Working Document to

Working Group on International Pelagic Surveys (WGIPS)
23 – 27 January 2023
and
Working Group on Widely Distributed Stocks (WGWIDE)
24 – 30 August 2022

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in April - May 2022

Post-cruise meeting on Teams, 14-16 June 2022

Are Salthaug[1], Erling Kåre Stenevik[1], Sindre Vatnehol[1], Åge Høines[1], Justine Diaz[1], Susanne Tonheim[1], Lea Hellenbrecht[1], Kjell Arne Mork[1], Cecilie Thorsen Broms[1]
RV G.O. Sars

Susan Mærsk Lusseau[2], Matthias Kloppmann[3], Sven Gastauer[3] and Serdar Sakinan[6]
RV Dana

Sigurvin Bjarnason[4]
RV Árni Friðriksson

Eydna í Homrum[5], Leon Smith[5]
RV Jákup Sverri

Fabio Campanella[7], Louise Straker Cox[7], Richard Humphreys[7], Samantha Barnett[7], Nicola Hampton[7], Gary Burt[7]
MS Resolute

[1] Institute of Marine Research, Bergen, Norway
[2] DTU-Aqua, Denmark
[3] Thünen-Institute of Sea Fisheries, Germany
[4] Marine and Freshwater Research Institute, Hafnarfjordur, Iceland
[5] Faroe Marine Research Institute, Tórshavn, Faroe Islands
[6] Wageningen Marine Research, Netherlands
[7] CEFAS, United Kingdom

Introduction

In April-May 2022, four research vessels and one hired commercial vessel participated in the International ecosystem survey in the Nordic Seas (IESNS); R/V Dana, Denmark (joint 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). It should be noted that this was the first year that UK participated in the survey, and the plan is to continue the participation in the coming years. The Barents Sea is usually surveyed by a Russian research vessel, but that was not possible in 2022. 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 also the EU participated (except 2002 and 2003) and from 2004 onwards it was more integrated into an ecosystem survey.

This report represents analyses of data from this International survey in 2022 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 03/2022. International Ecosystem survey in the Nordic Seas (IESNS) in 2022, Árni Friðriksson: Report on Survey A5-2022, Bjarnason, 2022, Jákup Sverri: Preliminary Report Cruise no. 2216).

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2022 and by correspondence. Planning of the acoustic transects and 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	22/04-20/05
G.O. Sars	Institute of Marine Research, Bergen, Norway	26/04-30/05
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	28/04-08/05
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	04/05-23/05
Resolute	CEFAS, United Kingdom	24/04-06/05

Note that Resolute covered the UK EEZ in the southernmost part of the IESNS survey area, but this area was also covered by G.O. Sars and Dana. The reason for this double coverage was to ensure consistency with previous year's surveys (the UK coverage went well and these data were used in the abundance estimation). 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. UK also covered an area south of the IESNS survey area and this is described in Annex A.

In general, the weather conditions did not affect the survey even if there were some days that were not favourable and trawling, WP2 and Multinet sampling at some stations were prevented. 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	8	6-9	6
Upper integration limit (m)	10	15	15	15	10
Absorption coeff. (dB/km)	10.05	10.1	10.5	10.3	10
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.425	3.06	
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	18	21.9	18
2-way beam angle (dB)	-20.5	-20.7	-20.3	-20.4	-20.7
Sv Transducer gain (dB)	25.31				
Ts Transducer gain (dB)		26.12	27.03	26.94	26.62
s_A correction (dB)	-0.61	-0.13	-0.04	-0.13	-0.04
3 dB beam width (dg)					
alongship:	6.98	6.42	6.43	6.47	6.35
athw. ship:	6.94	6.29	6.43	6.54	6.54
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 a 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 2022 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	44–55	30-50
Mesh size in codend (mm)	20/40	24	20	45	100
Typical towing speed (kn)	3.5-4.5	3.0–4.5	3.1–5.0	3.7 (3–4.5)	3.5-5
Plankton sampling					
Sampling net	WP2	WP2	WP2	WP2	WP2
Standard sampling depth (m)	200	200	200	200	200
Hydrographic sampling					
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 a coming age reading and stock identity workshop, genetic samples were collected of herring. 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	100-300	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	50	50
	Blue whiting	50	25-30	50	25-50	50
	Mackerel	0	25-30	50	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			25	50

* Number of weighed individuals significantly higher.

Acoustic data were analysed using the StoX software package (version 3.4.0) which has been used for some 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 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 WPII 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 mg total dry weight per m^2. 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. This front was sharper below 50 m than above. 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 6 °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 in most of the Norwegian Sea (Figure 7a). Below 50 m depth, the patterns were more fragmented, but the Norwegian Sea was still in general colder than the long-term mean (Figures 7b-c). Largest negative temperature anomalies were between Iceland and Faroe Islands due to a more southern located Iceland-Faroe front compared to the long-term mean. This was found for all depths, and the temperatures in this region were in some locations 3 °C lower than the mean (Figures 7a-c). Also, in the centre of the Norwegian Basin, the temperatures were 1 °C lower than the mean, probably because of a more eastern located Arctic front. Warmest regions, relative to the long-term mean, were in the eastern Greenland Sea, with temperatures 2 °C higher than the mean, and in some areas below 50 m depth in southern and southwestern parts of the Norwegian Sea.

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) in the upper 200 m is shown in Figure 8. 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 eastern and southeastern parts. Within the eastern area, several locations had high biomass and a large patch was found at ca. 3°W and 64.5°N. Lower biomasses were found in central and western parts of the Norwegian Sea.

Figure 9 shows the zooplankton 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 Sea Basin (covering the southern Norwegian Sea). The zooplankton biomass index for 2022 was respectively: 4563, 6627, 9237 and 9962 mg dry weight m^{-2}, and while the subareas east of Iceland and Jan Mayen arctic front showed a decrease compared to last year, the Lofoten- and Norwegian Basin increased. The zooplankton biomass indices for the Norwegian Sea in May have been estimated since 1995. All subareas had a high biomass period until mid-2000, and a lower period thereafter. The decrease was most pronounced in the Iceland Sea, where the reduction was 59 %. 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). 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 2022. 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 2022 can be used for assessment purpose. The herring was primarily distributed in the central and southwestern area (Figure 10). In the westernmost area old herring dominated, but in general, the 2016-year-class was the most abundant year class throughout the survey area. 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).

Six-year-old herring (2016-year class) dominated both in terms of number (49%) and biomass (48%) on basis of the StoX bootstrap estimates for the Norwegian Sea (Table 2). The abundance of the 2016 year-class decreased by 19 % compared to last year's estimate which could be expected since this year-class was fully recruited to the survey last year (Figure 12). The second largest year-class in the survey was the 2013 year-class (10% in numbers), and older age groups (10-18 years old) contributed with less than 10% to the abundance estimate. 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 21 % both for the total biomass and for the total numbers estimate, and the relative standard error for the dominating age groups is around 20-30 % (Figure 13).

The total estimate of herring in the Norwegian Sea from the 2022 survey was 19.8 billion in number and the biomass was 4.4 million tonnes. The biomass estimate is 13 % lower than the 2021 survey estimate and also the estimated number is about 13% lower than in 2021. The biomass estimate decreased significantly from 2009 to 2012 and has since then been rather stable at 4.2 to 5.9 million tonnes with similar confidence interval (Figure 14), with the lowest abundance occurring in 2017. The 2016 year class now appears to be fully recruited, distributed widely in the feeding area and more dominant than the older year classes.

There was no coverage of juvenile herring in strata 5 (the Barents Sea) in May 2022.

In the last 6 years, there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences – particularly older specimens appear to have uncertain ages. A scale and otolith exchange has been ongoing for some time, where scales and otoliths for the same fish have been sampled. As a follow-up on that work, a new exchange and following workshop are currently being planned for April 2023. The survey group emphasizes the necessity of having this workshop before next year's survey takes place.

With respect to age-reading concerns in the recent years, the comparison between the nations in this year's survey for the most part appeared to be in good agreement (Figure 15).

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 2022 are shown in Table 3. The estimated biomass was 1.5 million tons (CV=0.13) which is a 76 % increase from last year's estimate, and one of the two highest estimates after 2007 (together with the 2016 estimate). The estimated total abundance was 17.2 billion (CV=0.13) which is a 112 % increase from last year's estimate. The stock is totally dominated by 1 and 2 year old (2021 and 2022 year classes) and the estimates of total abundance, abundance of age 1 and abundance of age 2 are all the highest observed after 2007. 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 2022 is shown in Figure 16. As usual, most of the fish was registered in the eastern part of the Norwegian Sea. However, higher concentrations than in later years were observed in more central areas, in particular around the zero meridian in the southern part. This corresponds well with the high abundance estimate. The largest fish was found in the northwestern part of the of the survey area this year (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. This year the catches did not extend as far north as compared with recent years, only north to circa 64°N. This is the lowest northward extent of mackerel catches during IESNS after 2007 (first year with data from all participating vessels). 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. It is recommended that the the planned age reading workshop in April 2023 also includes a session n how to deal with stock components of herring in the IESNS-survey.	WG

Next year's post-cruise meeting

We will aim for next meeting in 13-15 June 2023. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2022 was generally below the long-term mean (1995-2021) in the Norwegian Sea, but the pattern was more fragmented below 50 m depth. The Arctic front in the southern Norwegian Sea was more southerly and easterly located in 2022 compared to the long-term mean.
- The 2022 indices of meso-zooplankton biomass in the Norwegian Sea and adjoining waters were fairly similar to last year's estimates.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 4.4 million tonnes, which is a 13 % decrease from the 2021 survey estimate. The estimate of total number of NSSH was 19.8 billion, which is 13 % lower than in the 2021 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 (49%) and biomass (48%). The abundance of the 2016 year-class decreased by 19 % compared to last year's estimate
- The biomass of blue whiting measured in the 2022 survey increased by 76 % from last year's survey and 112 % in terms of numbers. The stock is dominated by the 2020 and 2021 year classes) and the estimates of total abundance, abundance of age 1 and abundance of age 2 are all the highest observed after 2007.

References

Bratseth, A. M. (1986). Statistical interpolation by means of successive corrections. Tellus A 38A(5), 439-447.

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep. 144: 1–57.

ICES 2009. Report of the PGNAPES Scrutiny of Echogram Workshop (WKCHOSCRU) 17–19 February 2009, Bergen, Norway ICES CM 2009/RMC

ICES. 2012. Report of the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES), 23–26 January 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGESST:01. 27 pp.

ICES. 2015. Report of the Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT), 7-11 September 2015, Hamburg, Germany. ICES CM 2015/SSGIEOM:18. 107pp.

ICES. 2017. Workshop on Stock Identification and Allocation of Catches of Herring to Stocks (WKSIDAC). ICES WKSIDAC Report 2017 20-24 November 2017. Galway, Ireland. ICES CM 2017/ACOM:37. 99 pp.

ICES. 2020. Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR; outputs from 2019 meeting). ICES Scientific Reports. 2:29. 46 pp. http://doi.org/10.17895/ices.pub.5996

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019, 10:1523–1528.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Can.J. Fish. Aquat. Sci. 47: 1282-1291.

Kristiansen, I., Hátun H., Petursdottir, H., Gislason, A., Broms, C., Melle, W., Jacobsen, J.A., Eliasen S.K., Gaard E. 2019. Decreased influx of Calanus spp. into the south-western Norwegian Sea since 2003. Deep Sea Research, 149, 103048

Mork, K. A., Ø. Skagseth, V. Ivshin, V. Ozhigin, S. L. Hughes, and H. Valdimarsson (2014), Advective and atmospheric forced changes in heat and fresh water content in the Norwegian Sea, 1951–2010, Geophys. Res. Lett., 41, 6221–6228, doi:10.1002/ 2014GL061038.

Skagseth, Ø., and K. A. Mork (2012), Heat content in the Norwegian Sea, 1995–2010, ICES J. Mar. Sci., 69(5), 826–832.

Skjoldal, H.R., Dalpadado, P., and Dommasnes, A. 2004. Food web and trophic interactions. *In* The Norwegian Sea ecosystem. Ed. by H.R. Skjoldal. Tapir Academic Press, Trondheim, Norway: 447-506

Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2022.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	26/4-16/5	2495	20	36	253	873	35
Jákup Sverri	28/4-8/5	1464	19	23	325	1093	23
Árni Fridriksson	8/5-23/5	3013	14	40	863	2747	34
G.O. Sars	26/4-30/5	5103	37	60	375	1107	59
Resolute	24/4-06/5	1158	11	22	290	537	22
Total		**13233**	**101**	**181**	**2106**	**6357**	**173**

Table 2. IESNS 2022 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.

