Working Document

Post-cruise meeting of the Working Group on International Pelagic Surveys (WGIPS)
IJmuiden, Netherlands, 21. – 23. June 2016

Working Group on Widely distributed Stocks
Copenhagen, Denmark, 31. August - 6. September 2016

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2016

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Introduction

In May-June 2016, six 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 Arni Friðriksson, Island, R/V Johan Hjort and M/S M. Ytterstad, Norway and R/V Fridtjof Nansen, 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 compilation of data from this International survey stored in the PGNAPES databases and supported by national survey reports from each survey (Dana: Couperus, Staehr, Kloppmann 2016, Magnus Heinason: Homrum, Mortensen, FAMRI 1618-2016, Arni Friðriksson: Óskarsson 2016, Fridtjof Nansen: Rybakov PINRO 2016.

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2016. 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	01/5–22/5
Johan Hjort	Institute of Marine Research, Bergen, Norway	02/5-24/5
M.Ytterstad	Institute of Marine Research, Bergen, Norway	03/6-09/6
Fridtjof Nansen	PINRO, Russia	05/5–30/5
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	05/5- 16/5
Arni Friðriksson	Marine Research Institute, Island	03/5-23/5

Figure 1 shows the cruise tracks and the CTD/WP-2 stations and Figure 2 the cruise tracks and the trawl 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.

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 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).

	Dana	Johan Hjort	M.Ytterstad	Arni Friðriksson	Magnus Heinason	Fridtjof Nansen
Echo sounder	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK60	Simrad EK60	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 120, 200	**38**, 18, 70, 120, 200	**38**, 18, 120, 200	**38**,200	**38,** 120
Primary transducer	ES38BP	ES 38B	ES 38B	ES38B	ES38B	ES38B
Transducer installation	Towed body	Drop keel	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	3	8.7	8	8	3	5.2
Upper integration limit (m)	5	15	15	15	7	10
Absorption coeff. (dB/km)	6.9	9.7	10	10	10.2	10
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	2.43	2.425	2425	2.425
Transmitter power (W)	2000	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.5	-20.6	-20.6	-20.9	-20.8	-20.6
Sv Transducer gain (dB)						
Ts Transducer gain (dB)	25.17	26.61	26.34	24.64	25.61	25.37
s_A correction (dB)	-0.55	-0.56	-0.65	-0.84	-0.64	-0.62
3 dB beam width (dg)						
alongship:	6.8	7.08	6.84	7.31	7.1	7.09
athw. ship:	6.8	7.08	6.88	6.95	7.08	7.08
Maximum range (m)	500	500	500	500	500	450
Post processing software	LSSS	LSSS	LSSS	LSSS	Sonardata Echoview 7.0	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 2015a). Generally, acoustic recordings were scrutinized with the different software (see table above) 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	Johan hjort	M.Ytterstad	Arni Friðriksson	Magnus Heinason	Fridtjof Nansen
Circumference (m)		832	832	832	640	500
Vertical opening (m)	25-35	45–50	45-50	30–35	45–55	50
Mesh size in codend (mm)		40	40	40	40	16
Typical towing speed (kn)	3.0-40	4.0–4.5	4.0-4.5	3.0–4.5	3.0–4.0	3.3–4.5

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 and blue whiting were sexed, aged, and measured for length and weight, and their maturity status were estimated using established methods. An additional sample of 70–300 fish was measured for length.

Acoustic estimates of herring and blue whiting abundance were obtained during the surveys. This was carried out by visual scrutiny of the echo recordings using post-processing systems. The allocation of NASC-values to herring, blue whiting and other acoustic targets were based on the composition of the trawl catches and the appearance of echo recordings according to the agreed scrutinizing procedures (ICES 2009 and Annex 4 in ICES 2015a).

Acoustic data were analysed using the StoX software package recently adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. 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 2016. 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 3. 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).

In StoX a superindividual table is produced where abundance is linked to population parameters like age, length, weight, sex, maturity etc. (exact name: 1_FillMissingData_SuperIndividuals.txt). This table can be used to split the total abundance estimate by any combination of population parameters.

The hydrographical and plankton stations by survey are shown in Figure 1. Most vessels collected hydrographical data using a SBE 911 CTD (M. Ytterstad used a SAIV SD208 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 or the bottom to the surface. All samples were split in two and one half was preserved in formalin while the other half was dried and weighed. On the Danish, the Icelandic and the Norwegian vessels the samples for dry weight were size fractionated before drying. Data are presented as g dry weight per m^2. An average over all stations in the survey in Norwegian Sea (east of 14°W and west of 20°E) has been used to represent an inter-annual index of zooplankton abundance for the area in May. At WGINOR in 2015 (ICES, 2016), a new method was applied to obtain a time-series for four different areas. This method, where the zooplankton data were interpolated using objective analysis utilizing a Gaussian correlation function, was also applied on the 2016 data here. Thus, a new time-series are presented as well as comparison to the former one.

Stomach samples

Stomach samples from the three pelagic species (herring, blue whiting and mackerel) were collected by the Norwegian, Icelandic and Faroese vessels. These samples have however, not been analyzed yet and will be reported by other means later.

Results

Hydrography

Temperature distribution for April-June 2016

The temperature distributions in the ocean at 10m, 50m, 100, 200m and 400m depth are shown in Figures 4 and 5, and temperature 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 0°C in the Iceland and Greenland Sea to 9°C in the southern part of the Norwegian Sea (Fig. 6). The Arctic front was encountered slightly south of 65°N east of Iceland extending eastwards towards the 0° Meridian where it turned almost straight northwards around 70°N. The front was visible 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 north to 71° N in the surface layers.

Relative to a 22 years long-term mean, from 1995 to 2016, the temperatures at all depths in the south, between Iceland and the Faroese, and in the south-eastern area were considerable lower in 2016 compared to the long-term mean (Figures 6-8). Largest negative anomaly was in the surface layer. There, the anomaly was maximum 1°C. North of about 70°N and western Norwegian Sea over the Mohns and Jan Mayen Ridges the temperatures at all depth were in general higher than the long-term mean. In these areas the temperatures were about 1 °C above the mean.

Temperature, salinity and density in the upper 800 m at the Svinøy section are shown in Figure 9. Atlantic water is lying over the colder intermediate layer and reach down to 600 m at shelf edge and down to 400 m depth further west. The warmest and saltiest waters are located at 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 fresher waters. Relative to a long-term mean the temperatures in the eastern part of the section were lower in 2016 (Figure 10). There, the temperatures in the upper 400 m were about 0,5 °C lower than the long-term mean, which indicates colder and fresher inflowing Atlantic water than normal.

Zooplankton

Biomass of zooplankton dry weight at 0-200m at the sampling stations is shown in Figure 11, in comparison to the previous three years. Sampling stations were evenly spread over the area, and most oceanographic regions were covered. The zooplankton biomass was relatively uniform over the whole area, with the highest values off mid Norway and in the Iceland-Jan Mayen area. The index for zooplankton abundance for the Norwegian Sea (Lofoten Basin and S. Norwegian Sea) calculated with a Gaussian correlation function became 8.1 g dry weight m^{-2}, which is a slight increase from last year’s value (Figure 12a).

The new index for zooplankton abundance in the Norwegian Sea in May is similar to the older index for most years, which represents the average dry weight of all samples in the area between 14°W and 20°E (Figure 12b).

In the Barents Sea (east of 20°E), the mean zooplankton biomass was 1.6 g dry weight m^{-2}. It was noted that the Djedy net applied by the Russian vessel in Barents Sea seems to be less effective in catching zooplankton in comparison to WP2 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.

Norwegian Spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2016 and in line with previous years. Due to rudder problems of one of the participating vessels, the northwestern area was not covered (stratum 5), but for NSS herring the zero-line is believed to be reached for most of the area. It is therefore recommended that the results can be used for assessment purpose. The herring was primarily distributed in the central Norwegian Sea, with the highest densities observed in two aggregations separated at approximately 4°W and a third aggregation in the Jan Mayen area (Figure 13). Overall the herring density was relatively low. Registrations of NSS herring were low in the eastern part of the survey area – especially in stratum 2, except for some schools of young fish (mostly three year olds) near the boundary towards the Barents Sea.

As in previous years the smallest fish were found in the eastern area of the Norwegian Sea. This year young NSS herring were also caught in the Jan Mayen area. Size and age were found to increase to the west and south (Figure 14). Correspondingly, it was mainly older herring that appeared in the southwestern areas.

The herring stock is dominated by 3, 7 and 12 year old herring (year classes 2013, 2009 and 2004) in terms of numbers, with the 2004 contributing most to the biomass (Table 2). The four year classes from 2004, 2005, 2006 and 2009 contribute 17%, 10%, 10% and 13% respectively to the total biomass in the Norwegian Sea. The total number of herring recorded in the Norwegian Sea was 21.9 billion in 2016. Uncertainty estimates for numbers at age based on boostrapping with StoX are shown in Figure 21.

The total biomass estimate of herring in the Norwegian Sea from the 2016 survey was 5.4 million tonnes. This estimate is 0.4 million tonnes lower than in 2015. The biomass decreased from 2009 to 2012, but has been steady around 5 million tonnes 2013-2016 (Figure 15).

The abundance estimates of herring by age and length in the Barents Sea (Stratum 6) are shown in Table 3. The investigations of herring in the Barents Sea covered the area from 44°E to the 20°00´ E. The total abundance estimate was 1677 million individuals of age 1 (mean length of 10.7 cm and weight of 7.0 g), 5463 million individuals of age 2 (mean length of 16.1 cm and mean weight of 24.9 g), 1668 million individuals of age 3 herring (mean length of 22.1 cm and mean weight of 68.4 g) and 103 million individuals of age 4 herring (mean length of 26.3 cm and mean weight of 113.7 g). Only very few older herring were observed. Uncertainty estimates for numbers at age based on boostrapping with StoX are shown in Figure 22.

Blue whiting

The total biomass of blue whiting registered during the IESNS survey in 2016 was 1.54 million tons (Table 4), which is a 62% increase from the biomass estimate in 2015 (0.96). The stock estimate in number for 2016 is 20 billion, which is about 25% higher than in 2015. Age two is dominating the estimate (36% of the biomass and 40% by number). Uncertainty estimates for numbers at age based on boostrapping with StoX are shown in Figure 23. The distribution of blue whiting in 2016 was similar to the years before, with high abundance estimates in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope, as well as south of Iceland. The main concentrations were observed both in connections with the continental slopes of Norway and south of Iceland and in the open sea in the southern part of the Norwegian Sea (Figure 16). The largest fish were found in the western and northern part of the survey area. Mean length of blue whiting is shown in Figure 17. It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period and also that due to the lack of coverage in stratum 5 the zero line for blue whiting in the north was not reached.

Relationship with temperature

The distribution of the pelagic fish stocks is apparently linked to the temperature within the distribution area as shown on profiles of the two transects across the whole Norwegian Sea (Figure 18). For example, the herring was not found in surface waters (0-100m) in waters colder than 3°C as in the western part of the Norwegian Sea, even if found in colder waters deeper down. Blue whiting was on the other hand limited to waters warmer than around 2°C.

Mackerel

During the last ten years an increasing amount of mackerel has been observed in the catches during the May survey. Figure 19 indicates that the distribution did not extend further to the north after 2014. Also, after 2014, no mackerel was found in the catches in the area between Faroe Islands and Iceland.

