Working Document

Post-cruise meeting of the Working Group on International Pelagic Surveys (WGIPS)
Bergen, Norway, 20 – 22 June 2017

Working Group on Widely distributed Stocks
Copenhagen, Denmark, 30 August - 5 September 2017

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2017

Maxim Rybakov[4], Sergey Kharlin[4], Olga Kanischeva[4]
RV Fridtjof Nansen

Valantine Anthonypillai[2], Are Salthaug[2], Åge Høines[2], Kjell Arne Mork[2], Cecilie Thorsen Broms[2], Øystein Skagseth[2]
RV G.O. Sars

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

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

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

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

Introduction

In May-June 2017, 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 G.O. Sars 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 database and supported by national survey reports from each survey (Dana: Staehr, Bergès, Kloppmann, Kupschus 2016, Magnus Heinason: Homrum, Smith, FAMRI 1718-2017, Árni Friðriksson: Óskarsson et al. 2017, Fridtjof Nansen: Rybakov PINRO 2017.

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2017. 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	28/04-23/05
G.O. Sars	Institute of Marine Research, Bergen, Norway	02/5-5/6
Fridtjof Nansen	PINRO, Russia	24/5–17/6
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	04/5- 15/5
Arni Friðriksson	Marine and Freshwater Research Institute, Iceland	10/5-23/5

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	G.O. Sars	Arni Friðriksson	Magnus Heinason	Fridtjof Nansen
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)	3	8.5	8	3	5.2
Upper integration limit (m)	5	15	15	7	10
Absorption coeff. (dB/km)	10	9.8	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	2425	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	-20.8	-20.81	-20.8	-20.7
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.32	25.34	24.28	25.62	25.57
s_A correction (dB)	-0.56	-0.66	-0.61	-0.66	-0.59
3 dB beam width (dg)					
alongship:	6.8	7.06	7.31	7.1	6.89
athw. ship:	6.8	7.03	6.95	7.1	6.92
Maximum range (m)	500	500	500	500	450
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 7.1	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 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	G.O. Sars	Arni Friðriksson	Magnus Heinason	Fridtjof Nansen
Circumference (m)		832	832	640	500
Vertical opening (m)	25-35	45–50	30–35	45–55	50
Mesh size in codend (mm)		40	40	40	16
Typical towing speed (kn)	3.0-4.0	4.0–4.5	3.0–5.1	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, 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 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 2015).

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 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 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. 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. 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. 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.

Some preliminary results from ongoing work with sonar were presented at the meeting, and some of these are presented as appendices to this report (Appendix 1 and 2).

Results

Hydrography

Temperature distribution for April-June 2017

The temperature and salinity distributions in the ocean at 5m, 50m, 100, 200m and 400m depth are shown in Figures 4 and 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 0°C in the Iceland and Greenland Sea to 9°C in the southern part of the Norwegian Sea (Figure 6). The Arctic front was encountered slightly below 65°N east of Iceland extending eastwards towards 4-5° West where it turned almost straight northwards up 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 to nearly 70° N in the surface layers.

Relative to a 21 years long-term mean, from 1995 to 2015, the temperatures at all depths over the most of the Norwegian Sea and in the eastern part of the Iceland Sea were considerable higher in 2017 compared to the long-term mean (Figures 6-8). Relative warmest water was in the southern Norwegian and Iceland Sea where the temperatures in some regions were more than 1 °C higher than the mean. In the eastern area of the Norwegian Sea, along the continental shelf, the temperatures were closer to the long-term average.

The temperature in the upper 800 m at the Svinøy section in May 2017 is shown in Figures 9. Atlantic water is lying over the colder intermediate layer and reach down to 500 m at the shelf edge and down to 200 m depth further west. The warmest water is located near the shelf edge where the core of the inflowing Atlantic Water is located. Westward temperature is reduced due to mixing with colder water. Relative to a long-term mean the temperatures on the shelf were higher in 2017 while it was lower at the shelf edge where the main northward transport of Atlantic Water is located. In the western part of the section the temperatures in the upper 300 m were about 1°C higher than the long-term mean.

Zooplankton

Zooplankton biomass (g dry weight m^{-2}) at 0-200m at the sampling stations is shown in Figure 10. Sampling stations were evenly spread over the area, and most oceanographic regions were covered. Highest zooplankton biomass was observed north of Lofoten/Vesterålen, in the Norwegian Sea basin, and along the Mohn ridge separating the Norwegian and Greenland Seas.

The index for zooplankton biomass for the Norwegian Sea calculated using the objective analysis with a Gaussian correlation function was 10.9 g dry weight m^{-2}, which is an increase from last year's value (Figure 11). All four sub-areas showed the same trends with a period of high zooplankton biomass from mid-1990s to the beginning of 2000, followed by a period of lower zooplankton biomass. The last years, a tendency of an increase can be noted. The zooplankton biomass east of Iceland was in general higher compared with the other sub-areas throughout the time-series period. In the Barents Sea (east of 20°E), the mean zooplankton biomass was 1.9 g dry weight m^{-2} in 2017 compared to 1.6 in 2016. It was 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 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 2017 and in line with previous years. The zero-line was believed to be reached for NSS herring throughout the area. It is therefore recommended that the results can be used for assessment purpose. The herring was primarily distributed in the western Norwegian Sea (Figure 12), but there were also aggregations off the northern Norwegian coast. In the Barents Sea the main aggregations were observed in the eastern part. Registrations of NSS herring were low in the southeastern part of the survey area.

As in previous years the smallest fish were found in the eastern area of the Norwegian Sea. As last year, young NSS herring were also caught in and near the Jan Mayen area. Size and age were found to increase to the west and south (Figure 13). Correspondingly, it was mainly older herring that appeared in the southwestern areas. The 2013 year class (age 4) was observed widely in the northern survey area. Its number at age 4 (Table 2) is comparable to the 2009 year class at same age (Figure 14), which indicates that it is larger than the most recent year classes but not a large one like e.g. the 2004 year class.

The herring stock was dominated by 4, 12 and 13 year old herring (year classes 2013, 2005 and 2004) in terms of numbers, with the 2013 and 2004 year classes contributing equally to the biomass (Table 2). The three year classes from 2004, 2005 and 2013 contribute 13%, 13%, and 17%, respectively, to the total biomass in the Norwegian Sea. The total number of herring recorded in the Norwegian Sea was 17.7 billion in 2017. Uncertainty estimates for numbers at age based on bootstrapping within StoX are shown in Figure 15.

The total biomass estimate of herring in the Norwegian Sea from the 2017 survey was 4.2 million tonnes. This estimate is 1.2 million tonnes (23%) lower than in 2016. The biomass decreased from 2009 to 2012, and has then fluctuated from 4.2 to 5.9 million tonnes in the years 2013-2016 (Figure 16), with the lowest abundance occurring in 2017.

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 40°E to the 20°00´ E. The total abundance estimate was 14.7 billion individuals of age 1 (mean length of 12.7 cm and weight of 12.2 g) and 3.3 billion individuals of age 2 (mean length of

17.1 cm and mean weight of 29.9 g). No older herring were observed. StoX estimates of age 1 from the period 2009-2017 are shown in Figure 17, and these indicate a high index estimate for 2017.

Blue whiting

The spatial distribution of blue whiting in 2017 was similar to the years before, with high 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 and in the open sea in the southern part of the Norwegian Sea (Figure 18). 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 of blue whiting registered during the IESNS survey in 2017 was 0.93 million tons (Table 4), which is a 40% decrease from the biomass estimate in 2016 (1.54) but similar to 2015 (0.96). The total number for 2017 was 9.7 billion, which is about 50% lower than in 2016. Age 3 (2014 year class) is dominating the estimate (44% of the biomass and 44% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20.

Vertical profile across the Norwegian Sea

Two transects were taken by G.O. Sars across the whole Norwegian Sea (Figure 21). There was apparently no clear pattern in the relation between temperature and herring distribution, neither vertically or horizontally. The herring was mainly in the western part in the temperature range of 0-6°C. Distribution of blue whiting was limited to Atlantic waters warmer than around 1.5°C (Figure 21) as also represented by its spatial distribution where it was observed across the whole Norwegian Sea except for the cold and fresh East Iceland Current (Figures 4, 5 and 18).

Mackerel

During the last decade an increasing amount of mackerel has been observed in the catches during the May survey (see last year's survey report). This pattern continued in 2017 where mackerel was caught over a wide area in the eastern part of the Norwegian Sea (Figure 22). No quantitative information can be drawn from these data as this survey is not designed to monitor mackerel. Mackerel at age 1 (mean length 18.1 cm) was most numerous in the combined samples (not weighed by catch size), and amounted to 32%, followed by age 3 (21%) and age 5 (14%).

Discussion

Hydrography

Discussions related to the oceanographic condition in April/June 2017 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 the Norwegian Sea in May has been estimated since 1995 (Figure 11). For the period 1995-2002 the plankton index was relatively high (mean 11.2 g) even if varying between years. From 2003-2006, the index decreased continuously and has been at lower levels since then (mean 7.7 g for the period 2003-2017). A tendency of an increase can be noted in the last part of the low-biomass period. The index for 2017 (10.9 g) is closer in value to the high-biomass period than the low-biomass period. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea (Figure 11).