Length	Age in years (year class)																		Number	Biomass	Mean
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004		(10^6)	(10^6 kg)	(g)
17-18	18.6																		18.6	0.7	38.0
18-19	37.3																		37.3	1.6	42.5
19-20	27.4																		27.4	1.5	56.0
20-21	113.7																	4.2	117.8	7.2	59.5
21-22	107.8																		107.8	7.8	72.6
22-23	116.3																	0.6	116.9	9.7	82.9
23-24	71.4	22.9																	94.3	8.9	93.3
24-25		46.8	142.5		5.9													1.7	197.0	21.3	108.6
25-26		61.2	229.3																290.6	33.6	116.3
26-27		27.1	252.4	49.3															328.9	44.7	134.8
27-28		72.1	134.8	5.8	6.8														219.5	33.0	152.2
28-29		46.7	94.5	168.3	57.5	37.7				12.8									417.3	70.3	168.7
29-30	14.7	46.9	174.7	336.4	304.1	81.4	116.3		58.3										1 132.8	210.4	185.2
30-31		28.4	149.5	297.3	1411.4	239.3	378.3	187.0	29.2	26.0									2 746.4	549.4	199.1
31-32		30.8	24.6	212.9	3210.3	353.7	374.9	411.2	79.3			88.9							4 786.7	1034.1	215.0
32-33			4.7	203.8	2986.8	144.5	138.6	383.8	113.2	29.2	68.7	21.1							4 094.4	956.8	232.9
33-34				12.0	1427.9	98.0	163.1	243.8	121.0	6.9	110.7			6.5					2 189.9	554.7	254.2
34-35					190.5	157.7	213.7	491.8	10.9	4.8									1 069.5	299.5	280.0
35-36					29.5	38.3	197.5	235.6	56.4	77.0	39.2	31.1	10.4		7.2	15.6			737.8	219.3	296.8
36-37					2.7		57.8	99.3	70.3	80.7	60.1	32.4	29.5	35.6	6.1	14.1			488.7	154.9	316.9
37-38								11.1	38.1	60.1	32.6	97.2	72.0	56.7	33.9	10.9			412.5	139.7	338.7
38-39										24.2	13.6	22.7	3.4	28.6	26.1	17.6			136.2	49.7	363.3
39-40										17.1				5.4	7.0	6.0	5.6	0.2	41.5	15.1	366.1
40-41															5.0			2.5	7.5	3.1	408.0
TSN(mill)	507.2	383.0	1207.1	1285.8	9633.2	1150.5	1640.3	2063.6	576.6	338.9	324.9	293.4	115.3	132.9	85.4	64.2	5.6		19 817.1		
cv (TSN)	0.59	0.49	0.45	0.34	0.23	0.36	0.37	0.34	0.40	0.31	0.42	0.40	0.39	0.35	0.44	0.45	1.12		0.21		
TSB(1000 t)	37.7	58.0	182.1	252.4	2 132.2	266.1	400.6	531.5	152.2	102.0	89.7	86.2	37.1	45.1	29.8	20.5	2.0		4 427.0		
cv (TSB)	0.55	0.48	0.41	0.35	0.23	0.34	0.35	0.32	0.38	0.31	0.39	0.35	0.39	0.36	0.46	0.46	1.12		0.21		
Mean length(cm)	21.2	27.6	27.9	30.0	31.5	32.2	33.0	33.6	34.0	35.8	35.2	35.9	36.6	36.9	37.3	36.7	39.0				
Mean weight(g)	76.0	165.2	169.1	199.6	223.0	246.3	262.7	273.6	285.3	314.2	299.6	320.7	321.4	341.9	346.6	319.4	365.4				

Table 3. IESNS 2022 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.

Length	Age in years (year class)									Number	Biomass	Mean
	1	2	3	4	5	6	7	8	Unknown			weight
(cm)	2021	2020	2019	2018	2017	2016	2015	2014		(10^6)	(10^6 kg)	(g)
14-15	7.6								2.6	10.2	0.1	16.0
15-16	232.7									232.7	4.9	20.8
16-17	1304.5	29.8								1 334.3	32.5	24.4
17-18	4114.3	122.2								4 236.5	125.6	29.7
18-19	5637.5	135.3								5 772.8	199.4	34.6
19-20	4229.8	161.9	6.7							4 398.5	173.8	39.9
20-21	1206.1	387.6	66.5							1 660.2	78.4	47.5
21-22	271.7	1526.6	123.7							1 922.0	109.8	57.4
22-23	135.6	2649.2	58.5							2 843.2	183.6	65.5
23-24	1.9	2821.4	207.0							3 030.3	221.0	74.5
24-25	27.0	2116.0	308.7							2 451.8	199.0	83.2
25-26		495.9	277.6	12.9						786.4	72.5	93.1
26-27		117.2	145.7	27.8						290.7	30.4	105.0
27-28		11.7	34.6	25.9	31.6	7.1	9.4			120.2	14.2	118.4
28-29			50.1	13.5			4.9			68.5	9.0	128.6
29-30					2.3	9.2	16.7	12.9	0.0	41.2	5.9	141.6
30-31				17.6	20.8		10.0	17.7		66.1	10.5	159.2
31-32					26.5	20.2	5.7			52.3	9.7	182.3
32-33							46.2	16.4	0.2	62.8	12.6	199.5
33-34							9.5	8.0	0.1	17.7	4.2	239.4
34-35					7.9				3.4	11.3	3.0	271.5
35-36												
36-37					2.2					2.2	0.7	330.0
TSN(mill)	17169	10575	1279	98	91	36	102	55		29 411.9		
cv (TSN)	0.16	0.15	0.20	0.39	0.36	0.51	0.54	0.54		0.13		
TSB(1000 t)	603.3	729.5	105.7	11.9	15.2	5.9	17.7	10.5		1 500.6		
cv (TSB)	0.15	0.16	0.19	0.40	0.38	0.53	0.55	0.53		0.13		
Mean length(cm)	18.2	22.7	24.1	27.2	29.7	29.9	30.6	30.5				
Mean weight(g)	36	72	85	121	167	159	168	183				

Figures

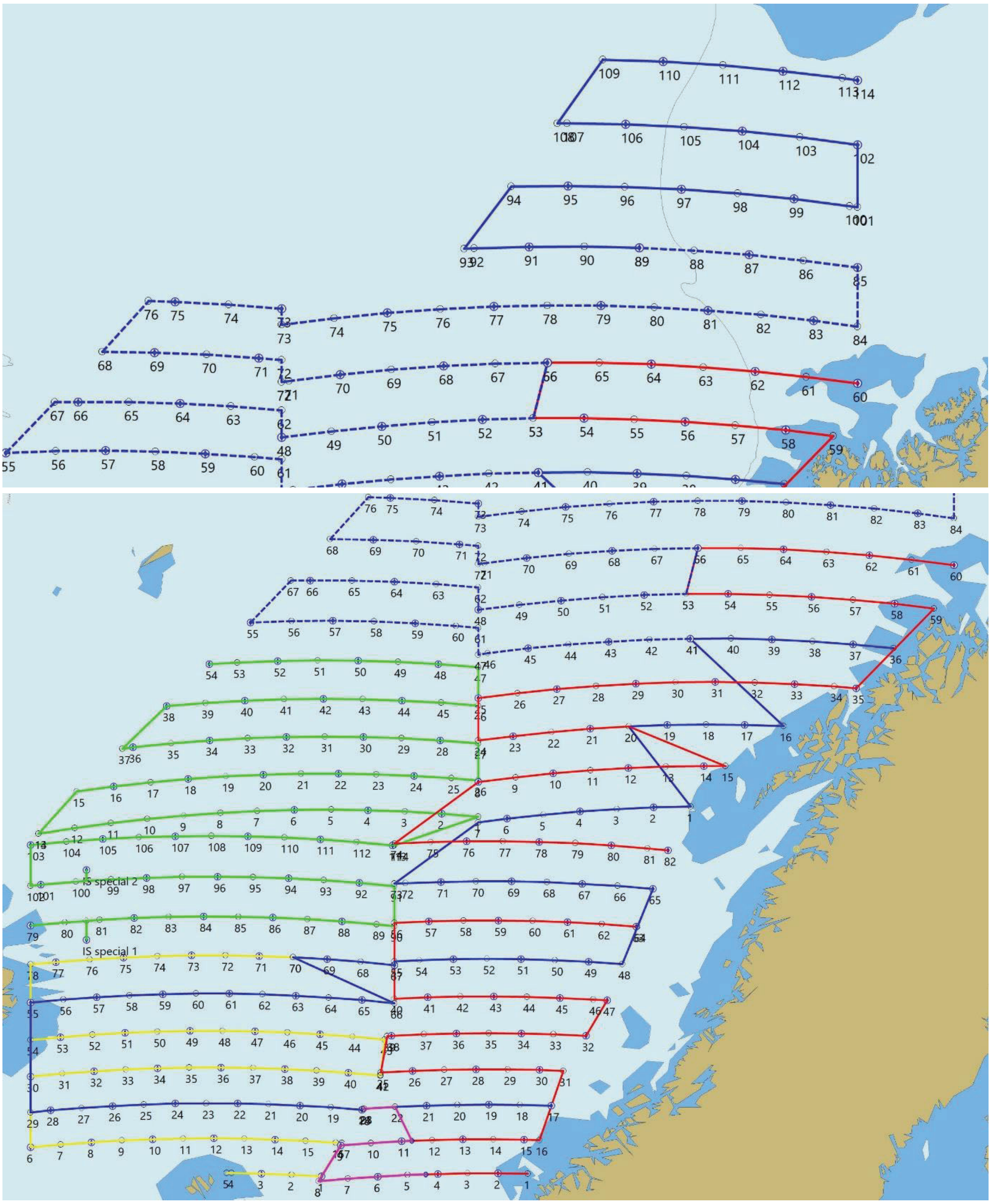


Figure 1. The pre-planned strata and transects for the IESNS survey in 2022 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: UK, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends**.**

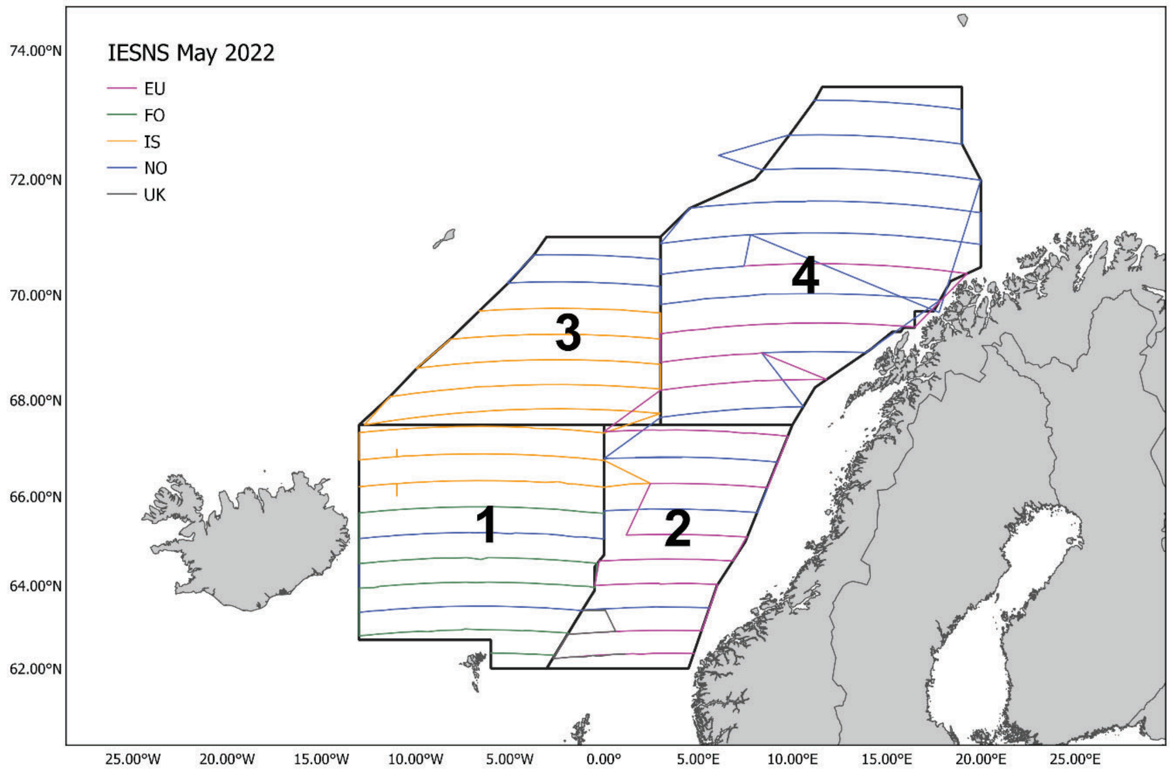


Figure 2. Cruise tracks and strata (with numbers) for the IESNS survey in May 2022.

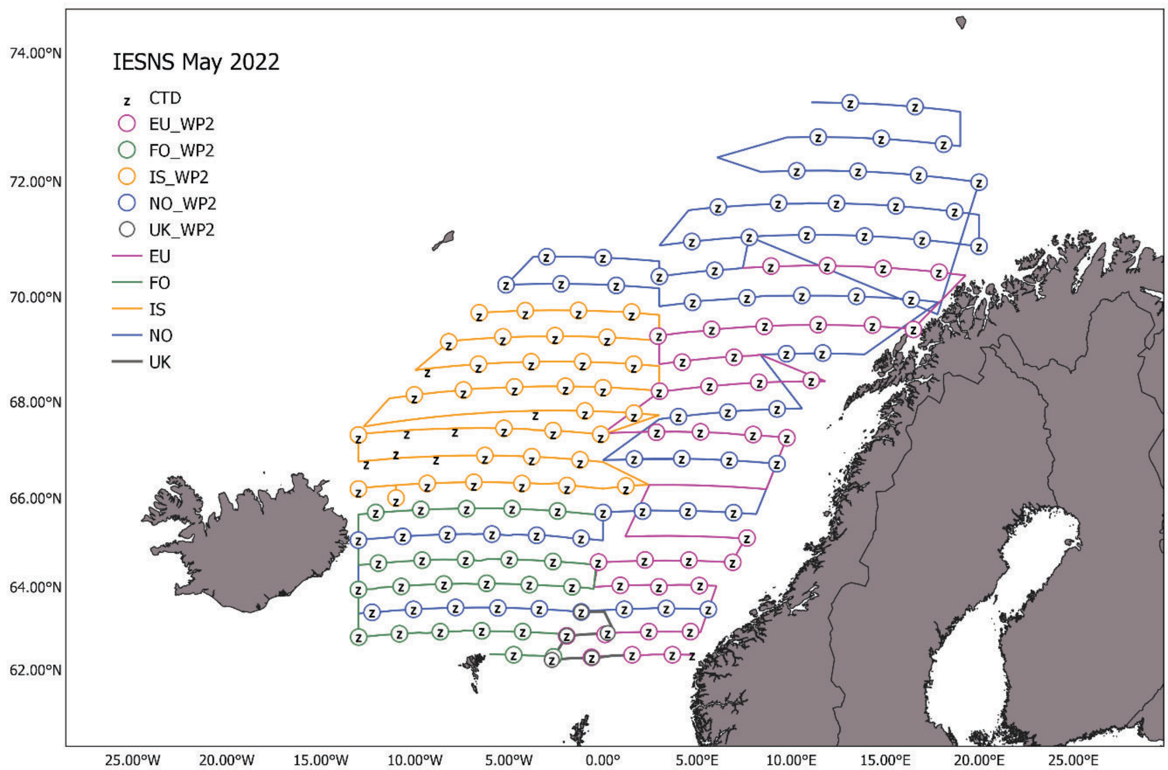


Figure 3. IESNS survey in May 2022: location of hydrographic and WPII plankton stations.