It should be noted, however, that the acoustic survey is not designed to monitor mackerel. The species is not scrutinized during the survey. Trawling data should be treated with care, as the trawl speed is relatively low for mackerel. Also, the distribution of catches containing mackerel may be influenced by its vertical distribution and differences in trawling of the individual research vessels. In addition differences in catch quantities between years may be caused by changes in trawling gears.

Discussion

Hydrography

Discussions related to the oceanographic condition in April/June 2016 are provided in the results section above, while more general patterns are introduced in this section.

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.

Plankton

The zooplankton biomass index for Norwegian Sea in May has been estimated since 1995 but the time-series was re-evaluated by WGINOR in 2015 by utilizing a new approach (ICES 2016a; Figure 12a). Over the years from 1995-2002 the plankton index was relatively high even if varying between years. From 2003-2006, the index decreased continuously and has been at relatively low levels since then even if a slight increase can be noted throughout the period. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea (Figure 12a).

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 zoo-plankton stocks.

The mean zooplankton biomass index in Barents Sea (east of 20°E) was 1.6 g dry weight m^{-2}, or twice the index for 2015 (0.80 g m^{-2}) but comparable to the years 2014, 2013 and 2012 (1.6, 1.5 and 1.7 g dry weight m^{-2}, respectively). As stated above, the biomass estimates for the Barents Sea taken with the Djedi net are not directly comparable to the other areas taken by WP2 nets, but are comparable among years within the Barents Sea. Also, it must be noted that the 2015 survey in Barents Sea was two weeks later than normally.

Summing up, the reason for the observed changes in zooplankton biomass is not clear to us and more ecological and environmental researches to reveal this are recommended. Quantitative researches 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 Norwegian spring-spawning herring is characterized by large dynamics with regard to migration pattern. This applies to wintering, spawning and feeding area. The following discussion will mainly concentrate on the distribution and situation in the feeding areas in May, but no attempt was done to draw up the likely feeding migration that is believed to be comparable to recent years.

The total biomass of herring measured in the 2016 survey in the Norwegian Sea was 7.3% lower than in 2015 (Figure 15). When considering the confidence interval of the indices the difference is less pronounced because of wider confidence interval in 2015. Furthermore, it shows that the 2016 estimate at similar level as the estimates from 2012-2014.

The approach of dividing the survey area into strata, which was used in 2014 for the first time, and this year’s application of StoX instead of BEAM is considered as valid improvements in terms of securing equivalent coverage among years, tracking how the estimates were derived and allowing for robust statistical analyses of uncertainty of the acoustic estimates.

In the last two years (2014 and 2015) there were concerns regarding age reading of herring, because the age distributions from the different participants showed differences. For example, there was an apparent difference in the age distribution in Stratum 4 between the Icelandic and the Norwegian vessel with respect to age groups 10-12 years, which might be a consequence of a “drift” of 2004 year class into the 2003 and 2005 year classes during the ageing. However, the differences might also reflect differing spatial distribution of age groups, and partly, they may reflect variable growth conditions for the stock, and consequently growth rate as seen on the fish scales and otoliths. These concerns were the motivation for an age estimation workshop in Bergen in November 2015 (ICES 2016b). Both scales and otoliths from the same fish had been sampled for this purpose. The results showed a low level of agreement (52%) between age readings and a general trend appeared where the scales were estimated to be one year older than the otoliths. This leads to an apparent loss of the strong year class of 2004. After reviewing the structures in plenary, it was clear that it was most often the first winter ring in the scale which was not clearly visible in the otoliths. However, the conclusion of the age reading workshop was that the different ages obtained from scale and otoliths readings could be due to a number of issues relating to identification of the first winter ring and age interpretation of older fish, confounded by stock mixing issues. Furthermore, they recommended that the sampling and stock mixing issues should be addressed separately by WGWIDE. With respect to these results, and the concerns in the recent two years, the comparison between the nations in this year’s survey showed some different results (Figure 20). The 2004 year class was in higher proportion by the Icelandic and Faroese readers than the Norwegian readers in Stratum 3 and 4, or the other way around than in recent years. We have no simple explanation for this.

In the 2016 IESNS there were no apparent discrepancies in the acoustic scrutinizing results between any neighbouring vessels like observed in the previous two surveys. Hence, there was no reason to revisit the acoustic data and the scrutinizing work during the post-cruise meeting.

Blue whiting

The abundance estimate of blue whiting in the IESNS survey 2016 showed a significant increase from the last years and the biomass estimate has increased even more and this increase is mainly because the dominating year class has grown to be one year older. A positive sign in development of the stock size was first observed in the 2011 survey where blue whiting at age 1 and 2 were in higher numbers than the previous years. This year, the number of 1 year old blue whiting was lower than last year, but still in the high end compared to previous years. The result from last year with a strong 2014 year class was confirmed with the two year olds as the most dominant year class in this year's survey (Table 4).

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

Next years post-cruise meeting

13-15 June 2017. Location will be decided at the next WGIPS meeting.

Concluding remarks

- Relative to a 21 years long-term mean, the temperatures was lower in the far south (-0.5°C), and higher (+0.5°C) in the remainder of the area.
- The 2016 index of meso zooplankton biomass in the Norwegian Sea is still relatively low when compared to the reference period from 1995-2016, particularly in the western most areas.
- The biomass estimate of NSSH in 2016 was 7.3 % lower compared to last year. The survey in the Norwegian Sea followed the pre-planned protocol and there are no obvious methodological reasons for the decrease in the biomass estimate of NSS-herring from the 2015 survey. The biomass is comparable in size to the estimates from 2012 to 2015. The survey group recommends using this estimate in the assessment.
- NSSH was dominated by the 2013, 2009 and 2004 year class in numbers, with the 2004 year class as main contributor to the biomass.
- No strong year classes of NSSH were observed in the Barents Sea indicating poor recruitment since 2004.
- The biomass of blue whiting measured in the 2016 survey area was 62 % higher compared to last year and by number 25% higher than in 2015.
- Age 2 (2014 ycl) blue whiting is dominating the acoustic estimate (36% of the biomass and 40% by numbers).

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Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2016.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	1/5-22/5	2061	33	34	443	2488	34
Magnus heinason	5/5-14/5	1097	11	19	369	603	17
Árni Fridriksson	4/5-21/5	3086	30	43	1064	3575	47
Johan Hjort	3/5-23/5	2146	45	65	639	2220	72
M. Ytterstad	4/6-8/6	782	11	14	79	302	14
Fridtjof Nansen	7/5-25/5	3145	30	78	252	256	76
Total		**12317**	**160**	**253**	**2846**	**9444**	**260**

Table 2. IESNS 2016 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
5-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	603	603	-	-
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5054	5054	293.1	58.00
20-21	10614	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10614	737.7	69.50
21-22	14330	11176	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25506	2092.7	82.05
22-23	-	149253	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	149253	13522.9	90.60
23-24	6033	432039	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	438073	47804.0	109.12
24-25	-	781206	24963	-	-	-	-	-	-	-	-	-	-	-	-	-	-	806169	96997.2	120.32
25-26	19122	886239	23579	-	-	-	-	-	-	-	-	-	-	-	-	-	-	928941	120589.5	129.81
26-27	24813	584818	221435	15508	-	9305	-	-	-	-	-	-	-	-	-	-	-	855880	124513.0	145.48
27-28	-	457558	455274	50871	-	-	-	-	-	-	-	-	-	-	-	-	-	963704	151679.0	157.39
28-29	-	141596	308129	401909	32792	27327	-	-	-	-	-	-	-	-	-	-	-	911752	159383.0	174.81
29-30	-	59406	282477	500081	181323	127661	57193	-	-	-	-	-	-	-	-	-	-	1208141	225846.3	186.94
30-31	-	25740	90888	449364	388344	175926	113207	35329	-	-	-	-	-	-	-	-	-	1278796	259766.2	203.13
31-32	-	19682	71873	308347	148641	207028	225851	58087	2447	27820	12237	44054	-	-	-	-	-	1126067	255283.2	226.70
32-33	-	-	25652	234778	253015	314457	85974	27984	13079	28319	25652	-	18248	-	-	-	-	1027156	253266.6	246.57
33-34	-	-	2104	169972	280074	534152	38100	81354	12824	49794	27277	34866	25149	-	-	-	-	1255666	336666.9	268.12
34-35	-	-	1617	81863	222117	718667	104633	211290	413873	228168	383650	28489	63641	-	-	-	-	2458008	708290.1	288.16
35-36	-	-	-	2685	188710	494935	189267	449764	636240	789944	1189574	201196	54352	-	-	-	-	4196666	1277261.0	304.35
36-37	-	-	-	-	56179	66588	97731	216803	576059	499631	841984	370261	203873	24050	51276	2074	-	3006509	964119.9	320.68
37-38	-	-	-	-	27659	6498	16595	60778	93777	176018	331720	201018	66556	35897	966	-	-	1017481	341689.3	335.82
38-39	-	-	-	-	-	-	-	1849	21267	51645	58384	49480	7397	7397	9247	-	-	206666	75101.9	363.40
39-40	-	-	-	-	-	-	-	-	-	-	6797	-	-	-	5562	-	-	12359	4506.9	364.66
TSN(1000)	74913	3548714	1507991	2215377	1778853	2682543	928550	1143238	1769566	1851338	2877275	929365	439216	67344	67051	2074	5658	21889065	-	-
TSB(1000 kg)	8978.7	474005.0	258165.2	460003.0	432317.8	704894.6	244226.4	335717.8	549787.9	567083.9	905342.8	294113.5	137966.9	23957.6	21854.5	701.8	293.1	-	5419410.5	-
Mean length (cm)	23.82	25.32	28.07	30.28	32.28	33.22	32.97	34.76	35.39	35.45	35.56	35.87	35.66	36.89	36.60	36.00	17.95	-	-	-
Mean weight (g)	119.85	133.57	171.20	207.64	243.03	262.77	263.02	293.66	310.69	306.31	314.65	316.47	314.12	355.75	325.94	338.30	58.00	-	-	247.59

Table 3. IESNS 2016 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	5	Number (1E3)	Biomass (1E3kg)	Mean W (g)
8-9	35813	-	-	-	-	35813	125.3	3.50
9-10	167872	-	-	-	-	167872	895.3	5.33
10-11	530474	-	-	-	-	530474	3006.0	5.67
11-12	835742	-	-	-	-	835742	6602.4	7.90
12-13	107438	-	-	-	-	107438	1092.3	10.17
14-15	-	434228	-	-	-	434228	7421.3	17.09
15-16	-	1709855	-	-	-	1709855	36020.9	21.07
16-17	-	1819779	-	-	-	1819779	45059.3	24.76
17-18	-	1204843	-	-	-	1204843	37331.3	30.98
18-19	-	294052	-	-	-	294052	10249.8	34.86
19-20	-	-	34435	-	-	34435	1566.8	45.50
20-21	-	-	152155	-	-	152155	8026.2	52.75
21-22	-	-	360368	-	-	360368	21762.2	60.39
22-23	-	-	733550	-	-	733550	51541.5	70.26
23-24	-	-	304311	-	-	304311	24192.7	79.50
24-25	-	-	83285	-	41643	124928	11389.2	91.17
26-27	-	-	-	68870	-	68870	7386.3	107.25
27-28	-	-	-	34435	-	34435	4356.1	126.50
TSN(1000)	1677338	5462758	1668104	103306	41643	8953148	-	-
TSB(1000 kg)	11721.3	136082.8	114043.8	11742.4	4434.9	-	278025.2	-
Mean length (cm)	10.68	16.07	22.11	26.33	24.50	-	-	-
Mean weight (g)	6.99	24.91	68.37	113.67	106.50	-	-	31.05