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. The zooplankton biomass index in the Barents Sea (east of 20°E) was 1.9 g dry weight m^{-2}, which is higher than the previous years 2012-2016 where the biomass was within 0.8-1.7g. 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.

Summing up, the reason for the observed changes in zooplankton biomass is not clear to us and more ecological and environmental research to reveal this 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 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, but it is believed to be comparable to recent years.

The total biomass of herring measured in the 2017 survey in the Norwegian Sea was 23% lower than in 2016 (Figure 16). When considering the addition of the 2013 year class to the biomass in 2017 (constituted to 17% of the biomass in 2017), the decrease in the estimates between 2016 and 2017 in the adult stock is even more pronounced. This biomass estimate in 2017 is comparable to the estimates from 2012 and 2014, which had also similar confidence interval.

The estimate on number of age 1 in the Barents Sea in 2017 is higher than seen for the most recent years (Figure 17). It is for example two times higher than the estimates of the 2013 year class in 2014. However, the uncertainty around these estimates are large, and larger than indicated on Figure 17 as it only accounts for the sampling variability but not for the uncertainty related to spatial restriction and number of biological samples behind the estimates (e.g. only two samples that were large enough behind the 2017 estimate, taken close to each other).

In the last three years (2014-2016) there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences. A scale and otolith exchange is in progress at the moment, where scales and otoliths for the same fish have been sampled. It is recommended that a workshop based on this exchange will take place before next year's survey.

With respect to age-reading concerns in the recent years, the comparison between the nations in this year's survey showed some different results (Figure 23). The 2004 year class was in higher proportion by the Icelandic and Norwegian readers than the Faroese readers in Stratum 3.

In the 2017 IESNS there were no apparent discrepancies in the acoustic scrutinizing results between any neighbouring vessels. 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 2017 showed a significant decrease from 2016. The biomass estimate decreased as well but not as much as the abundance. A positive sign in development of the stock size was observed in the 2011 survey when blue whiting at age 1 and 2 were in higher numbers than the previous years. In 2017, the number of 1 year old blue whiting was lower than the last three years, indicating a small 2016 year class. The result from the last years showing a strong 2014 year class was confirmed with the three year olds as the most dominant year class in this year's survey in both abundance and biomass (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
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

Next years post-cruise meeting

19-21 June 2017. Location will be decided at the next WGIPS meeting.

Concluding remarks

- Relative to a 21 years long-term mean, the temperatures at all depths over most of the Norwegian Sea and adjacent waters were considerable higher in 2017, especially in the south and west.
- The 2017 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters increased from last year and is now comparable to the mean of the earlier high-biomass period, but is still relatively low in the westernmost areas.
- The biomass estimate of NSSH in 2017 was 23% 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 2016 survey. The biomass is comparable in size to the estimates from 2012 and to 2014. The survey group recommends using this estimate in the assessment.
- The 2013 year class was most numerous for NSSH followed by six year classes at similar levels – representing relatively equal and wide age distribution in the stock.
- The 2013 year class appears to be around the level of the 2009 year class, i.e. not a strong year class.
- Number of age 1 of NSSH in the Barents Sea was higher than in recent years, which might indicate improved recruitment, but the uncertainty around the estimate is high.
- The biomass of blue whiting measured in the 2017 survey decreased by 40% from last year's survey and by 50% in number.
- Age 3 (2014 ycl) blue whiting is dominating the acoustic estimate (44% of the biomass and by numbers), while the 2016 year class appears to be small.

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.

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 2017.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	28/04-23/05	1895	38	33	539	2094	33
Magnus heinason	4/5-15/5	1312	13	19	220	249	19
Árni Fridriksson	10/5-23/5	2633	22	33	1167	4611	30
G.O.Sars	3/5-4/6	3397	64	73	535	1586	84
Fridtjof Nansen	24/5-14/6	2441	32	42	108	536	42
Total		**10956**	**169**	**200**	**2567**	**8648**	**208**

Table 2. IESNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
15-16	15177	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15177	394.6	26.00
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4052	4052	194.5	48.00
19-20	-	22251	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22251	1162.6	52.25
20-21	-	19229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19229	1184.5	61.60
21-22	-	17168	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17168	1150.3	67.00
22-23	-	27042	55740	13521	-	-	-	-	-	-	-	-	-	-	-	-	-	-	96304	8004.8	83.12
23-24	-	14104	57586	14104	9403	-	-	-	-	-	-	-	-	-	-	-	-	-	95196	8927.3	93.78
24-25	-	-	71211	8901	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80112	8763.4	109.39
25-26	-	-	58204	8315	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66519	8028.0	120.69
26-27	-	-	80848	134646	-	-	-	-	-	-	-	-	-	-	-	-	-	-	215494	28942.6	134.31
27-28	-	3859	58256	655062	175367	3859	-	-	15993	-	-	-	-	-	-	-	-	-	912396	136634.4	149.75
28-29	-	-	124515	1587403	266718	103829	39342	16801	8401	-	40573	-	-	-	-	-	-	-	2187581	363199.7	166.03
29-30	-	48752	123836	1292518	466835	144089	255304	100936	107742	7210	14419	-	-	-	-	-	-	-	2561640	467762.9	182.60
30-31	-	-	25275	375838	322900	482681	396049	300700	32109	16055	8027	4247	-	-	-	-	-	-	1963883	388336.2	197.74
31-32	-	-	55075	91341	205455	306798	139438	193542	9918	94249	39895	19920	-	-	-	-	-	-	1155631	247578.9	214.24
32-33	-	-	-	39423	67657	161887	167789	77472	39659	52978	-	8133	16266	-	-	-	-	-	631265	150063.3	237.72
33-34	-	-	-	27011	25779	261891	60042	133604	-	47003	30361	-	-	12554	-	-	-	-	598246	159406.0	266.46
34-35	-	-	-	2523	3784	146352	169525	302871	53578	98219	144700	121888	58517	-	-	-	-	-	1101958	320351.3	290.71
35-36	-	-	-	-	-	16766	114851	421072	100574	288085	385833	488082	364027	67044	2579	-	-	-	2248913	684408.7	304.33
36-37	-	-	-	761	-	7142	-	108500	48347	195272	275787	737466	711932	170005	47211	-	-	-	2302422	732145.3	317.99
37-38	-	-	-	-	-	-	-	32997	13294	32783	69313	341930	375002	171728	50671	11693	-	-	1099411	367395.0	334.17
38-39	-	-	-	-	-	-	-	-	-	56	7441	32246	138962	69453	16123	12402	8682	-	285366	101572.2	355.94
39-40	-	-	-	-	-	-	-	-	-	-	-	30308	4849	-	-	-	-	-	35158	12737.9	362.31
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1169	1169	-	-
TSN(1000)	15177	152404	710547	4251368	1543898	1635293	1342340	1688494	429616	831909	1016351	1784220	1669556	490783	116584	24096	8682	5221	17716540	-	-
TSB(1000 kg)	394.6	16365.5	104963.0	726324.7	285624.0	363304.7	299412.4	439230.6	110400.6	241048.7	299872.1	561357.4	536599.2	161452.7	39804.4	8642.5	3352.8	194.5	-	4198344.3	-
Mean length (cm)	15.50	23.89	26.89	28.59	29.50	31.25	31.37	32.99	32.56	34.44	34.74	35.84	36.10	36.46	36.76	37.51	38.00	22.93	-	-	-
Mean weight (g)	26.00	107.38	147.72	170.84	185.00	222.16	223.05	260.13	256.98	289.75	295.05	314.62	321.40	328.97	341.42	358.67	386.20	48.00	-	-	236.99

Table 3. IESNS 2017 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	Number (1E3)	Biomass (1E3kg)	Mean W (g)
9-10	179234	-	179234	806.6	4.50
10-11	437156	-	437156	2295.1	5.25
11-12	834968	-	834968	7410.3	8.88
12-13	6959522	-	6959522	77066.5	11.07
13-14	4555164	-	4555164	61989.8	13.61
14-15	1512559	-	1512559	25146.3	16.63
15-16	179234	358468	537702	11560.6	21.50
16-17	-	935514	935514	23762.0	25.40
17-18	-	1254637	1254637	38983.4	31.07
18-19	-	537702	537702	19715.7	36.67
19-20	-	179234	179234	6990.1	39.00
TSN(1000)	14657837	3265555	17923392	-	-
TSB(1000 kg)	178209.6	97516.8	-	275726.4	-
Mean length (cm)	12.68	17.10	-	-	-
Mean weight (g)	12.16	29.86	-	-	15.38