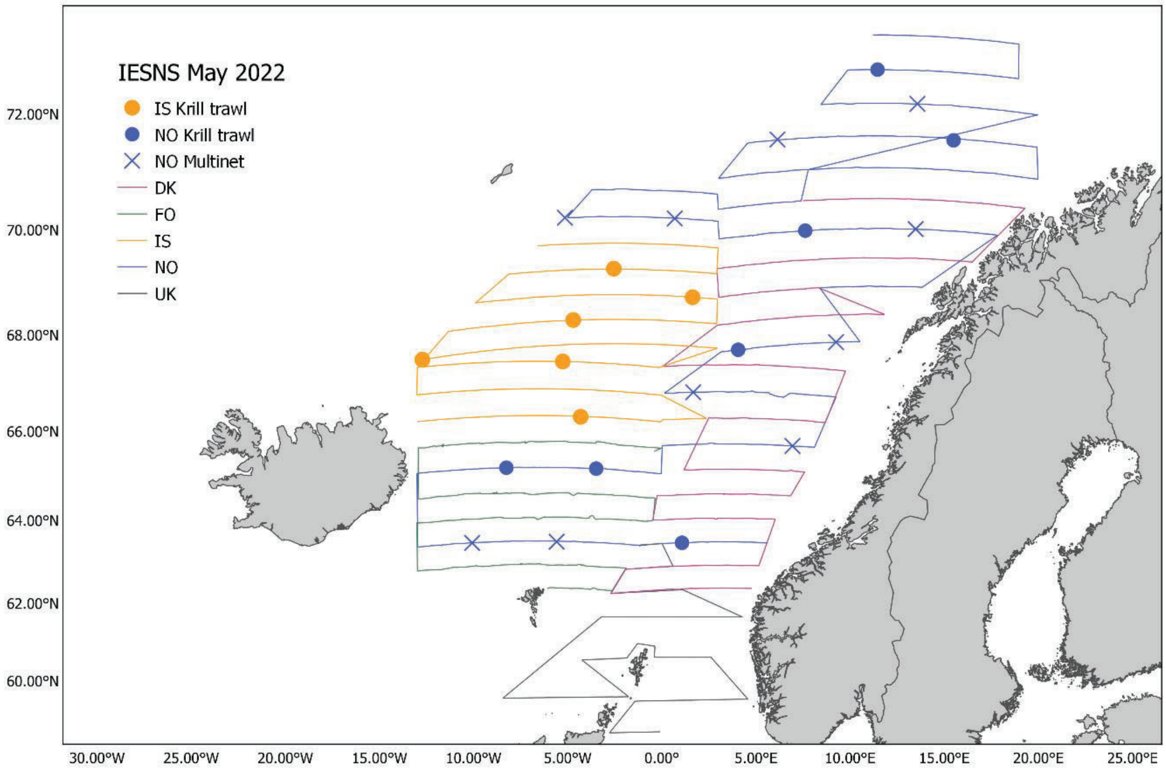


Figure 4. IESNS survey in May 2022: location of Macroplankton/Krill trawl and Multinet stations.

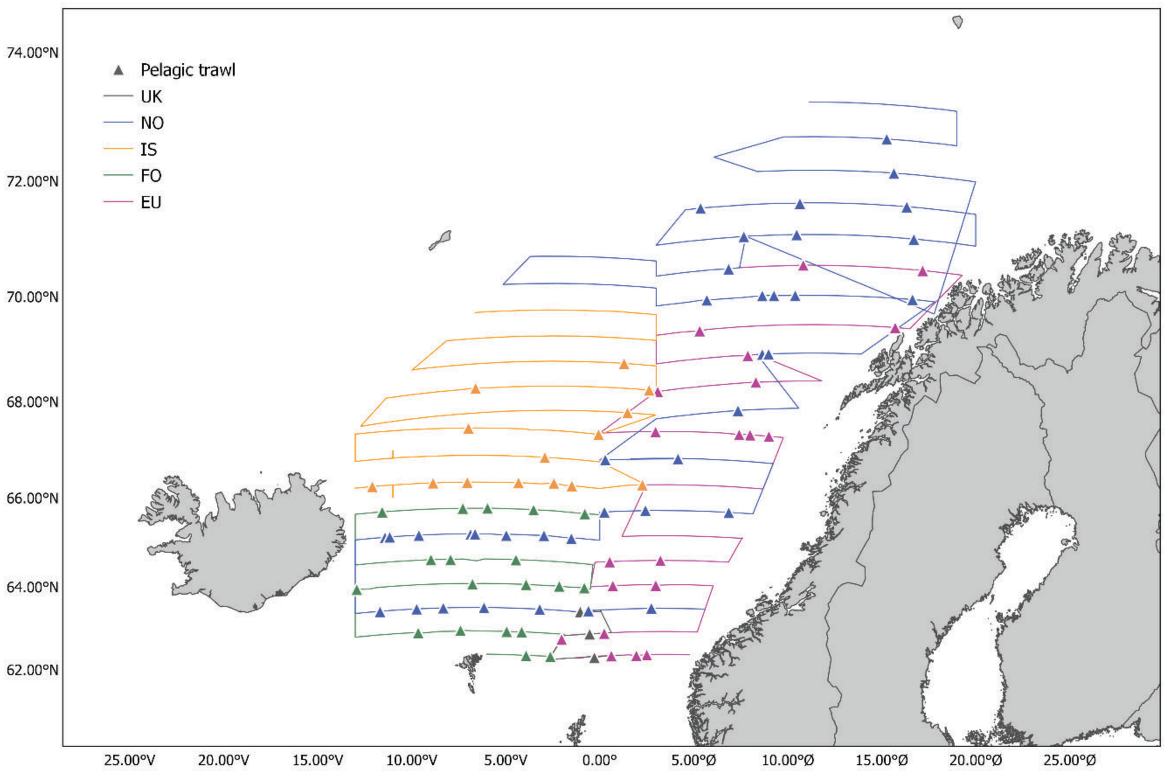


Figure 5. IESNS survey in May 2022: location of pelagic trawl stations.

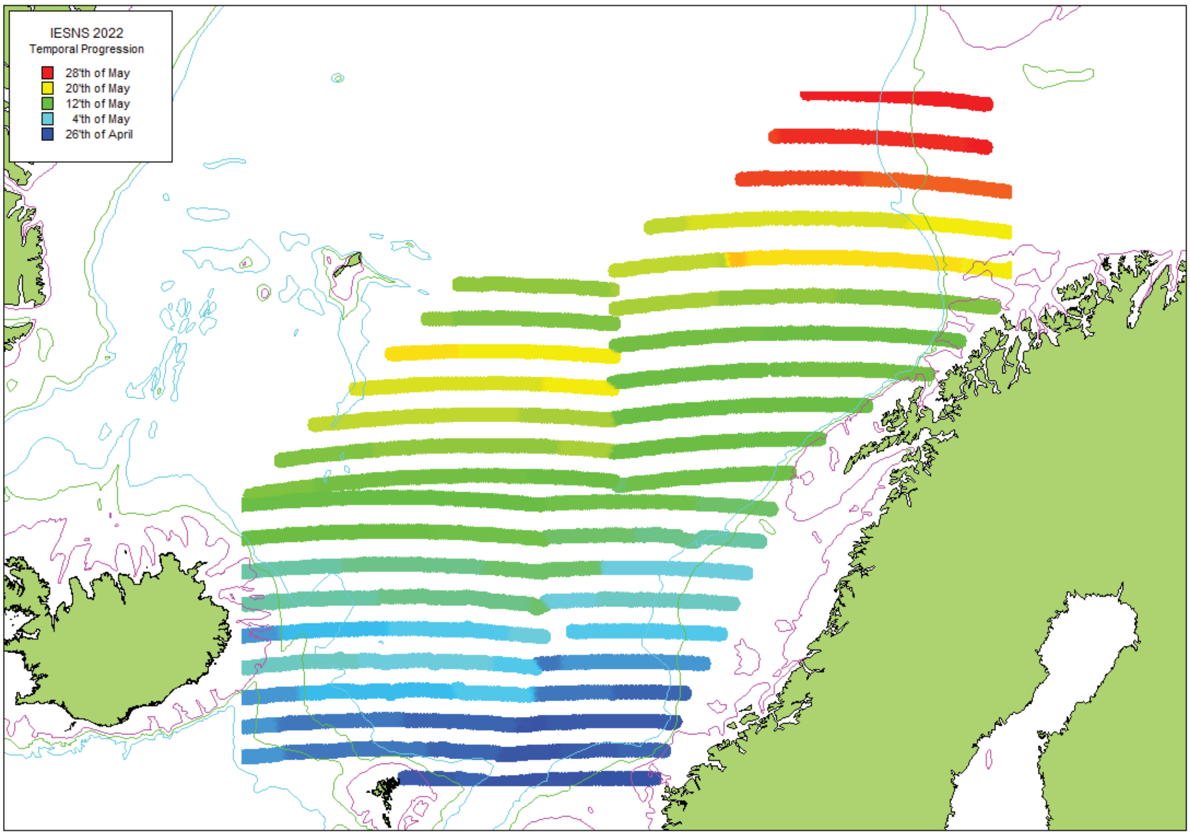


Figure 6. Temporal progression IESNS in April-May 2022.

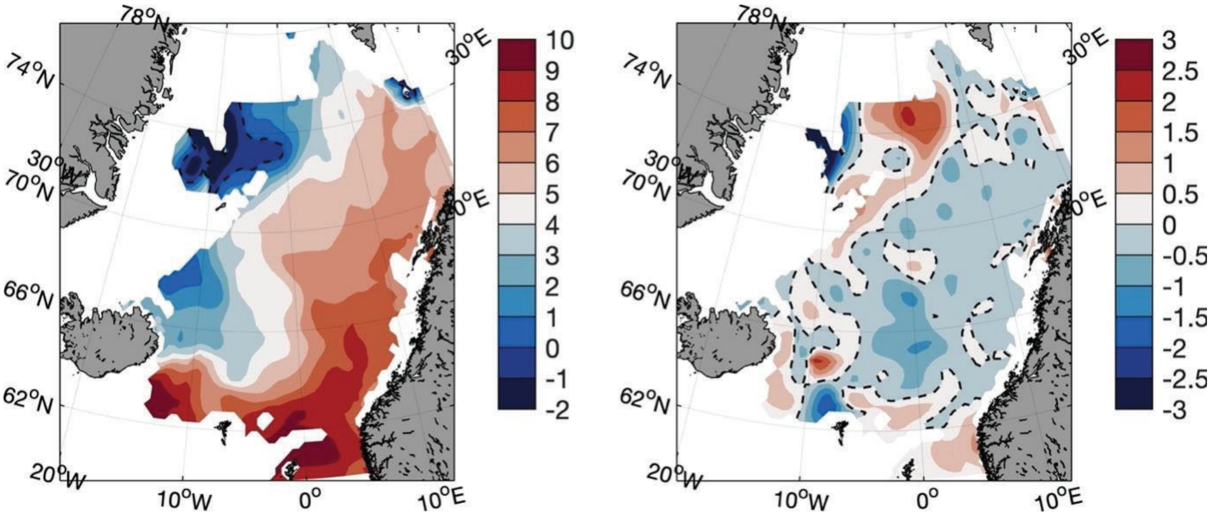


Figure 7a. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2021. Anomaly is relative to the 1995-2019 mean.

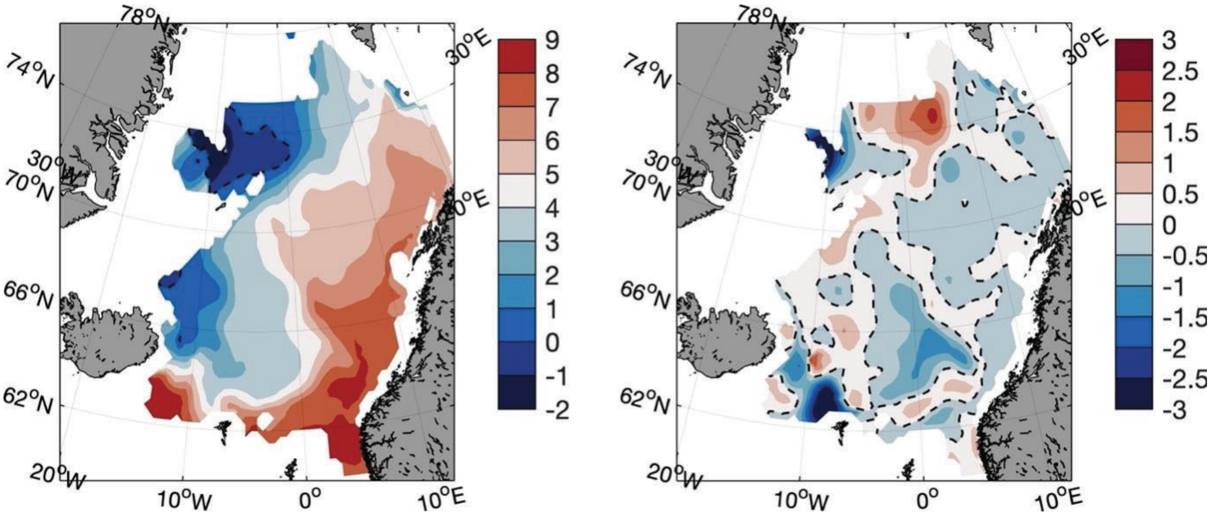


Figure 7b. Same as above but averaged over 50-200 m depth.