Table 4. IESNS 2016 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

	age																				
LenGrp	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2283	2283	-	-
17-18	121097	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	121097	3191.5	26.35
18-19	575602	65737	-	4219	-	-	-	-	-	-	-	-	-	-	-	-	-	-	645559	20479.0	31.72
19-20	1091856	286293	54210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1432359	53848.8	37.59
20-21	1317851	370668	210227	2979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1901725	83977.5	44.16
21-22	776849	938389	317077	16489	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2048805	106237.4	51.85
22-23	271617	1804132	485448	7424	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2568620	159185.4	61.97
23-24	61744	2237791	926111	63241	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3288886	235931.2	71.74
24-25	6534	1485763	961558	147752	20323	-	-	-	-	-	-	-	-	-	-	-	-	-	2621930	210395.0	80.24
25-26	-	713500	564608	168230	50984	22214	14516	-	-	-	-	-	-	-	-	-	-	-	1534052	139891.4	91.19
26-27	-	152287	346502	345846	86450	33728	4188	-	-	-	-	-	-	-	-	-	-	-	969002	103860.2	107.18
27-28	-	24154	179532	245841	171375	100961	6128	14778	3695	-	-	-	-	-	-	-	-	-	746465	90909.0	121.79
28-29	-	10423	131255	247424	165250	73067	21161	19833	7933	-	-	-	-	-	-	-	-	-	676347	91731.1	135.63
29-30	-	-	33323	200807	130232	77461	52949	18910	3782	17019	-	-	-	-	-	-	-	-	534484	81355.8	152.21
30-31	-	-	-	34272	206434	27378	93508	32570	-	-	-	-	-	-	-	-	-	-	394163	65916.0	167.23
31-32	-	-	-	27438	58285	37254	25269	21836	10410	-	-	-	-	-	-	6246	-	-	186739	34932.5	187.07
32-33	-	-	-	5380	28380	24021	11362	14840	21200	-	5764	-	-	-	-	-	-	-	110947	22185.9	199.97
33-34	-	-	-	-	-	-	7583	7583	-	11352	-	-	-	-	-	-	-	-	26519	5118.3	193.01
34-35	-	-	-	-	2235	8624	4469	-	5783	2235	5749	-	-	-	5783	-	1928	-	36806	8656.9	235.21
35-36	-	-	-	-	-	1286	-	22501	1286	-	12759	2900	-	-	-	-	-	-	40733	10658.1	261.66
36-37	-	-	-	-	-	-	-	5050	2864	-	5050	12876	-	-	-	-	-	-	25841	7095.6	274.58
37-38	-	-	2695	-	-	2695	4248	1348	1348	2900	-	-	3865	5801	-	-	-	-	24900	7447.0	299.08
38-39	-	-	-	-	-	-	9578	-	-	-	-	-	-	-	-	-	-	-	9578	2937.4	306.67
39-40	-	-	-	-	-	-	3208	-	-	-	-	-	-	-	-	-	-	-	3208	904.6	282.00
42-43	-	-	-	-	-	-	-	2900	-	-	-	-	-	-	-	-	-	-	2900	1035.5	357.00
TSN(1000)	4223151	8089138	4212548	1517342	919948	408690	258168	162151	58301	33507	29323	15777	3865	5801	5783	6246	1928	2283	19953948	-	-
TSB(1000 kg)	180464.3	549964.0	337163.3	177962.8	130827.8	60454.4	44018.5	30429.3	11559.7	6767.1	8046.9	4434.6	1047.4	1418.3	1617.3	1315.8	389.4	-	-	1547881.0	-
Mean length (cm)	19.84	22.77	23.80	26.75	28.50	28.71	30.31	31.20	31.60	31.58	34.70	35.98	37.50	37.00	34.00	31.33	34.50	16.25	-	-	-
Mean weight (g)	42.73	67.99	80.04	117.29	142.21	147.92	170.50	187.66	198.28	201.96	274.43	281.08	271.00	244.50	279.67	210.67	202.00	-	-	-	77.58

Figures

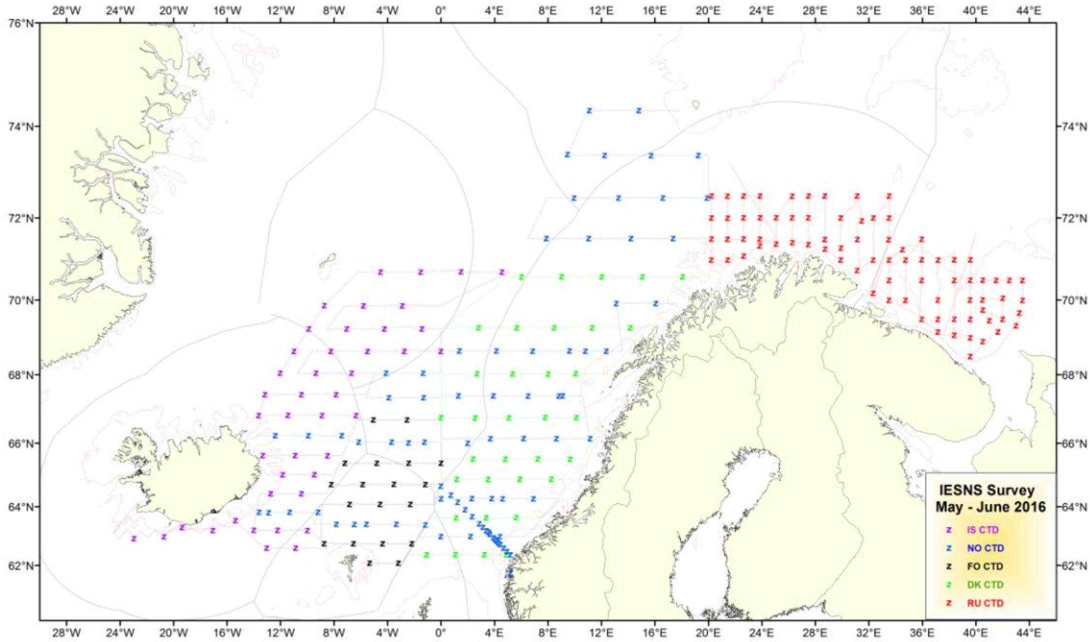


Figure 1. Cruise tracks and CTD stations by country for the IESNS survey in May-June 2016.

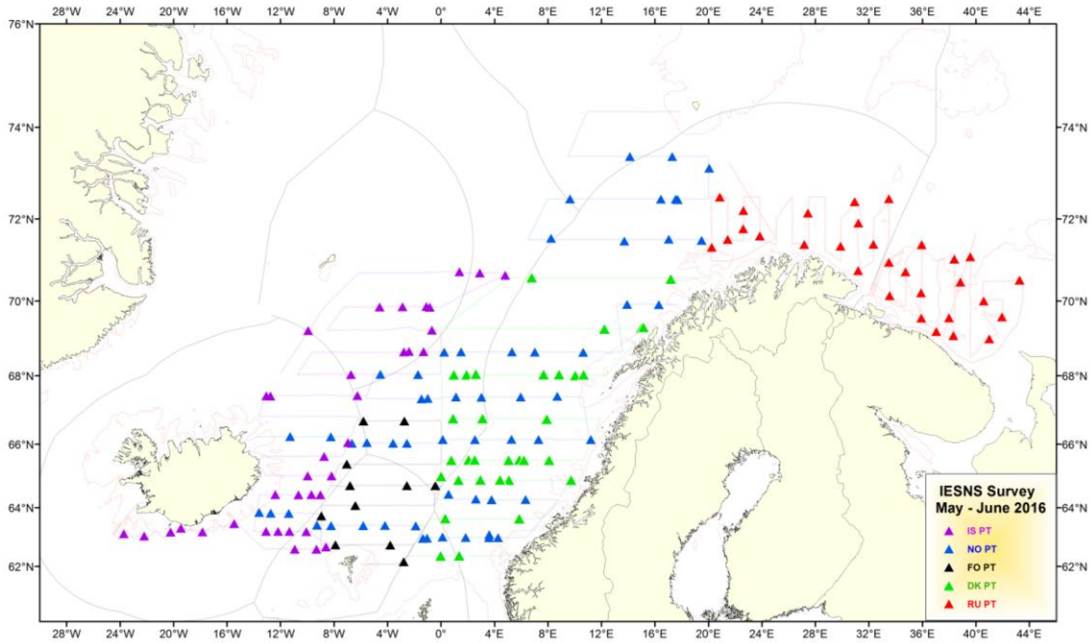


Figure 2. Cruise tracks during the IESNS survey in May-June 2016 and location of trawl stations (both for fish and macro zooplankton).

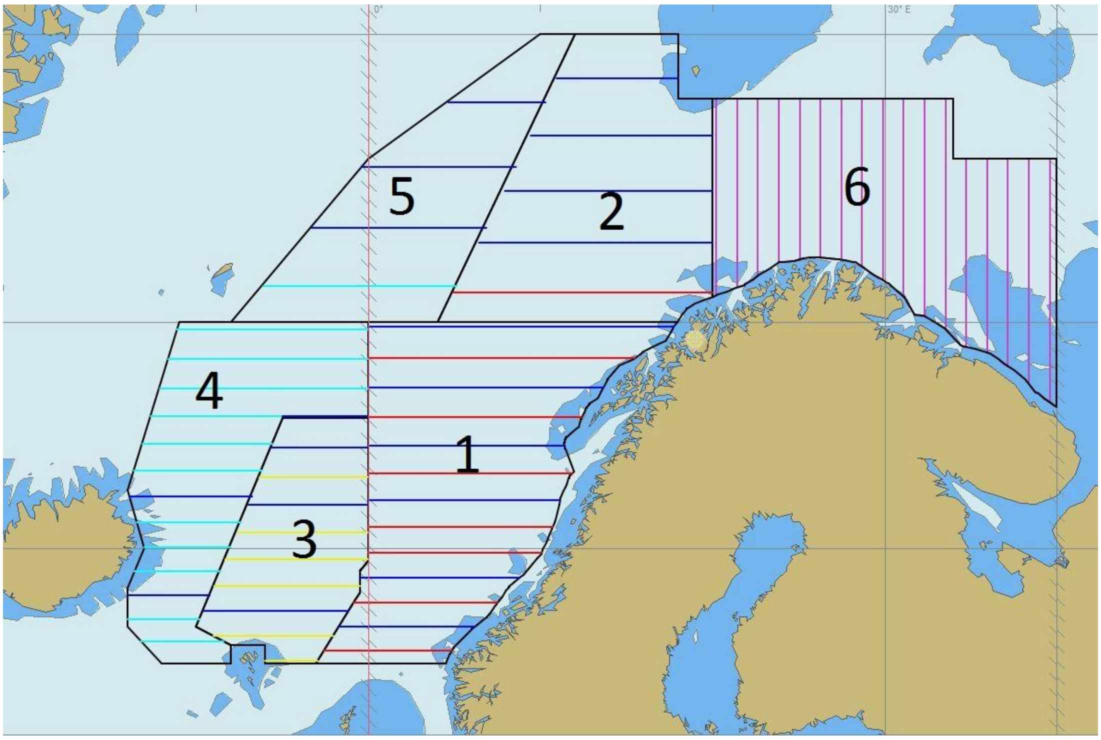


Figure 3. The pre-planned strata and transects for the IESNS survey in 2016 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, light blue: Iceland).

