Working Document to

Working Group on International Pelagic Surveys (WGIPS)
Reykjavík, Iceland, 18 – 20 June 2019
and
Working Group on Widely distributed Stocks (WGWIDE)
Santa Cruz, Tenerife, Spain, 28 August - 3 September 2019

Preliminary report on the INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2019

Post-cruise meeting, Reykjavik, Iceland, 18-20 June 2019

Are Salthaug[2], Erling Kåre Stenevik[2], Åge Høines[2], Valantine Anthonypillai[2], Kjell Arne Mork[2], Cecilie Thorsen Broms[2], Øystein Skagseth[2], Evgeny Sentyabov[4]
RV G.O. Sars

Karl-Johan Stæhr[3], Serdar Sakinan[6], Mathias Kloppmann[8], Sven Kupschus[9]
RV Dana

Guðmundur J. Óskarsson[7], Hildur Pétursdóttir[7]
RV Árni Friðriksson

Eydna í Homrum[5], Ebba Mortensen[5], Leon Smith[5]
RV Magnus Heinason

[2] Institute of Marine Research, Bergen, Norway
[3] DTU-Aqua, Denmark
[5] Faroese Marine Research Institute, Tórshavn, Faroe Islands
[6] Wageningen Marine Research, IJmuiden, The Netherlands
[7] Marine and Freshwater Research Institute, Reykjavik, Iceland
[8] vTI-SF, Hamburg, Germany
[9] Cefas, Lowestoft, UK

Introduction

In May-June 2019, five research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherland, Sweden and UK), R/V Magnus Heinason, Faroe Islands, R/V Árni Friðriksson, Iceland, R/V G.O. Sars, Norway and R/V Vilnyus, Russia participated in the International ecosystem survey in the Nordic Seas (IESNS). 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 biomass 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 is represents analyses of data from this International survey in 2019 that are stored in the PGNAPES database and supported by national survey reports from each survey (Dana: Staehr, Sakinan, Kloppmann, Kupschus 2019, Magnus Heinason: Homrum et al, FAMRI 1918-2019, Árni Friðriksson: Óskarsson et al. 2019).

Note that the Russian vessel had not finished the survey in the Barents Sea when this report was compiled so it should be considered as a preliminary report until the results from Barents Sea have been included. The final report will then be ready by the end of August 2019.

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2019 and by correspondence. Planning of the acoustic transects and hydrographic stations and plankton stations were carried out by using the recently developed survey planner function in the r-package Rstox version 1.11 (see www.imr.no/forskning/prosjekter/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, the transects now follow great circles instead of a constant latitude as before, so 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	Danish Institute for Fisheries Research, Denmark	2/5-31/05
G.O. Sars	Institute of Marine Research, Bergen, Norway	29/4-3/6
Vilnyus	PINRO, Russia	Not confirmed
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	02/5- 14/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	08/5-19/5

Figure 2 shows the cruise tracks, Figure 3a the hydrographic stations, Figure 3b the pelagic trawl stations and Figure 3c the plankton stations. Survey effort by each vessel is detailed in Table 1. Frequent 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 4.

In general, the weather condition did not affect the survey even if there were some days that were not favourable and prevented for example WP2 and Multinet sampling at some stations. 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).
(Data for Vilnyus will be updated for final report in August 2019)

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason	Vilnyus
Echo sounder	Simrad EK 60	Simrad EK 80	Simrad EK60	Simrad EK60	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 120, 200	**38**,200	**38,** 120
Primary transducer	ES38BP	ES 38B	ES38B	ES38B	ES38B
Transducer installation	Towed body	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	5	8.5	8	3	4.5
Upper integration limit (m)	5	15	15	7	10
Absorption coeff. (dB/km)	10	10.1	10	10.1	10
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	1.573	2.43	2.425	2.425	2.425
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.5	-20.7	-20.81	-20.8	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.32	26.07	24.36	25.64	25.76
s_A correction (dB)	-0.56	-0.15	-0.58	-0.66	-0.64
3 dB beam width (dg)					
alongship:	6.8	6.48	7.28	7.02	7.09
athw. ship:	6.8	6.22	7.23	7.00	7.01
Maximum range (m)	500	500	500	500	500
Post processing software	LSSS1	LSSS	LSSS	Sonardata Echoview 9.1	LSSS

Post-processing software differed among the vessels but all participants used the same post-processing procedure, which is 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. All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason	Vilnyus
Circumference (m)		496	832	640	500
Vertical opening (m)	25-35	25-30	30–35	45–55	50
Mesh size in codend (mm)	16	24	40	40	16
Typical towing speed (kn)	3.5-4.0	3.0–4.5	3.6–4.5	3.0–3.5	3.3–4.5

NB! Data for Vilnyus will be updated for final report in August 2019.

Catches from trawl hauls were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. Normally, a subsample of 30–100 herring, blue whiting and mackerel were sexed, aged, and measured for length and weight, and their maturity status was estimated using established methods. For the Norwegian, Icelandic and Faroese vessel, a smaller subsample of stomachs was sampled for further analyses on land. An additional sample of 70–300 fish was measured for length.

Acoustic data were analysed using the StoX software package which has been used for some years now for WGIPS coordinated surveys. A description of StoX can be found here: www.imr.no/forskning/prosjekter/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 as agreed during the WGIPS in January 2017. 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 1. 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

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 3a and 3c. Most vessels collected hydrographical data using a SBE 911 CTD. Maximum sampling depth was 1000 m. Zooplankton was sampled by a WPII on all vessels except the Russian vessel which used a Djedi net, 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 g total dry weight per m^2. For the zooplankton distribution map, all stations are presented. For the time series, stations in the Norwegian Sea delimited to east of 14°W and west of 20°E have been included. The zooplankton data were interpolated using objective analysis utilizing a Gaussian correlation function to obtain a time-series for four different areas. The results are given as inter-annual indexes of zooplankton abundance in May. This method was introduced at WGINOR in 2015 (ICES, 2016) and the results match the former used average index. It has been noted that the Djedy net applied by the Russian vessel in the Barents Sea seems to be less effective in catching zooplankton in comparison to WPII net applied by other vessels in an overlapping area. Thus, the biomass estimates for the Barents Sea are not directly comparable to the other areas, but are comparable among years within the Barents Sea.

Results and Discussion

Hydrography

The temperature for selected depths in the Norwegian Sea is shown in Figure 5. 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 6-8. The temperatures in the surface layer (0-50 m) ranged from below 0°C in the Greenland Sea to 9°C in the southern part of the Norwegian Sea (Figure 6). The Arctic front was encountered south of 65°N east of Iceland extending eastwards towards about 2° West where it turned northeastwards to 65°N and then almost straight northwards. This front was well-defined at 200-500 m depth while shallower it was unclear. Further to west at about 8° West another front runs northward to Jan Mayen, the Jan Mayen Front, that was distinct throughout the observed water column. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures >7 °C to 69° N in the surface layer.

Relative to a 23 years long-term mean, from 1995 to 2017, the temperatures at 0-50 m and 50-200 m over the western Norwegian Sea, roughly west of the 0 meridian, were higher in 2019 compared to the long-term mean (Figures 6-7). Relative warmest water was in the south- and northwestern Norwegian Sea where the temperatures in some regions were 1.0 °C higher than the mean. In the eastern area of the Norwegian Sea, the temperatures were instead lower than normal, where temperatures in few areas were 0.5 °C lower than the mean. At 200-500 m depth, both higher and lower temperatures than the long-term mean can be observed in whole region.

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in May 2019 are shown in Figure 9. Atlantic water is lying over the colder and fresher intermediate layer and reach down to 500 m at the shelf edge and shallower westward. The warmest water is located near the shelf edge where the core of the inflowing Atlantic Water is located. Westward, temperature and salinity are reduced due to mixing with colder and less saline water. Relative to a long-term mean, from 1978 to 2007, the temperatures in 2019 were substantial higher in the western part (west of 2.5° E) where temperatures were 3.0 °C higher than the mean between 200 m and 400 m depth. In the eastern part the temperatures were in general lower than 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 only in the last three decades that a similar layer has been observed all over the Norwegian Sea.
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 (g dry weight m^{-2}) in the upper 200 m is shown in Figure 10. Sampling stations were evenly spread over the area, covering Atlantic water, Arctic water, and the Arctic frontal zone. The Svinøy transect was not included in this survey but covered in a separate survey. The highest zooplankton biomasses were not concentrated in a specific area but spread over several locations covering the entire sampling area, except from the southernmost part and especially the area south-east of Iceland which contained low biomasses. High biomasses were found in an area around Lofoten/Vesterålen and north and northwest of that area, and in the Norwegian Sea basin.

Figure 11 shows the zooplankton index given for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional difference in the biomass, the total area were divided into 4 subareas 1) Southern Norwegian Sea including the Norwegian Sea Basin, 2) The Northern Norwegian Sea including the Lofoten Basin, 3) Jan Mayen Arctic front, and 4) East of Iceland. The mean index of subarea 1 and 2 is also given. The zooplankton biomass index for the Norwegian Sea and nearby areas was in 2019 10.8 g dry weight m^{-2}, which is an increase from last year. A similar increase was observed in all sub-areas, except from East of Iceland.

The zooplankton biomass index for the Norwegian Sea in May has been estimated since 1995. For the period 1995-2002 the plankton index was relatively high even if varying between years. From 2003-2006, the index decreased continuously and was at lower levels for several years, but since 2010 there has been an increasing trend. For the period 2003-2019 the mean was 7.9 g, compared to 11.5 for the period 1995-2002. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea. In 2019 the biomass index for the Norwegian Sea was comparable to the high-biomass period. The zooplankton biomass at the Jan Mayen Arctic front was high until 2007 but has since then been at the same level as the Norwegian Sea. The zooplankton biomass East of Iceland was in general higher compared with the other sub-areas until 2015.

The reason for this fluctuation in the zooplankton biomass is not obvious to us. The unusually 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 are 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. Timing effects, as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. It is also worth noting that the period with lower zooplankton biomass coincides with lower-than-average heat contents in the Norwegian Sea (ICES 2019). More ecological and environmental research to reveal inter-annual variations and long-term trends in zooplankton abundance are recommended. Quantitative research on carnivorous zooplankton stocks (such as krill and amphipods) across the whole survey area, is an important step in that direction and needs a further effort by all participating countries.

Norwegian spring-spawning herring

The zero-line was not fully reached in the north western part of the distribution area of the adult NSS herring. However, based on the zero-line reached south and east of this area, the vast majority of the NSS herring stock is believed to be contained within the survey area. It is therefore recommended that the results from IESNS 2019 can be used for assessment purpose. The herring was primarily (~2/3) distributed in the south western Norwegian Sea (Figure 12) but a third of the biomass was distributed between 69°N and 72°N and this was still primarily the 2013 year class but also the 2014 and 2016 year classes were numerous.

As in previous years the size and age of herring were found to increase towards west and south in the Norwegian Sea (Figure 13). Correspondingly, it was mainly older herring that appeared in the southwestern areas. The 2013 year class (age 6) was observed across most of the survey area.

Six year old herring (year class 2013) dominated both in terms of number and biomass (24 %) on basis of the StoX estimations for Norwegian Sea (Table 2). Its number at age 6 (Table 2) is higher than for the 2009 year class at same age, but only half the size of the large 2004 year class (Figure 14), which puts the size of the 2013 year class into perspective. The large 2004 year class, which has dominated the stock together with the 2002 year class, has contributed significantly to the biomass of older age-groups (see paragraph on issues with age determination below). Herring aged 12-15 years old thus comprised 19% of the numbers and 25% of the biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 15.