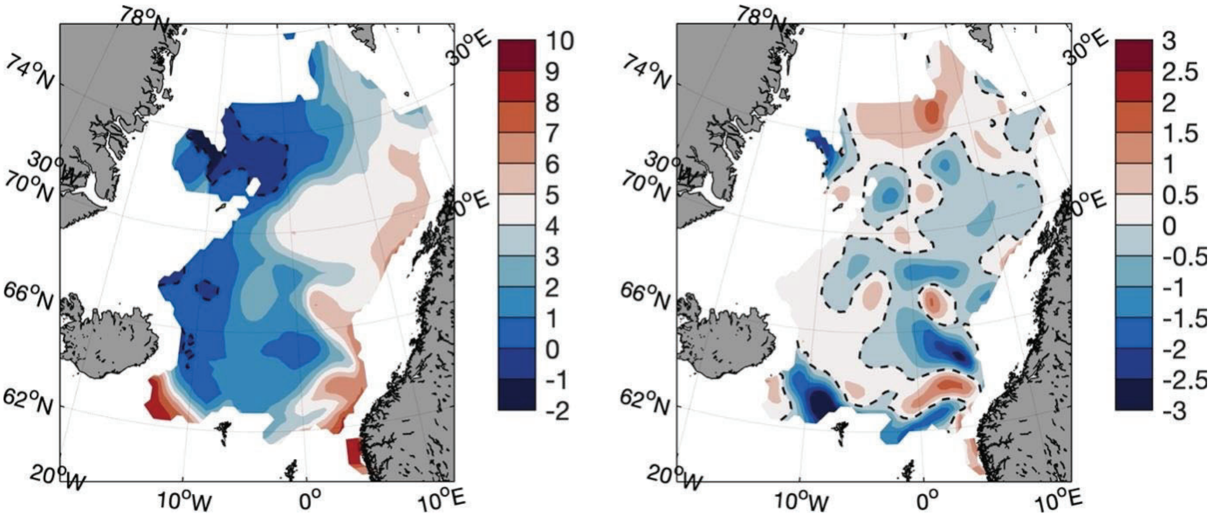


Figure 7c. Same as above but averaged over 200-500 m depth.

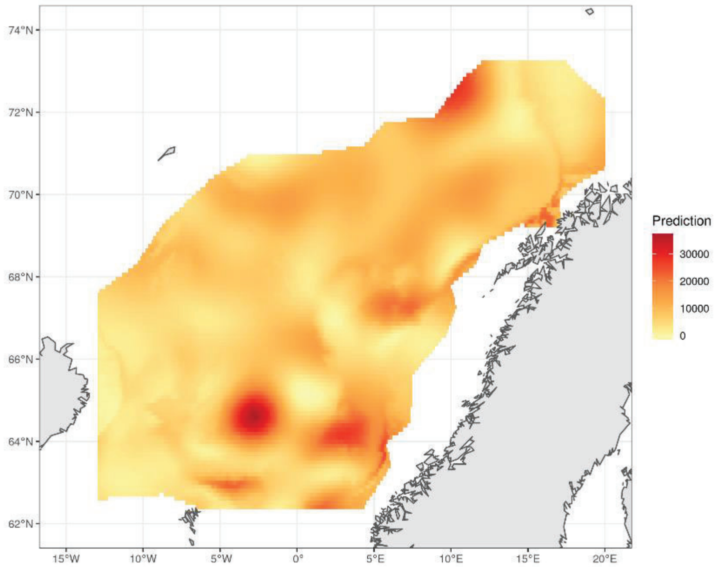


Figure 8. Distribution of zooplankton biomass (mg dry weight m^{-2}) in the upper 200 m in May 2022.

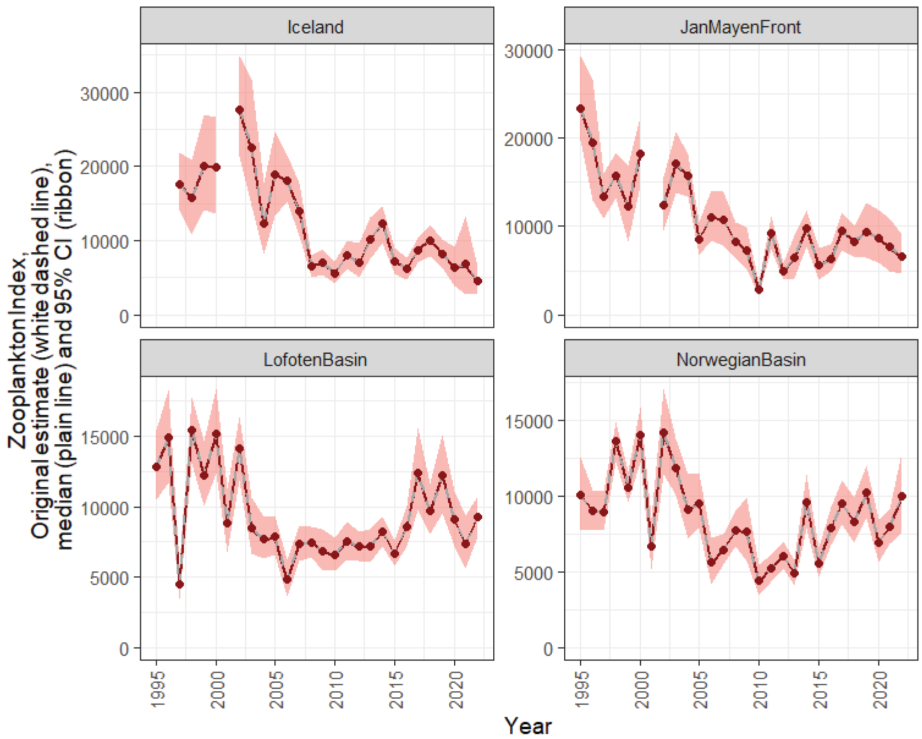
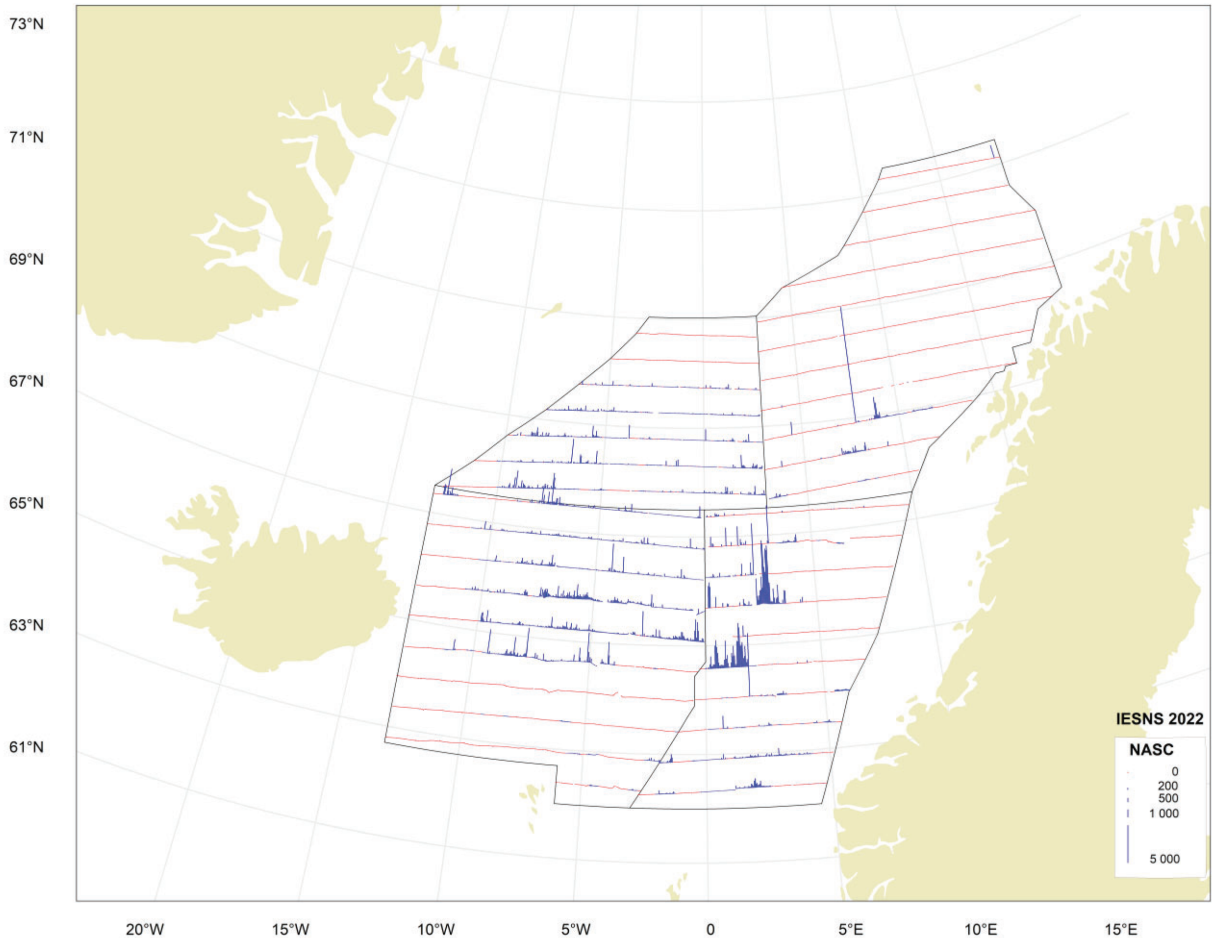


Figure 9. Indices of zooplankton biomass (mg dry weight m^{-2}) sampled by WP2 in May in the Norwegian Sea and adjacent waters from 1995-2022.

(a)



(b)

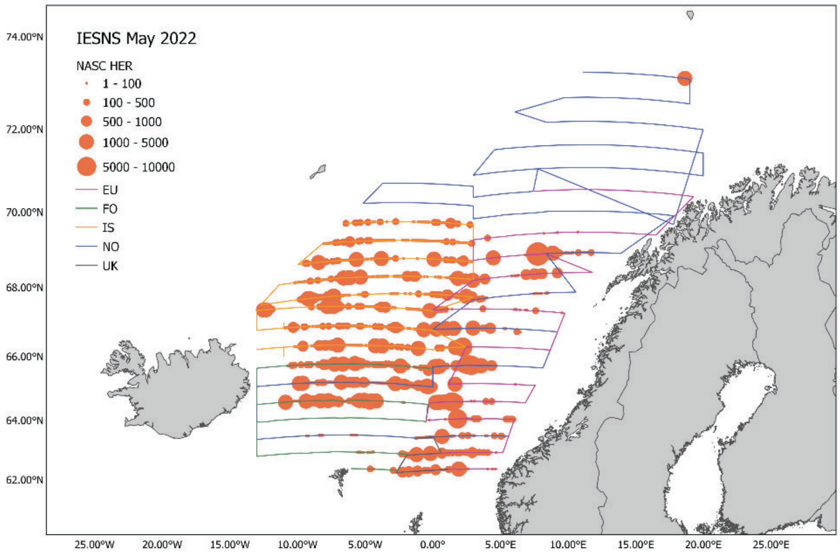


Figure 10. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2021 in terms of NASC values (m²/nm²) averaged for every 1 nautical mile.

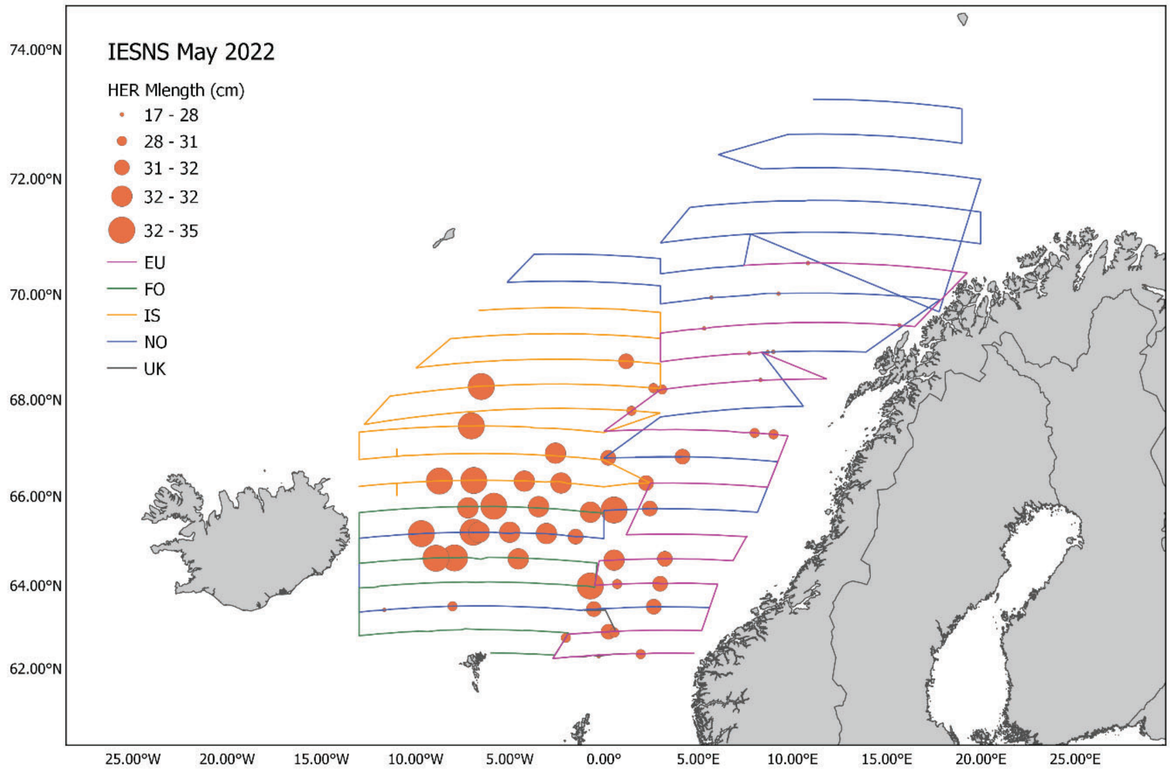


Figure 11. Mean length of Norwegian spring-spawning herring in all hauls in May 2022.