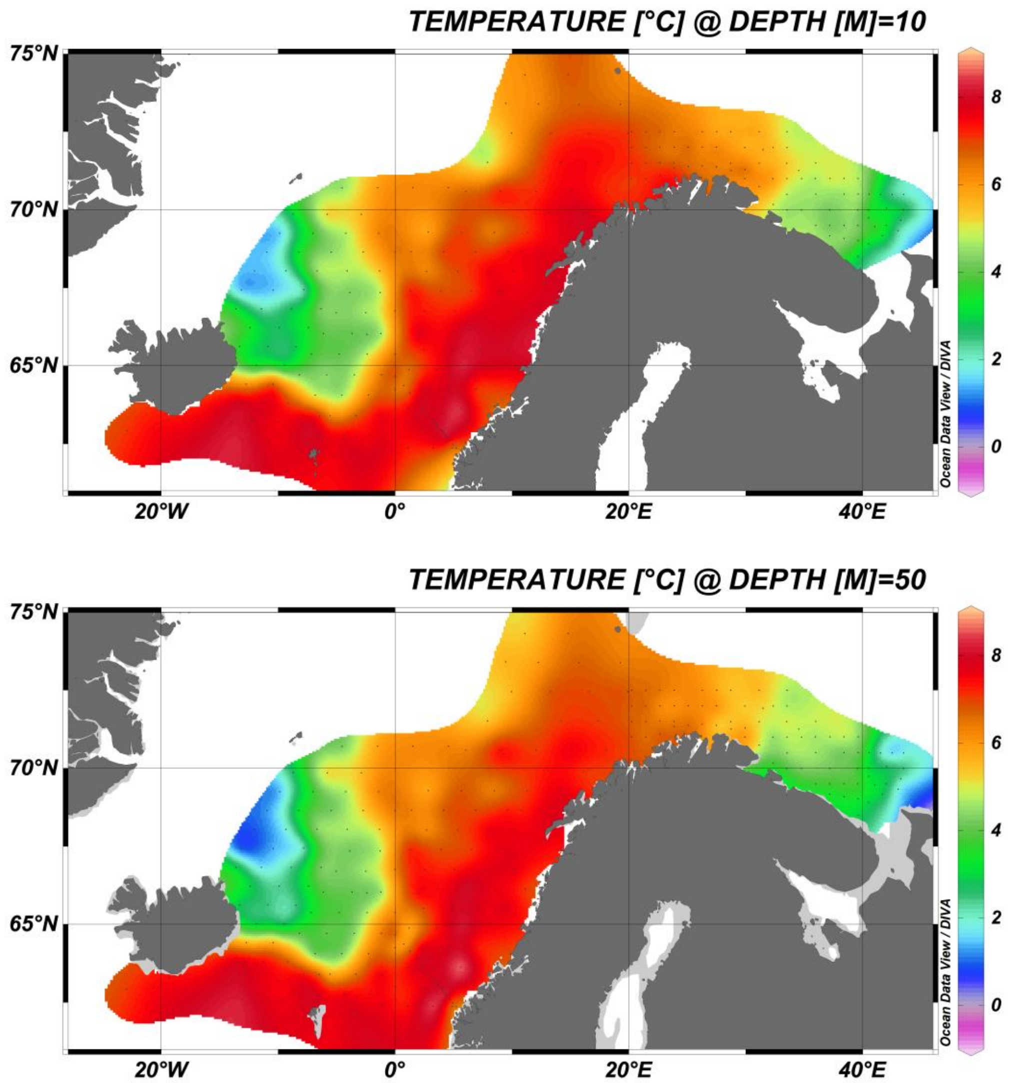


Figure 4. The horizontal distribution of temperatures at 10 m (surface) and 50 m depth in May-June 2016.

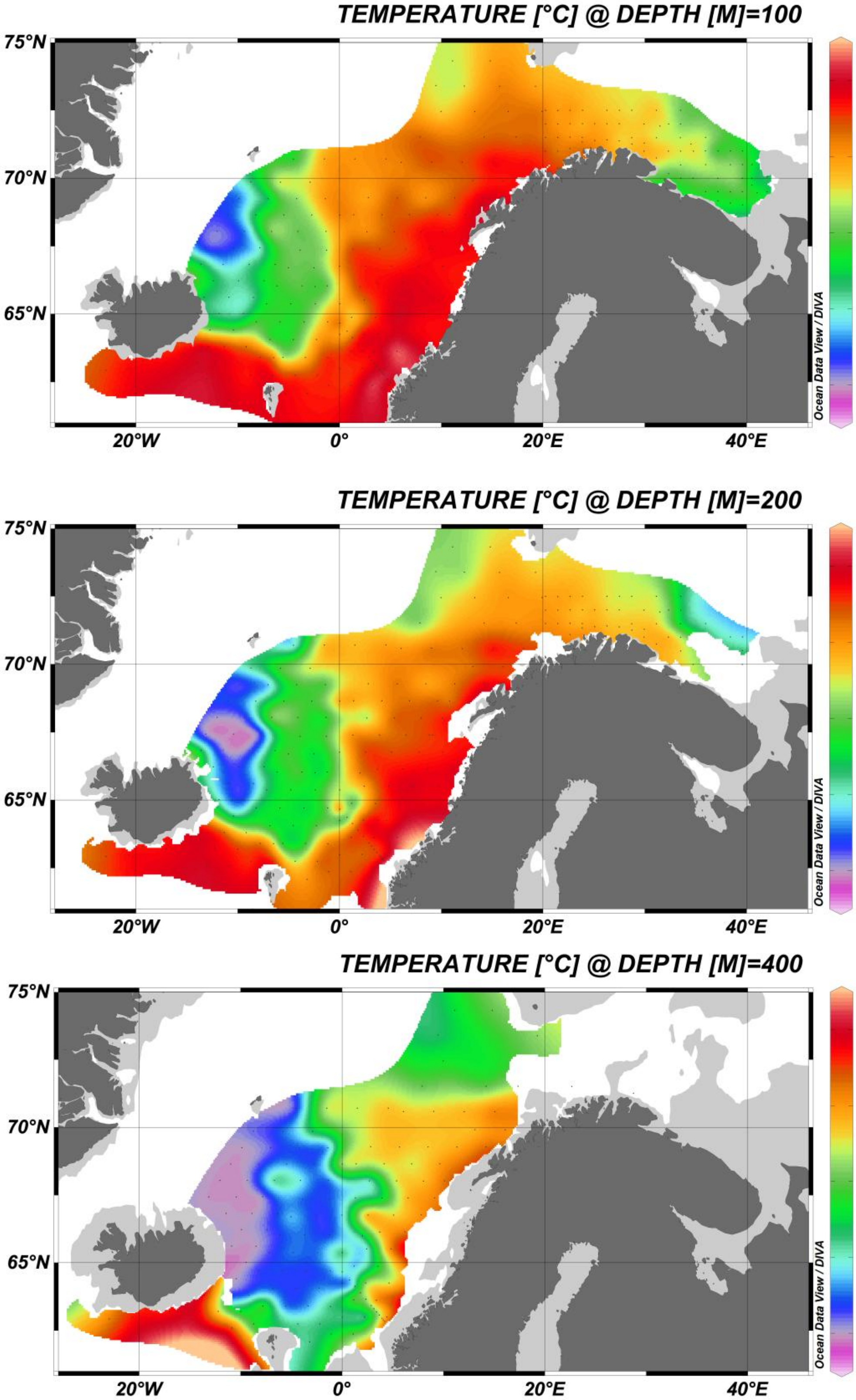


Figure 5. The horizontal distribution of temperatures at 100, 200 and 400 m depth in May-June 2016.

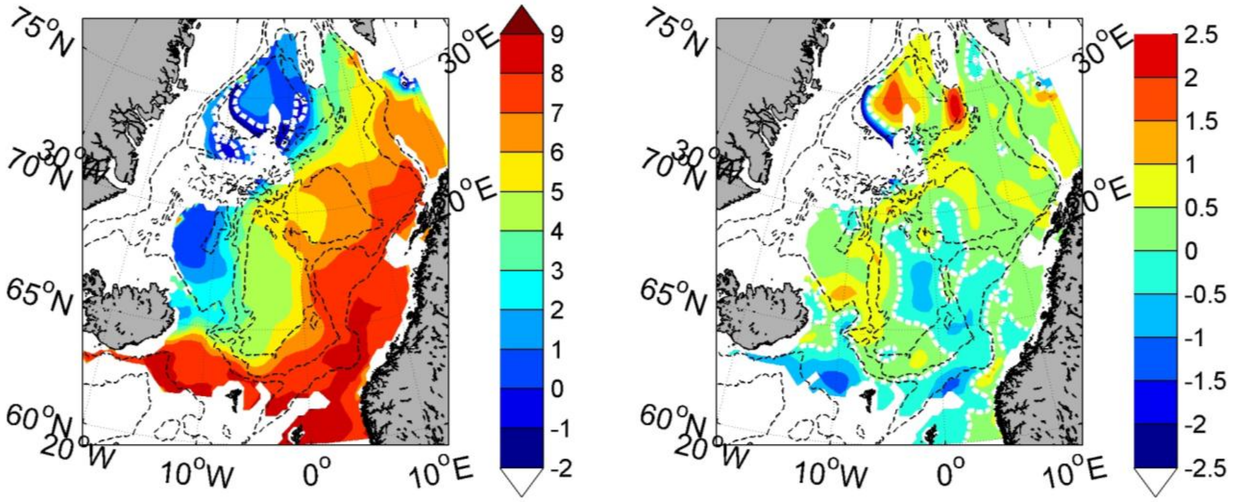


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth. Anomaly is relative to the 1995-2015 mean.

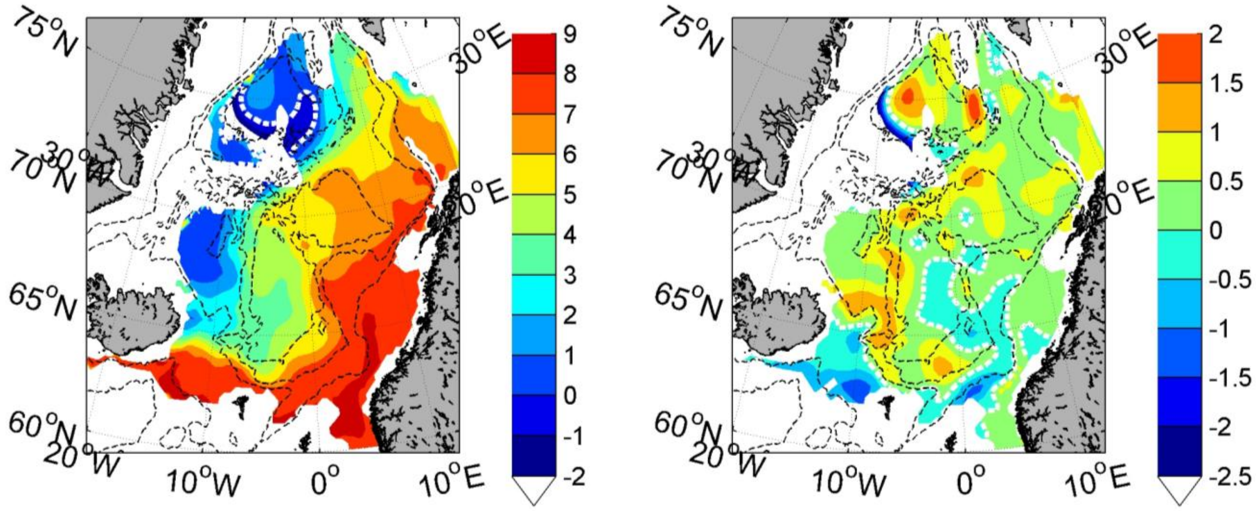


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth. Anomaly is relative to the 1995-2015 mean.

