

IESNS post-cruise meeting, Copenhagen 19-21/6 2018

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

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Introduction

In May-June 2019, five research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherlands, 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 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:

$$\text{Blue whiting: } TS = 20 \log(L) - 65.2 \text{ dB (ICES 2012)}$$

$$\text{Herring: } TS = 20.0 \log(L) - 71.9 \text{ dB}$$

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 WP11 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 $>7^\circ\text{C}$ 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.

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- 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 |

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

| LenGrp | age | | | | | | | | | | | | | | | | | Unknown | Number (1E3) | Biomass (1E3kg) | Mean W (g) | | | | |
|------------------|-------|---------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|--------|---------|-----------------|--------------------|---------------|---------|----------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | | | | | | | | |
| 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 |

IESNS post-cruise meeting, Copenhagen 19-21/6 2018

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 | | | | | Unknown | Number (1E3) | Biomass (1E3kg) | Mean W (g) |
|------------------|---------|----------|---------|--------|--------|----------|-----------------|--------------------|---------------|
| | 1 | 2 | 3 | 4 | | | | | |
| 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 | - |

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

| LenGrp | age | | | | | | | | | | | Unknown | Number (1E3) | Biomass (1E3kg) | Mean W (g) | | |
|------------------|----------|---------|---------|----------|----------|---------|--------|--------|--------|--------|--------|---------|-----------------|--------------------|---------------|---------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | | | | |
| 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

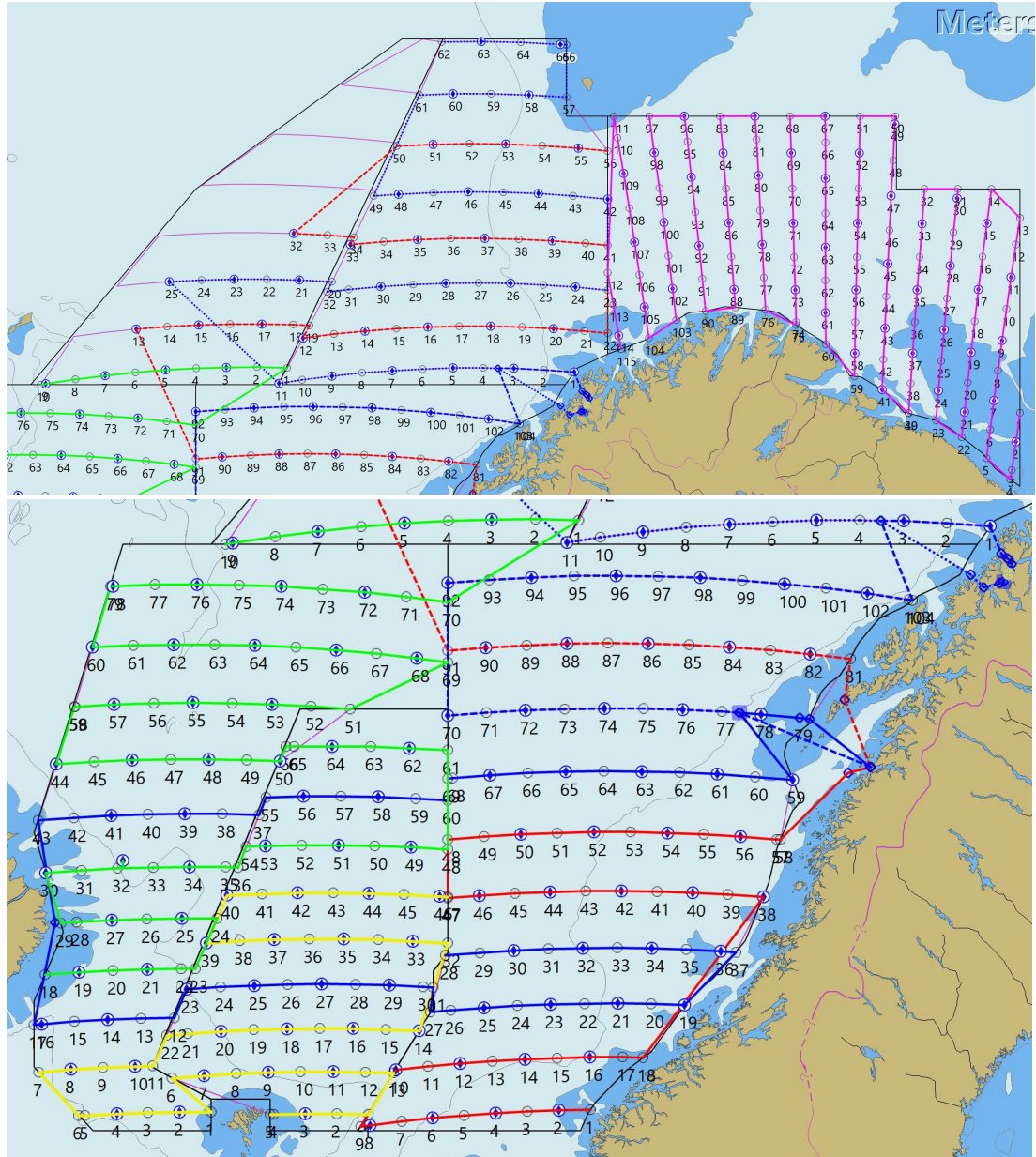


Figure 1. The pre-planned strata and transects for the IENSNS survey in 2019 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30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

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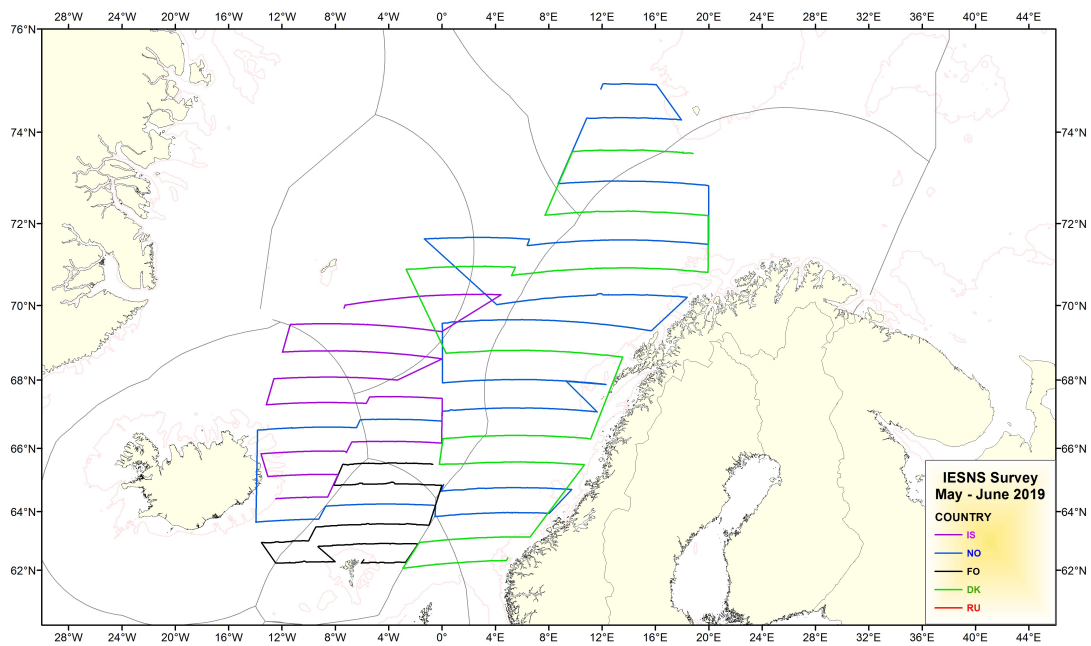


Figure 2. Cruise tracks for the IESNS survey in May 2019.