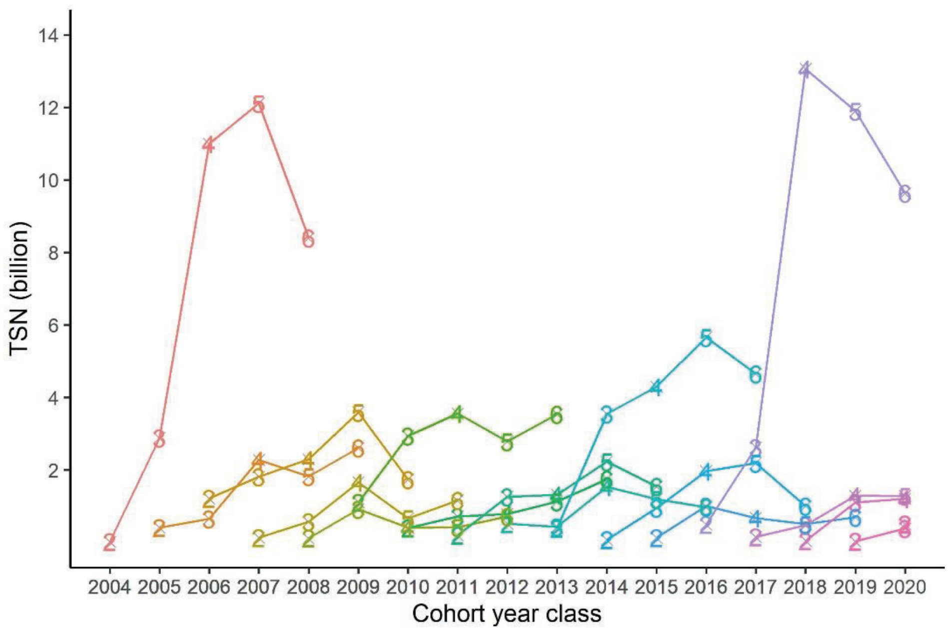


Figure 12. Tracking of the Total Stock Number at age (TSN, in billions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

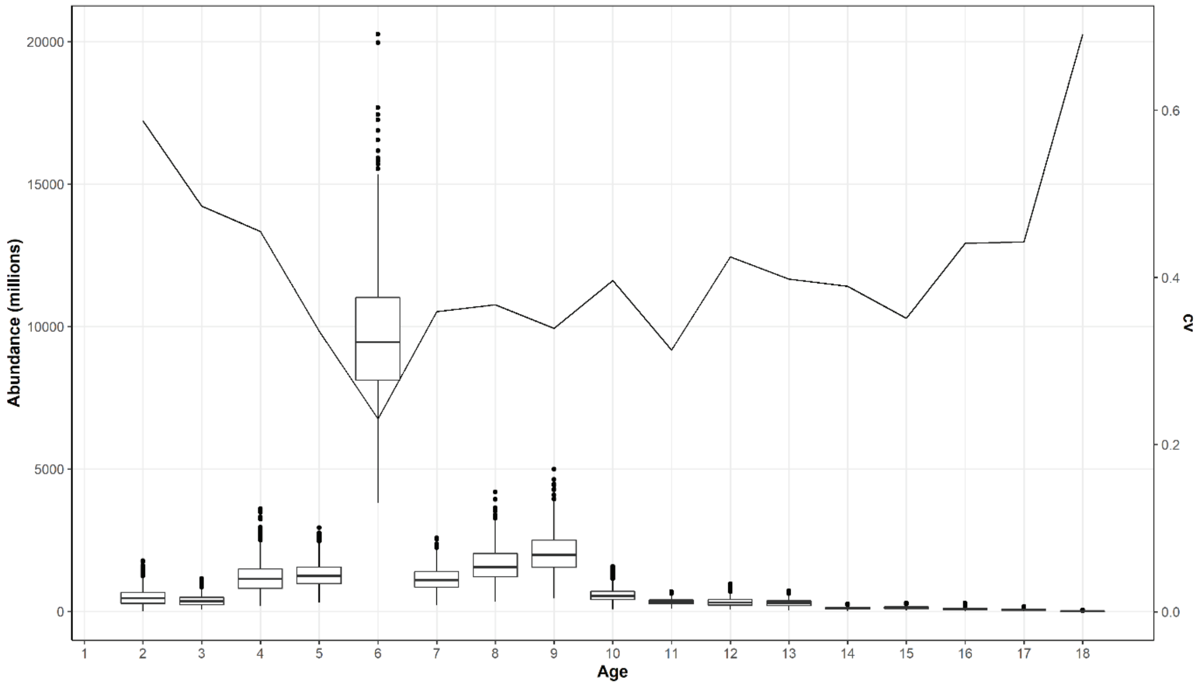


Figure 13. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

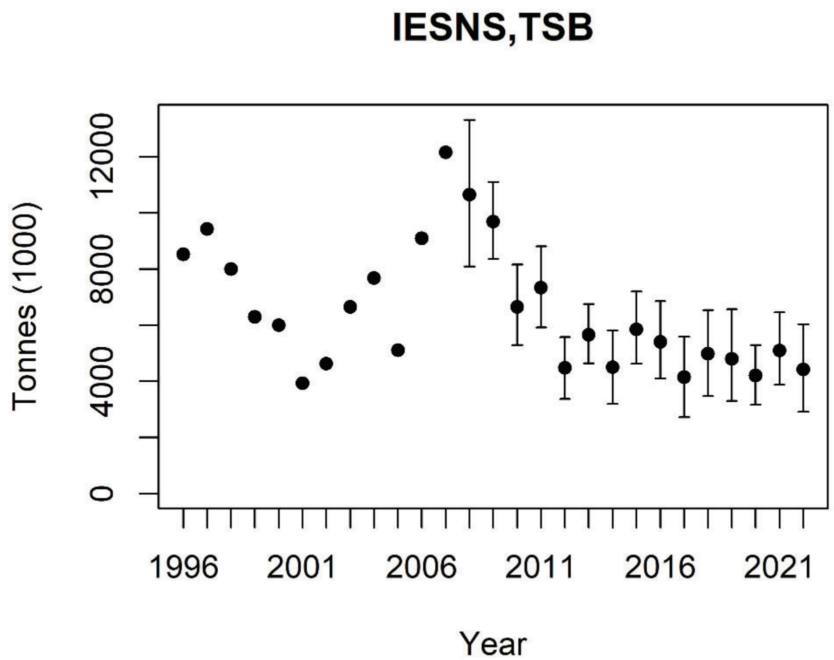


Figure 14. Biomass estimates of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2022 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2021; bootstrap means with 90% confidence interval; calculated on basis of standard stratified transect design).

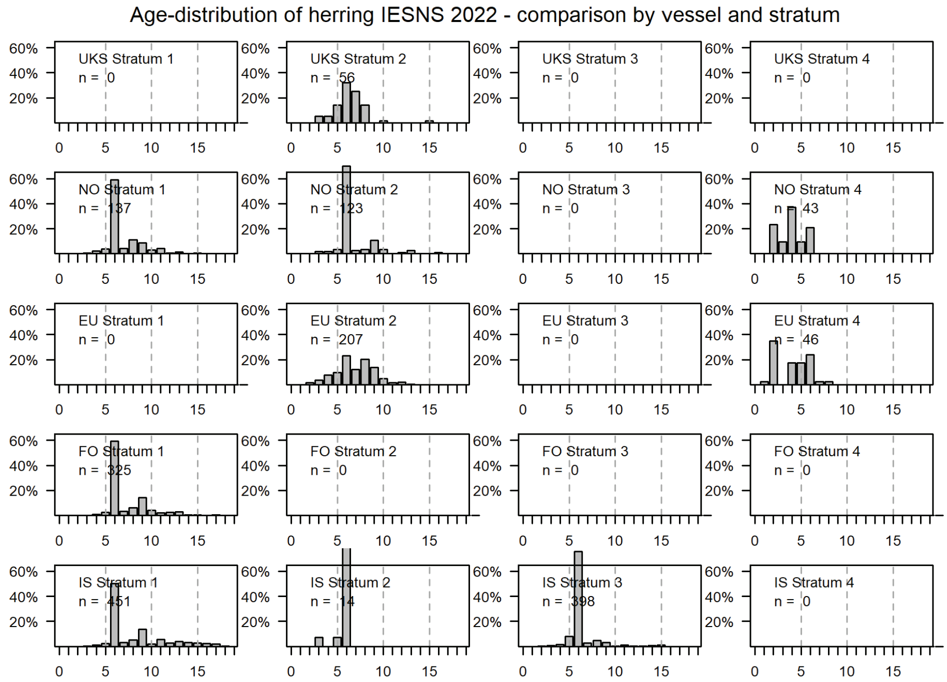
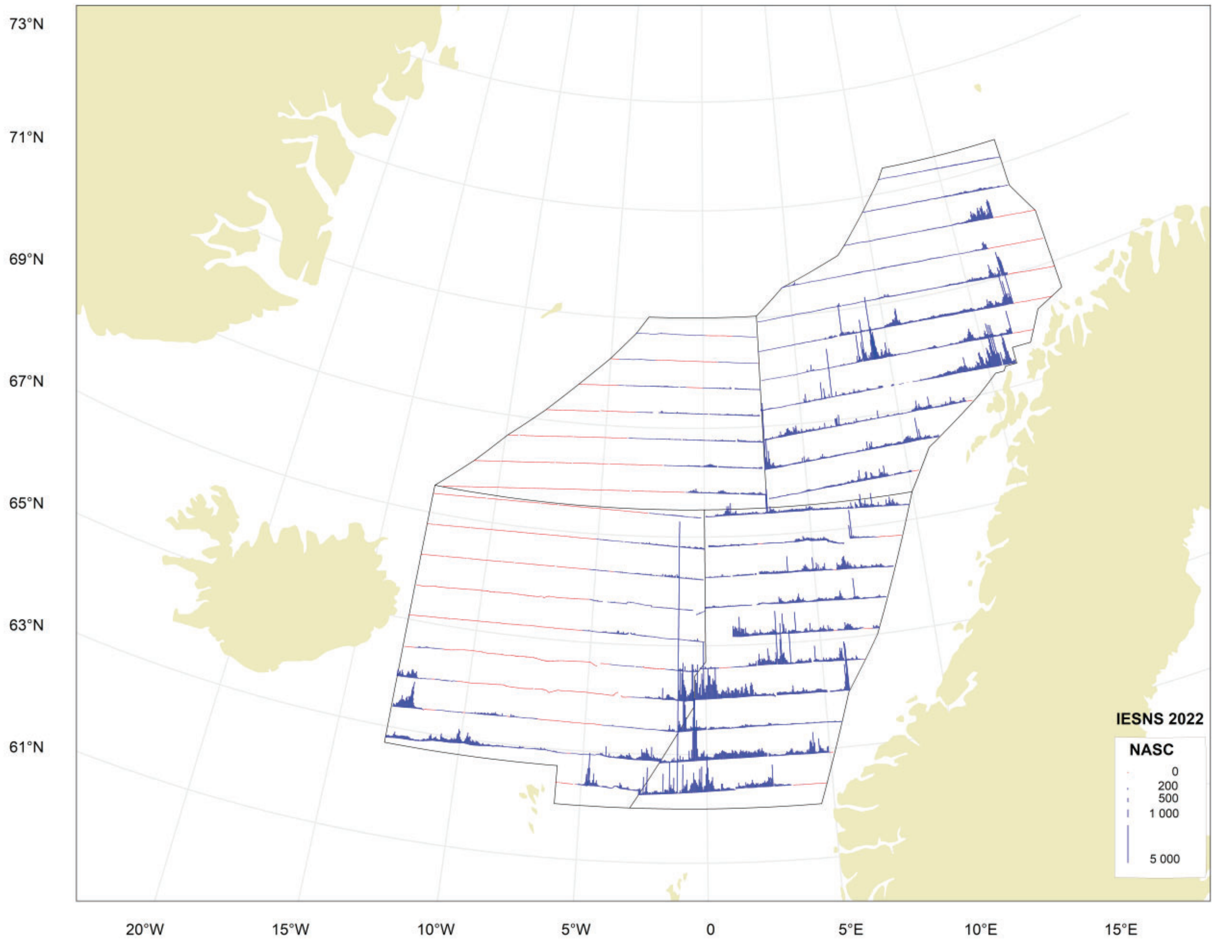


Figure 15. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2022. The strata are shown in Figure 3.

(a)



(b)

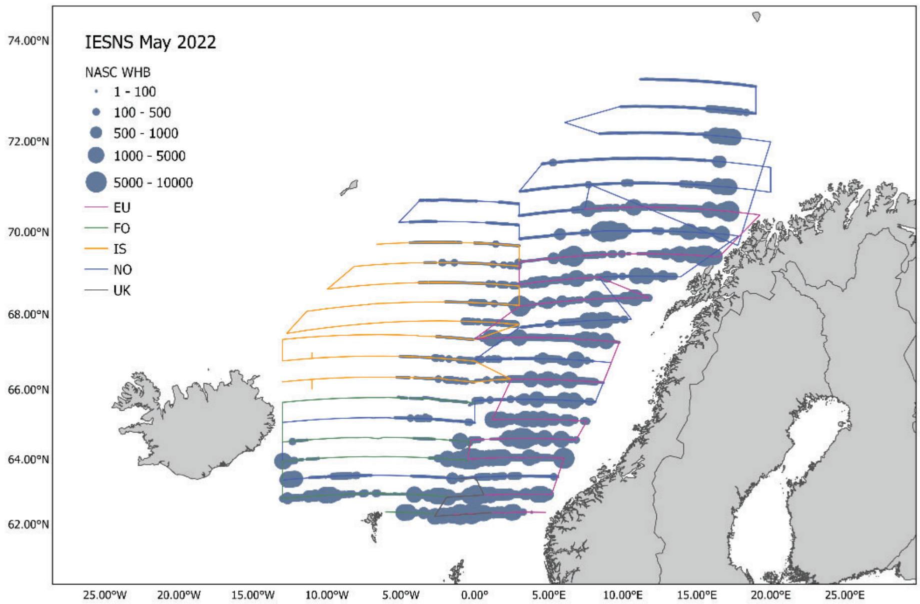


Figure 16. Distribution of blue whiting as measured during the IESNS survey in May 2022 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile.