The total estimate of herring in the Norwegian Sea from the 2019 survey was 19.7 billion in number and the biomass 4.87 million tonnes. This estimate is 0.17 million tonnes (3 %) decrease from the 2018 survey estimate. 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 16), with the lowest abundance occurring in 2017. Although there is only little change in total abundance and biomass, there is a gradual shift in age and size composition with the 2013 and 2014 year classes becoming more dominant than the old 2004 year class. The 2016 year class had entered the Norwegian Sea while it is not clear until the Russian part of the survey is finished if significant part of it still remains in the Barents Sea. Consequently, a reliable estimation on its abundance is not available yet; in addition, the year class size can be poorly determined at age-3 (e.g. the 2004 y.c., Figure 14) and uncertainty around the age-3 estimates are normally relatively large (Figure 15).

In the last 5 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 period, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop was planned in the spring 2018 to discuss the results. This workshop was postponed indeterminately. 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 showed a similar difference as observed in recent years (Figure 22). For example, the 2004 year class was in higher proportion by the Norwegian readers than the Faroese and the Icelandic readers in Stratum 3 and 4, which had higher proportions of the 2005 and 2006 year classes. These three year classes are in the plus group in the analytical assessment (age 12+).

In the IESNS survey in 2019 there was good agreement in the acoustic scrutinizing results between any neighbouring vessels.

Blue whiting

The spatial distribution of blue whiting in 2019 was similar to the years before, with the highest abundance estimates in the southern and eastern part of the Norwegian Sea, along the Norwegian continental slope. The main concentrations were observed in connections with the continental slopes of Norway and along the Scotland – Iceland ridge (Figure 18). Blue whiting was distributed similar as last year and not as far west into the Norwegian Sea as in the years before. The largest fish were found in the western and northern part of the survey area (Figure 19). It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period.

The total biomass index of blue whiting registered during the IESNS survey in 2019 was 0.53 million tonnes, which is a 6 % increase from the biomass estimate in 2018 (0.50). The abundance index for 2019 was 6.2 billion, which is 41 % higher than in 2018. The main reason for this is the incoming 2018 year class. Ages 4, 1 and 5 are dominating the acoustic estimate (71 % of the biomass and 80% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20.

In this year's IESNS survey, one-year old blue whiting was more numerous as compared to IESNS 2017 and 2018. The survey group compared age and length distributions by vessel and strata (Figure 23 and 24) and no clear differences were found.

Vertical profile across the Norwegian Sea

Two "transects" were carried out by G.O. Sars across the southern part of the Norwegian Sea (Figure 21). Herring was distributed mainly to the west of 2 - 3° W, in the temperature range 0 - 4 °C. The largest aggregations of older herring were observed acoustically between 6 and 10° W in the high-gradient thermal zone near the border of the cold East Icelandic Current in a layer from 150 to 400 m. The blue whiting, as in previous years, was distributed in Atlantic waters, preferring a layer between 300 and 400 m. Its schools were registered mainly in areas with high temperature gradients from the "warm side" of the frontal zone between the Atlantic and Arctic waters and in the bottom layer above the shelf and continental the slope of Norway. Some blue whiting were observed in the southwestern area to south from Faroe-Iceland Ridge in layer 350-450 m under temperature 6-7 °C.

General recommendations and comments

Recommendation	Adressed to
1. Continue the methodological research in distinguishing between Herring and blue whiting in the interpretation of echograms.	WGIPS
2. It is recommended that a workshop based on the ongoing otolith and scale exchange will take place before next year's IESNS survey.	WGBIOP, WGWIDE
3. It is recommended that the WGIPS meeting in 2020 includes a workshop on how to deal with stock components of herring in the IESNS-survey.	WGIPS
4. It is recommended that the WGIPS meeting in 2020 discusses whether cruise-planning with zig-zag transects in some strata is a possibility for the IESNS survey in order to optimise survey coverage.	WGIPS
5. It is recommended that the WGIPS meeting in 2020 discusses the possible implementation of sonar observations in IESNS and other acoustic surveys.	WGIPS

Next year's post-cruise meeting

We will aim for next meeting in Copenhagen 16-18 June 2020. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2019 at 0-200 m depth was above long-term mean (1995-2017) in the western and central Norwegian Sea but below the mean in the eastern and southern areas of the Norwegian Sea.

- The 2019 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters increased a bit from last year and is comparable to the mean of the earlier high-biomass period, but is still relatively low in the westernmost areas.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 4.87 million tonnes, which is a 3 % decrease from the 2018 survey estimate. The survey followed the pre-planned protocol and the survey group recommends using the abundance estimates in the analytical assessment.
- The 2013 year class dominated in the survey indices both in numbers and biomass (24 %). Despite relatively high number at age 6 of this year class, it is half the size of the large 2004 year class at the same age.
- The abundance estimation on age 3 (2016 year class) in the Norwegian Sea cannot be considered to provide reliable estimation on its year class strength because the year class size can be poorly determined at age-3, which has often relatively large uncertainty.
- The biomass of blue whiting measured in the 2019 survey increased by 6 % from last year's survey and 41 % in terms of numbers.
- Ages 4, 1 and 5 (2015, 2018 and 2014 year classes) of blue whiting are dominating the acoustic estimate (71 % of the biomass and 80 % by numbers).

References

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. 2016. Report of the Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR), 7-11 December 2015, Reykjavik, Iceland. ICES CM 2015/SSGIEA:10. 150 pp.

ICES. 2019. Report of the Working Group on Integrated Ecosystem Assessments for the Norwegian Sea (WGINOR). ICES WGINOR REPORT 2018, 26-30 November 2018. Reykjavik, Iceland. ICES CM 2018/IEASG:10. 123 pp.

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.

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 2018.

Data for Vilnyus will be updated for final report in August 2019.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	06/05-26/05	2058	20	38	473	1559	38
Magnus Heinason	2/5-12/5	1496	12	19	349	554	19
Árni Fridriksson	8/5-19/5	2320	13	35	914	2515	34
G.O.Sars	01/5-31/5	4887	53	55	564	1680	54
Vilnyus	Not confirmed						
Total		**10761**	**98**	**147**	**2300**	**6308**	**145**

Table 2. IESNS 2019 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	-	-	-	24512	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24512	713.3	29.10
17-18	-	55317	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55317	2012.6	36.38
18-19	6030	18091	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24121	978.7	40.58
19-20	-	4923	4923	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9846	537.9	54.63
20-21	-	19696	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19696	1288.0	65.39
21-22	-	19967	54564	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	74531	5233.6	70.22
22-23	-	27108	275402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	302510	24142.4	79.81
23-24	-	-	640302	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	640302	59839.0	93.45
24-25	-	-	592054	7461	-	-	-	-	-	-	-	-	-	-	-	-	-	-	599515	61842.0	103.15
25-26	-	19111	290836	23889	-	-	-	-	-	-	-	-	-	-	-	-	-	-	333836	39115.4	117.17
26-27	-	-	401494	3375	3375	-	-	-	-	-	-	-	-	-	-	-	-	-	408244	54944.1	134.59
27-28	-	3180	177549	80370	85869	3180	6361	-	-	-	-	-	-	-	-	-	-	-	356510	54080.0	151.69
28-29	-	-	143631	118774	217920	141779	13128	-	18379	13128	-	-	-	-	-	-	-	-	666739	115694.5	173.52
29-30	-	-	5557	205671	456082	392370	66183	2364	33091	7091	7091	-	-	-	-	-	-	-	1175500	220984.3	187.99
30-31	-	-	9045	153768	409969	488625	177890	69347	106231	15075	3015	-	9045	-	-	-	-	-	1442012	299482.5	207.68
31-32	-	-	-	21795	539092	780021	99941	76904	108269	86403	49970	-	-	-	-	-	-	-	1762397	394334.4	223.75
32-33	-	-	-	5894	263760	1499818	198994	152871	23574	67810	42406	5894	36986	-	-	-	-	-	2298006	562165.2	244.63
33-34	-	-	-	45209	110186	931985	274370	223970	60198	21066	1289	-	-	-	-	-	-	-	1668273	437728.9	262.38
34-35	-	-	-	-	40303	307932	302795	233985	123268	215323	30847	55462	53724	28961	6806	-	-	-	1399405	404735.9	289.22
35-36	-	-	-	-	28359	196578	70759	331745	208858	309430	198001	198257	200157	174175	44490	35448	-	-	1996256	620313.0	310.74
36-37	-	-	-	-	3566	33763	13372	72161	198850	350525	261806	224979	548152	264010	254163	2674	-	-	2228021	723676.3	324.81
37-38	-	-	-	-	11522	9048	22708	44157	41219	198577	206531	147545	404944	371497	261547	54879	5027	-	1779201	615561.3	345.98
38-39	-	-	-	-	-	-	8613	-	-	10179	3915	51722	108650	82144	90090	18009	-	-	373323	137998.6	369.65
39-40	-	-	-	-	-	-	-	-	-	-	-	-	19045	17102	3420	33866	-	-	73433	28858.9	393.00
40-41	-	-	-	-	-	-	-	-	-	-	-	2750	-	-	-	5499	-	-	8249	3737.3	453.06
41-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8306	8306	3584.1	431.50
TSN(1000)	6030	167393	2595359	690716	2170003	4785101	1255113	1207504	921939	1294606	804871	686609	1380702	937888	660516	150376	5027	8306	19728061	-	-
TSB(1000 kg)	253.3	10528.0	288485.2	124080.6	461558.3	1146871.7	322436.5	342043.3	258763.5	394139.7	254213.4	224025.6	453514.2	312166.5	222575.8	52598.7	1743.5	3584.1	-	4873582.1	-
Mean length (cm)	18.00	20.09	24.60	28.68	30.49	31.90	32.62	33.81	33.73	34.98	35.47	36.04	36.22	36.45	36.76	37.27	37.00	41.00	-	-	-
Mean weight (g)	42.00	62.89	111.15	179.64	212.70	239.68	256.90	283.26	280.67	304.45	315.84	326.28	328.47	332.84	336.97	349.78	346.85	431.50	-	-	247.04

Table 3. IESNS 2018 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring. (The table will be updated for the final report in August 2019)

LenGrp	age 1	2	3	4	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
8-9	-	-	-	-	520041	520041	-	-
9-10	1387351	-	-	-	-	1387351	6705.5	4.83
10-11	3454174	-	-	-	-	3454174	23047.7	6.67
11-12	1729698	-	-	-	-	1729698	14235.4	8.23
12-13	87114	580761	-	-	-	667875	7482.1	11.20
13-14	55348	525809	-	-	-	581157	8302.2	14.29
14-15	152238	418656	-	-	-	570894	9971.6	17.47
15-16	-	2482188	-	-	-	2482188	55037.4	22.17
16-17	-	4567488	-	-	-	4567488	118814.1	26.01
17-18	-	3502545	-	-	-	3502545	108991.0	31.12
18-19	-	752673	-	-	-	752673	27545.4	36.60
19-20	-	1795332	96523	-	-	1891855	90606.3	47.89
20-21	-	1583094	98943	-	-	1682038	89929.6	53.46
21-22	-	1003720	54748	-	-	1058468	66592.3	62.91
22-23	-	118952	288884	-	-	407836	32057.6	78.60
23-24	-	72411	90513	-	-	162924	14029.6	86.11
24-25	-	-	78268	-	-	78268	8609.4	110.00
25-26	-	-	235335	-	-	235335	25886.9	110.00
27-28	-	-	-	9227	-	9227	1324.0	143.50
TSN(1000)	6865924	17403628	943215	9227	520041	25742035	-	-
TSB(1000 kg)	48040.8	581618.4	78185.0	1324.0	-	-	709168.2	-
Mean length (cm)	10.47	17.15	22.56	27.50	8.50	-	-	-
Mean weight (g)	7.00	33.42	82.89	143.50	-	-	-	28.12

