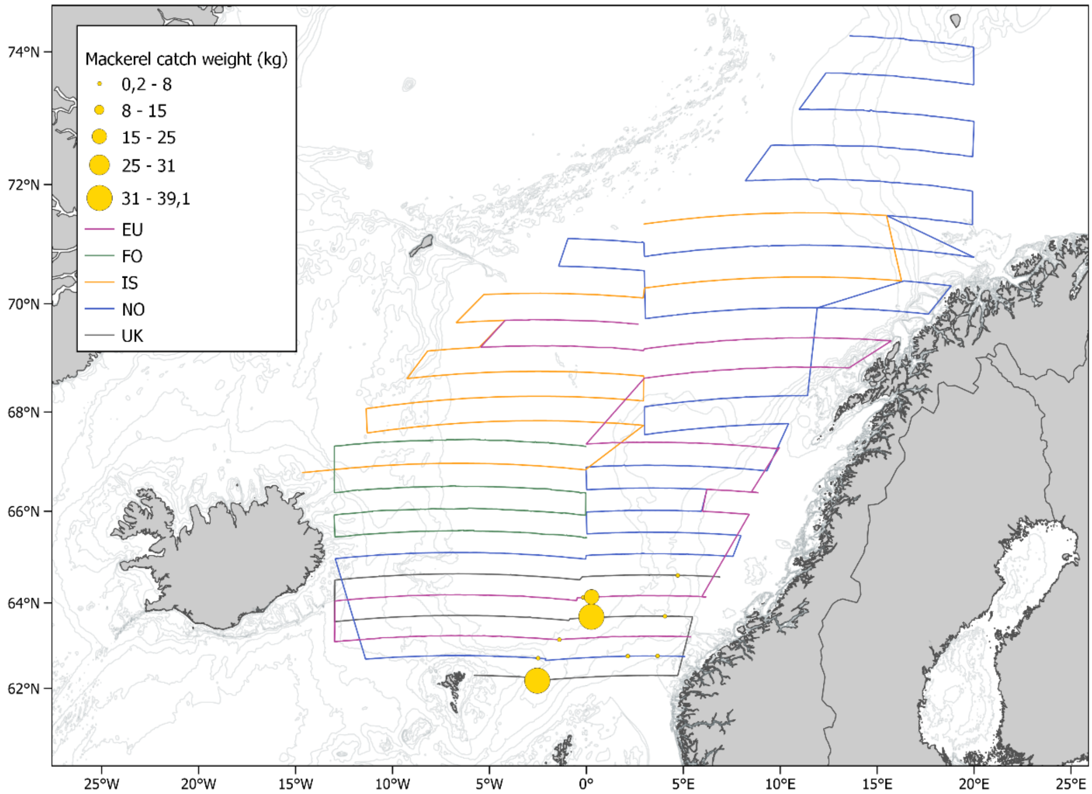



**Figure 21**. Pelagic trawl catches of mackerel in IESNS 2023.