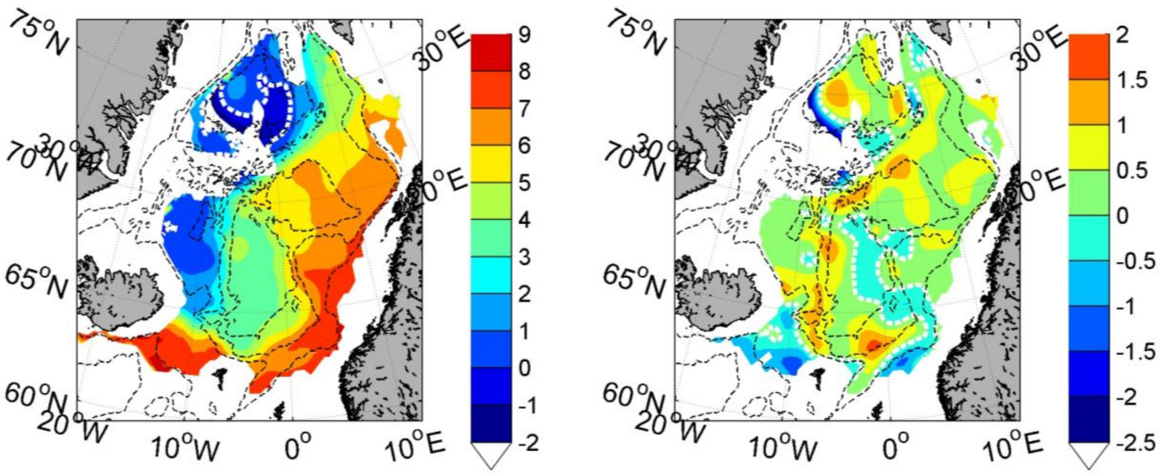


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth. Anomaly is relative to the 1995-2015 mean.

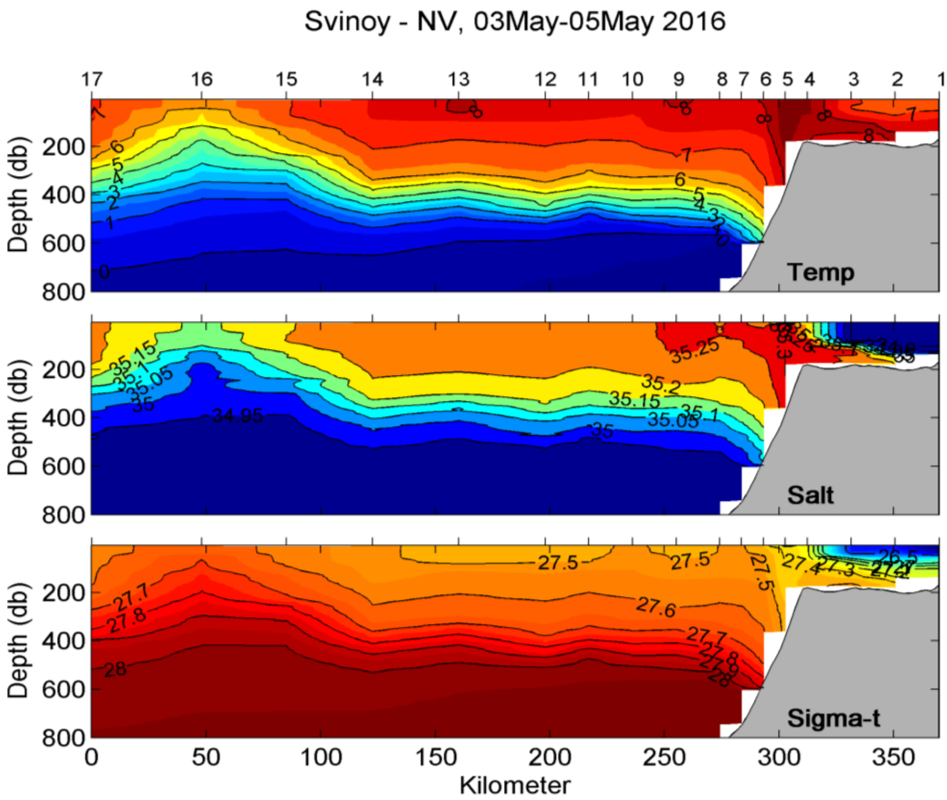


Figure 9. Temperature, salinity, density (sigma-theta) in the Svinøy section, May 2016.

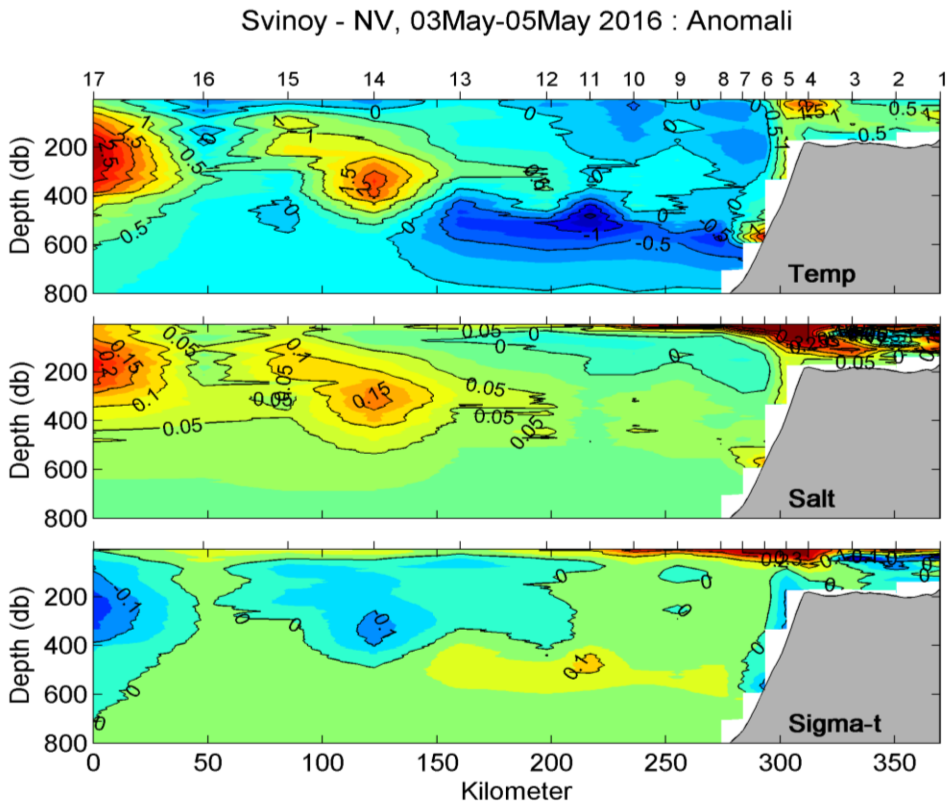


Figure 10. Temperature, salinity, density (sigma-theta) anomaly in the Svinøy section, May 2016. Anomalies are relative to a 30 years long-term mean (1978-2007).

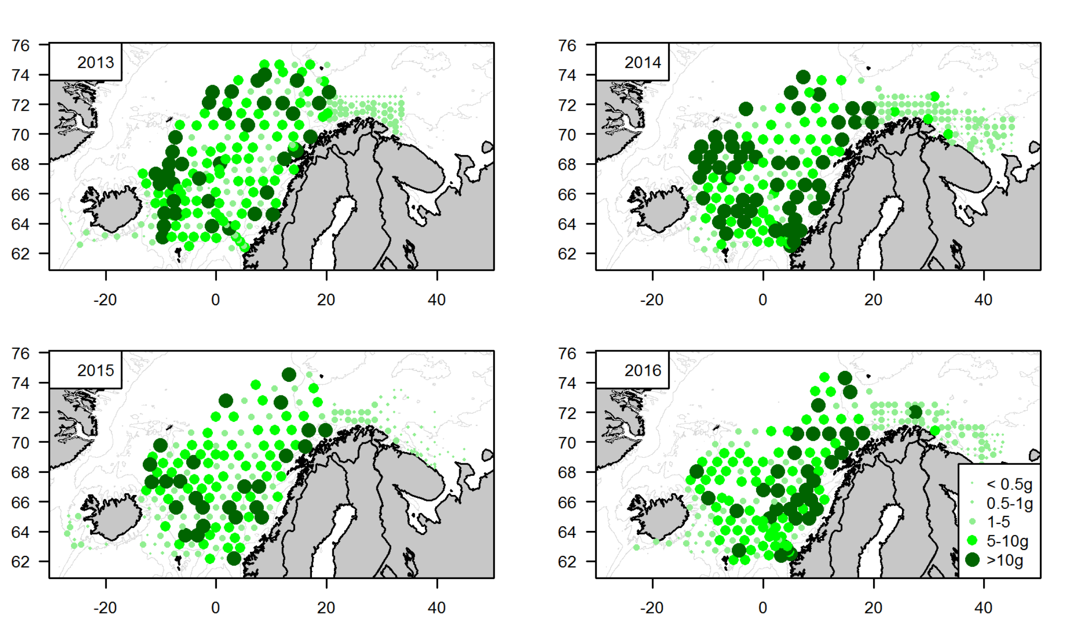
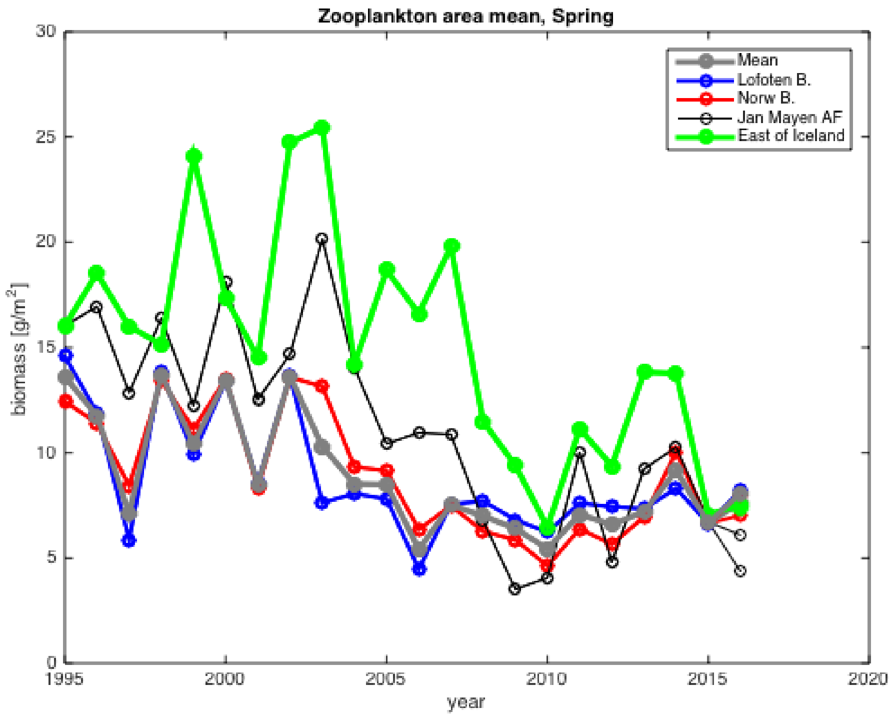


Figure 11. Zooplankton biomass (g dw m-2; 200–0 m in April-June 2013-2016.