Table 4. IESNS 2019 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
15-16	-	-	-	-	-	-	-	-	-	-	-	1414	1414	-	-
16-17	201748	-	-	-	-	-	-	-	-	-	-	-	201748	4521.1	22.41
17-18	401046	-	-	-	-	-	-	-	-	-	-	-	401046	10793.4	26.91
18-19	728972	-	-	-	-	-	-	-	-	-	-	-	728972	24964.6	34.25
19-20	928754	-	-	-	-	-	-	-	-	-	-	-	928754	36072.1	38.84
20-21	522045	1388	-	-	-	-	-	-	-	-	-	-	523433	24431.9	46.68
21-22	220569	-	-	-	-	-	-	-	-	-	-	-	220569	12334.4	55.92
22-23	99456	-	-	13369	-	-	-	-	-	-	-	-	112825	7075.0	62.71
23-24	38055	6732	-	-	-	-	-	-	-	-	-	-	44787	3167.4	70.72
24-25	-	36494	61170	18643	4460	-	-	-	-	-	-	-	120766	10226.7	84.68
25-26	12528	61556	87524	86038	11008	-	-	-	-	-	-	-	258654	25551.0	98.78
26-27	-	109246	146840	177200	41030	9914	-	4265	-	-	-	-	488496	53790.1	110.11
27-28	3427	-	225124	245039	152288	32593	1940	-	2397	-	-	-	662808	83509.6	125.99
28-29	-	-	25770	274957	216755	66846	4182	1835	-	-	-	-	590344	83894.2	142.11
29-30	-	-	37072	121687	270425	75085	17977	-	-	-	-	-	522247	79843.0	152.88
30-31	-	-	47156	41705	104185	39331	6605	3642	-	-	-	-	242625	40925.2	168.68
31-32	-	-	-	33566	21461	29717	1989	32377	-	-	-	-	119110	21843.1	183.39
32-33	-	-	-	-	8489	6589	4237	2909	970	-	997	-	24191	4666.4	192.90
33-34	-	-	-	-	-	10386	1888	-	-	3944	-	-	16218	3382.1	208.54
34-35	-	-	-	-	-	-	-	-	4543	-	-	-	4543	1065.6	234.58
35-36	-	-	-	-	1058	2115	-	-	-	-	-	-	3173	928.0	292.47
36-37	-	-	-	-	-	-	-	5123	2115	-	-	-	7239	1912.6	264.22
TSN(1000)	3156598	215417	630655	1012205	831158	272577	38819	50152	10025	3944	997	1414	6223961	-	-
TSB(1000 kg)	123807.7	22738.5	74785.7	131456.3	122102.7	41704.6	6033.0	9147.8	2094.0	826.0	201.2	-	-	534897.5	-
Mean length (cm)	18.86	25.28	26.70	27.46	28.57	29.22	29.75	31.17	32.92	33.00	32.00	15.00	-	-	-
Mean weight (g)	39.22	105.56	118.58	129.87	146.91	153.00	155.41	182.40	208.87	209.46	201.75	-	-	-	85.96

Figures

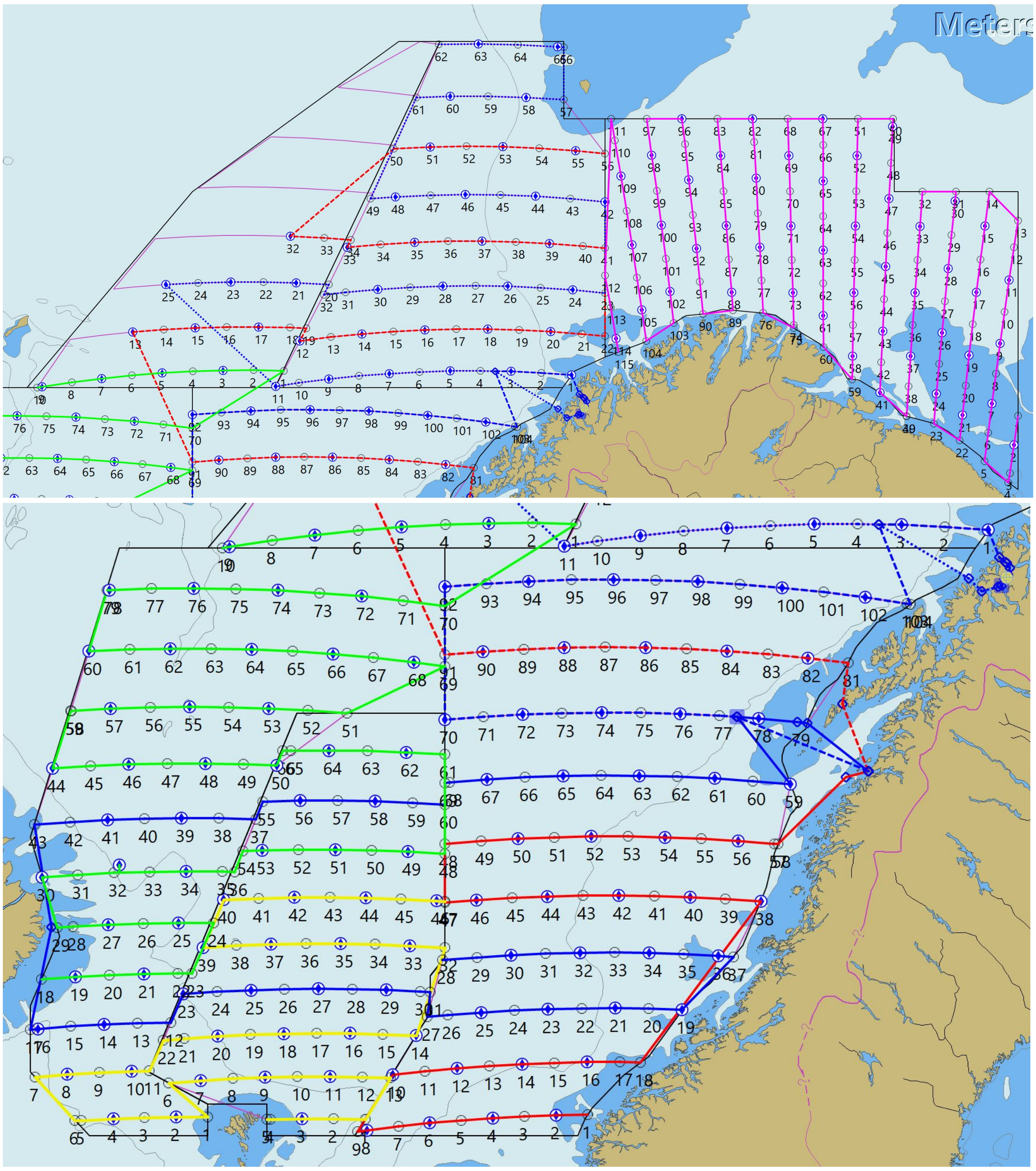


Figure 1. The pre-planned strata and transects for the IESNS survey in 2019 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends.

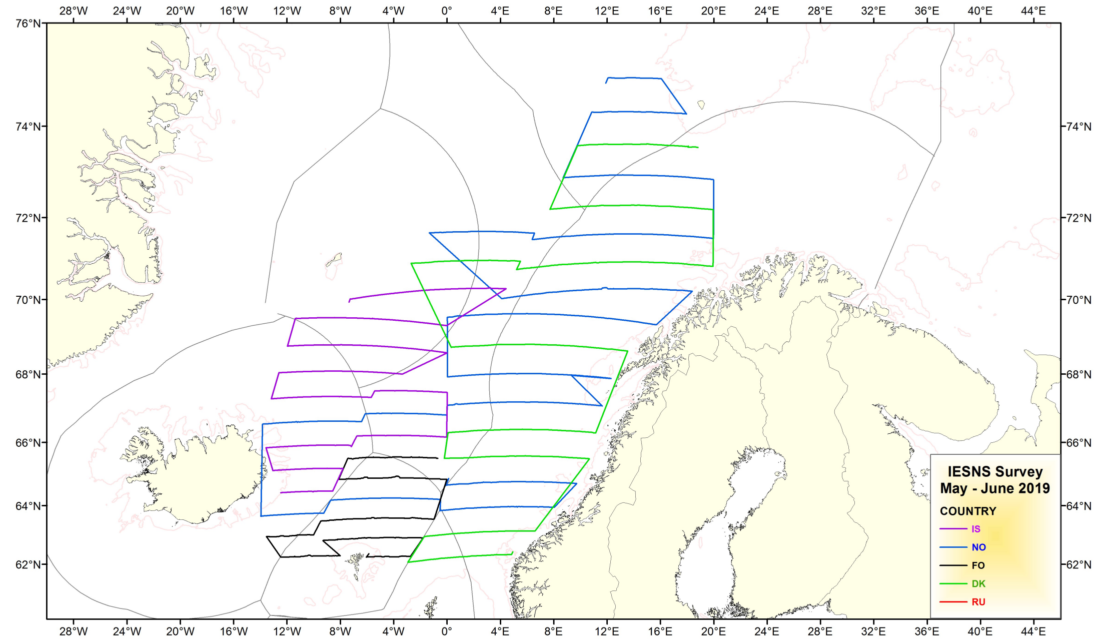


Figure 2. Cruise tracks for the IESNS survey in May 2019.

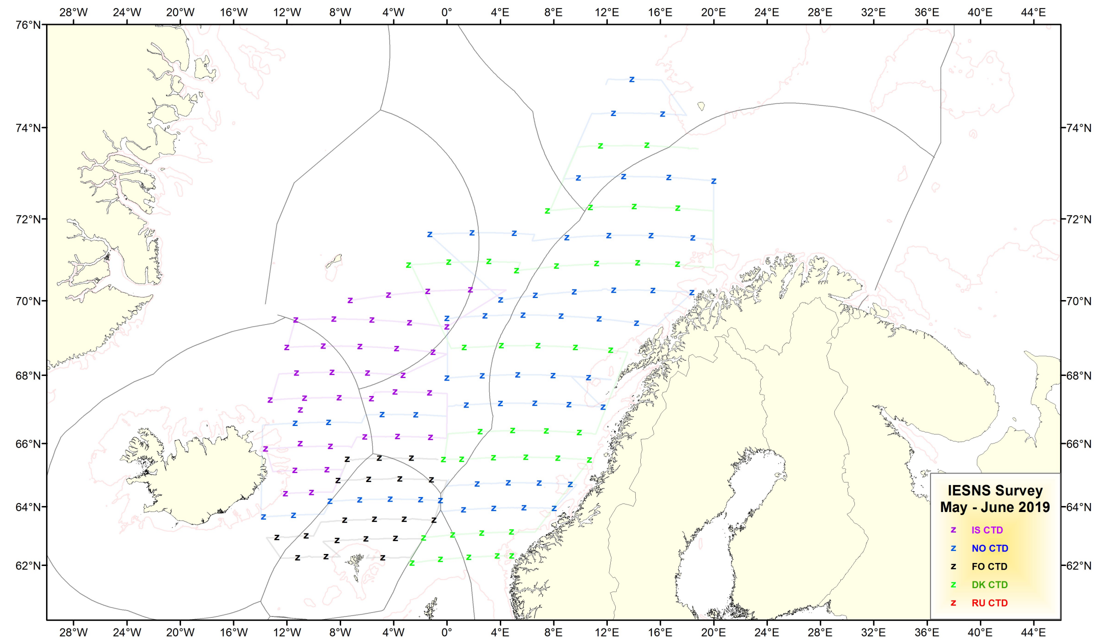


Figure 3a. IESNS survey in May 2019: location of hydrographic stations.