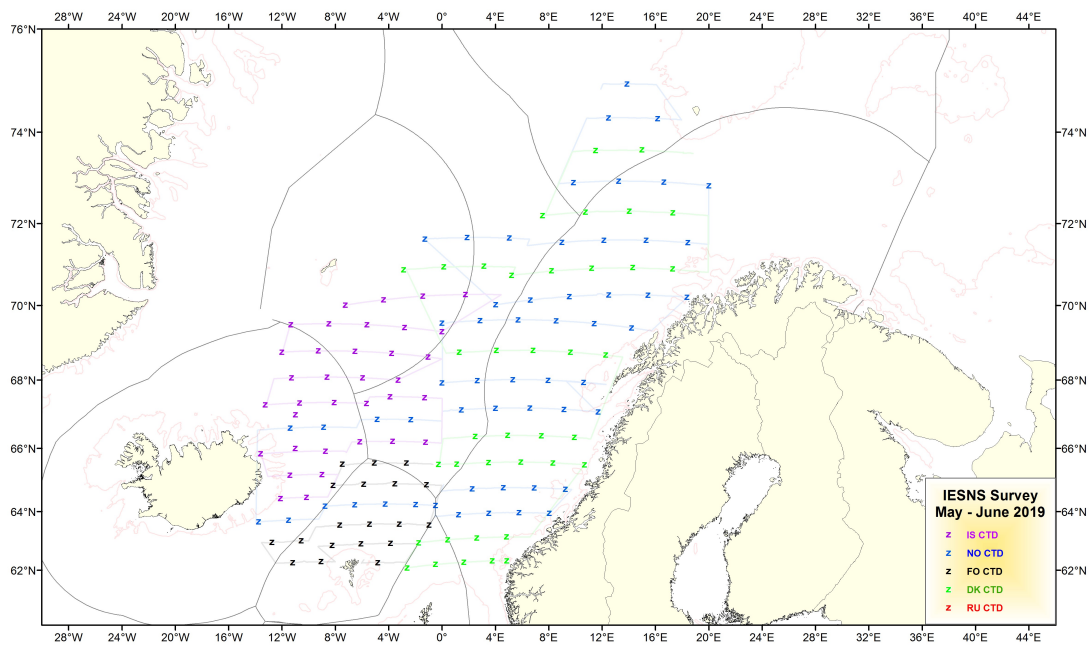


Figure 3a. IESNS survey in May 2019: location of hydrographic stations.

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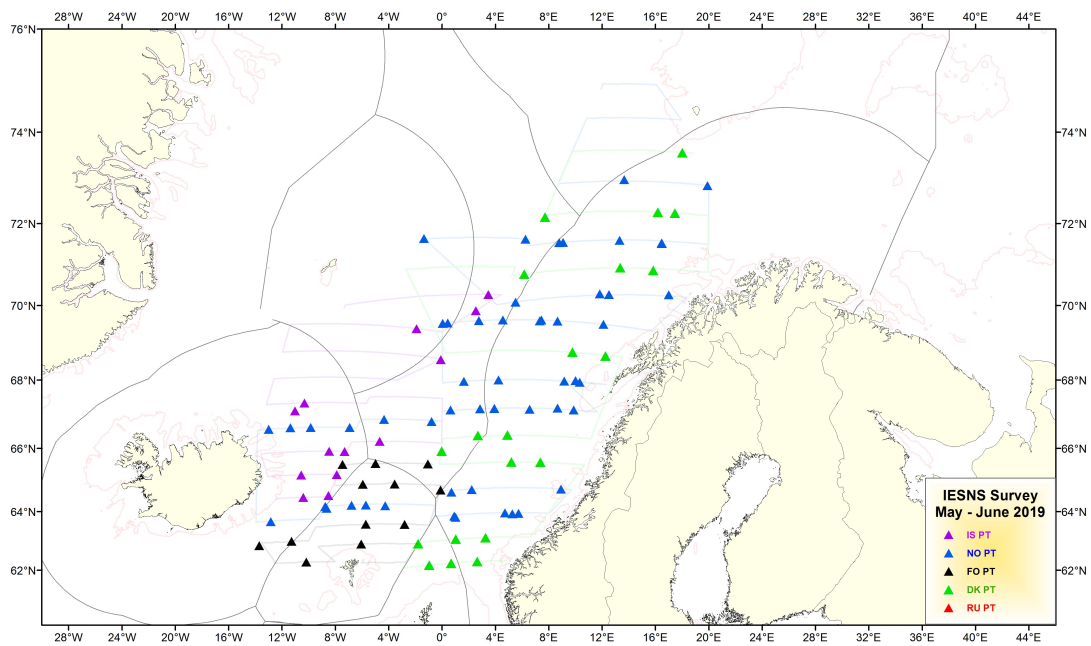


Figure 3b. IESNS survey in May 2019: location of pelagic trawl stations.

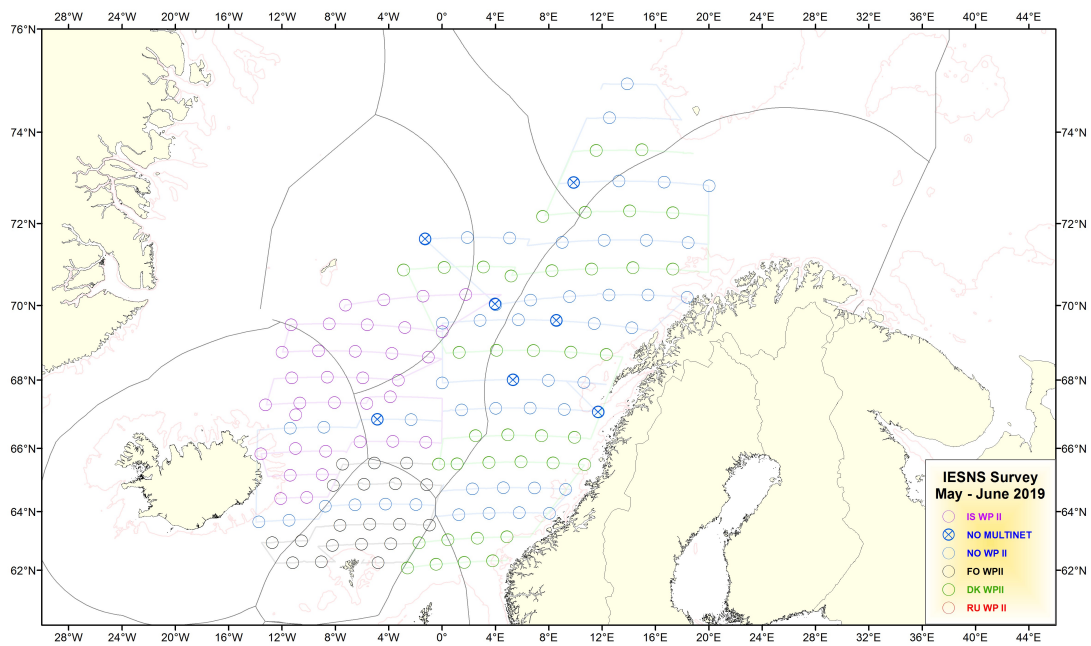


Figure 3c. IESNS survey in May 2019: location of plankton stations

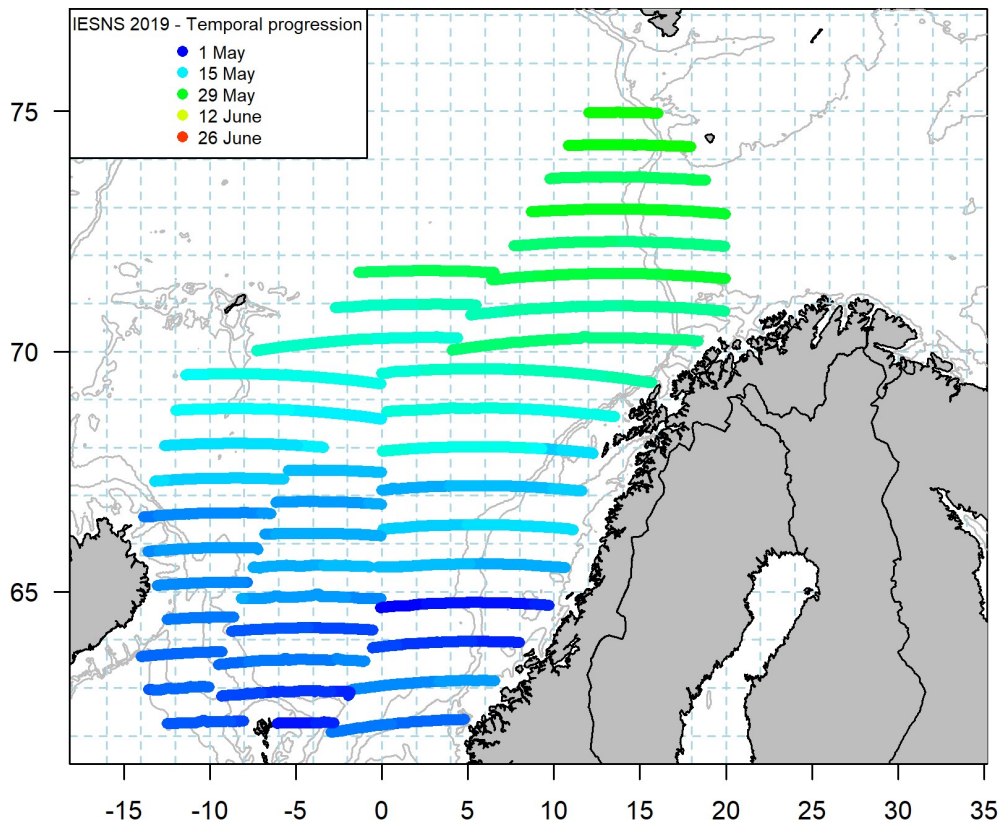


Figure 4. Temporal progression IESNS in May-June 2019. (The cruise track of the Russian vessel in the Barents Sea will be updated in August 2019)