Table 4. IESNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	888	-	-	-	-	-	-	-	-	-	-	-	-	-	888	24.9	28.00
18-19	10673	-	-	-	-	-	-	-	-	-	-	-	-	-	10673	371.5	34.81
19-20	153892	-	-	-	-	-	-	-	-	-	-	-	-	-	153892	6065.6	39.41
20-21	489175	11555	1050	2101	-	-	-	-	-	-	-	-	-	-	503881	22873.0	45.39
21-22	426936	100999	29146	-	-	-	-	-	-	-	-	-	-	-	557081	29544.5	53.03
22-23	132310	299671	159889	11743	-	-	-	-	-	-	-	-	-	-	603614	38007.7	62.97
23-24	1416	547747	384647	43969	-	-	-	-	-	-	-	-	-	-	977779	71838.0	73.47
24-25	-	533293	768481	95421	11362	-	-	-	-	-	-	-	-	-	1408558	117529.1	83.44
25-26	-	352916	1187677	197584	27080	-	-	-	-	-	-	-	-	-	1765258	164992.9	93.47
26-27	-	127464	1070151	291865	29068	-	889	-	-	-	-	-	-	-	1519436	157785.8	103.84
27-28	-	28728	456905	334981	55334	17098	1937	-	-	-	-	-	-	-	894982	103290.4	115.41
28-29	4172	11918	135333	154586	91713	23408	9383	-	-	-	-	-	-	-	430513	56328.5	130.84
29-30	-	-	41130	76079	46520	30785	14436	-	-	1110	-	-	-	-	210061	30838.6	146.81
30-31	-	-	11669	13784	54593	35082	42643	-	-	-	-	-	-	-	157771	25319.1	160.48
31-32	-	-	2783	-	85213	16542	7505	1251	-	-	-	-	-	-	113294	20019.9	176.71
32-33	-	-	-	2772	7718	18121	8316	12183	-	5544	9805	-	-	5544	70003	14774.5	211.06
33-34	-	-	-	2350	10246	17297	12596	9402	-	11752	4701	4701	2350	2350	77746	16124.1	207.39
34-35	-	-	-	1891	2811	11245	2811	7713	2811	8433	2811	14825	-	2811	58163	14472.9	248.83
35-36	-	-	-	-	-	-	19464	9278	13917	13917	9278	-	-	-	65856	17896.9	271.76
36-37	-	-	-	-	2897	-	2897	2897	8690	5793	2897	-	-	-	26070	7815.2	299.78
37-38	-	-	-	-	-	-	-	-	4549	4549	-	-	-	-	9098	2563.4	281.75
38-39	-	-	-	-	-	-	-	-	-	-	-	2187	14825	-	17012	5163.2	303.50
39-40	-	-	-	-	-	-	3645	-	-	-	-	-	14825	-	18470	6003.4	325.03
40-41	-	-	-	-	-	-	-	-	-	-	-	1094	-	-	1094	371.8	340.00
TSN(1000)	1219462	2014292	4248861	1229126	424555	169578	126523	42723	29968	51100	29492	22807	32000	10706	9651193	-	-
TSB(1000 kg)	59301.3	159034.9	404116.7	136270.4	61391.6	29216.4	23616.6	10193.2	8102.7	13254.8	7350.7	5945.3	9774.4	2445.9	-	930014.8	-
Mean length (cm)	20.50	23.71	25.24	26.51	28.90	30.33	31.60	33.71	35.75	34.40	33.78	34.51	38.13	32.87	-	-	-
Mean weight (g)	48.63	78.95	95.11	110.87	144.60	172.29	186.66	238.59	270.38	259.39	249.24	260.68	305.45	228.47	-	-	96.36

Figures

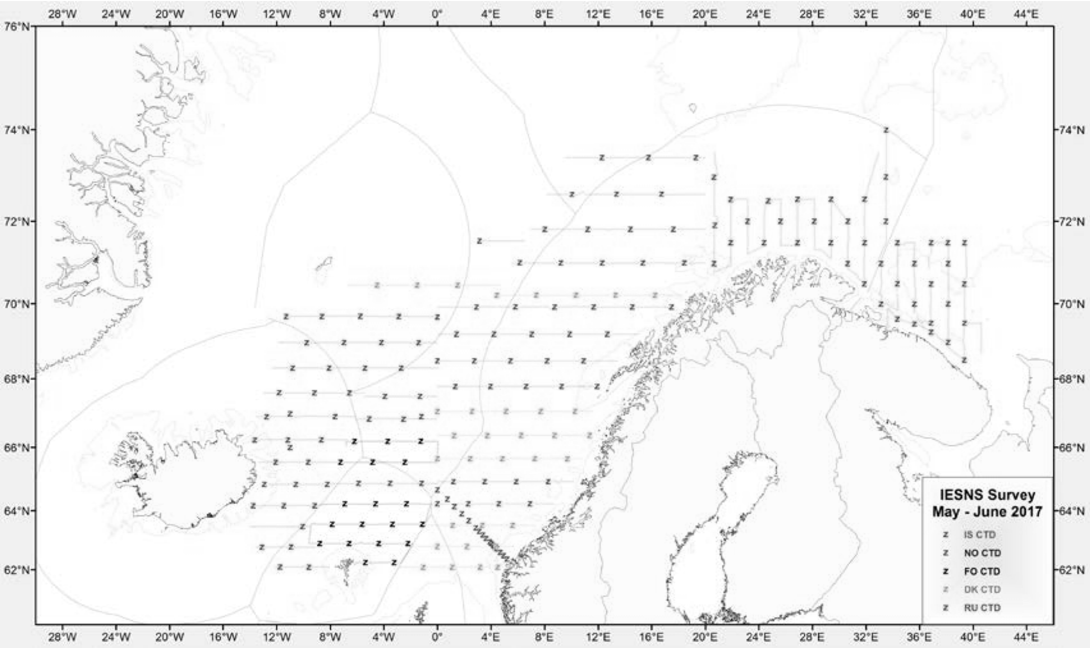


Figure 1. Cruise tracks and CTD stations by country for the IESNS survey in May-June 2017.

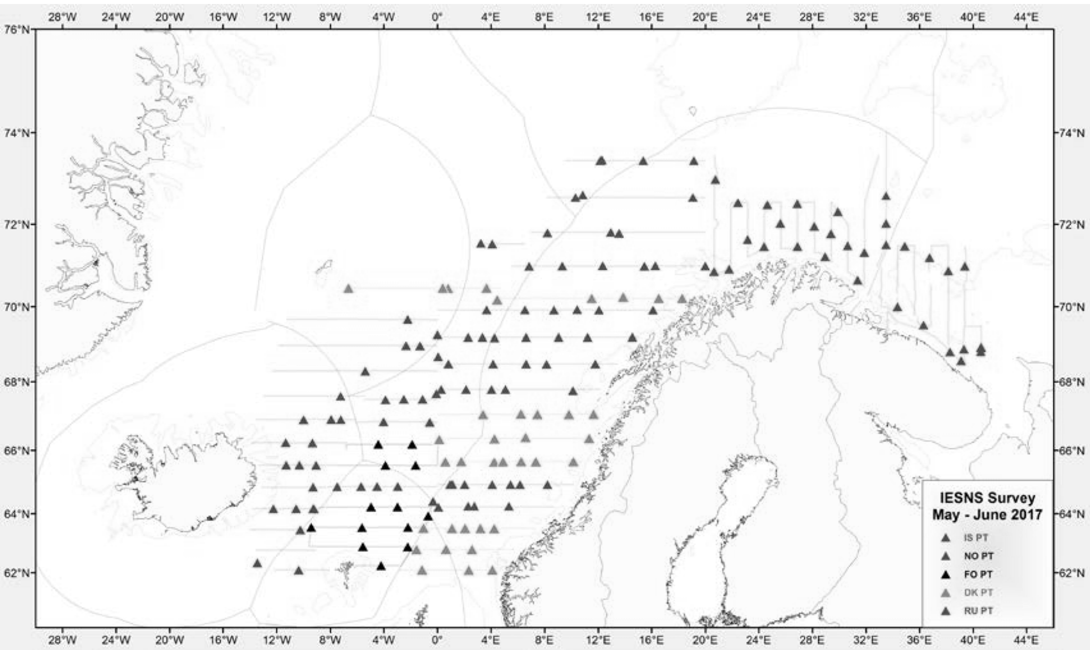


Figure 2. Cruise tracks during the IESNS survey in May-June 2017 and location of trawl stations.

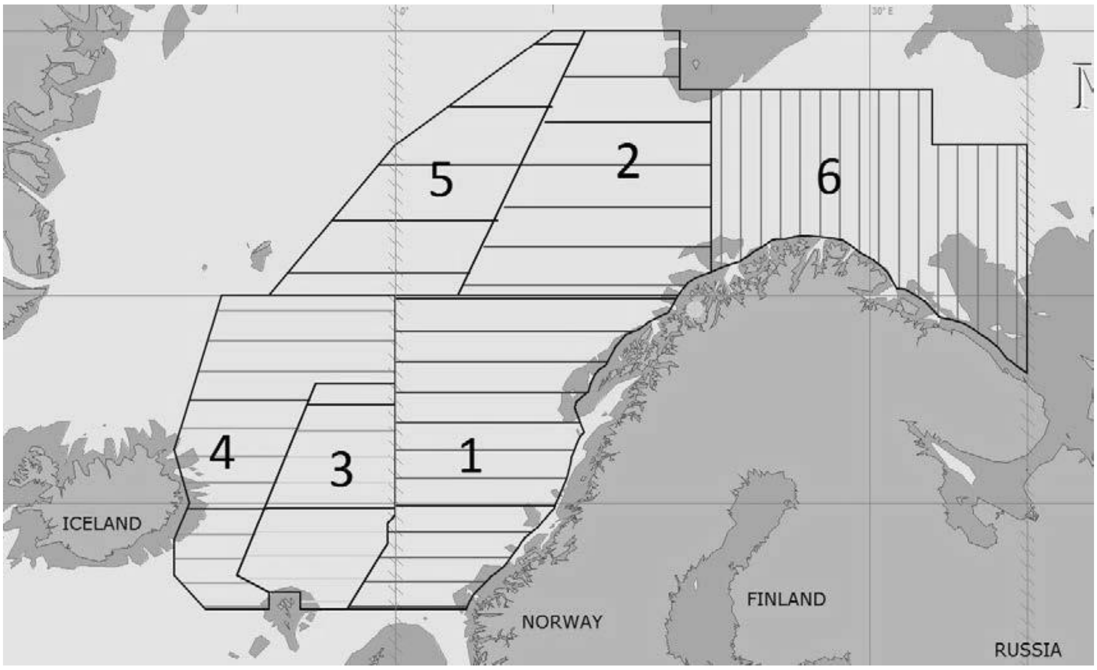


Figure 3. The pre-planned strata and transects for the IESNS survey in 2017 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland).