(a)



(b)

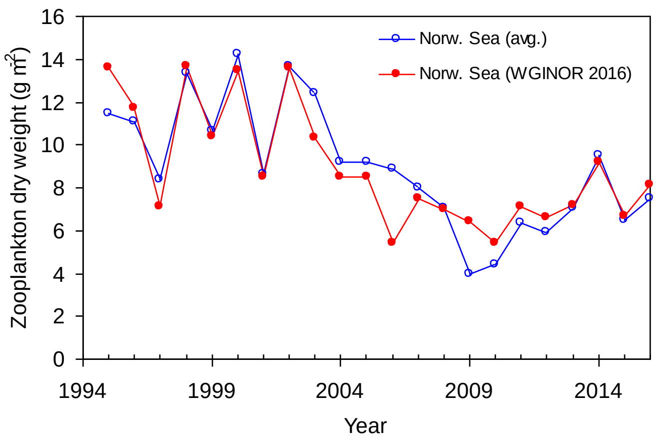


Figure 12. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2016 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016a) and (b) comparison of the Gaussian derived times-series for the Norwegian Sea (red filled circles) and average dry weight across all stations in the Norwegian Sea (blue open circles; the previous index).

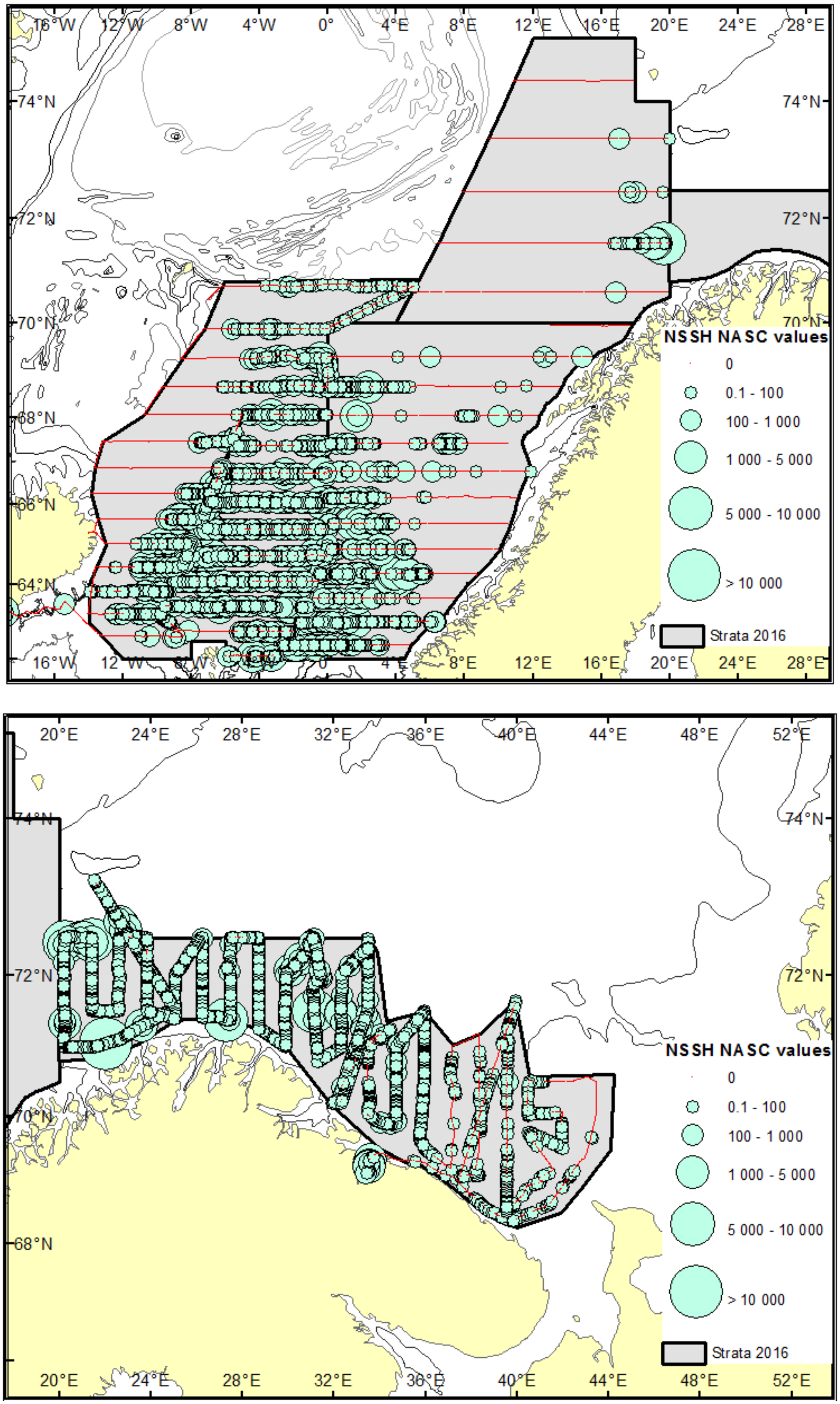


Figure 13. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2016 in terms of NASC values (m^2/nm^2) for every 1 nautical mile in Norwegian Sea (upper panel) and in the Barents Sea (lower panel). The stratification of the survey area is shown on the maps.

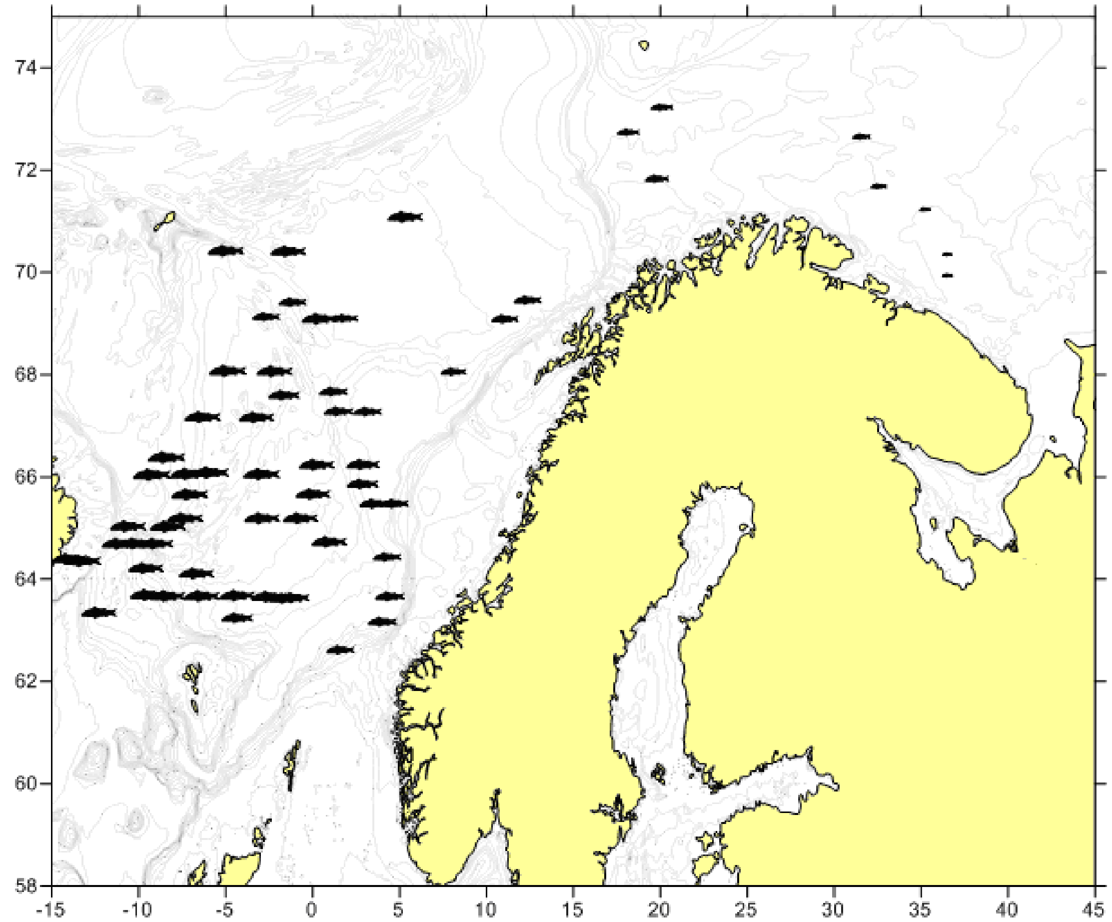


Figure 14. Mean length of Norwegian spring-spawning herring in all hauls in April-June 2016. Size of fish symbols represent relative mean lengths of the species caught in the hauls that contained 10 or more specimens (minimum mean length 13.7; maximum mean length 37.5).

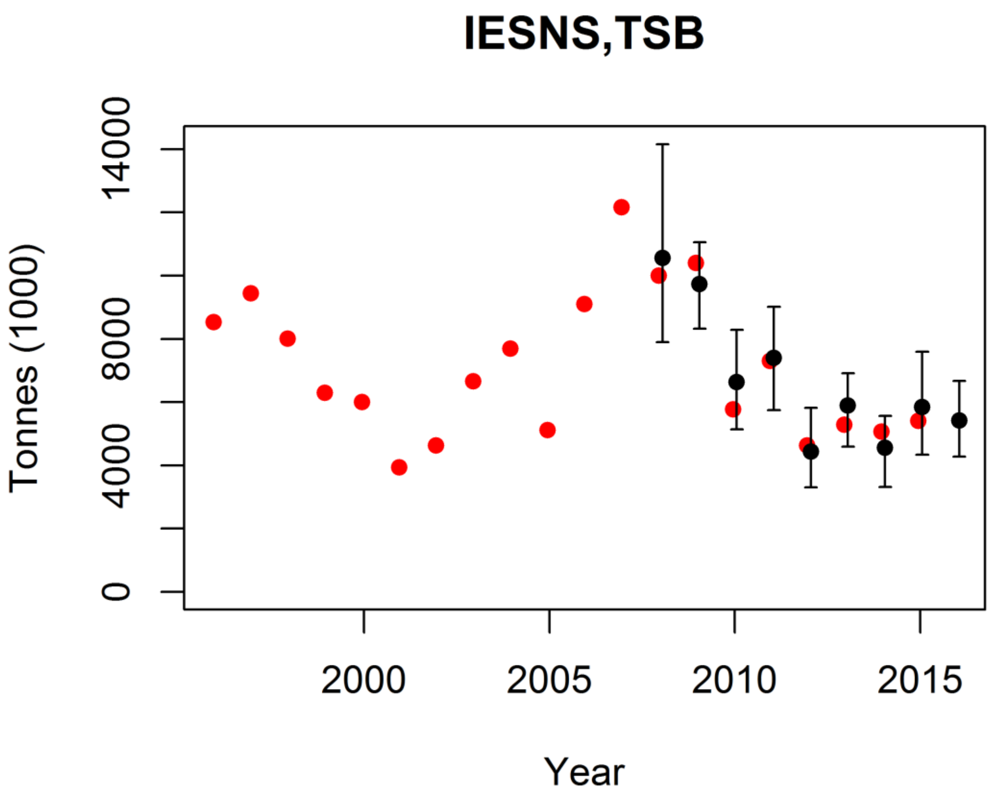


Figure 15. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2016 as estimated using BEAM (red dots; calculated on basis of rectangles) and as estimated with the software StoX (black dots with 95% confidence interval; calculated on basis of standard stratified transect design).