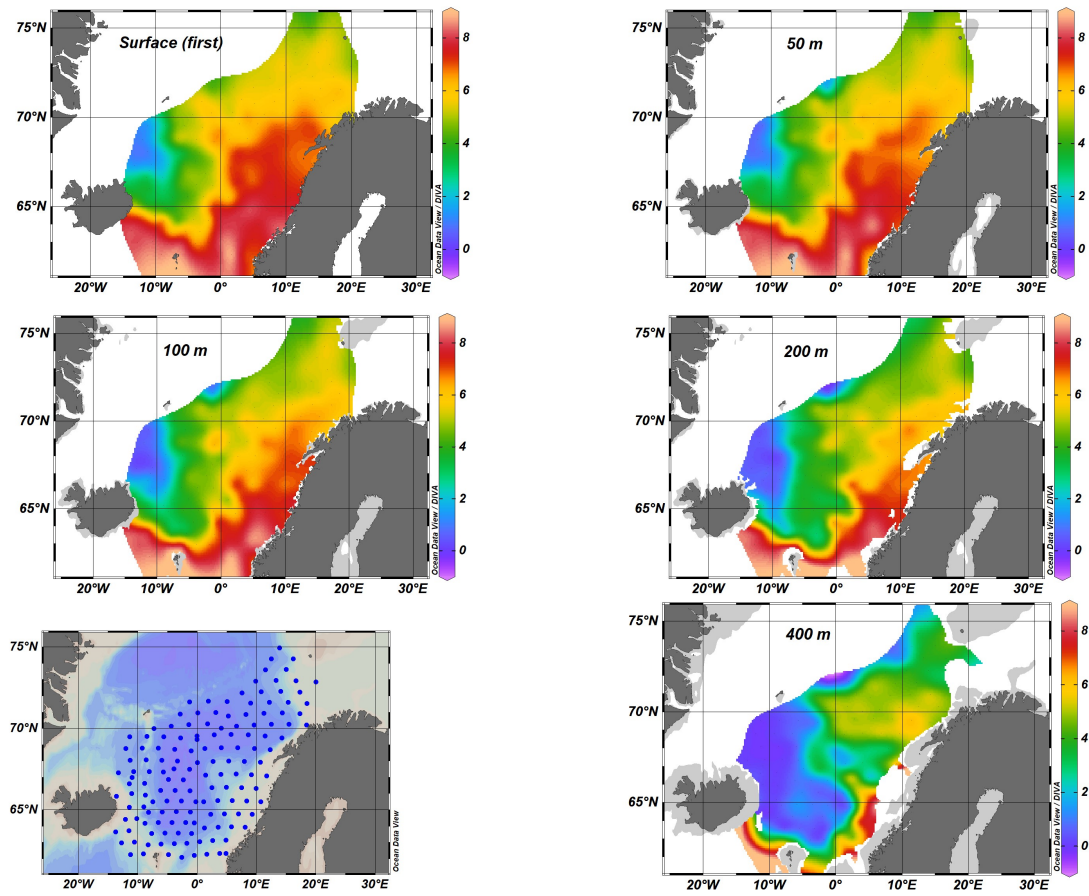


Figure 5. The horizontal distribution of temperatures ($^{\circ}\text{C}$) at surface, 50m, 100m, 200m and 400m depth in IESNS in May-June 2019.

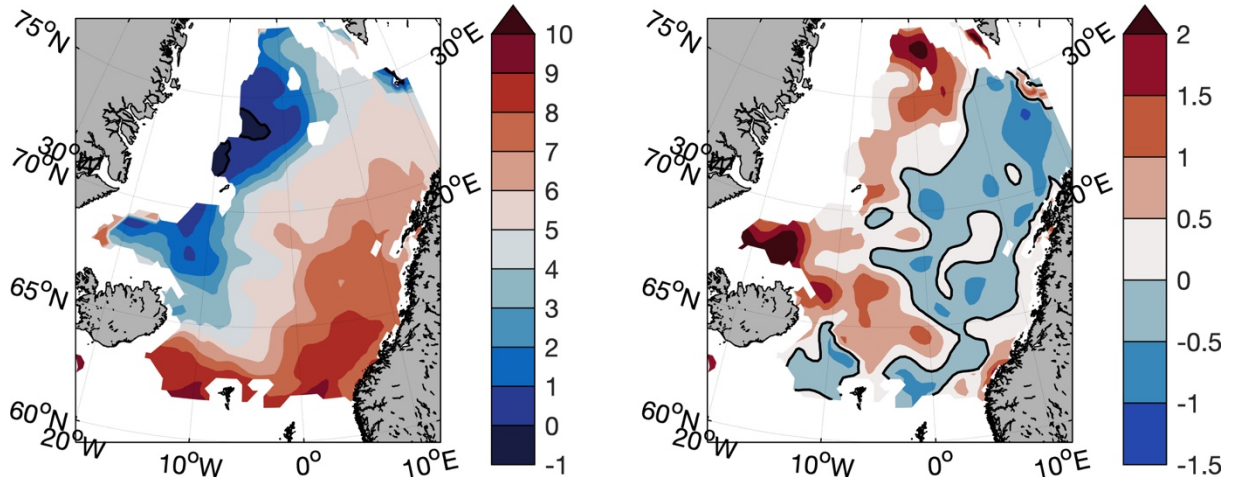


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

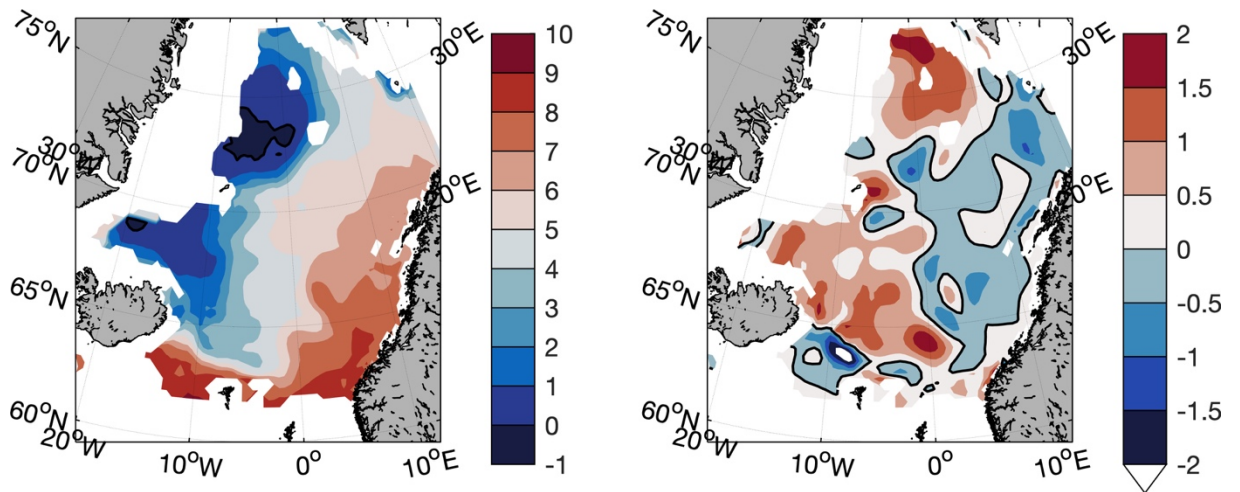


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

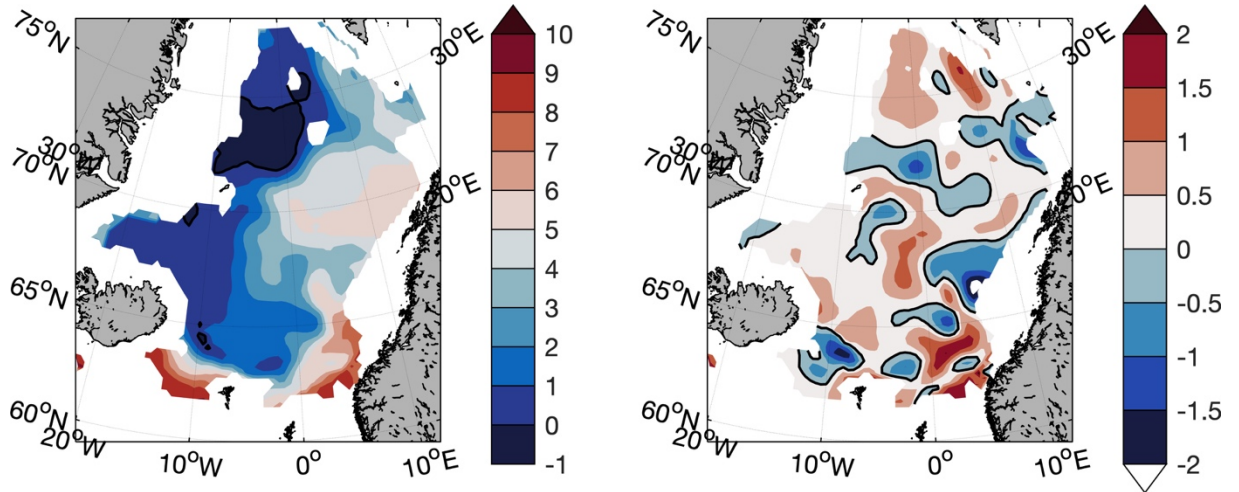


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth in May 2019. Anomaly is relative to the 1995-2017 mean.