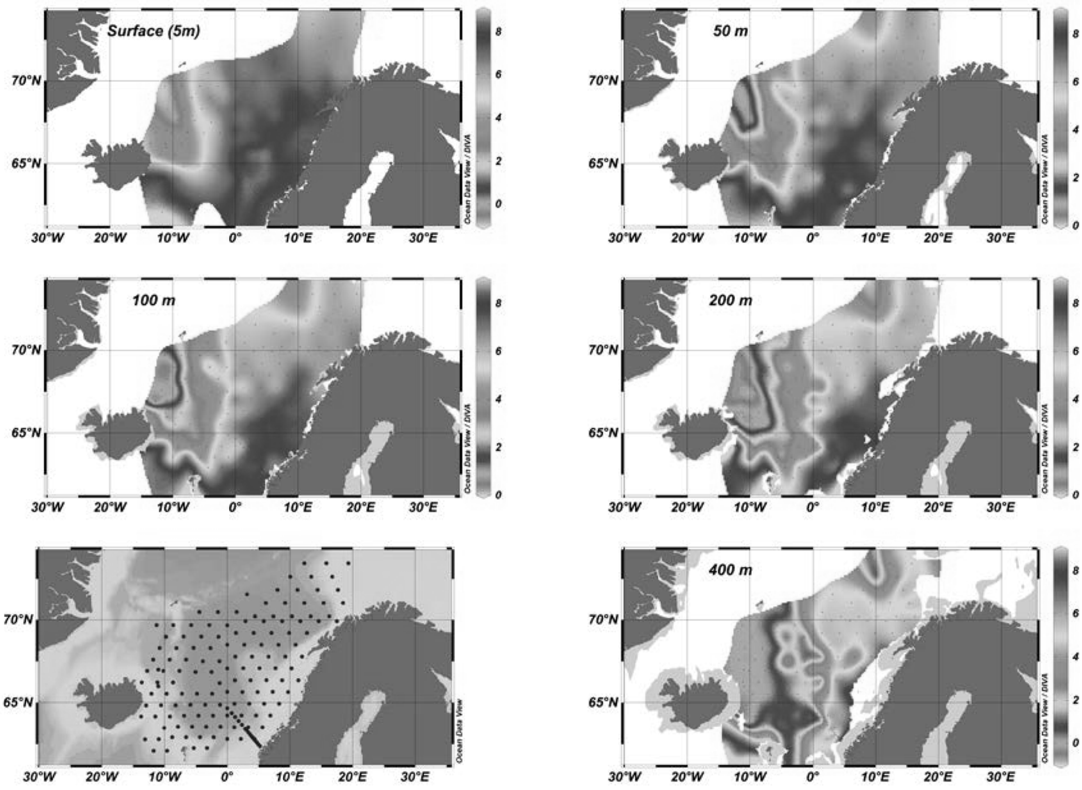


Figure 4. The horizontal distribution of temperatures (°C) at 5 m (surface), 50m, 100m, 200m and 400m depth in IESNS in May-June 2017.

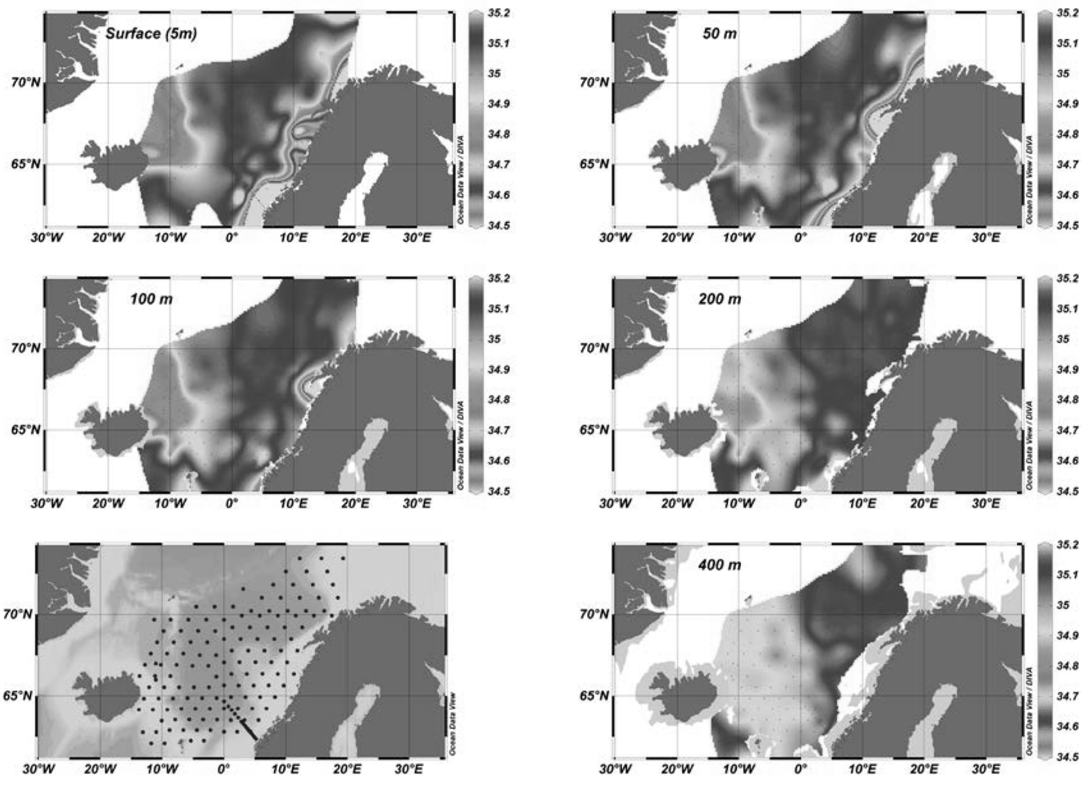


Figure 5. The horizontal distribution of salinity at 5 m (surface), 50m, 100m, 200m and 400m depth in IESNS in May-June 2017.

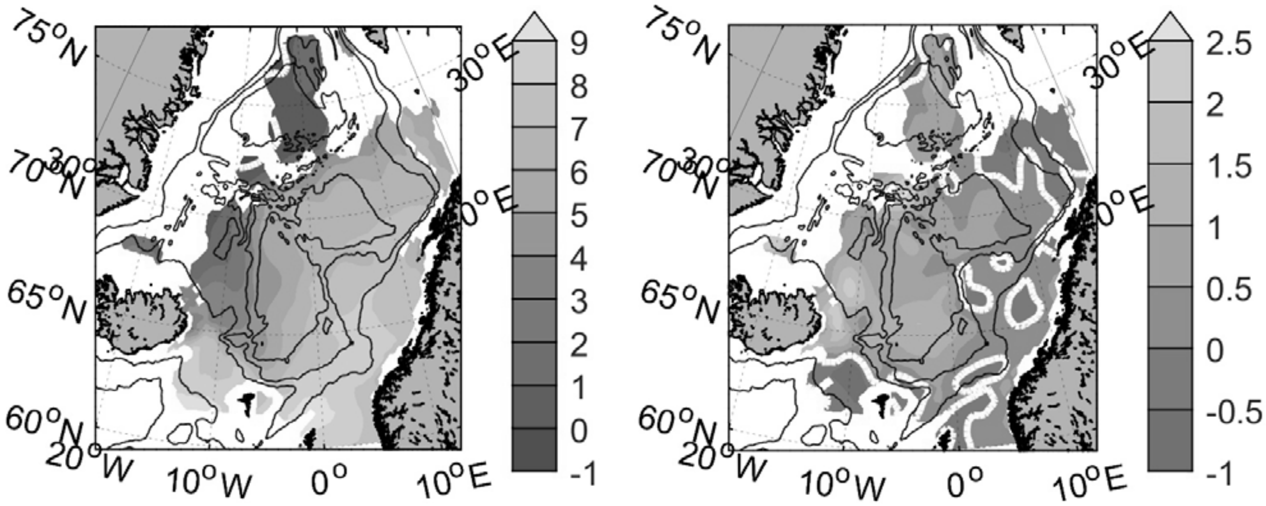


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2017. Anomaly is relative to the 1995-2015 mean.