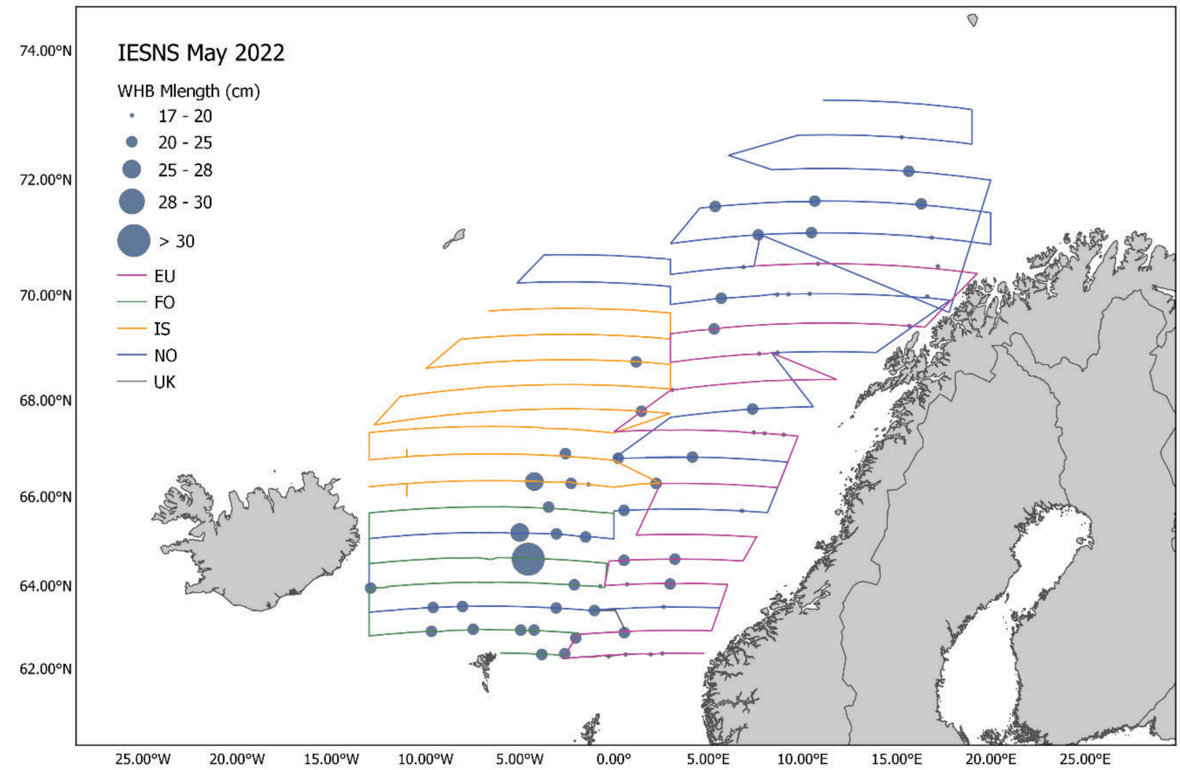


Figure 17. Mean length of blue whiting in all hauls in IESNS 2022. The strata are shown.

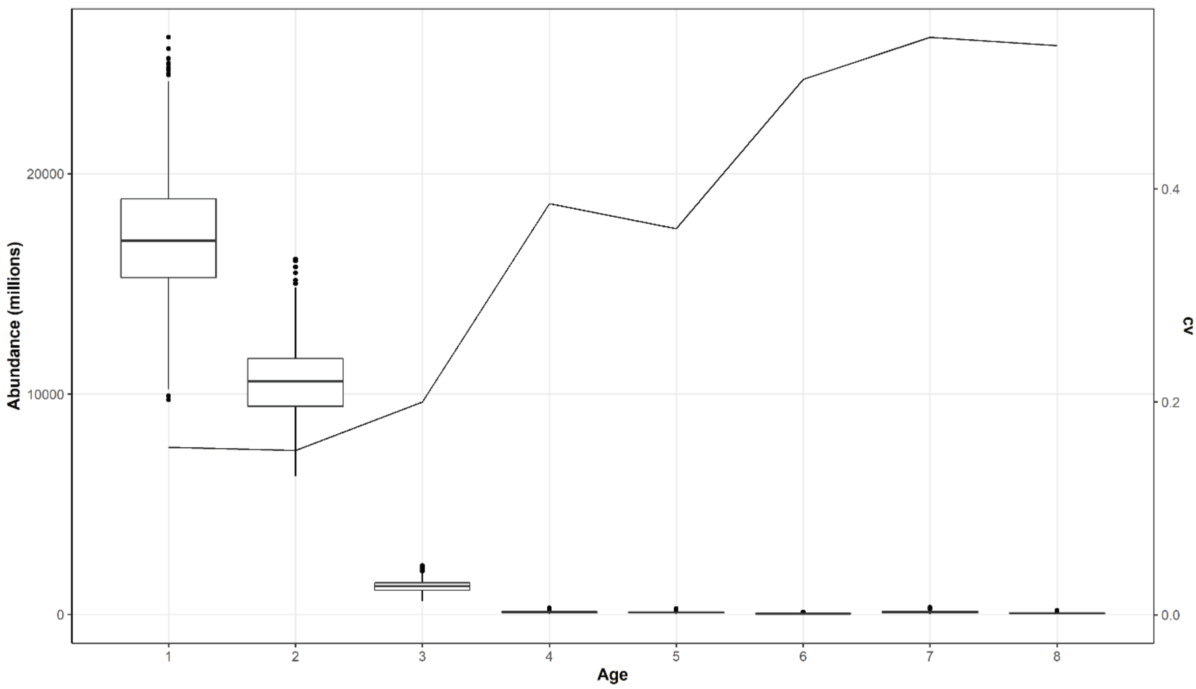


Figure 18. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

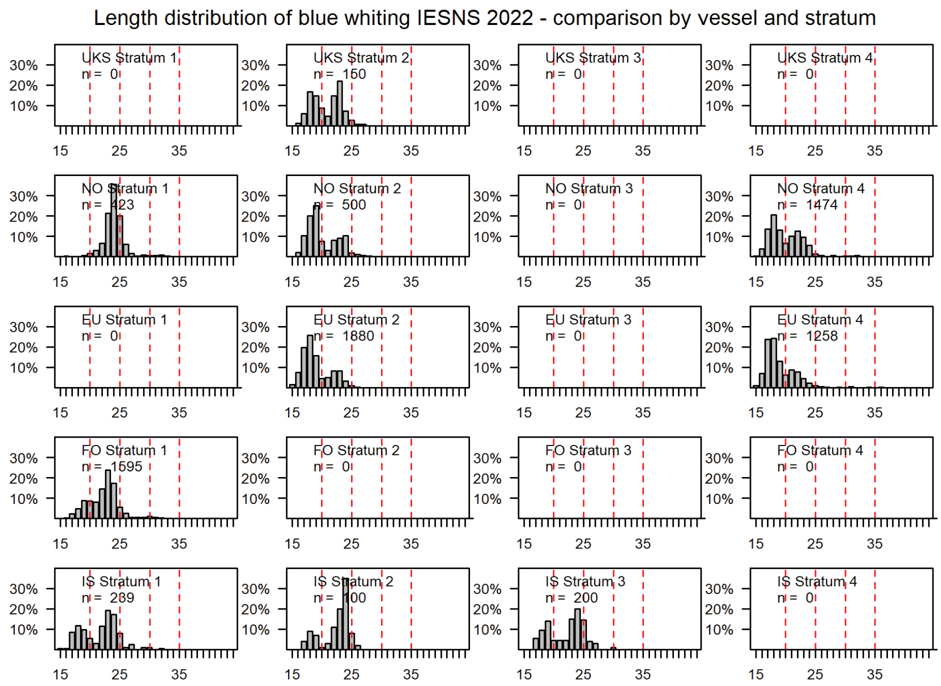


Figure 19. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2022. The strata are shown in Figure 3.

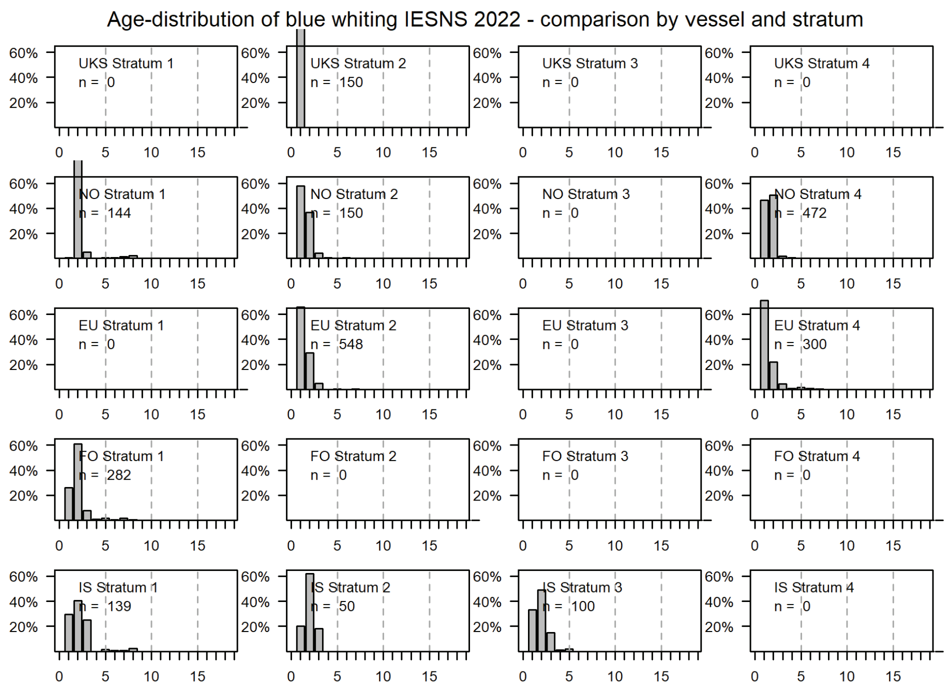


Figure 20. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2022. The strata are shown in Figure 3.

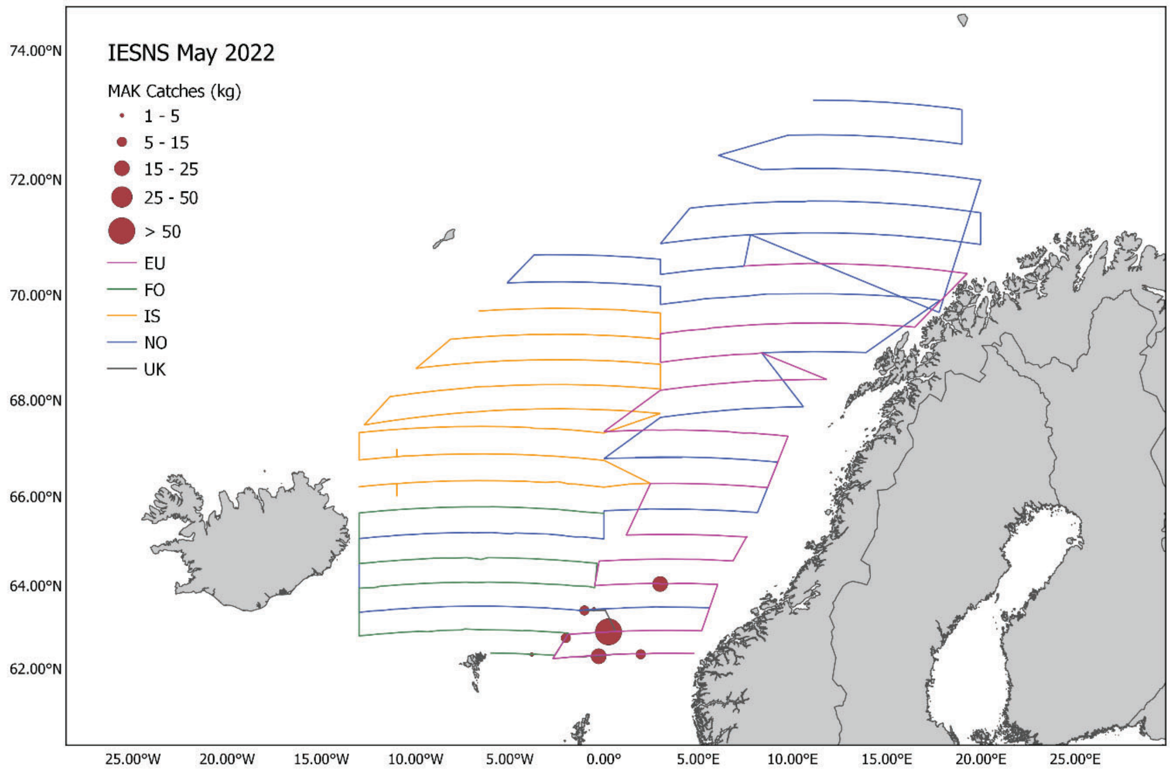


Figure 21. Pelagic trawl catches of mackerel in IESNS 2022.

ANNEX A

UK contribution to IESNS 2022

Background

In 2022 the UK participated to the IESNS survey by running a full survey on a chartered vessel that covered the UK EEZ within the IESNS survey area and an additional area south to 62° N, which is currently considered as the southern boundary of the Norwegian Spring-spawning herring stock. The main objective of the survey was to determine the distribution abundance and age structure of herring and blue whiting in the area south to the IESNS traditional coverage and detect and quantify potential mixing between different herring stocks (e.g. NSSH, NSAS, WoS).

Materials and methods

The survey was conducted onboard the commercial pelagic trawler F/V Resolute from 24/04/2022 to 06/05/2022. All the details about characteristics of the vessel, sampling, acoustic settings used, and data processing are listed in the previous section of this report. The acoustic transects and location of the hydrographic and plankton stations are shown in fig. A1. The survey area was split into 2 strata: a northern stratum that included the area north of 62° N which overlapped with the same area covered by the RV Dana and a southern stratum that covered the rest of the survey area (Fig. A2-a). For blue whiting, the southern stratum was further split into 2 additional strata to account for the habitat preferences of the species (Fig.A2-b).