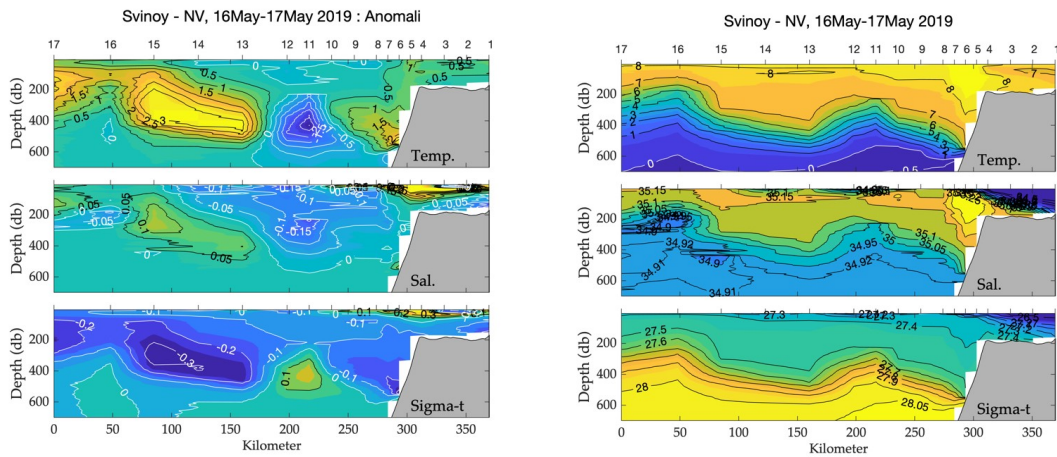


Figure 9. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinoy section, May 2019. Anomalies are relative to a 30 years long-term mean (1978-2007).

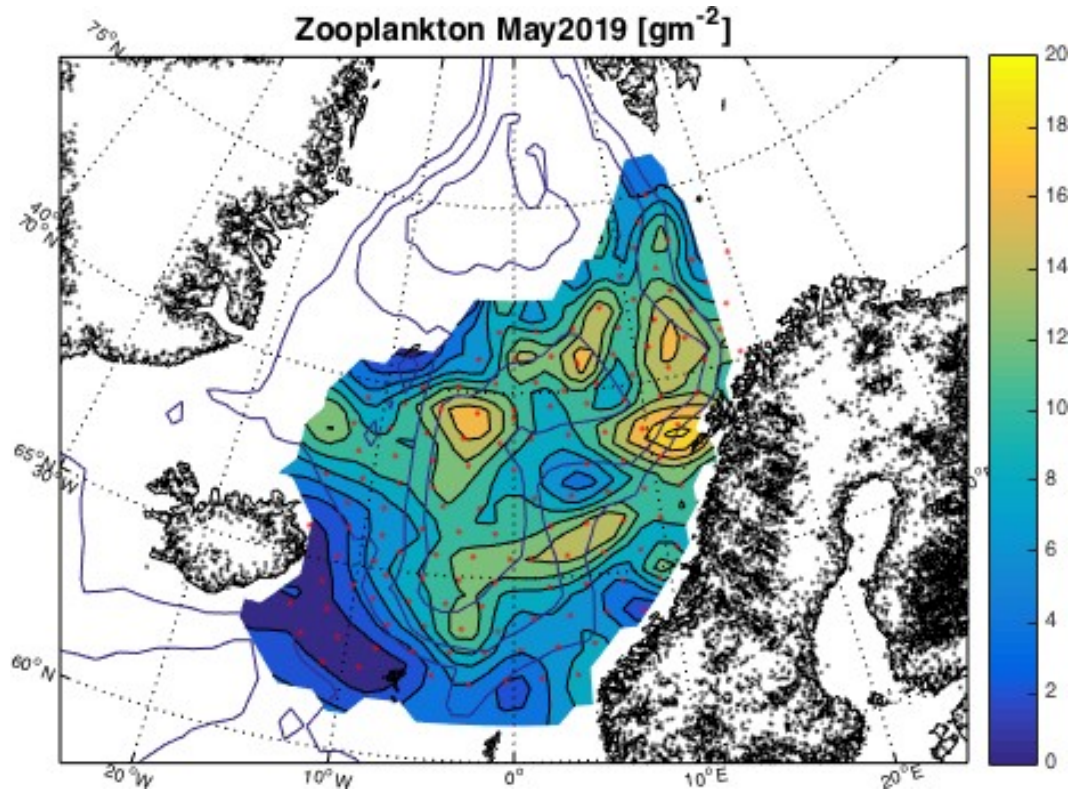


Figure 10. Representation of zooplankton biomass ($\text{g dry weight m}^{-2}$; at 0-200 m depth) in May 2019.

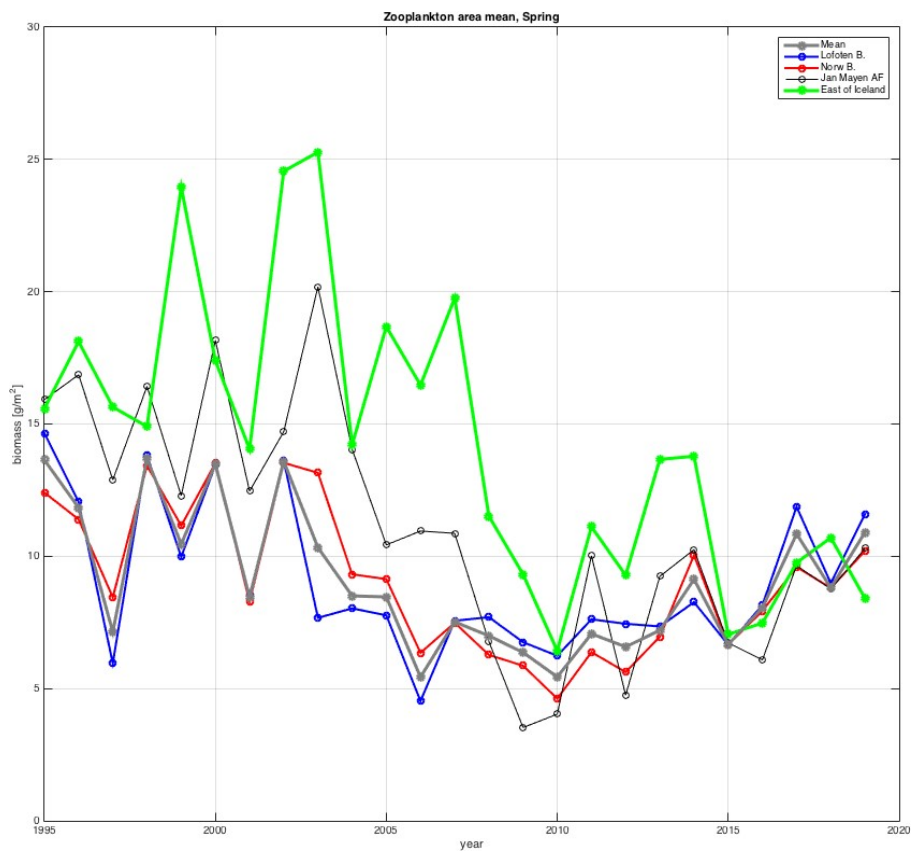
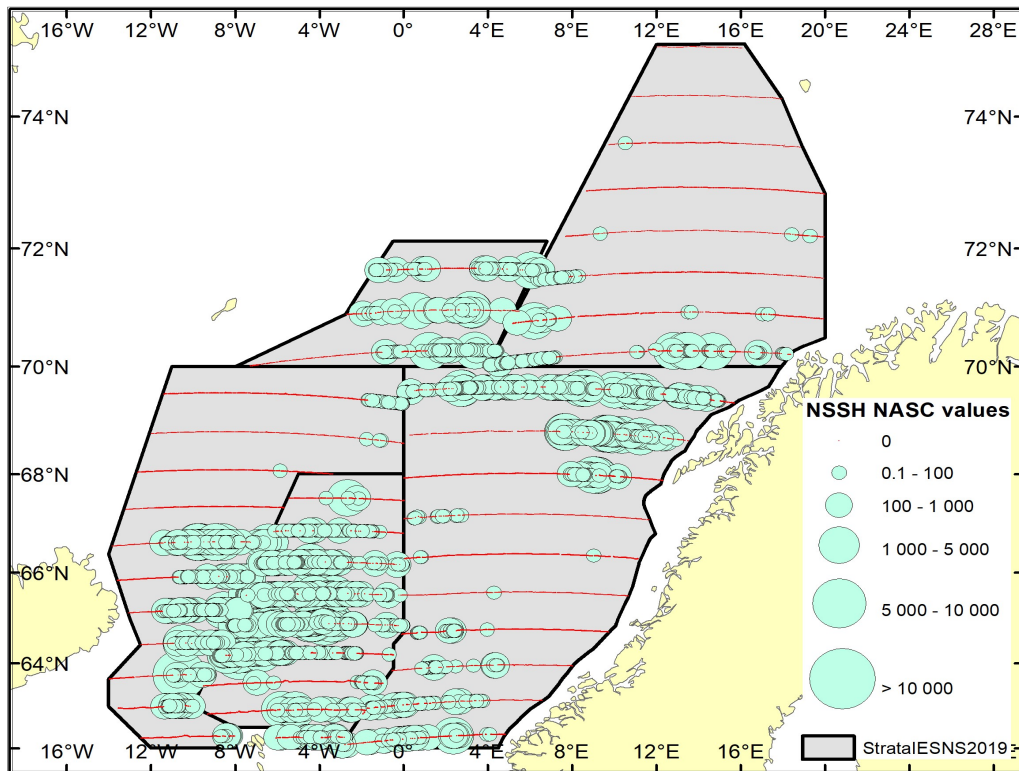