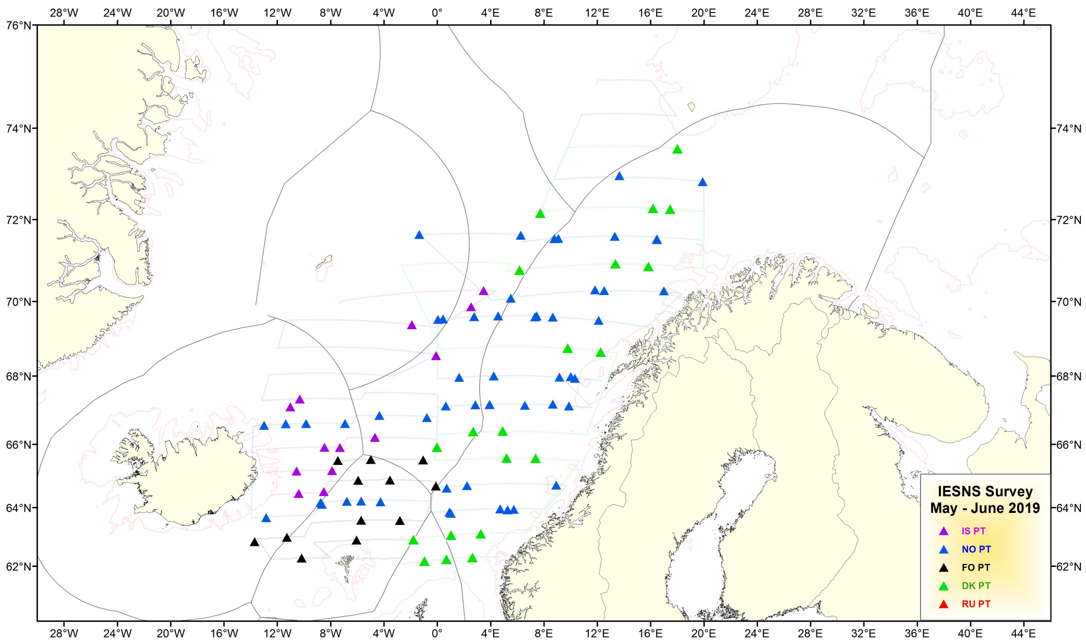


Figure 3b. IESNS survey in May 2019: location of pelagic trawl stations.

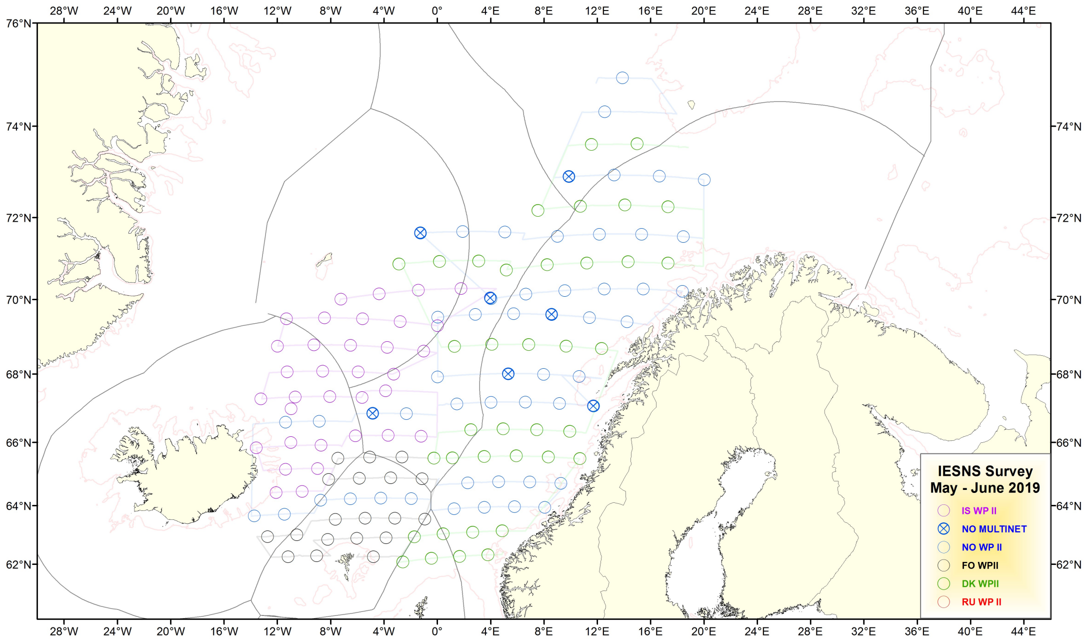


Figure 3c. IESNS survey in May 2019: location of plankton stations

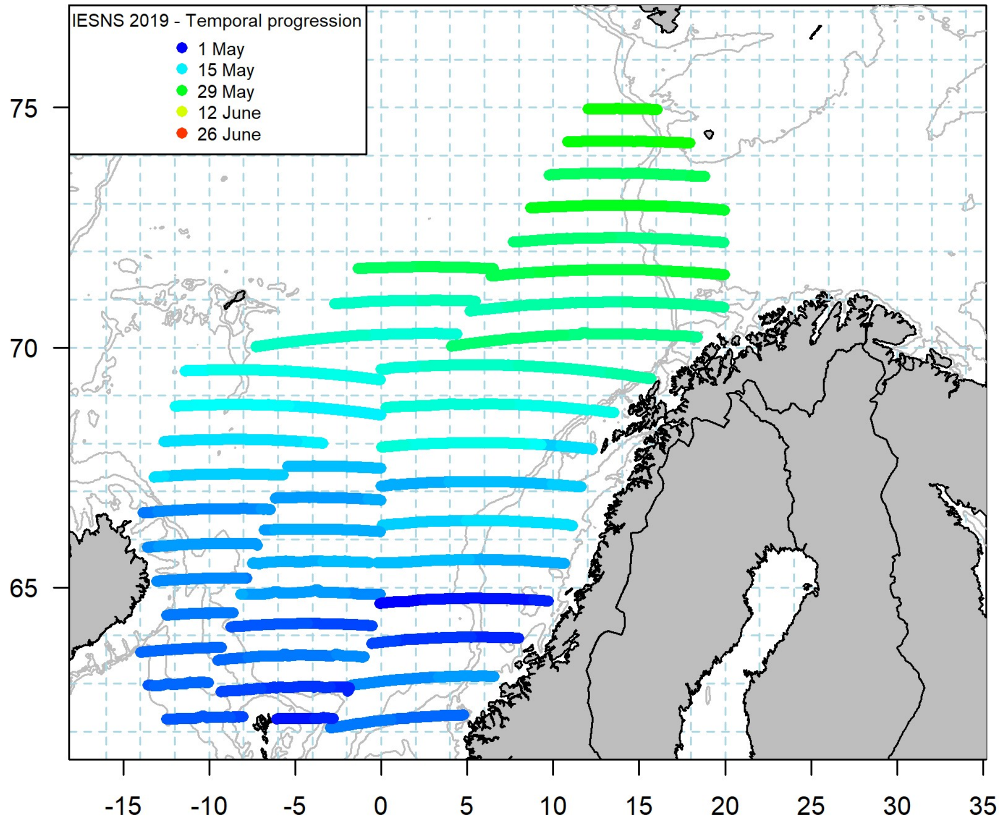


Figure 4. Temporal progression IESNS in May-June 2019. (The cruise track of the Russian vessel in the Barents Sea will be updated in August 2019)

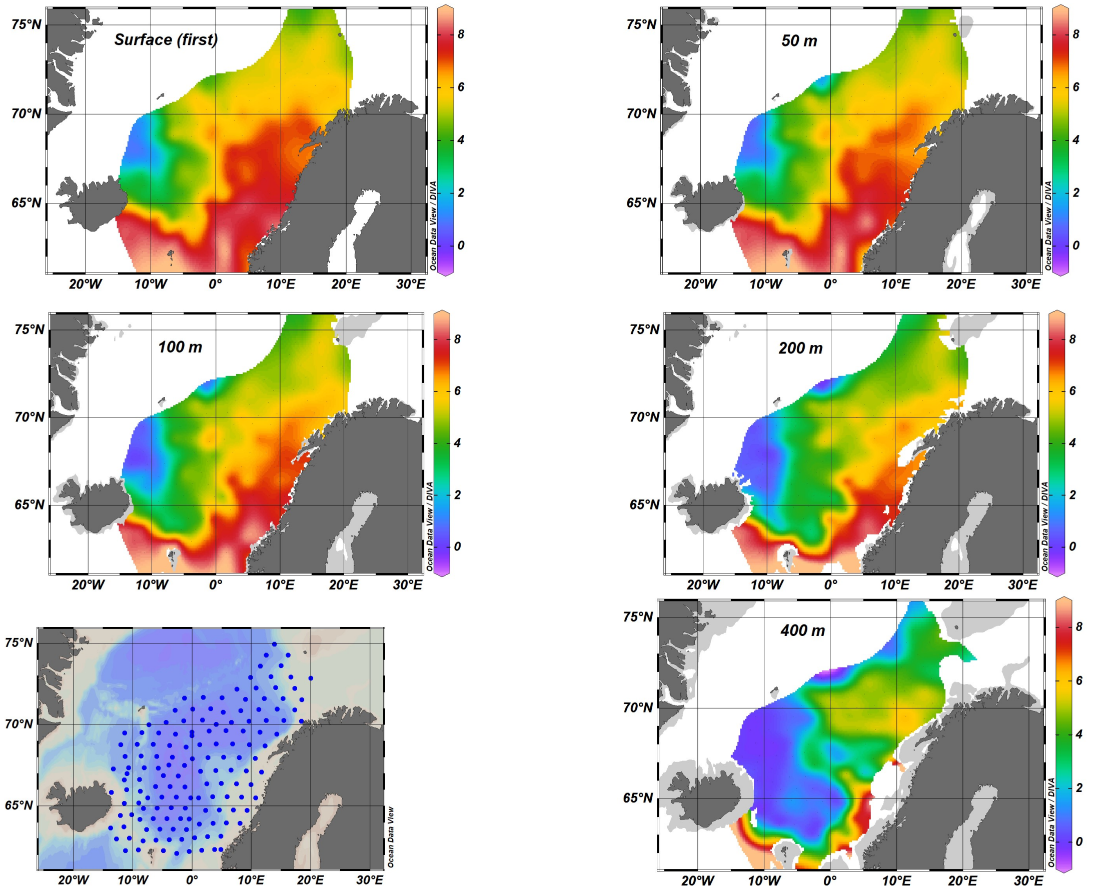


Figure 5. The horizontal distribution of temperatures (°C) at surface, 50m, 100m, 200m and 400m depth in IESNS in May-June 2019.