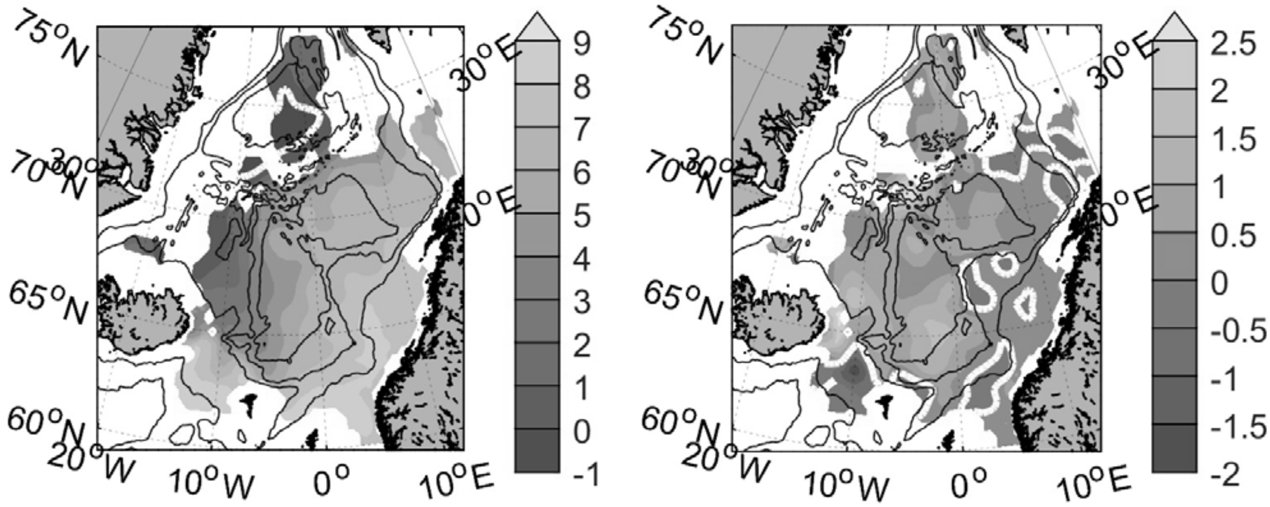


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth in May 2017. Anomaly is relative to the 1995-2015 mean.

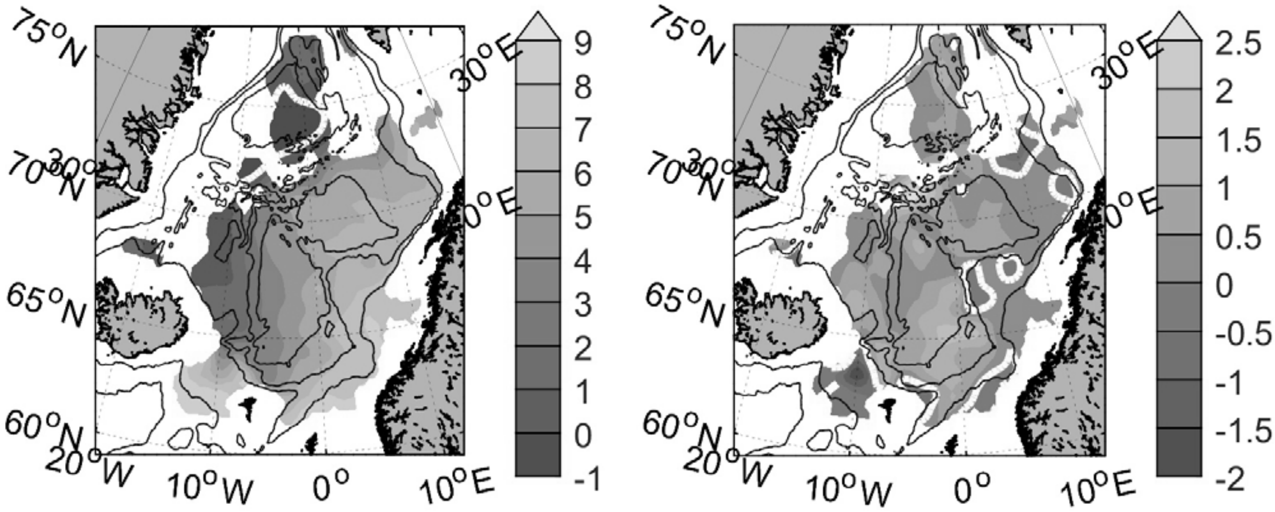


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth in May 2017. Anomaly is relative to the 1995-2015 mean.

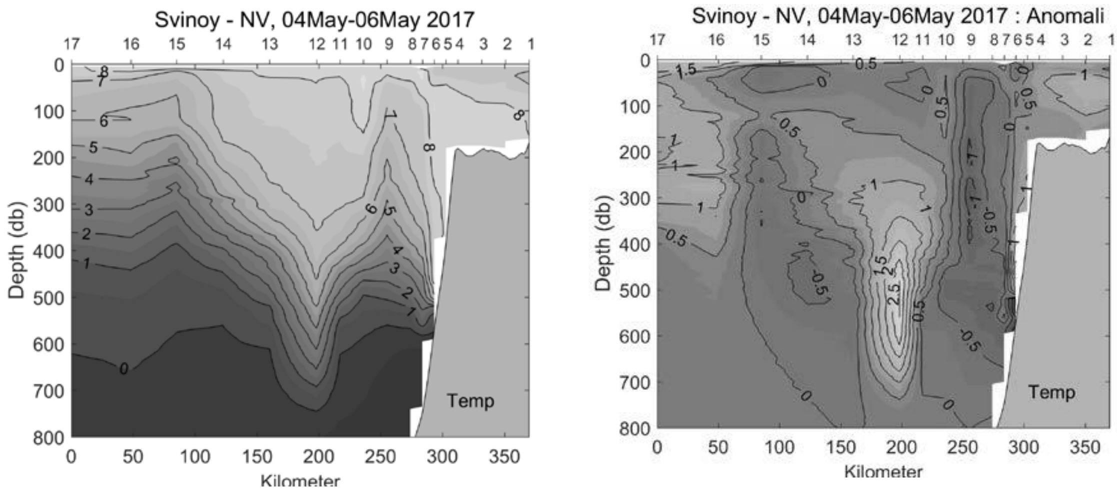


Figure 9. Temparature (left) and temperature anomaly (right) in the Svinøy section, May 2017. Anomalies are relative to a 30 years long-term mean (1978-2007).

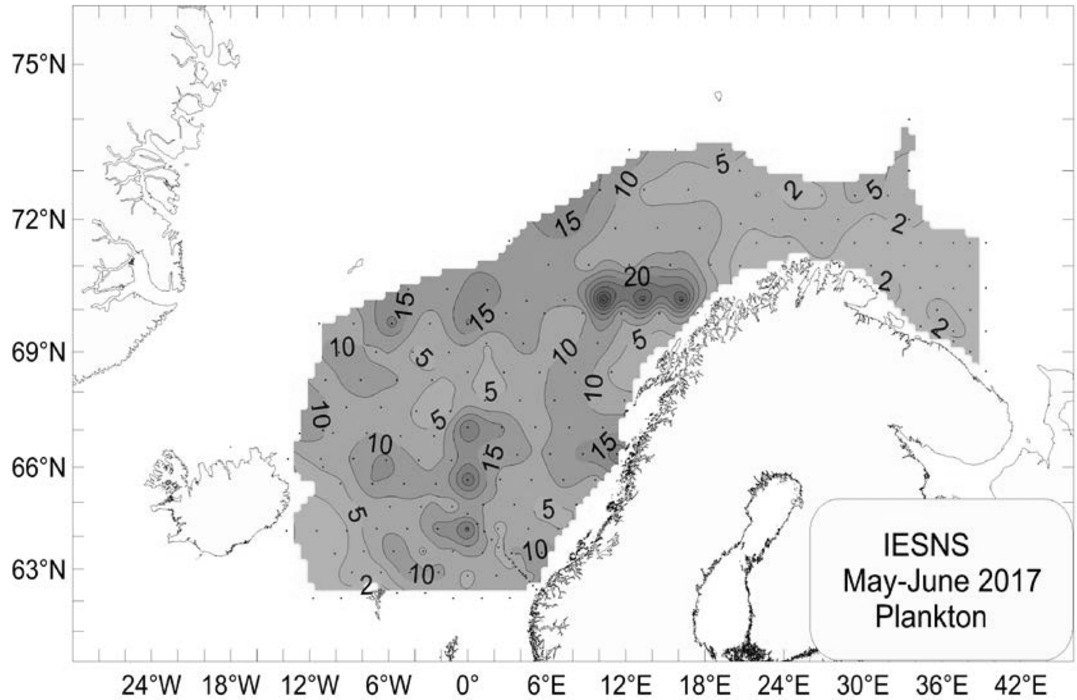


Figure 10. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May-June 2017.