Figure 11. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2019 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

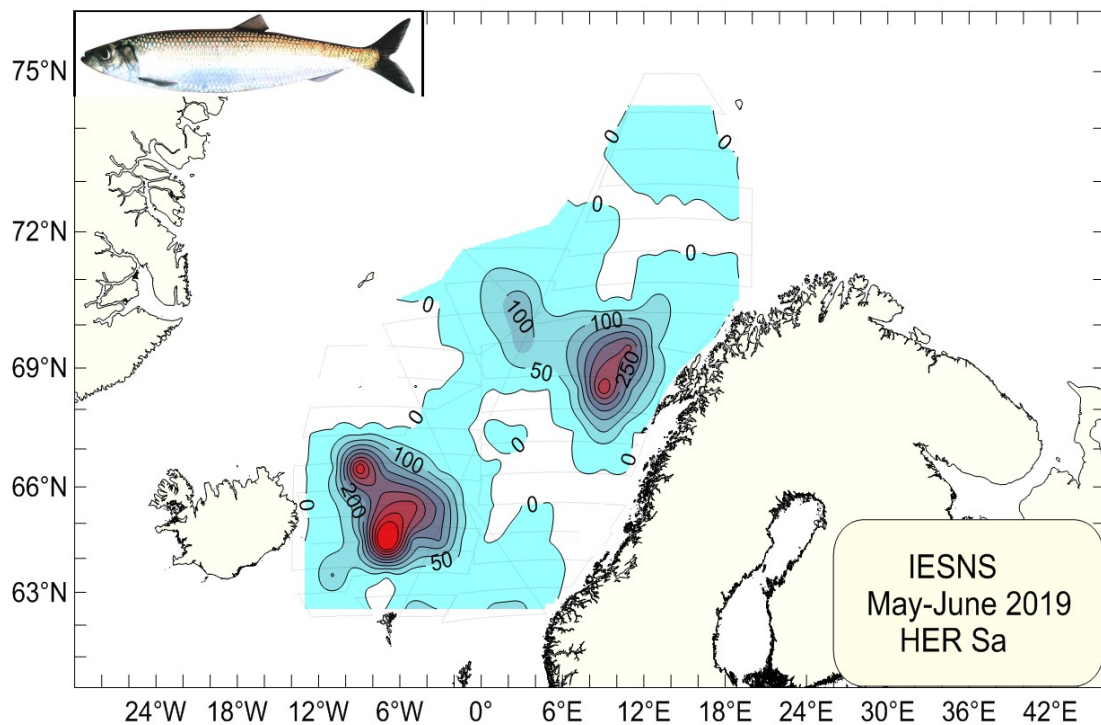


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2019 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

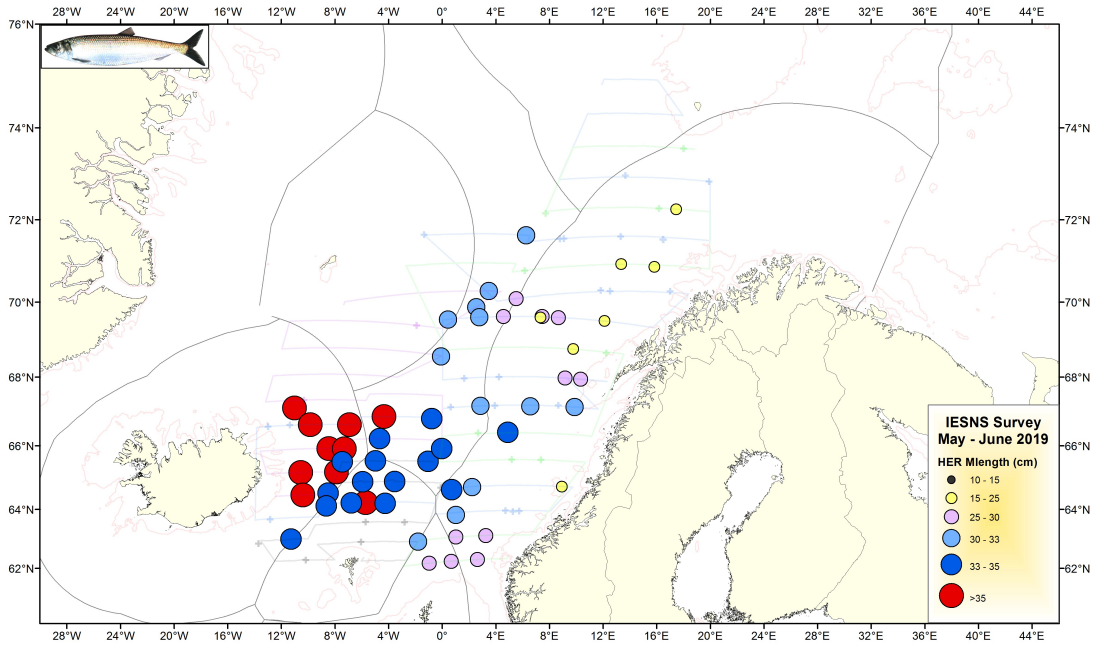


Figure 13. Mean length of Norwegian spring-spawning herring in all hauls in May 2019.