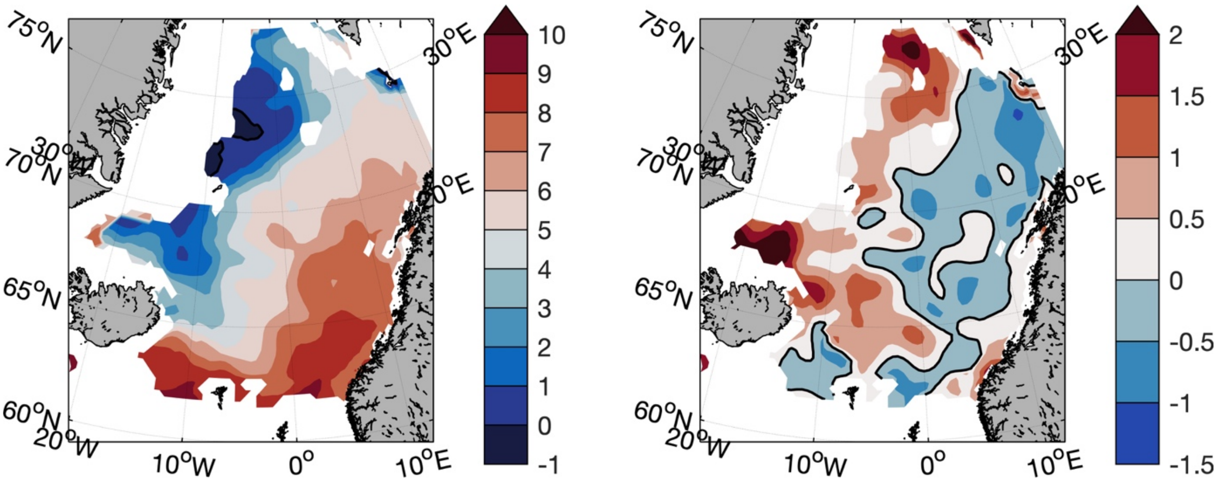


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

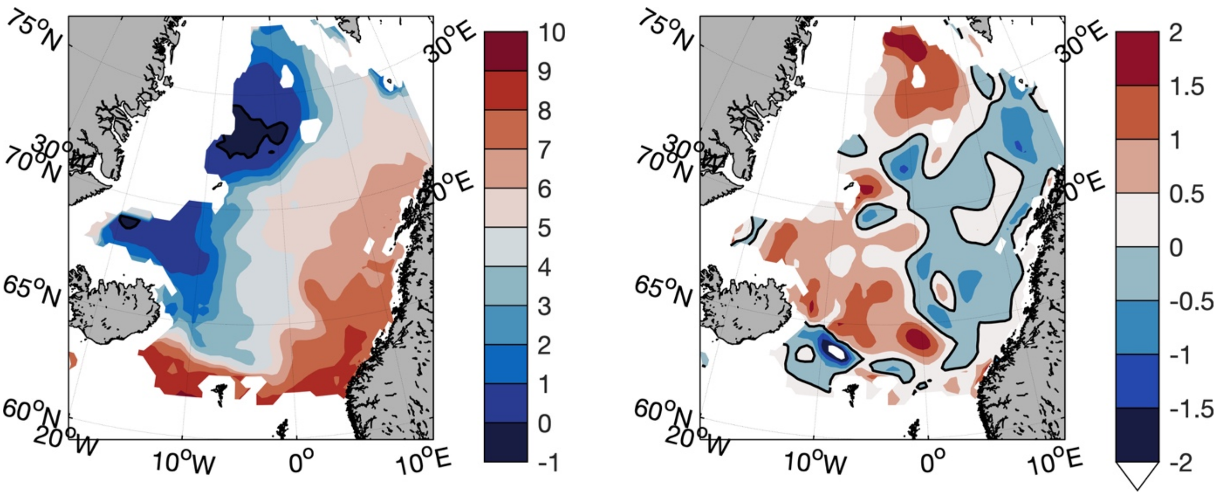


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

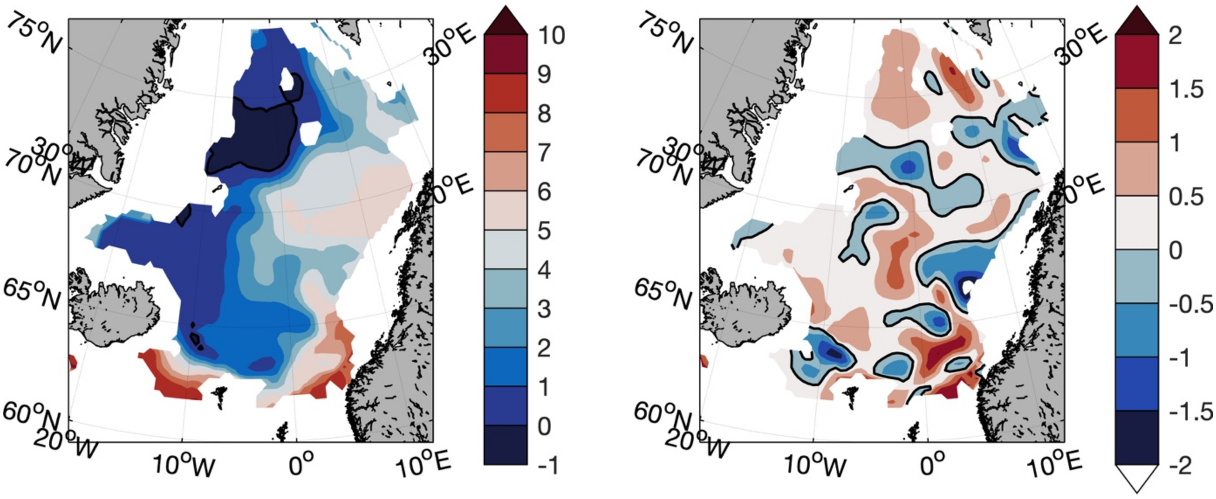


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

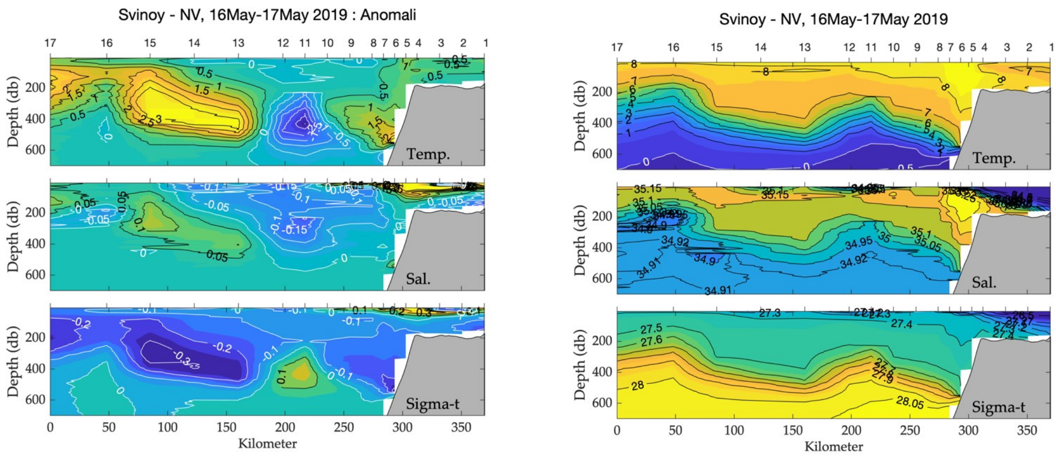


Figure 9. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinøy section, May 2019. Anomalies are relative to a 30 years long-term mean (1978-2007).

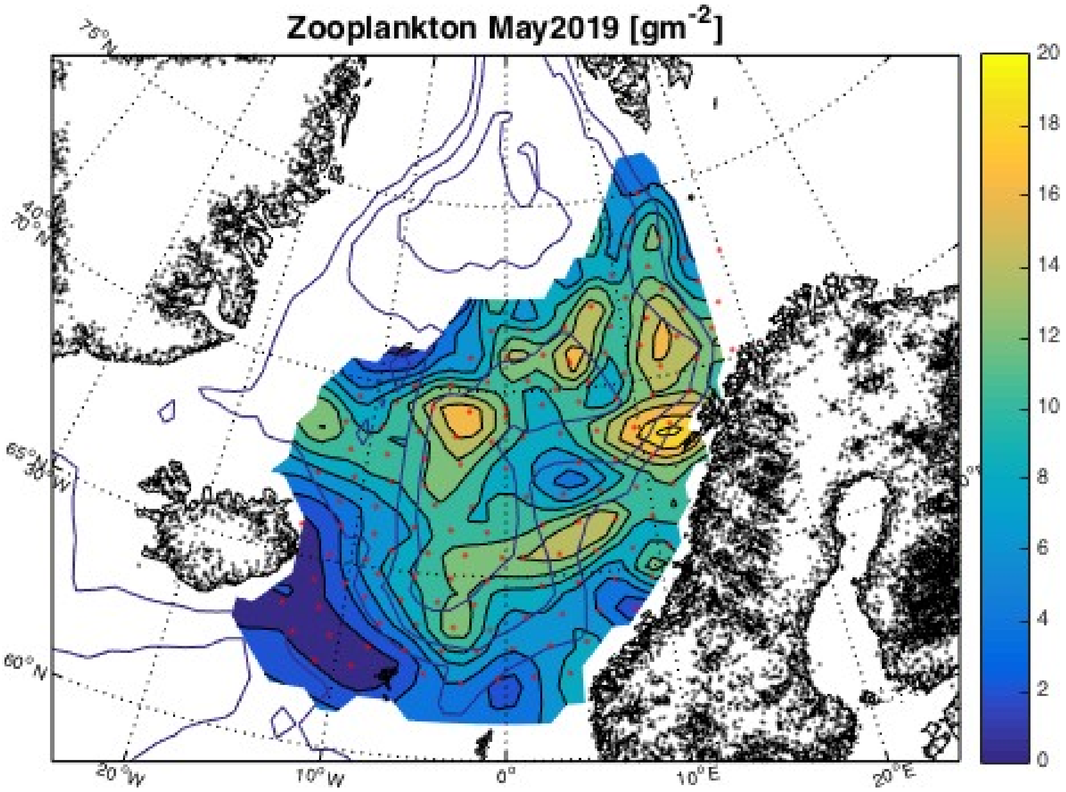


Figure 10. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May 2019.

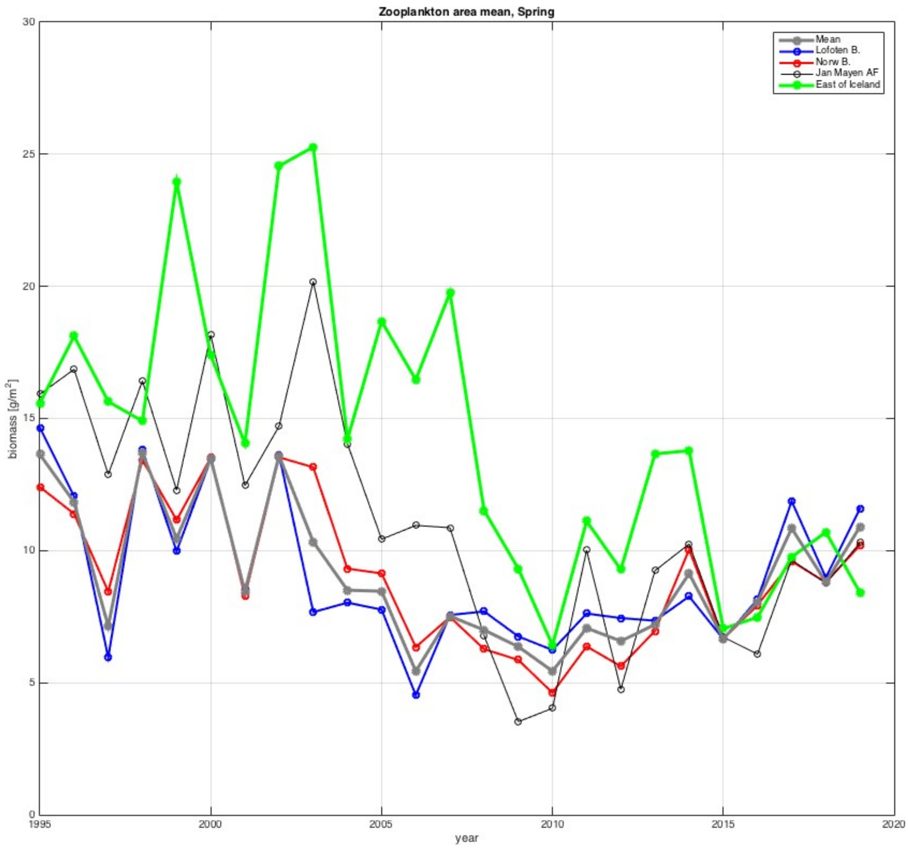
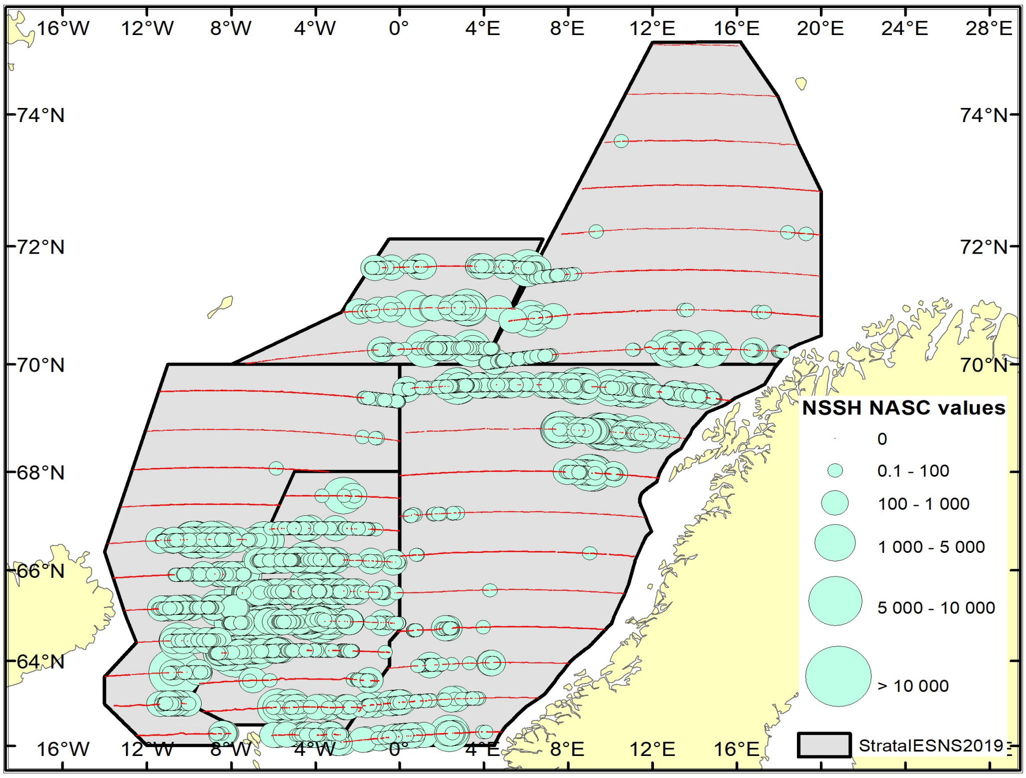