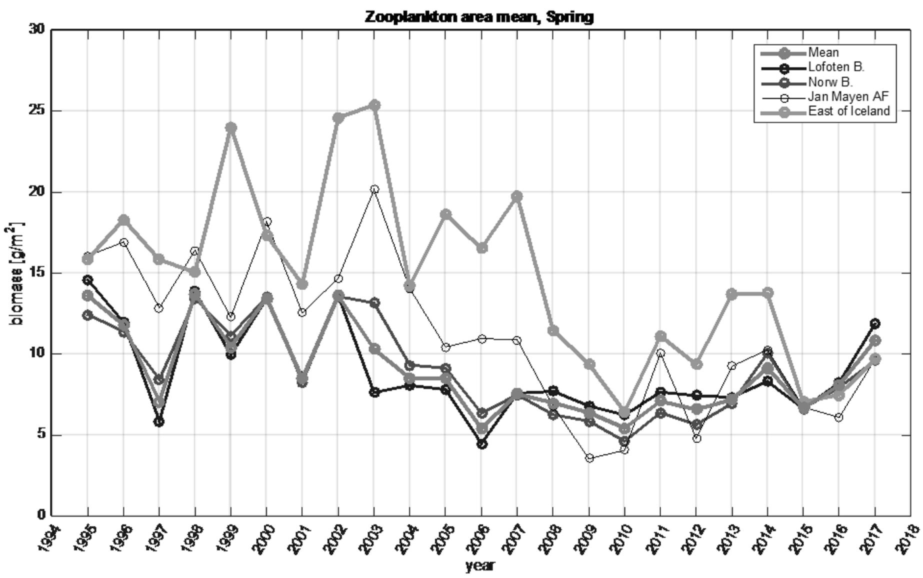
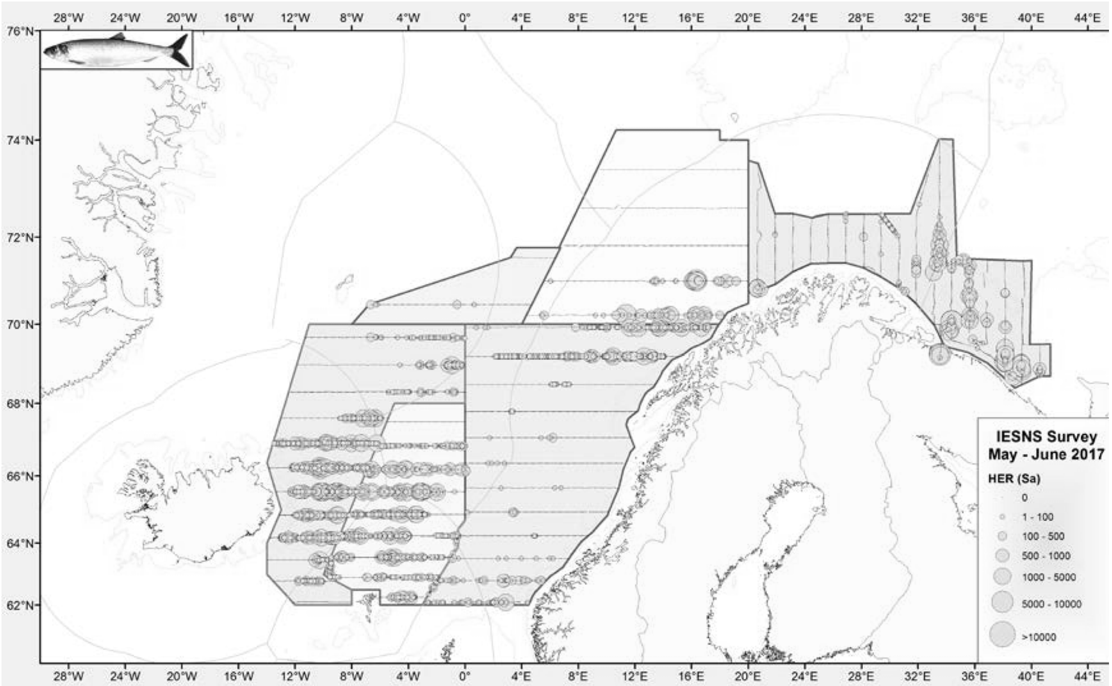


Figure 11. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2017 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

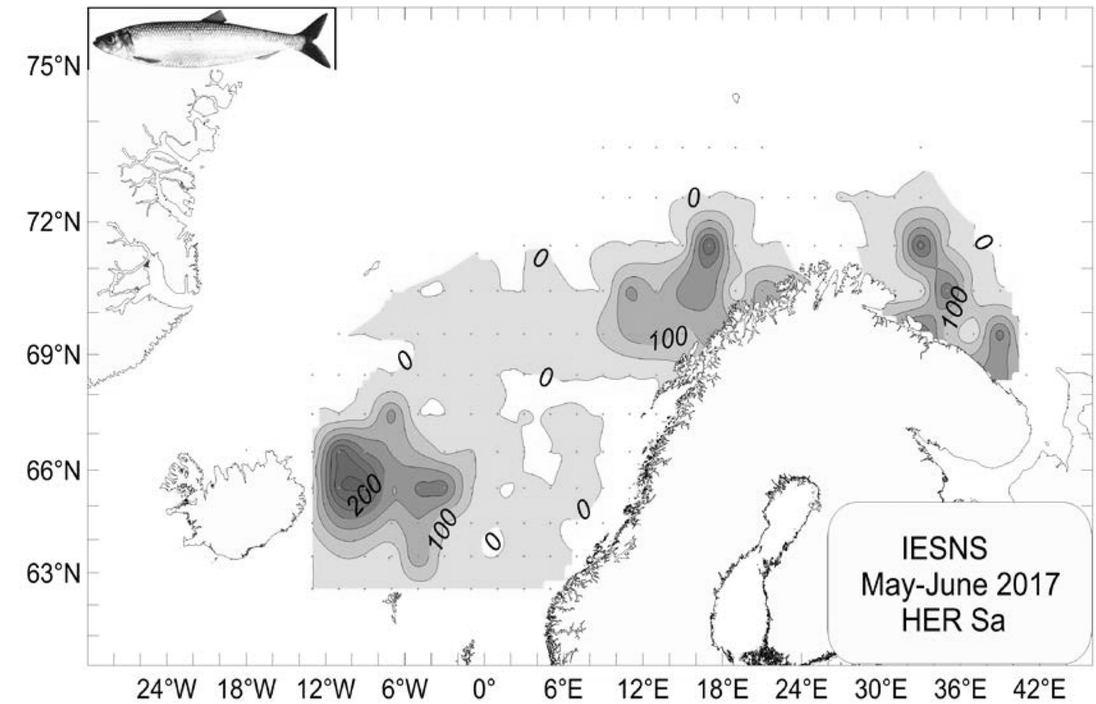


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2017 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

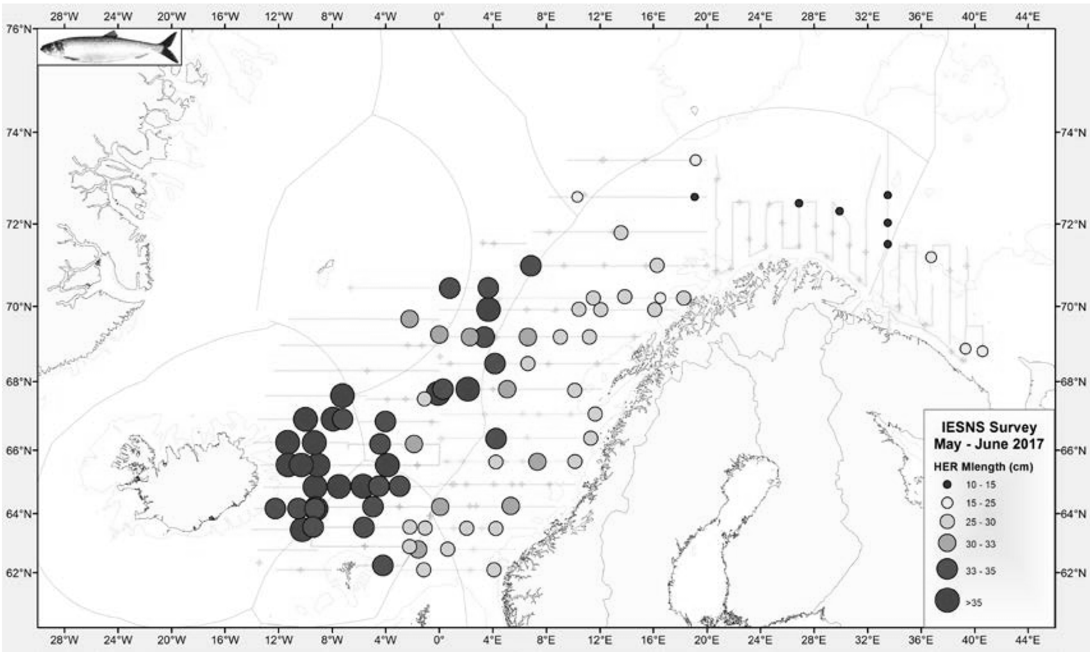


Figure 13. Mean length of Norwegian spring-spawning herring in all hauls in April-June 2017.