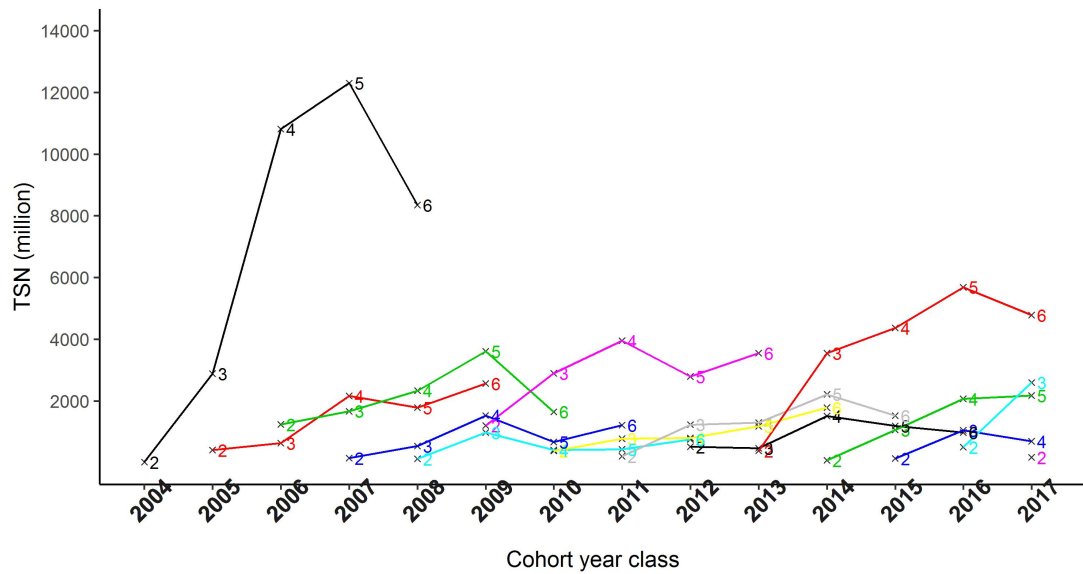


Figure 14. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

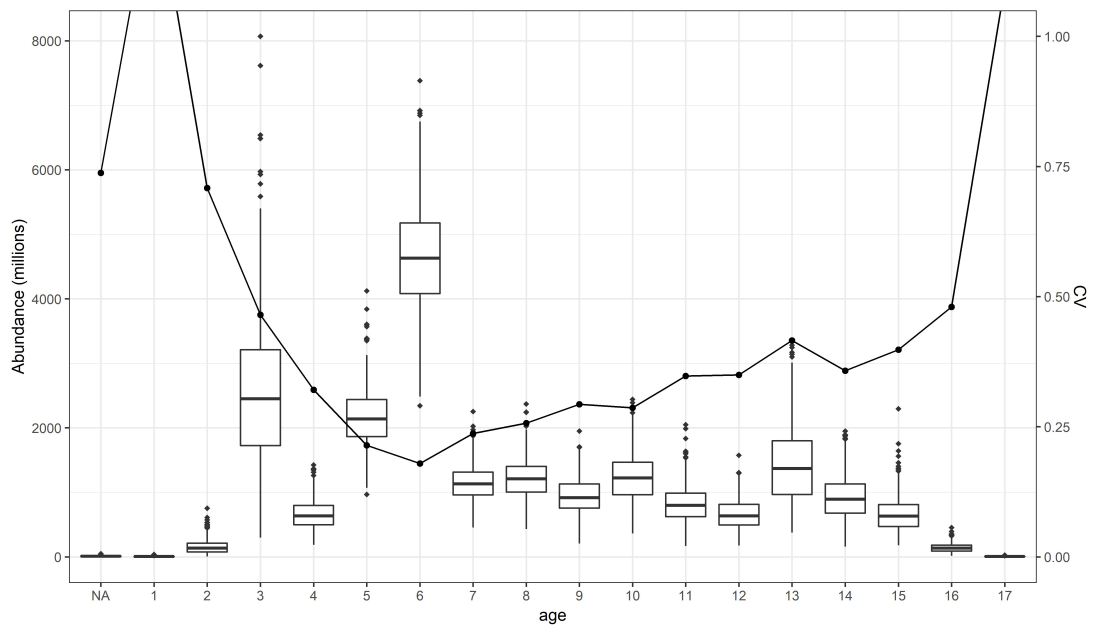


Figure 15. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

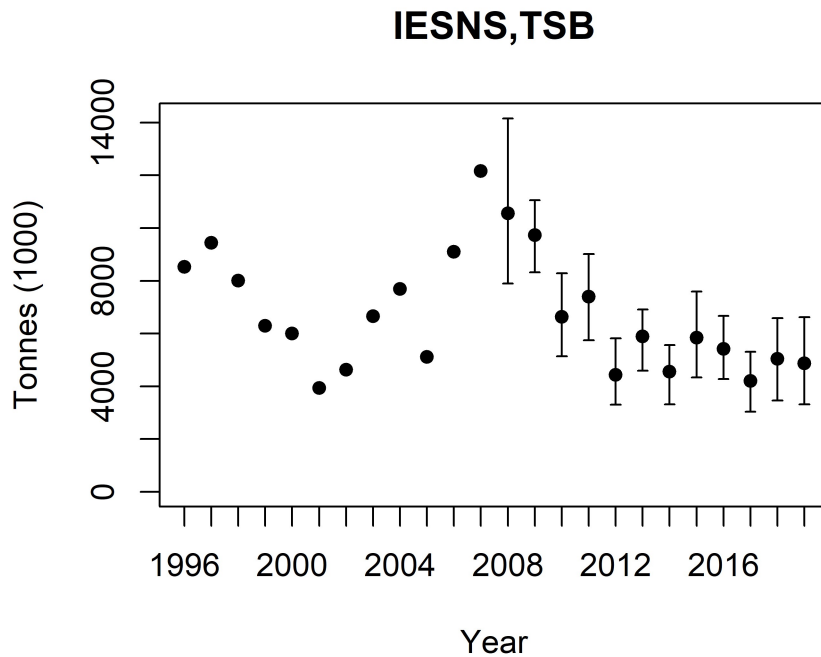


Figure 16. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2019 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2019; with 90% confidence interval;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

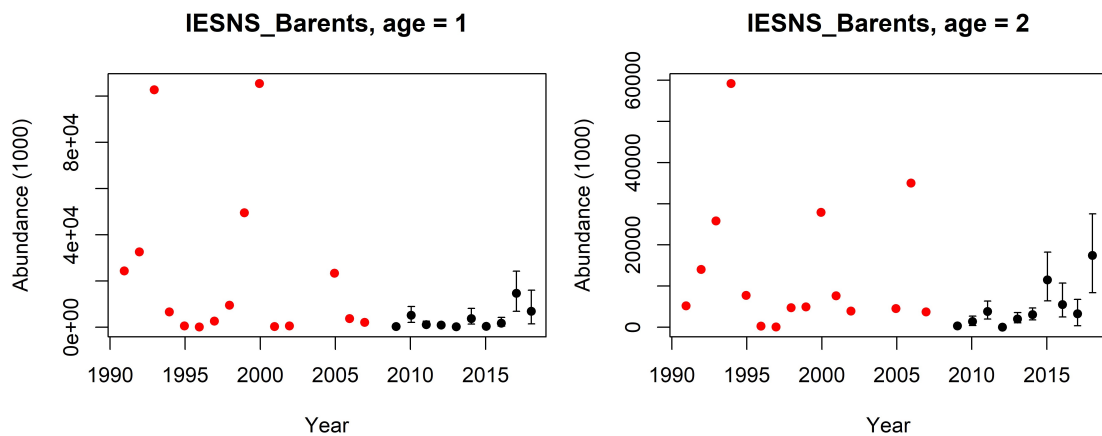
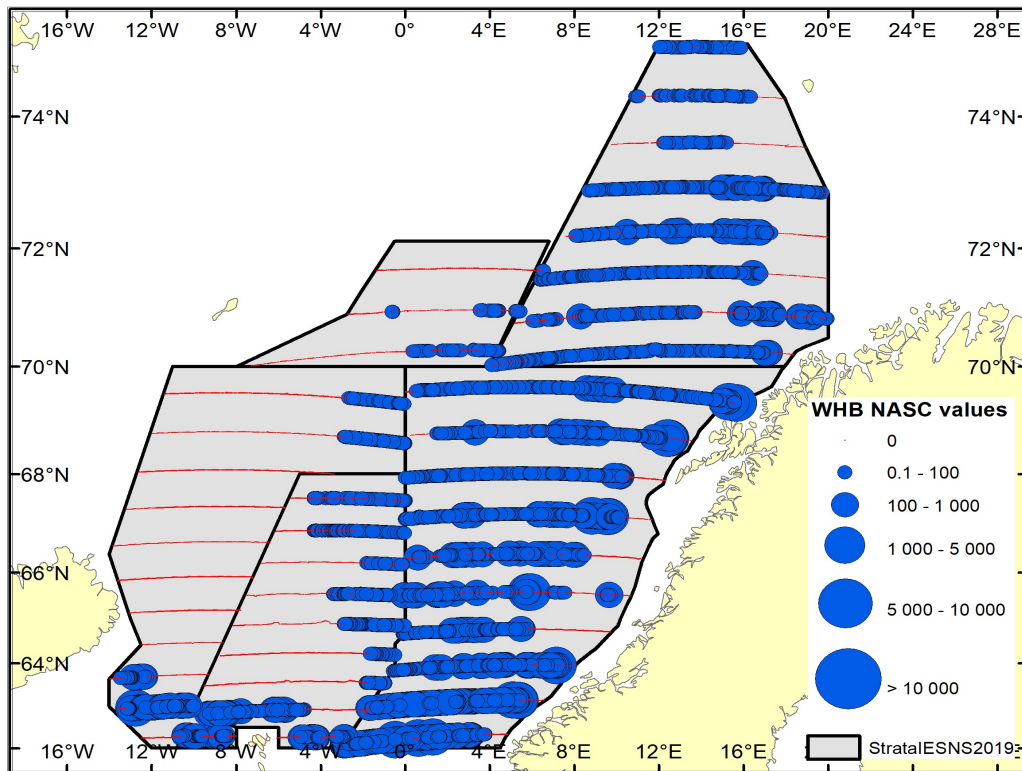


Figure 17. OBS!! – This figure will be updated for the final report in August 2019. Numbers at age 1 (to left) and age 2 (right) herring in the Barents Sea in April-June as estimated using BEAM (red dots; calculated on basis of rectangles) and the software StoX (black dots with 90% confidence interval;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

(a)



(b)