Results and discussion

In total 9 acoustic transects were completed covering a total of 1158 nmi of acoustic sampling unit. A total of 11 pelagic trawls were carried out to provide groundtruth information about the species and size composition and to collect biological information (Fig. A3). In addition, CTD and plankton sampling were performed on 22 fixed stations.

Herring was patchily distributed over the whole survey area with higher densities located primarily around the Shetlands and at the southernmost transect of the survey located west of Orkney (Fig. A4). Herring size ranged from 21 to 33.5 cm with larger sizes found in the northern part of the survey area (Fig. A5). The total biomass estimate was 450,258 t (northern stratum: 43.550, southern stratum: 406,708) and a total number of 2.89 billion. Three-years-old and four-years-old herring were the most abundant age classes in terms of numbers accounting for 23% and 21% respectively of the total estimate (Fig. A6). The relative standard error (CV) is 40 % for both the total biomass and for the total numbers estimate.

Blue whiting was mainly distributed over the slope area in the north and western part of the survey areas (Fig. A7). Blue whiting aggregations primarily consisted of continuous and dense layers distributed between 200-400 m depth in the water column. Blue whiting size ranged from 16 to 33.5 cm with an overall average of 22.5 cm (Fig. A8). The total biomass estimate was 449,656 t (northern stratum: 261,872 t, southern stratum: 187,784 t) and a total number of 6.4 billion. Two-years-old was the most abundant age class in terms of numbers accounting for 89% of the total estimate (Fig A9). The relative standard error (CV) is 24 % for both the total biomass and for the total numbers estimate.

Mackerel was caught in almost all the trawls carried out. The size ranged from 18 to 41 cm with an overall average size of 33 cm (Fig. A10). No further quantitative information can be drawn from these data as this survey was not designed to monitor mackerel.

Future work

Genetic analysis is planned to be performed on herring fin clips samples collected during the survey (290 samples collected across 7 locations) to characterise the different stocks present in the survey area and the potential level of mixing with the Norwegian spring spawning herring.

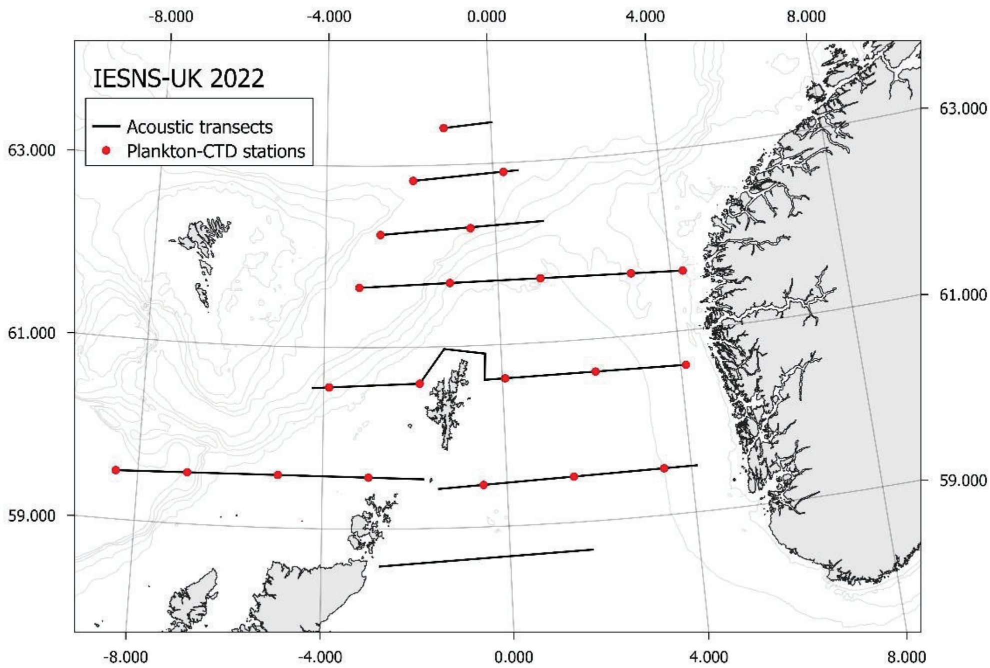


Figure A1 – Acoustic transects and location of hydrographic and plankton stations.

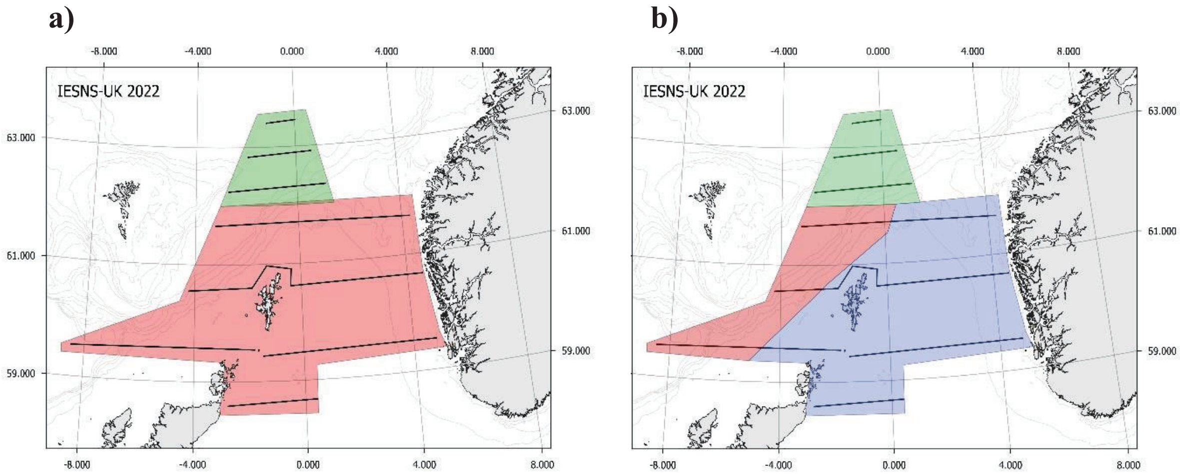


Figure A2 – Strata used for biomass estimation for herring (a) and blue whiting (b).

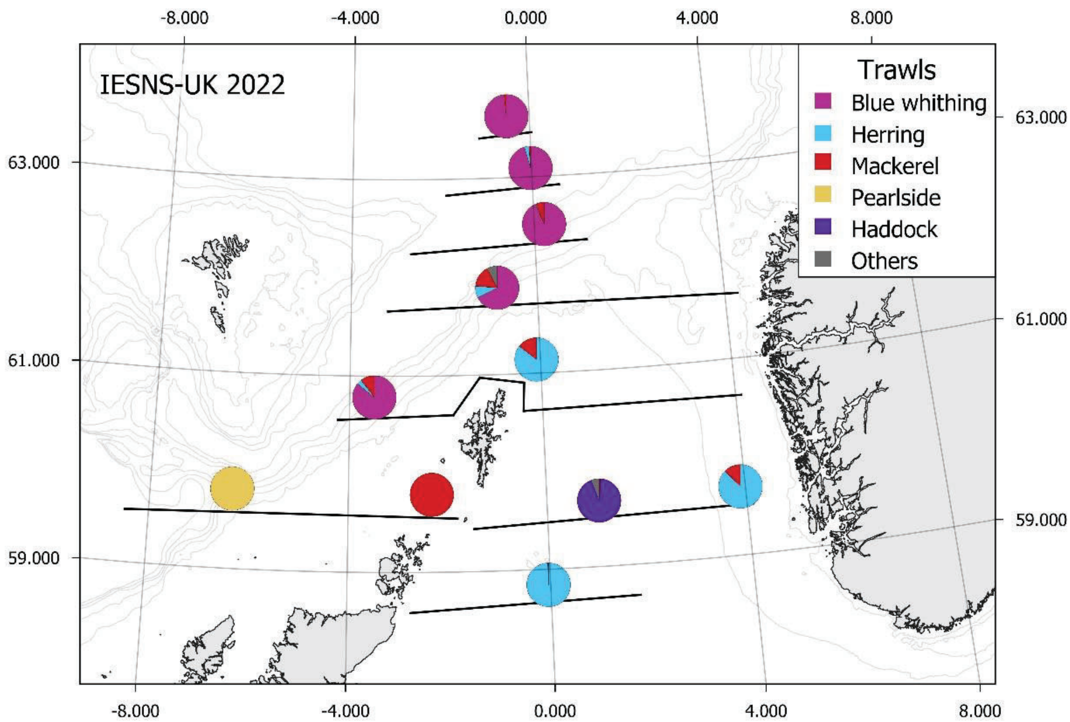


Figure A3 - Location and catch composition of the pelagic trawl stations.

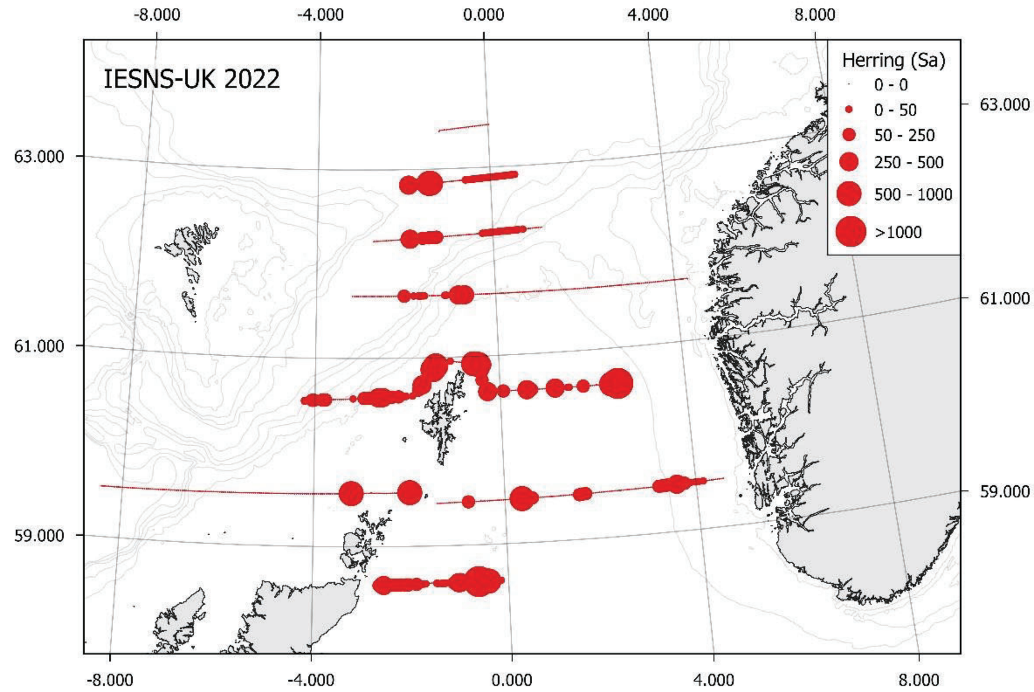


Figure A4 - Distribution of herring in terms of NASC values (m^2/nm^2) averaged for every 1 nautical mile.

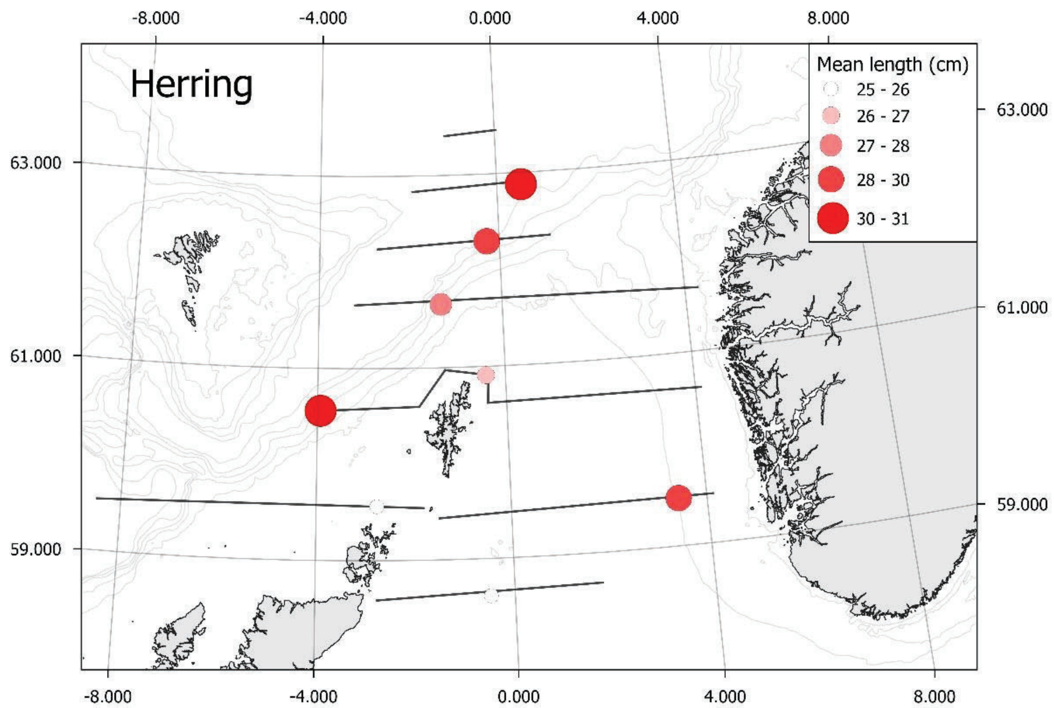


Figure A5 – Distribution of the mean length of herring measured in the pelagic trawl catches.