Figure 11. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

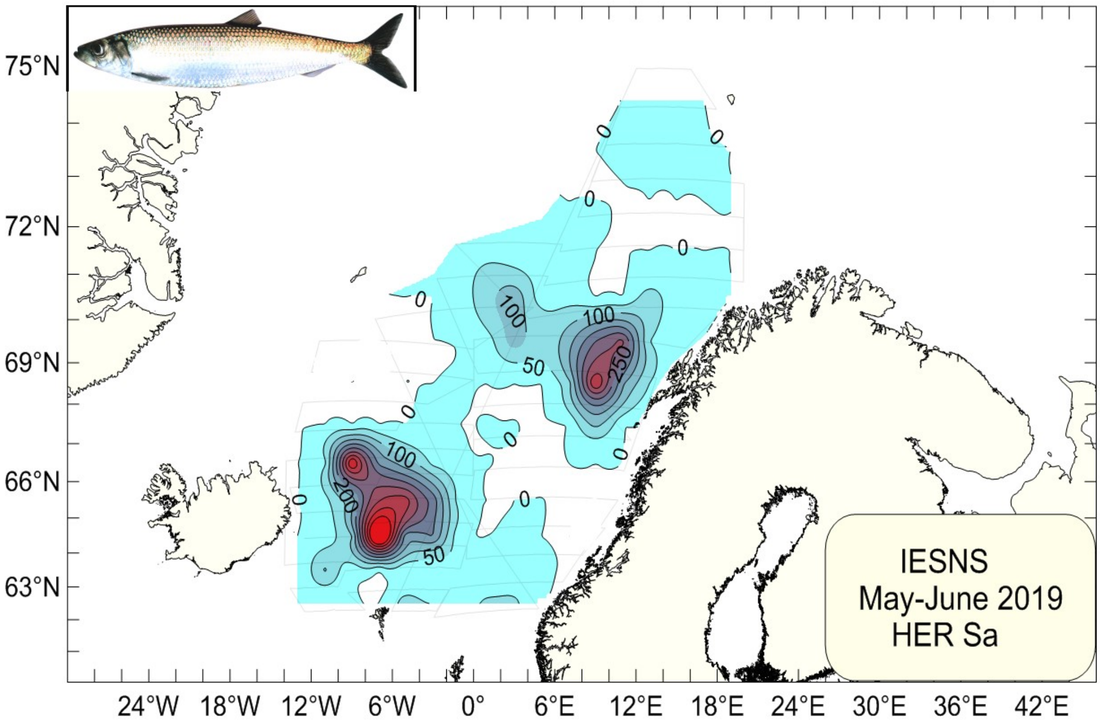


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2019 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

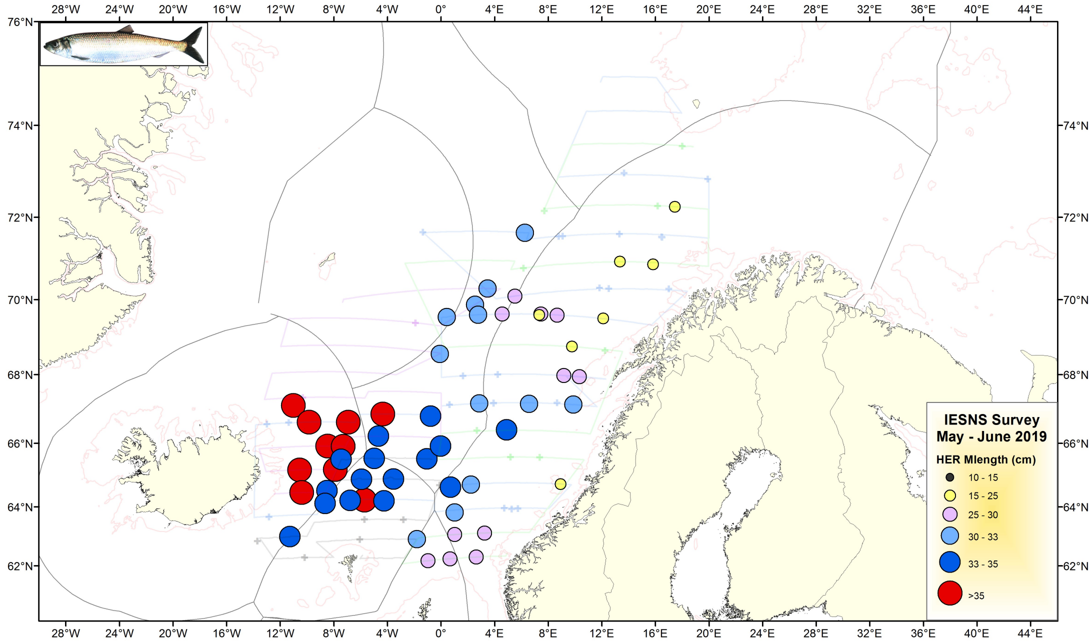


Figure 13. Mean length of Norwegian spring-spawning herring in all hauls in May 2019.

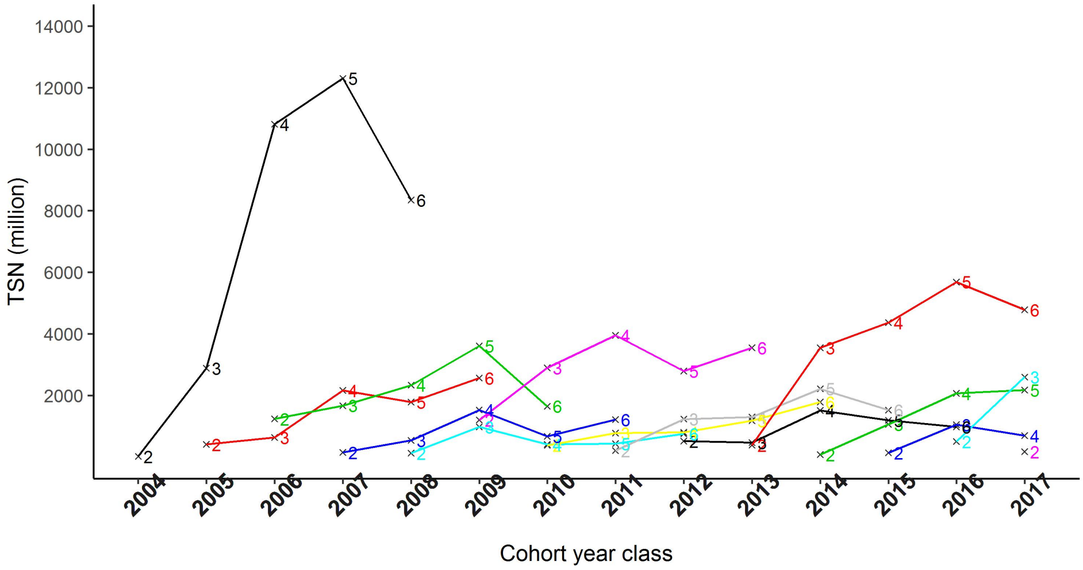


Figure 14. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

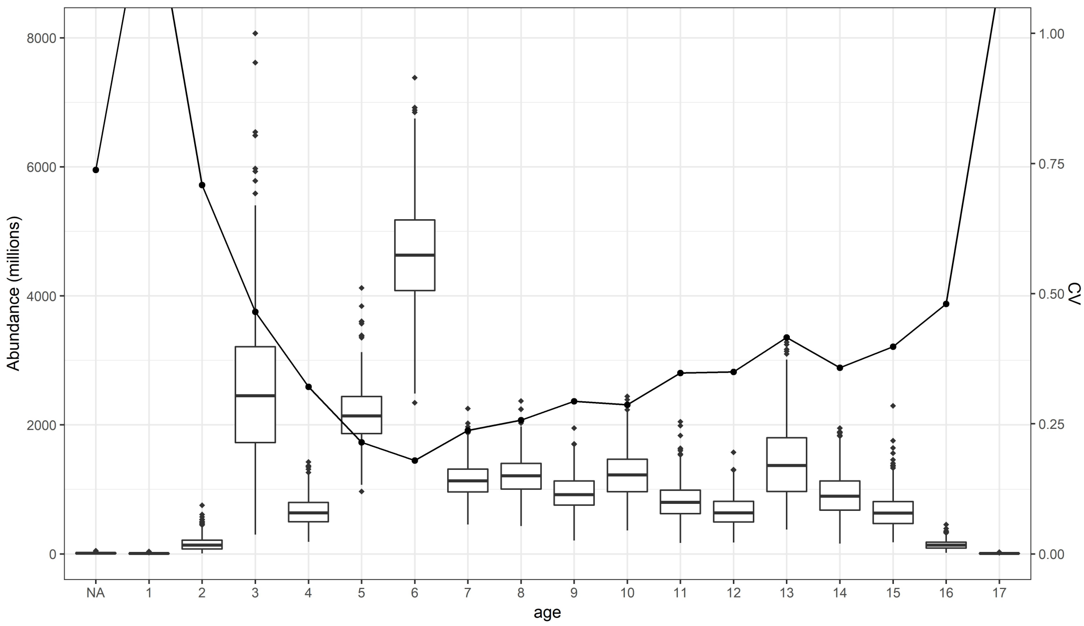


Figure 15. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

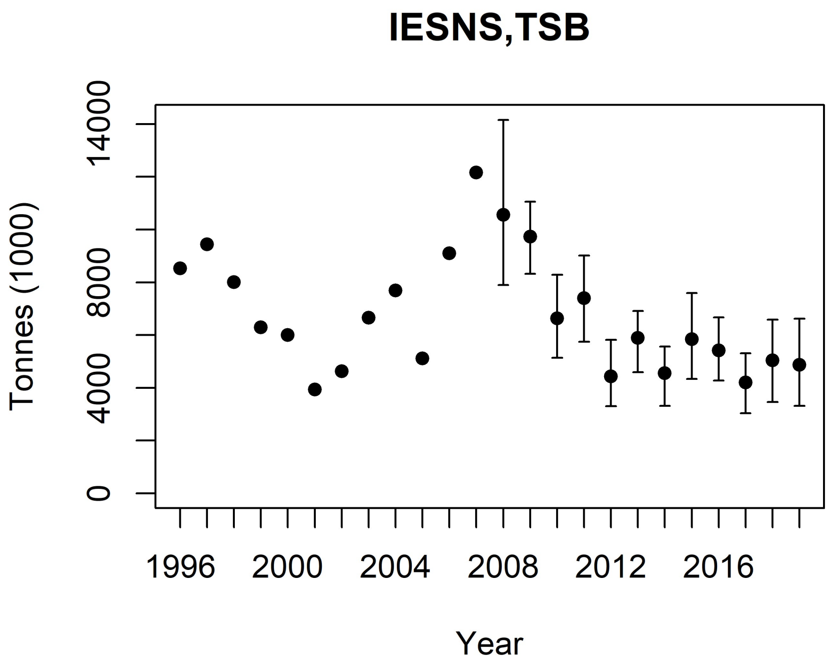


Figure 16. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2019 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2019; with 90% confidence interval; calculated on basis of standard stratified transect design).