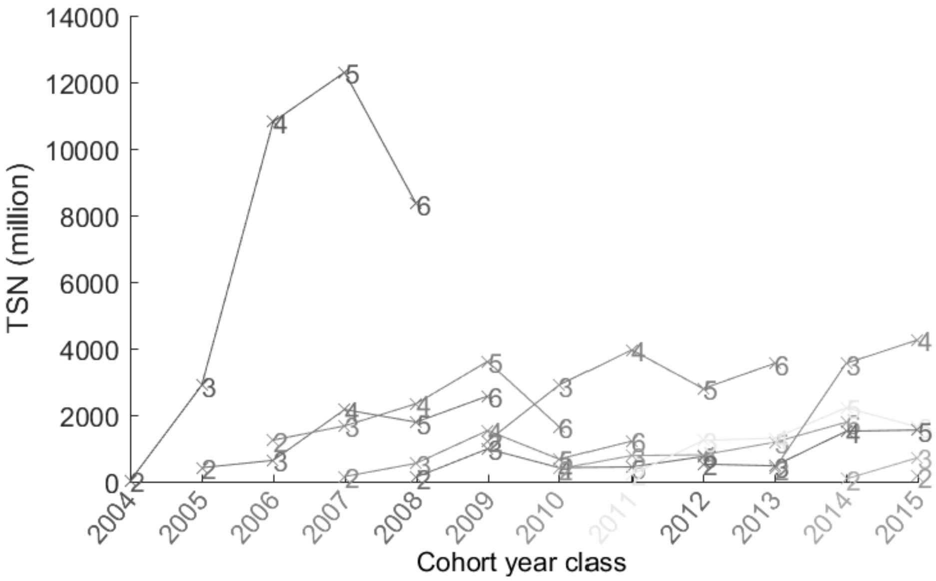


Figure 14. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

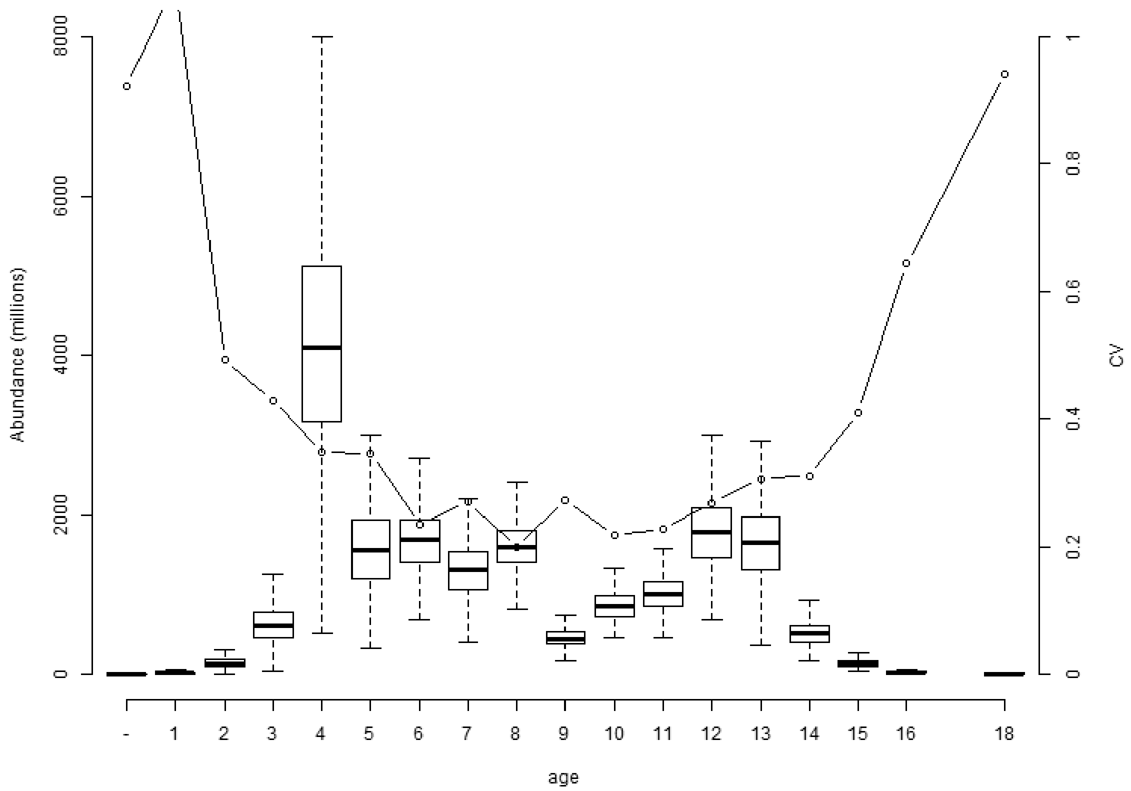


Figure 15. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

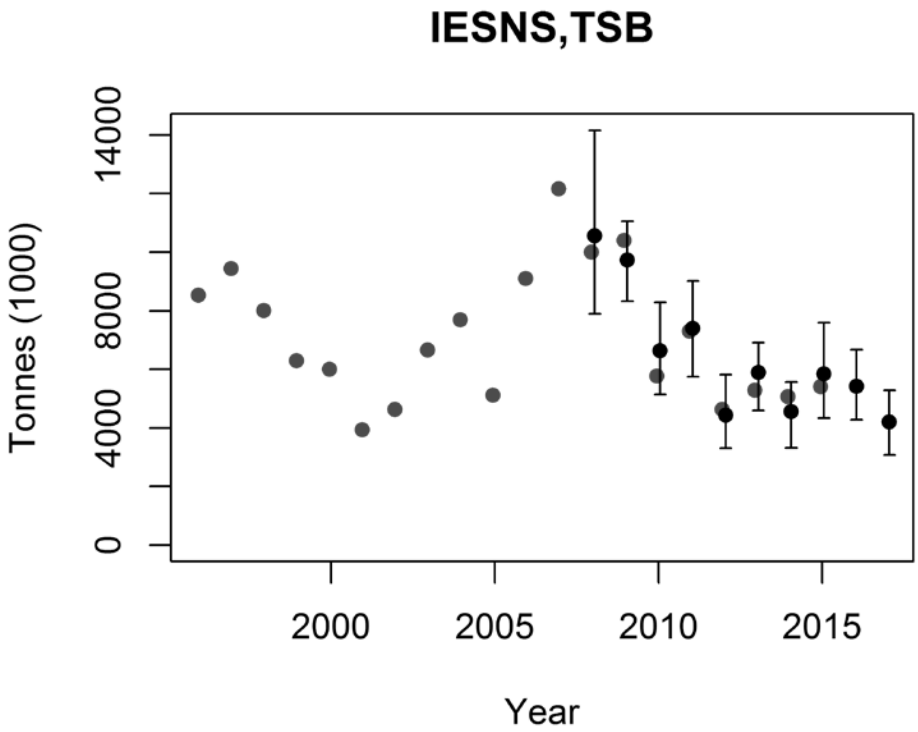


Figure 16. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2017 as estimated using BEAM (red dots; calculated on basis of rectangles) and as estimated with the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).

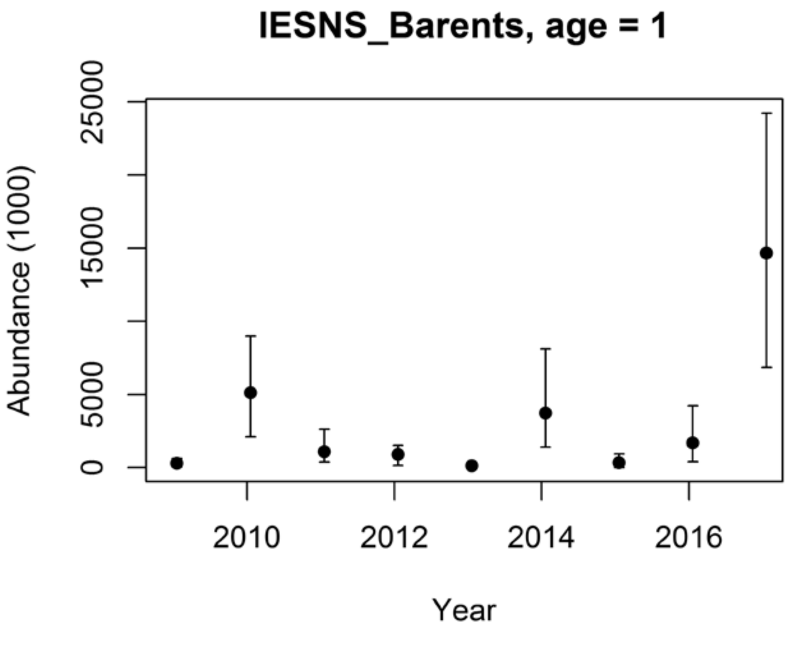
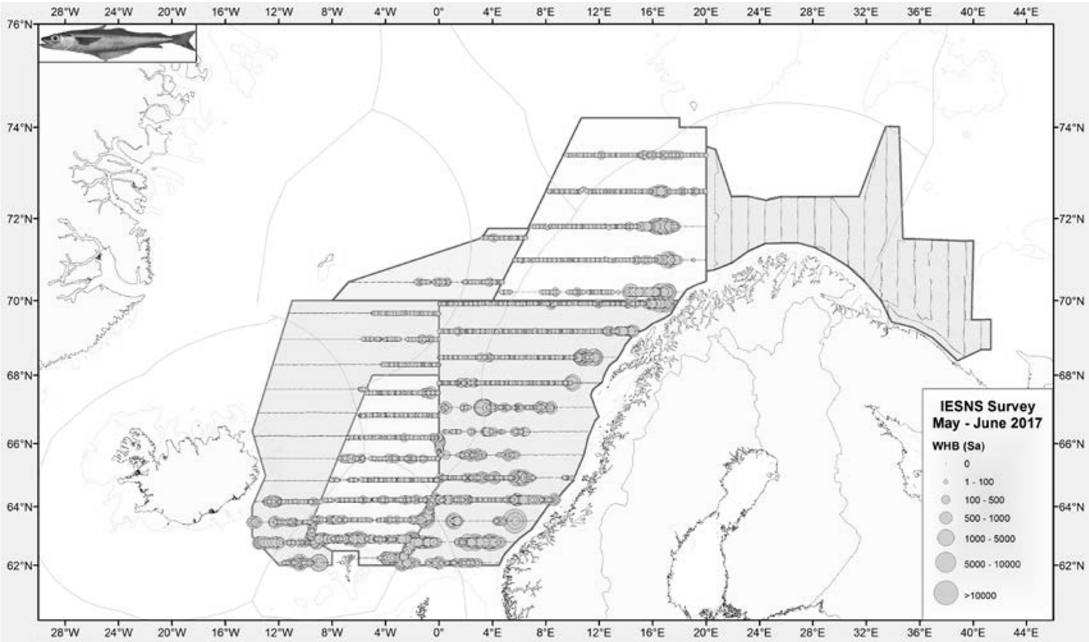