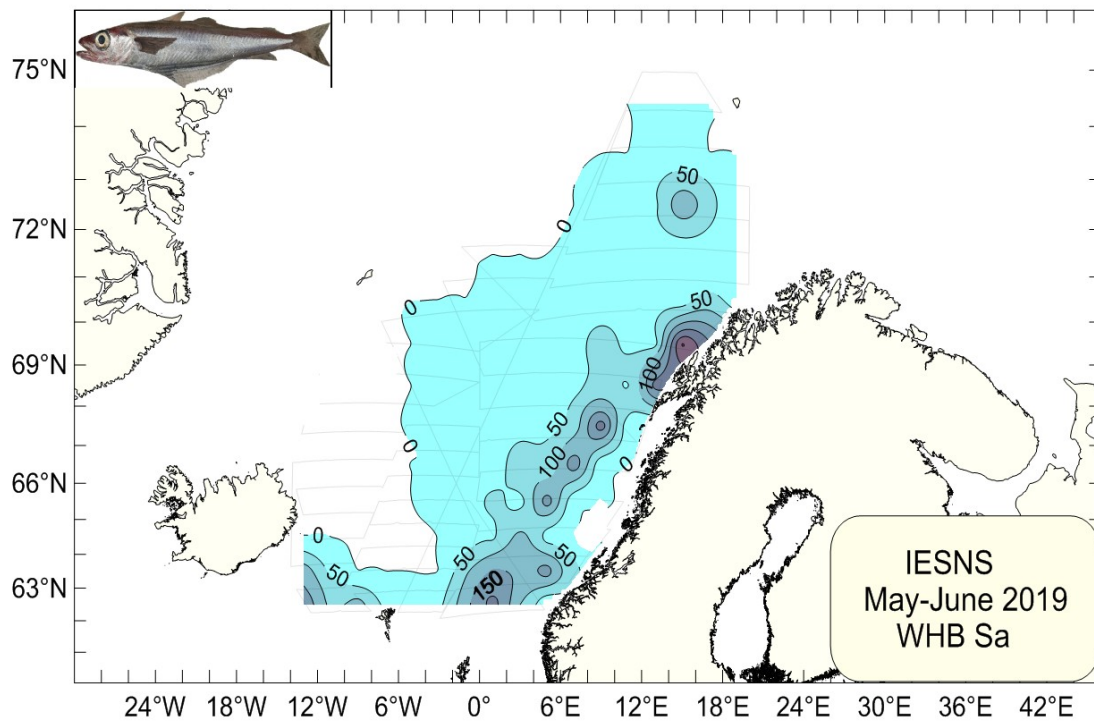


Figure 18. Distribution of blue whiting as measured during the IESNS survey in May 2019 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

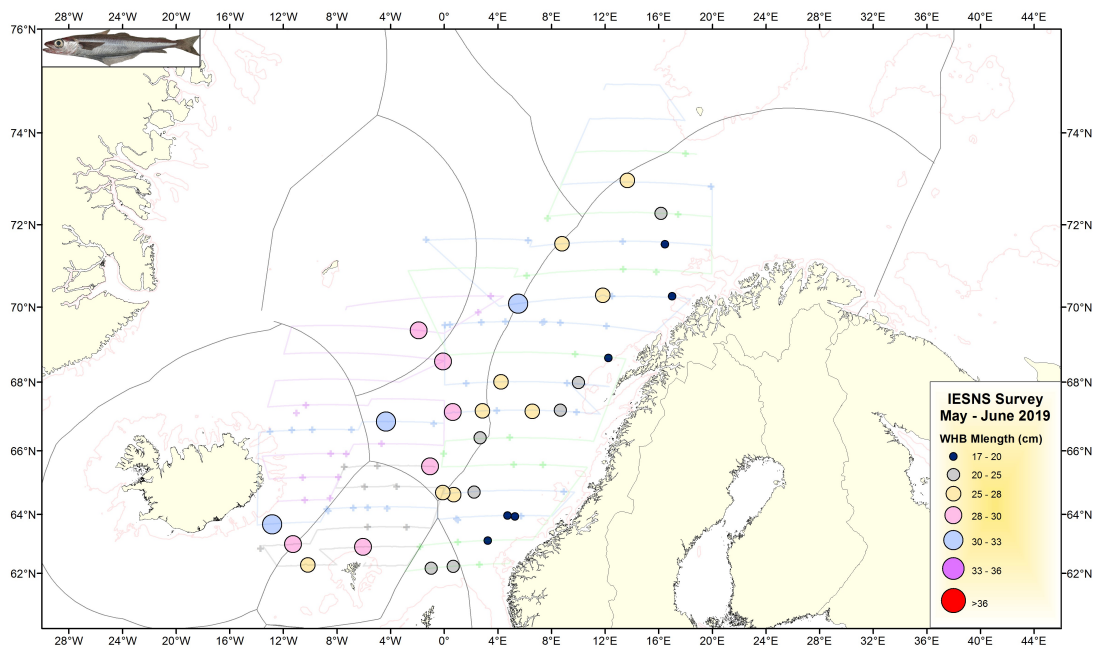


Figure 19. Mean length of blue whiting in all hauls in IESNS 2019.

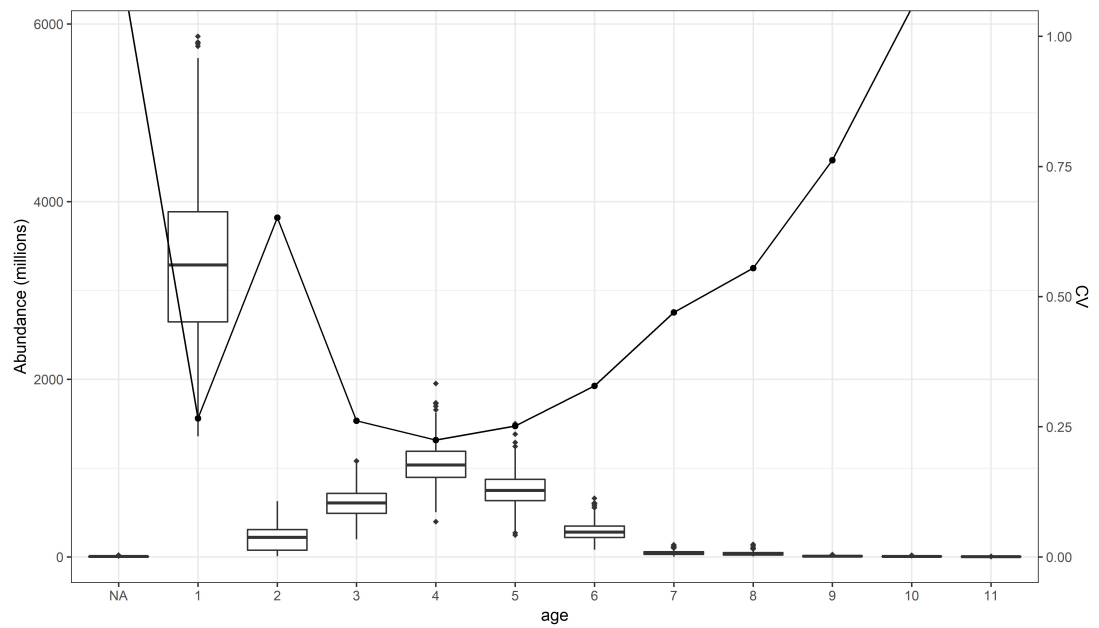


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

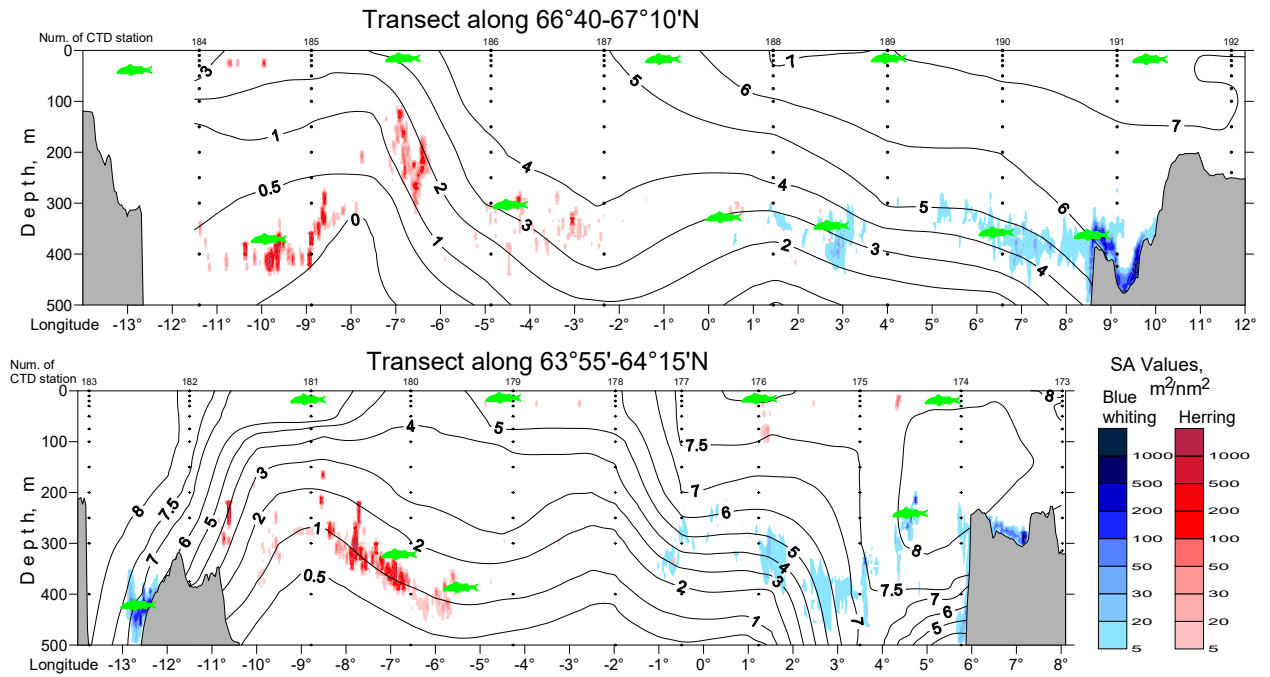


Figure 21. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2019, covered by "G.O. Sars".