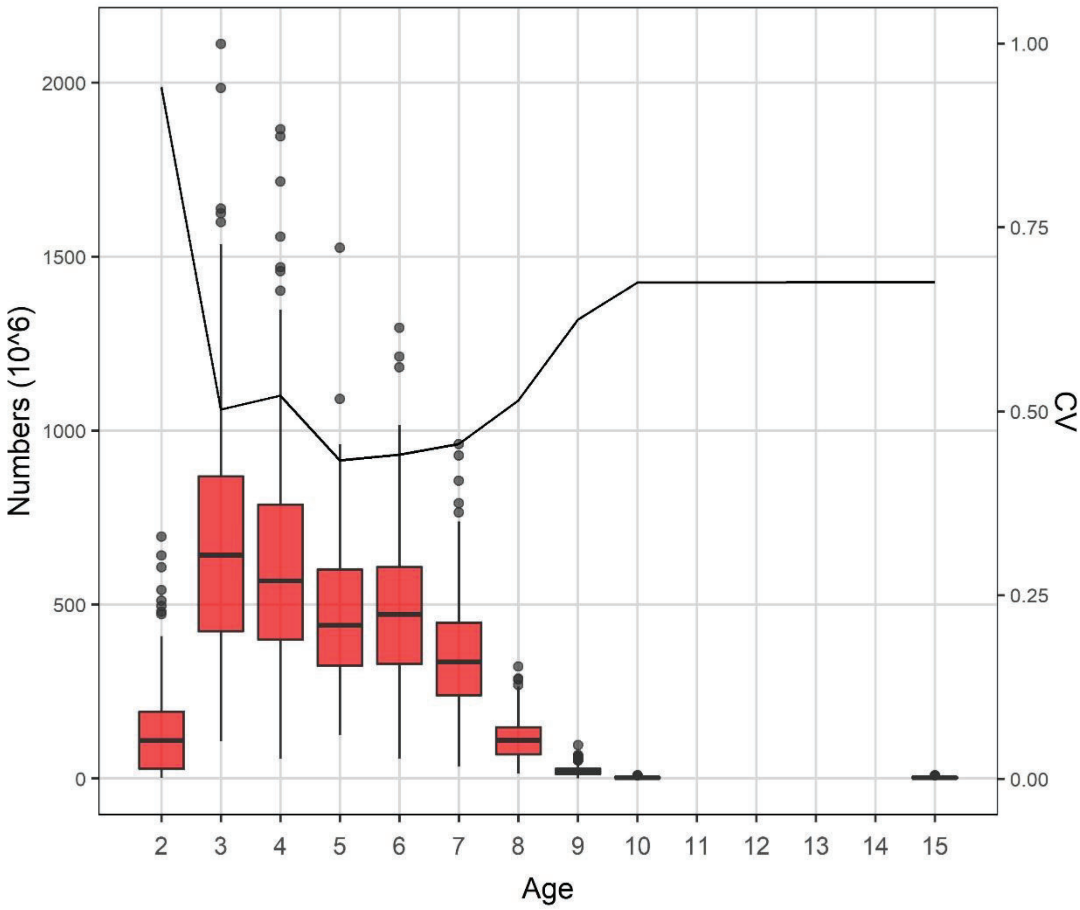


Figure A6 - Boxplot of herring abundance at age and relative standard error (CV) obtained by bootstrapping using the StoX software.

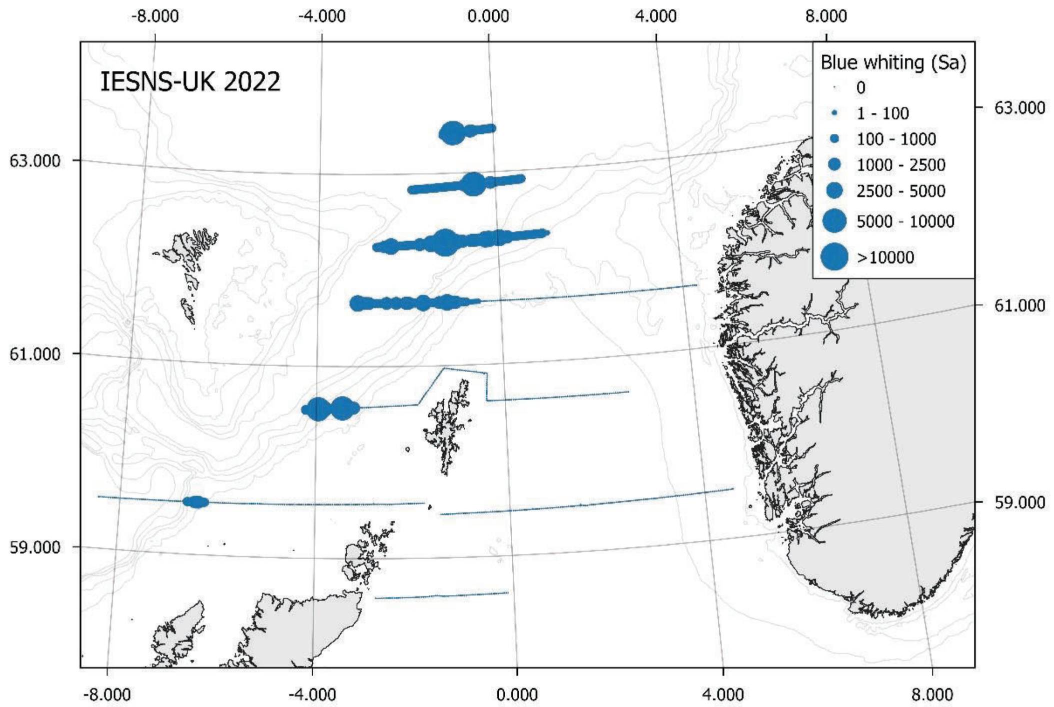


Figure A7 - Distribution of blue whiting in terms of NASC values (m^2/nm^2) averaged for every 1 nautical mile.

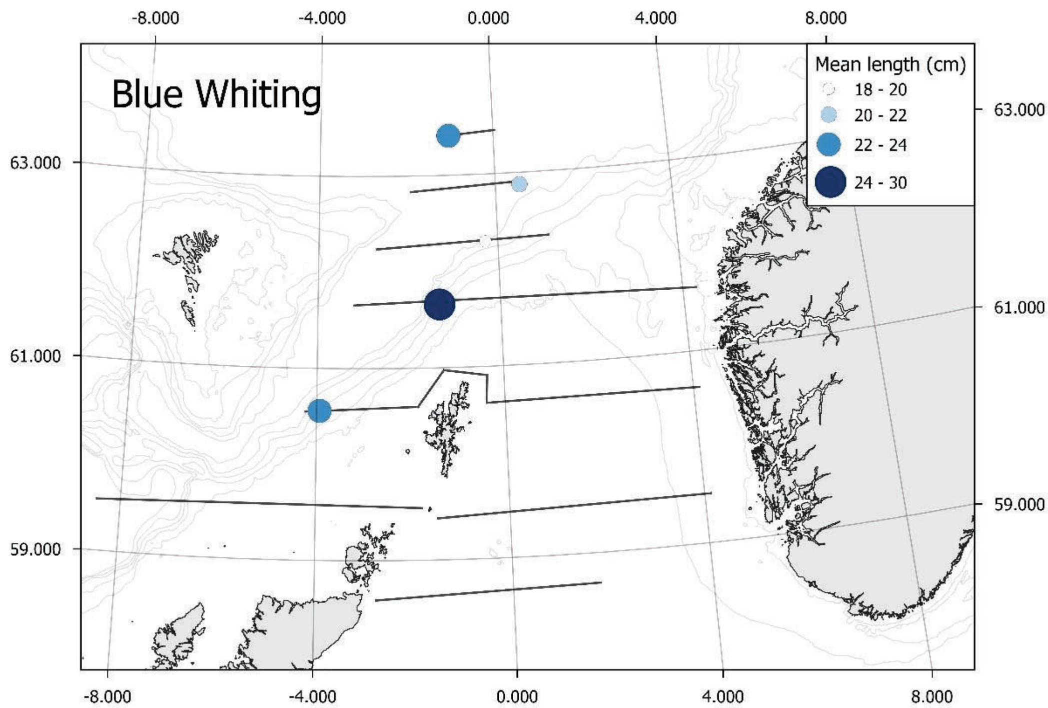


Figure A8 – Distribution of the mean length of blue whiting measured in the pelagic trawl catches.

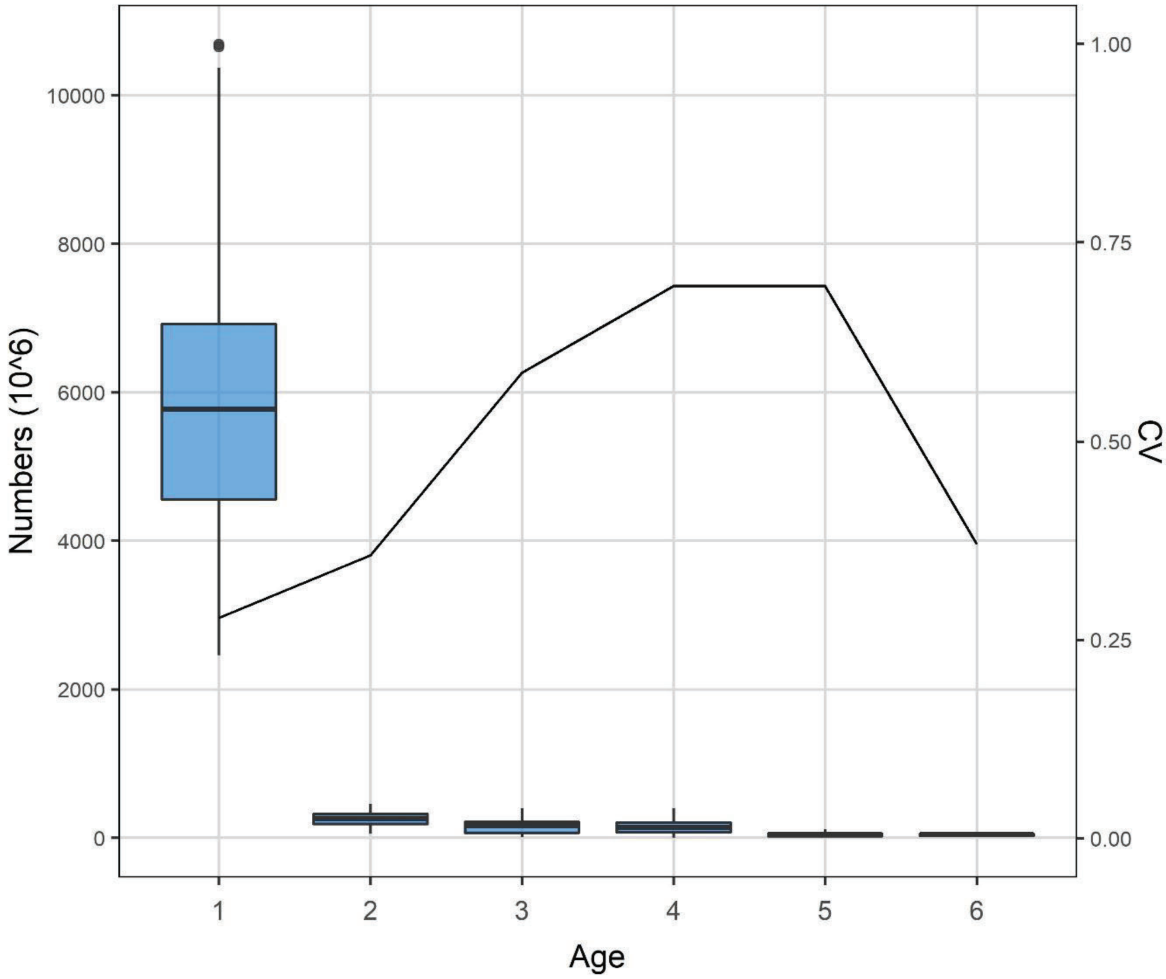


Figure A9 - Boxplot of blue whiting abundance at age and relative standard error (CV) obtained by bootstrapping using the StoX software.

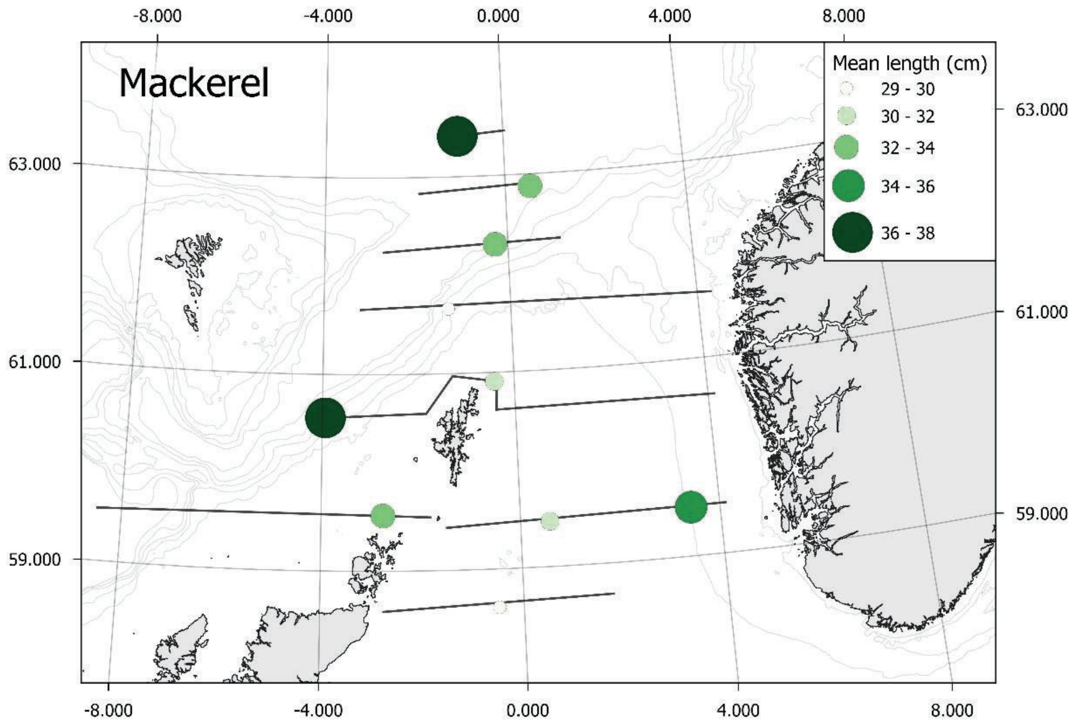


Figure A10 – Distribution of the mean length of mackerel measured in the pelagic trawl catches.