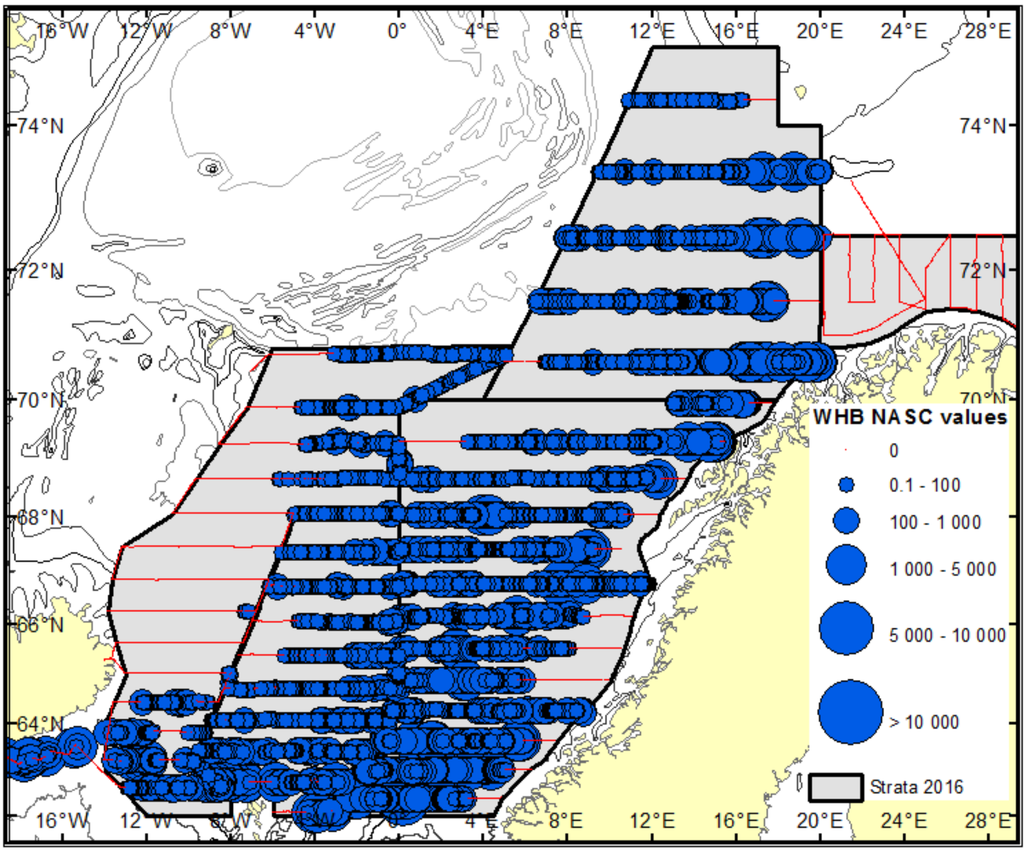


Figure 16. Distribution of blue whiting as measured during the IESNS survey in April-June 2016 in terms of NASC values (m^2/nm^2) for every 1 nautical mile. The stratification of the survey area is shown on the map.

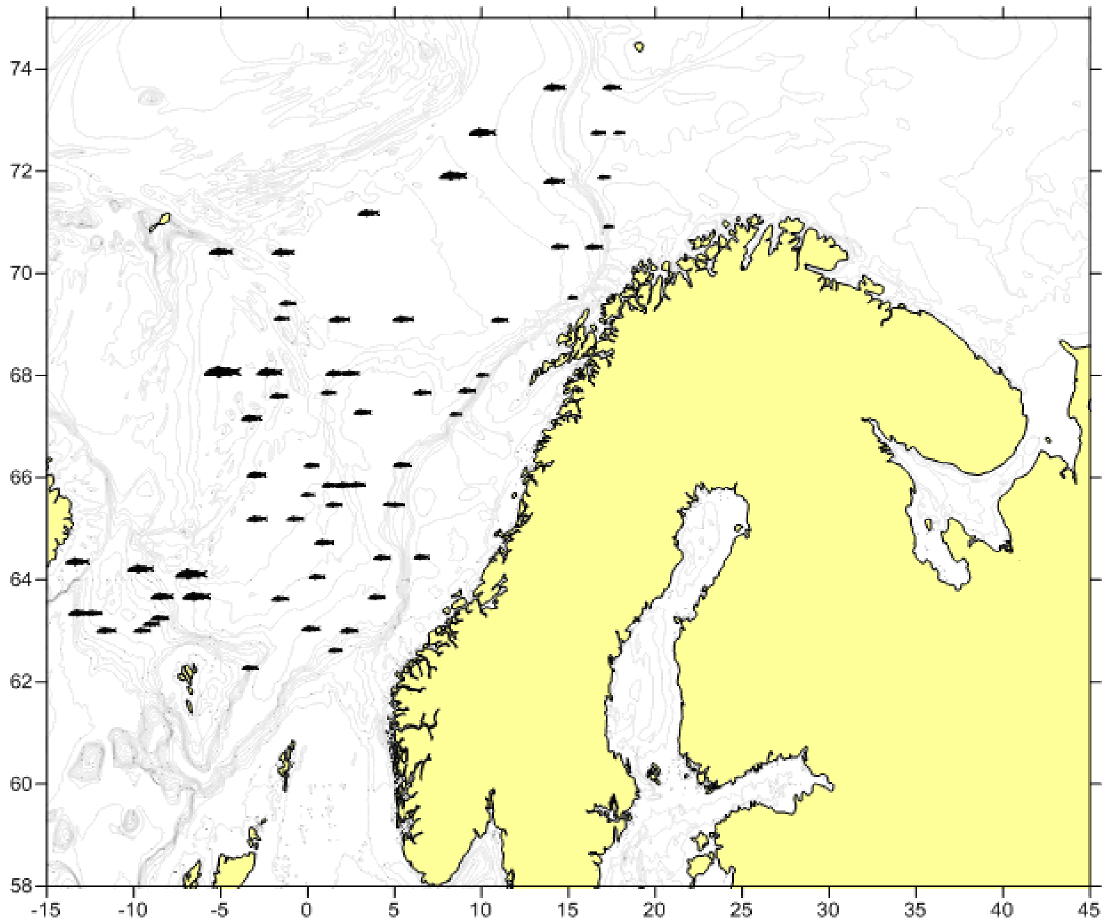


Figure 17. Mean length of blue whiting in all hauls in IESNS 2016. Size of fish symbols represent relative mean lengths of the species caught in the hauls that contained 10 or more specimens (minimum mean length 19.2; maximum mean length 32.9).

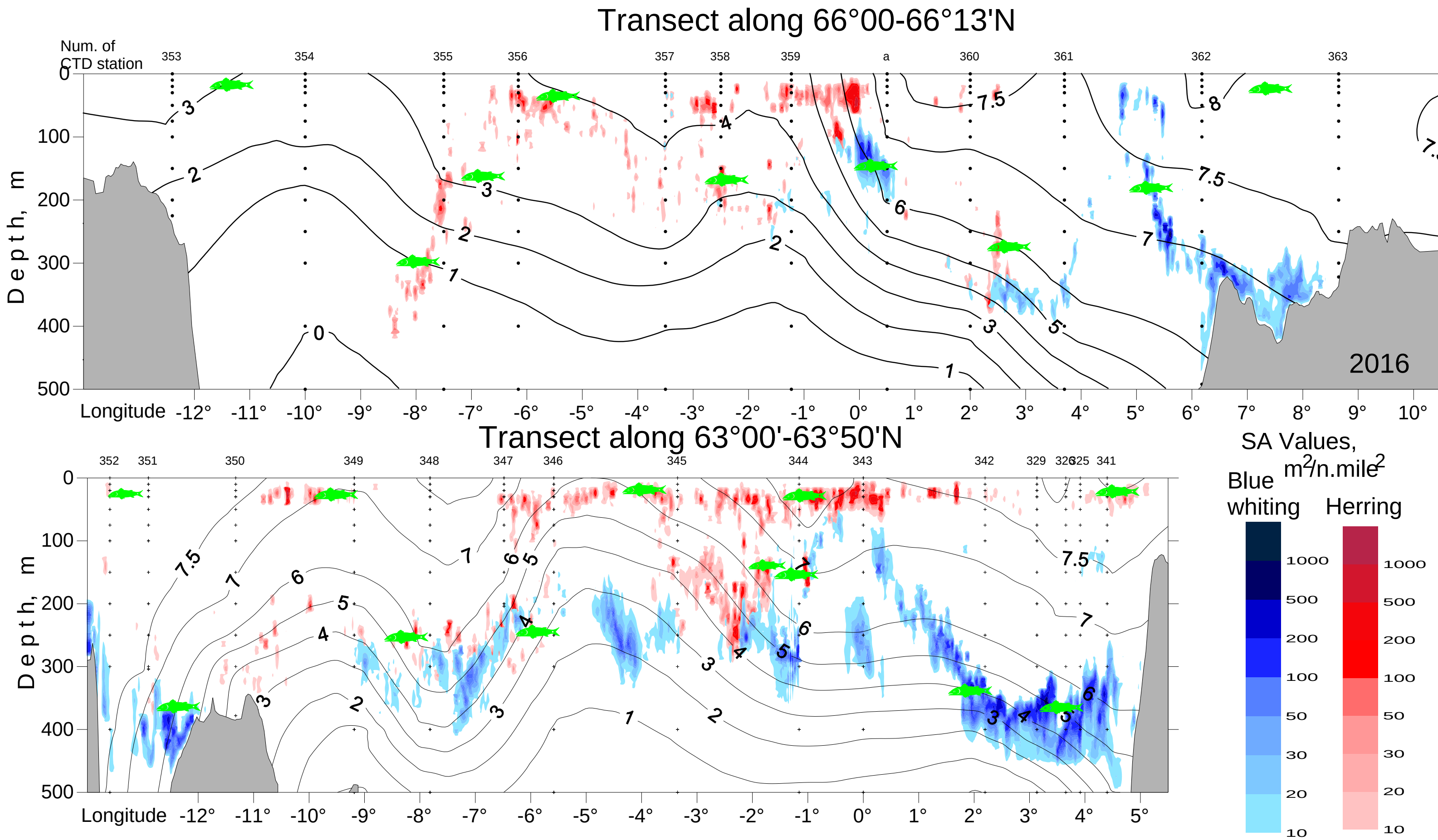


Figure 18. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2016 covered by "Johan Hjort".