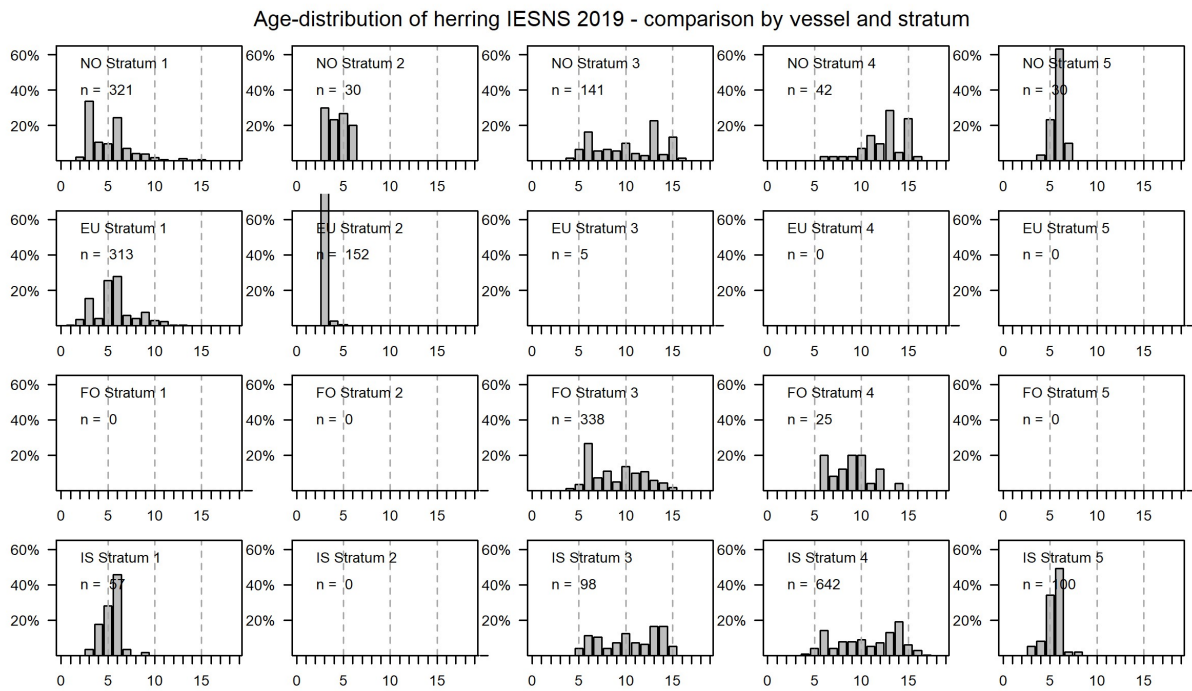


Figure 22. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2019. The strata are shown in Figure 3.

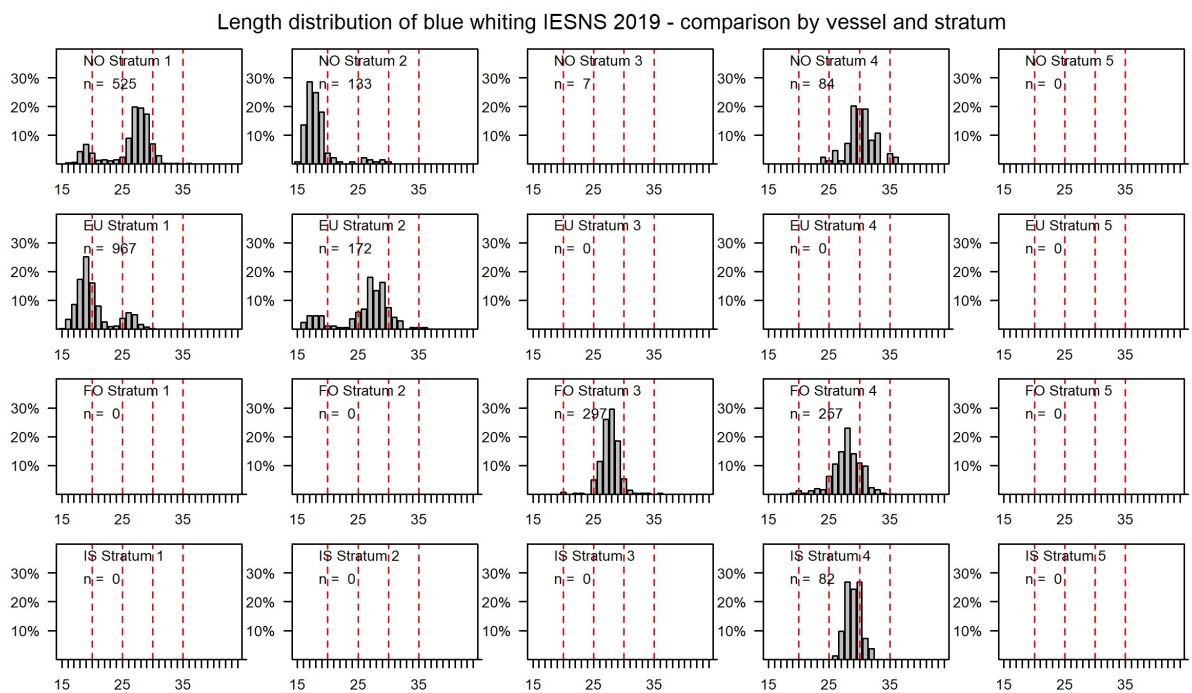


Figure 23. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2019. The strata are shown in Figure 3.

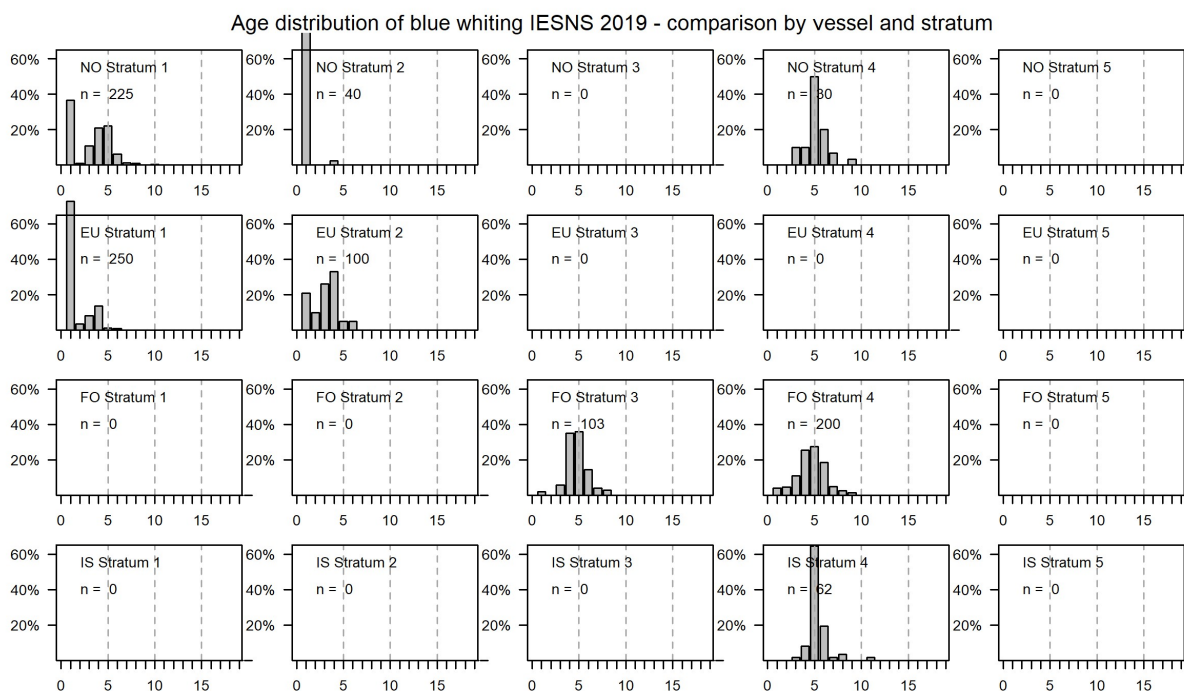


Figure 24. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2019. The strata are shown in Figure 3.