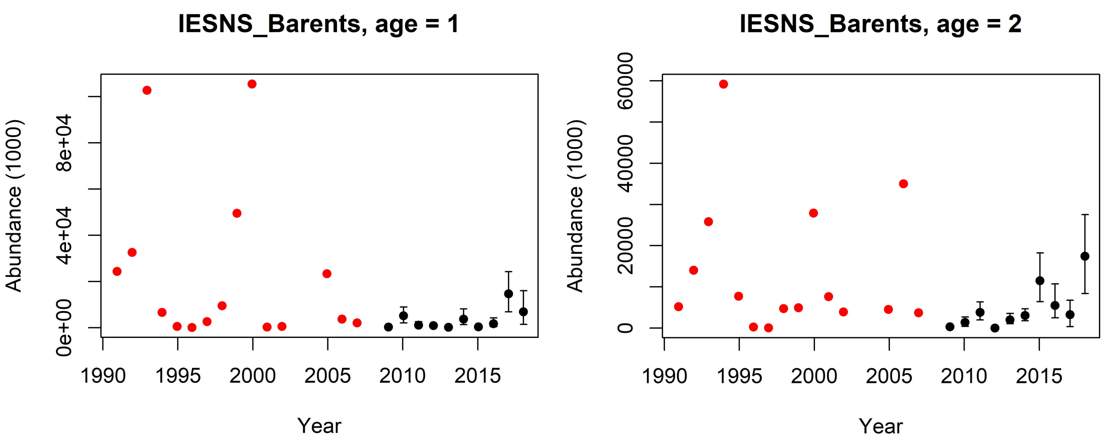
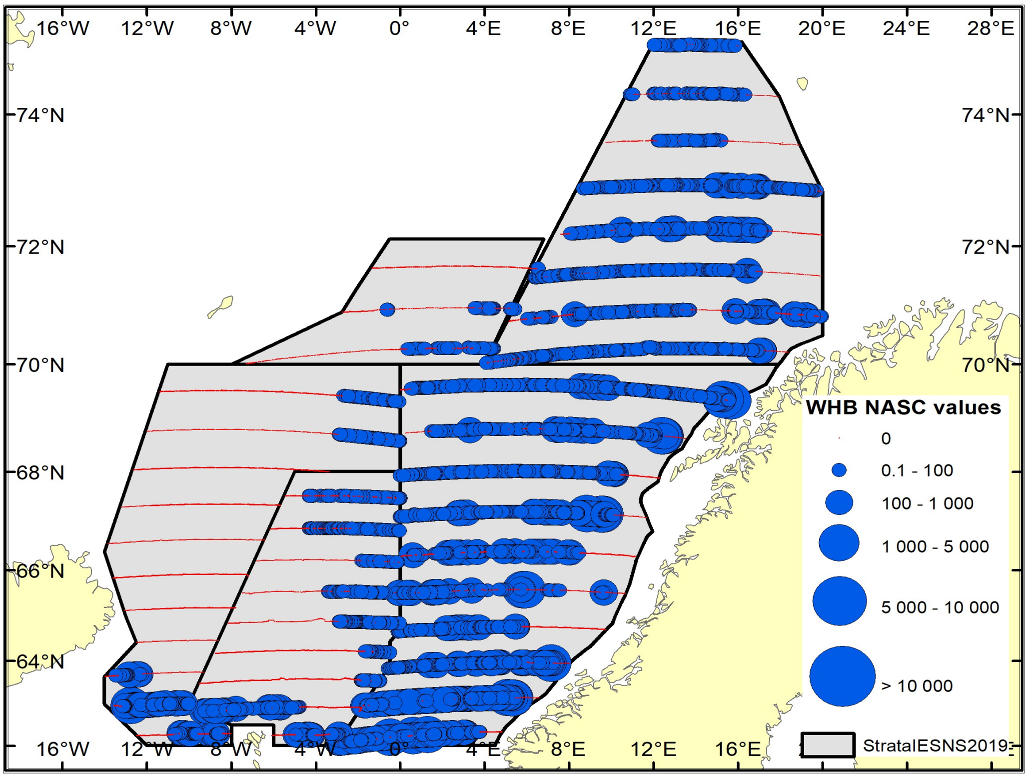


Figure 17. <u>OBS!! – This figure will be updated for the final report in August 2019</u>**. Numbers at age 1 (to left) and age 2 (right) herring in the Barents Sea in April-June as estimated using BEAM (red dots; calculated on basis of rectangles) and the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).**

(a)



(b)

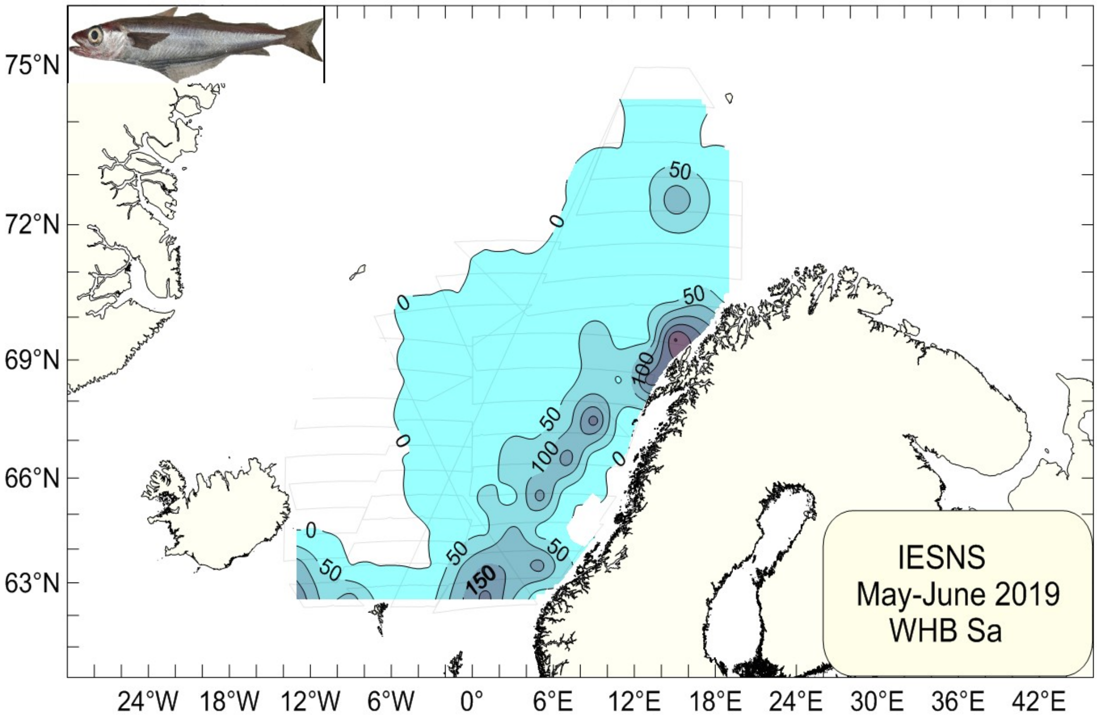


Figure 18. Distribution of blue whiting as measured during the IESNS survey in May 2019 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

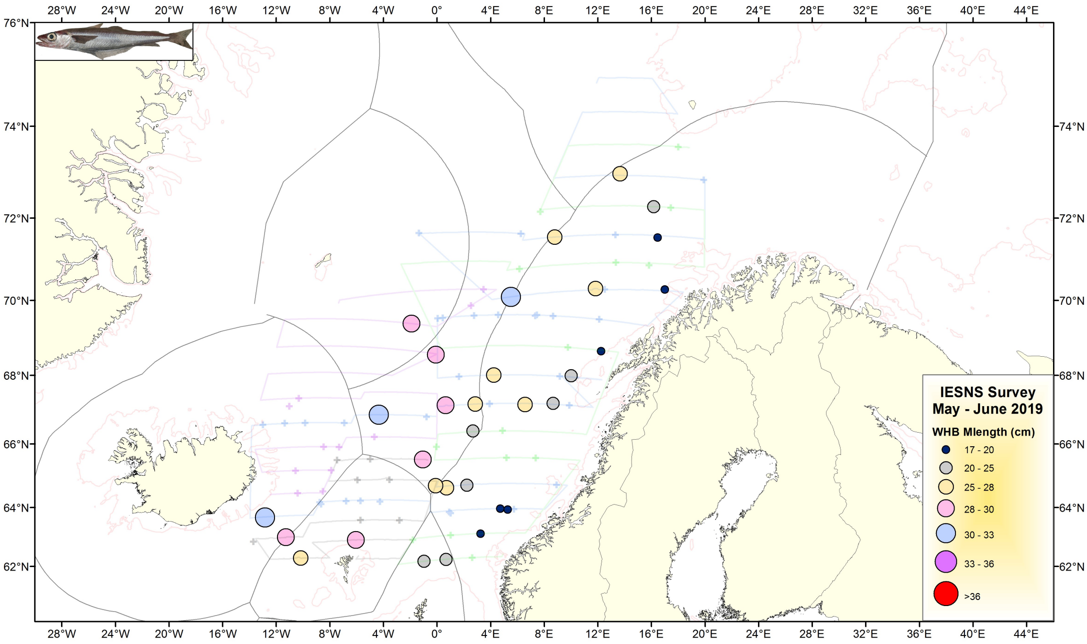


Figure 19. Mean length of blue whiting in all hauls in IESNS 2019.