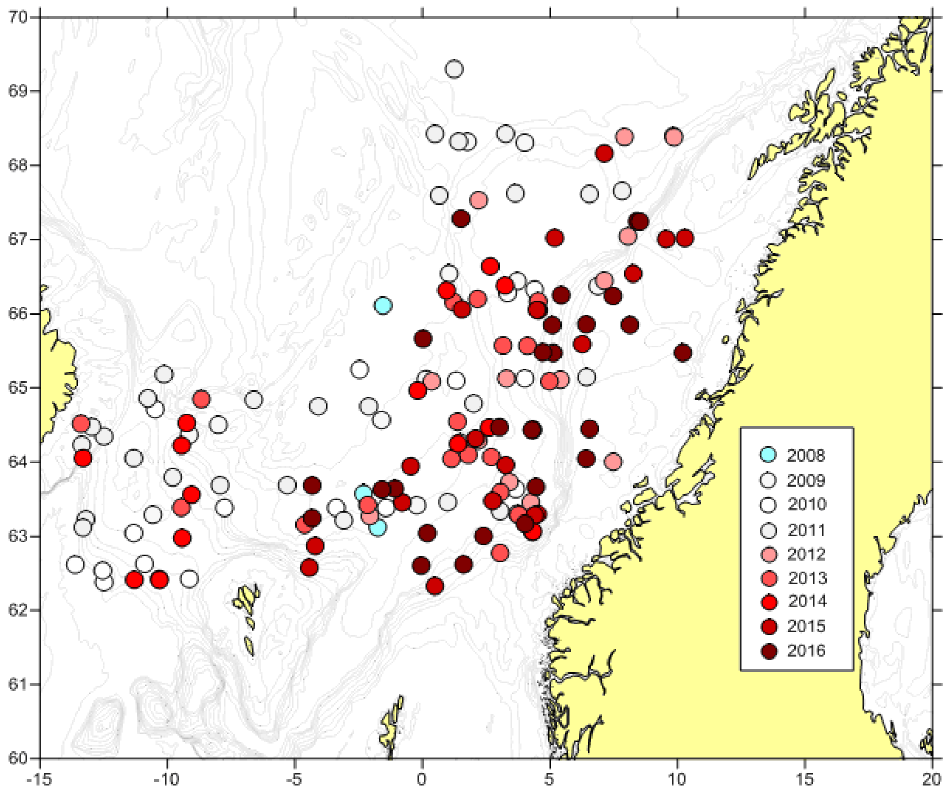


Figure 19. Distribution of hauls containing mackerel in IESNS surveys during 2008-2016.

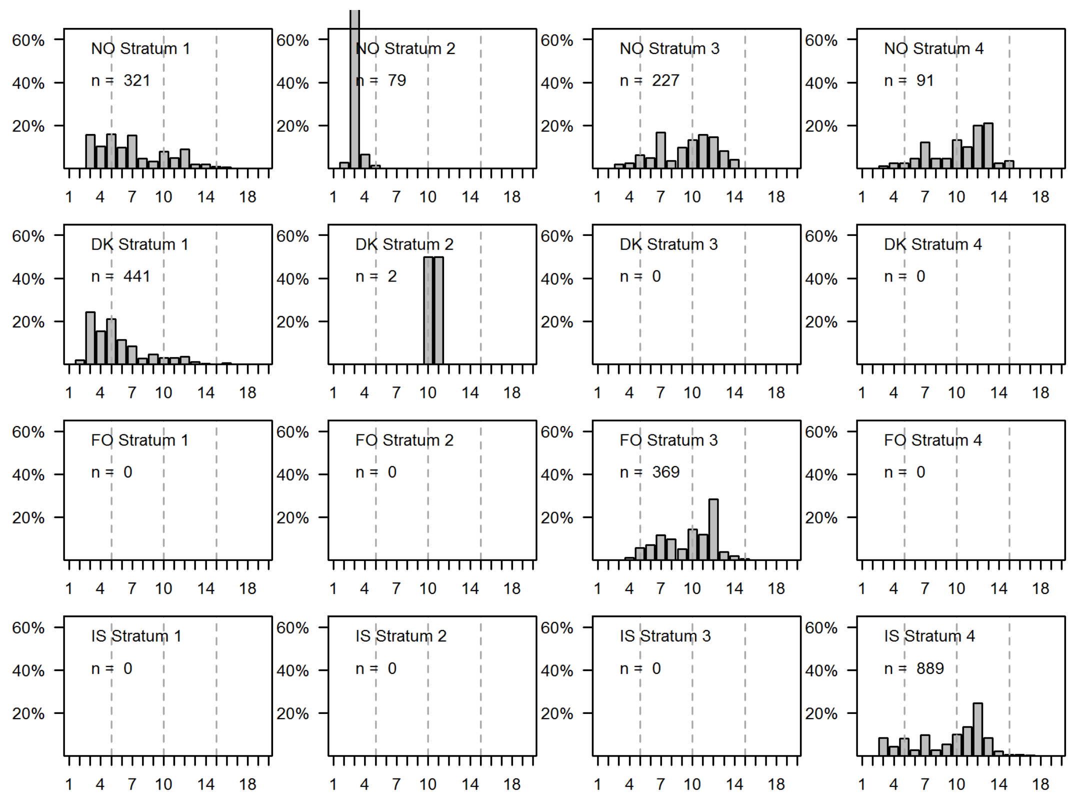


Figure 20 Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2016. The strata are shown in Fig. 3.

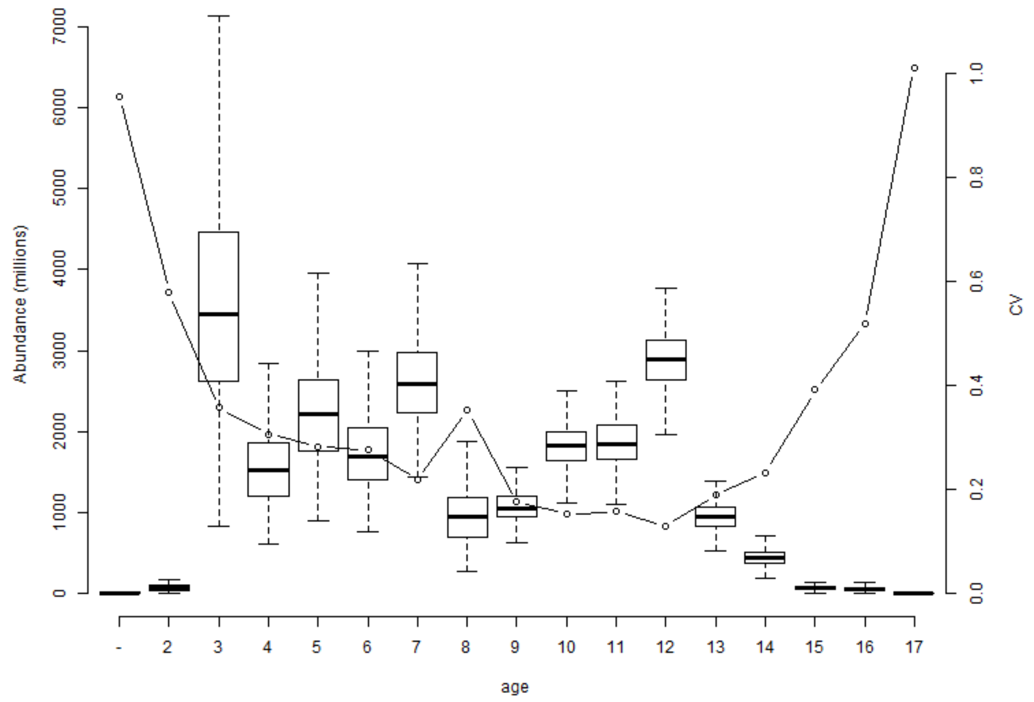


Figure 21. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

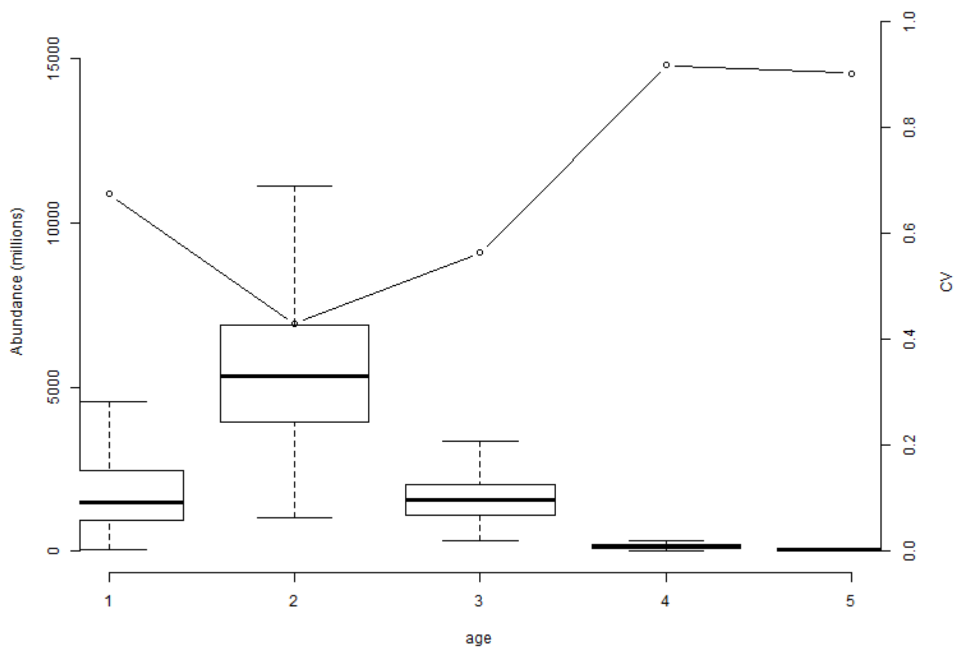


Figure 22. Norwegian spring-spawning herring in the Barents Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

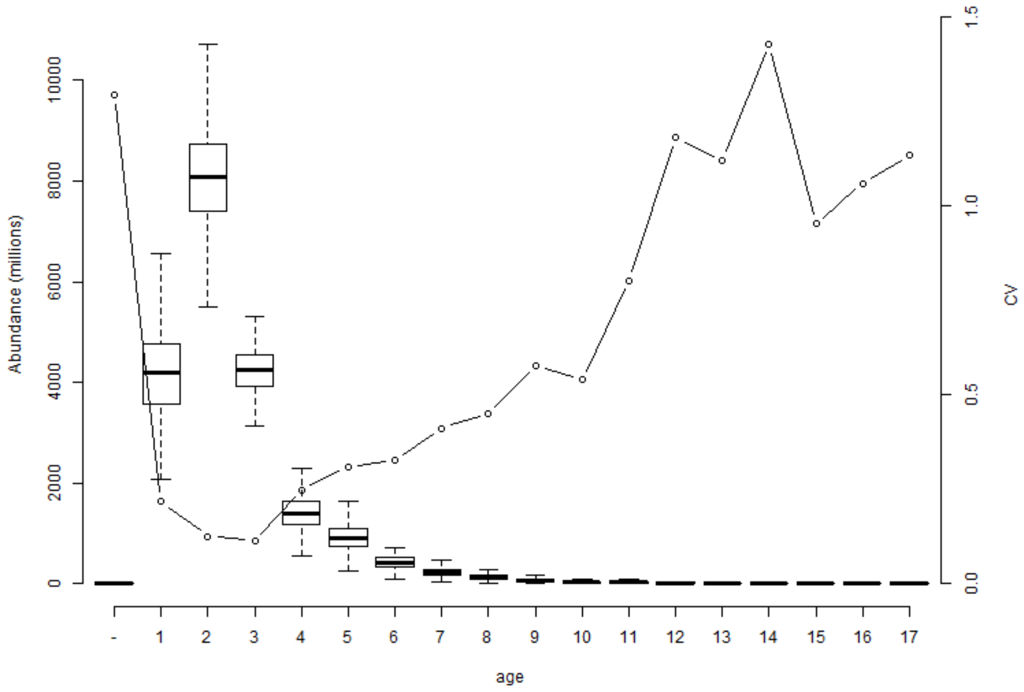


Figure 23. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.