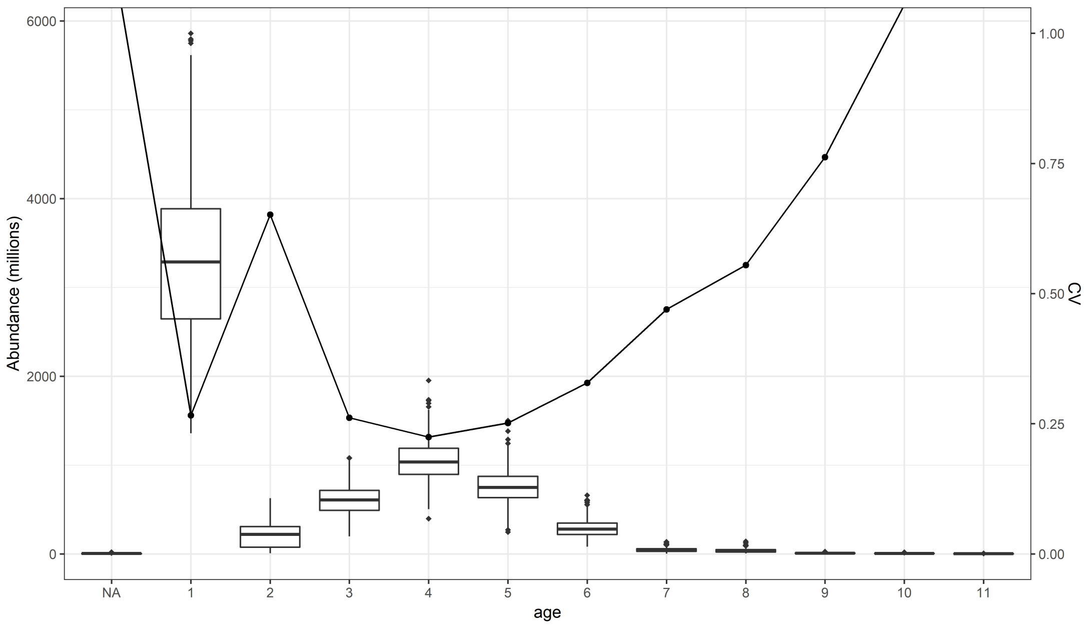


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

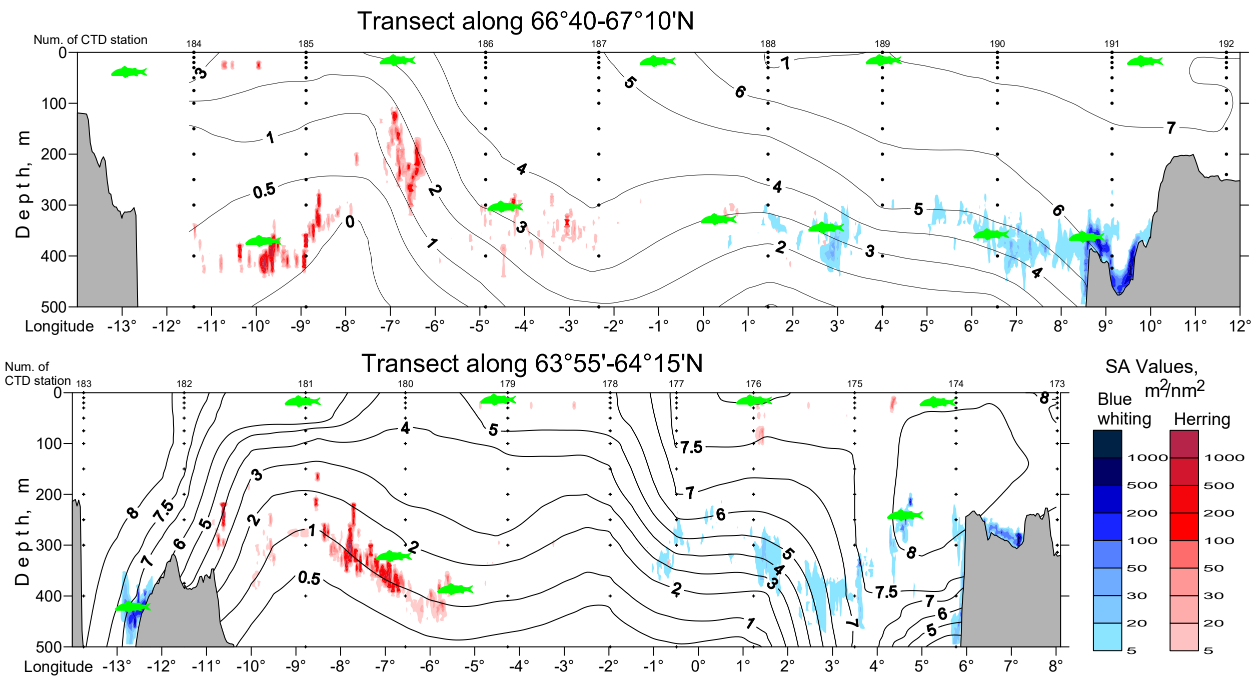


Figure 21. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2019, covered by "G.O. Sars".

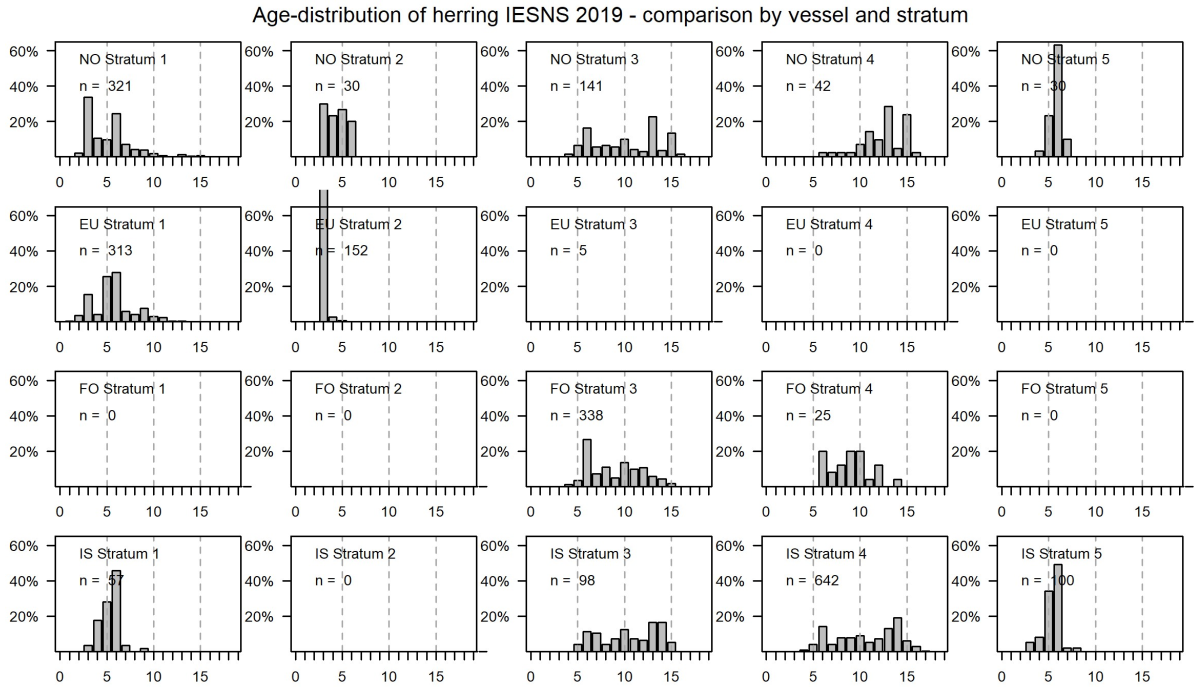


Figure 22. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2019. The strata are shown in Figure 3.

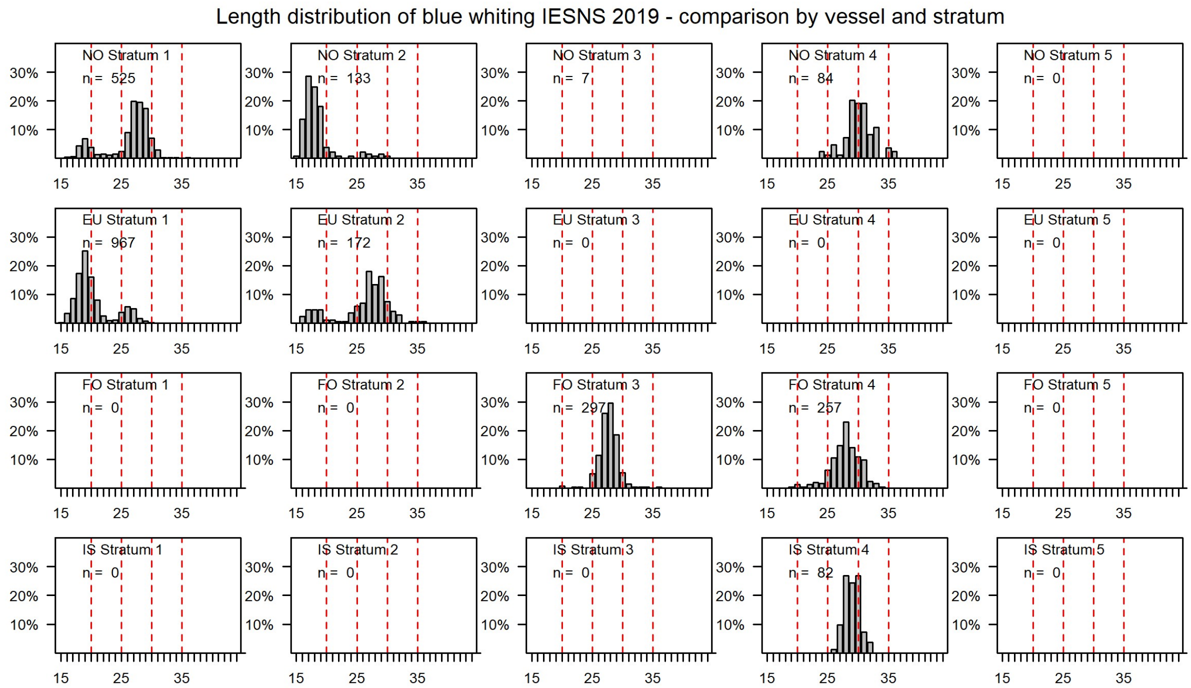


Figure 23. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2019. The strata are shown in Figure 3.

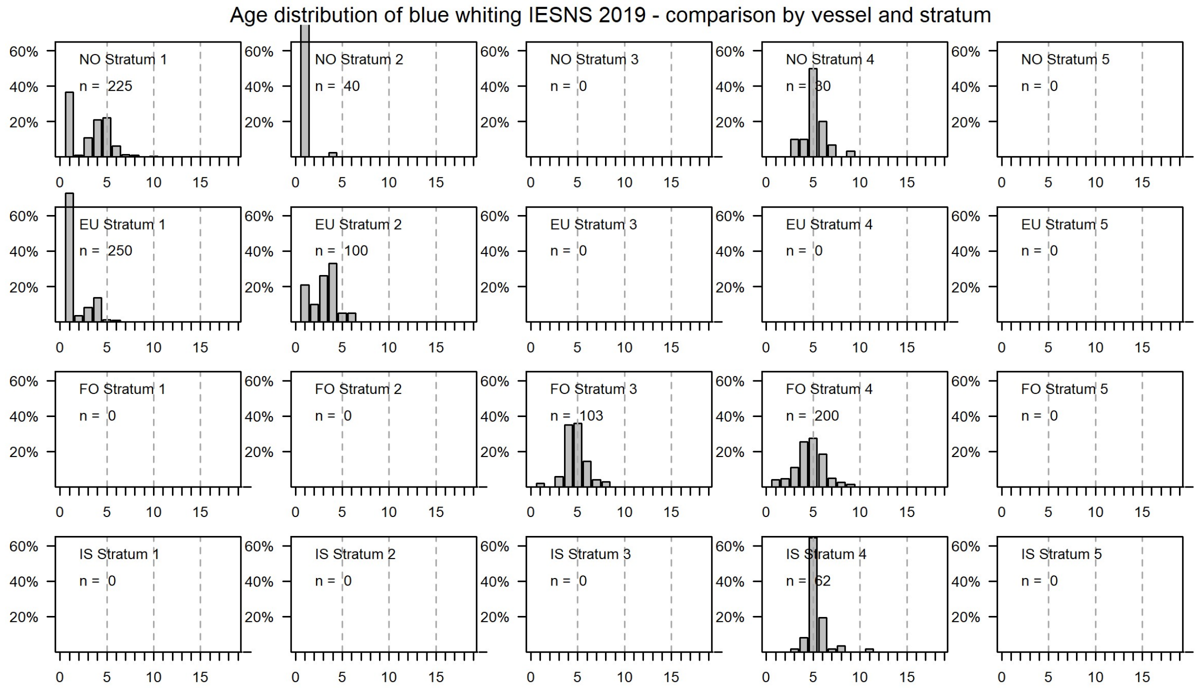


Figure 24. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2019. The strata are shown in Figure 3.