Figure 17. Numbers of one year old herring in the Barents Sea in April-June as estimated with the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).

(a)



(b)

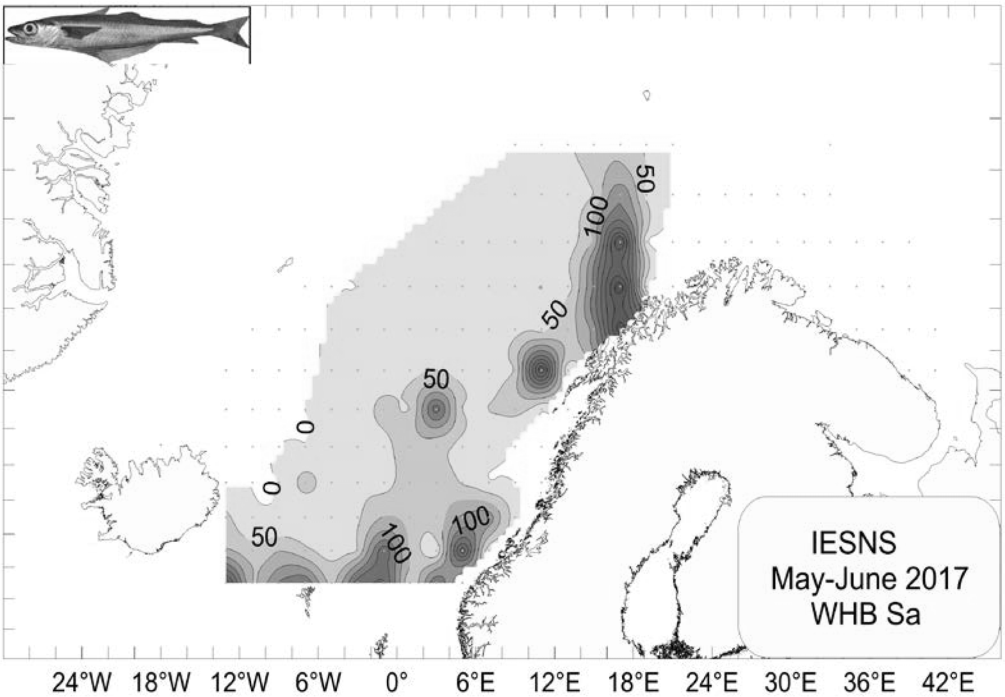


Figure 18. Distribution of blue whiting as measured during the IESNS survey in April-June 2017 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

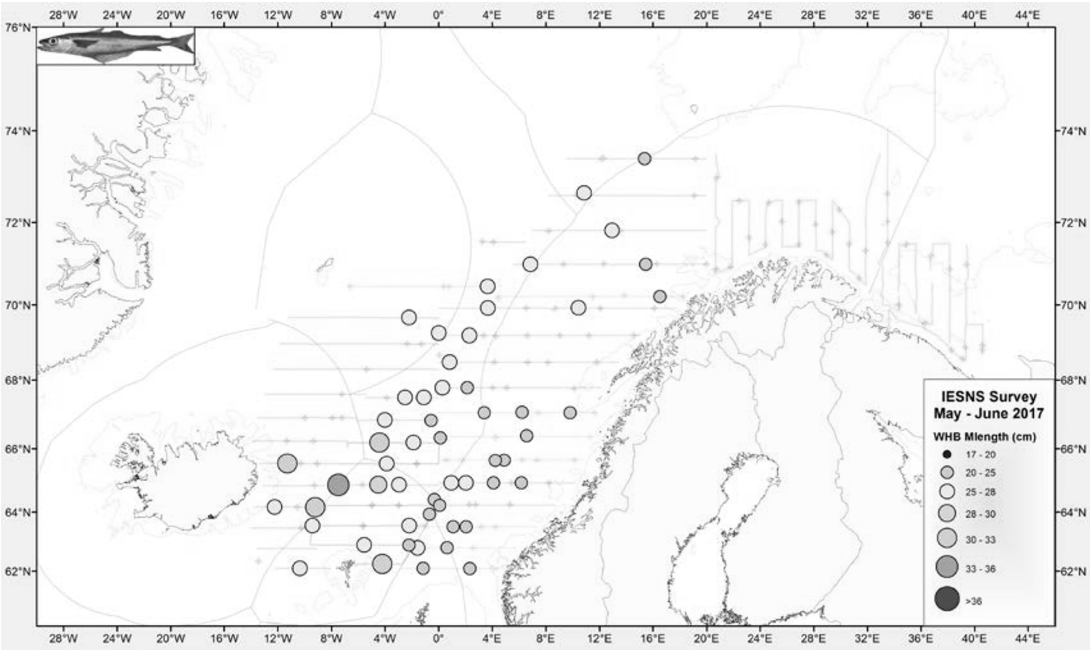


Figure 19. Mean length of blue whiting in all hauls in IESNS 2017.

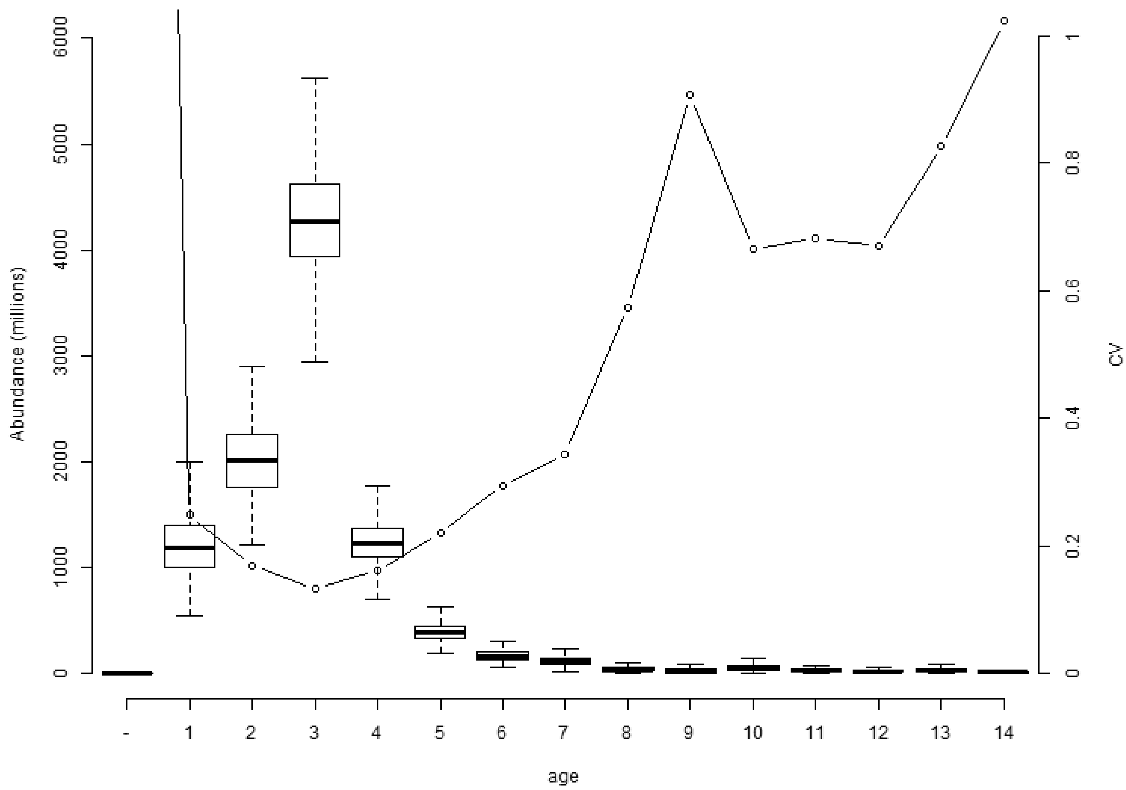


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

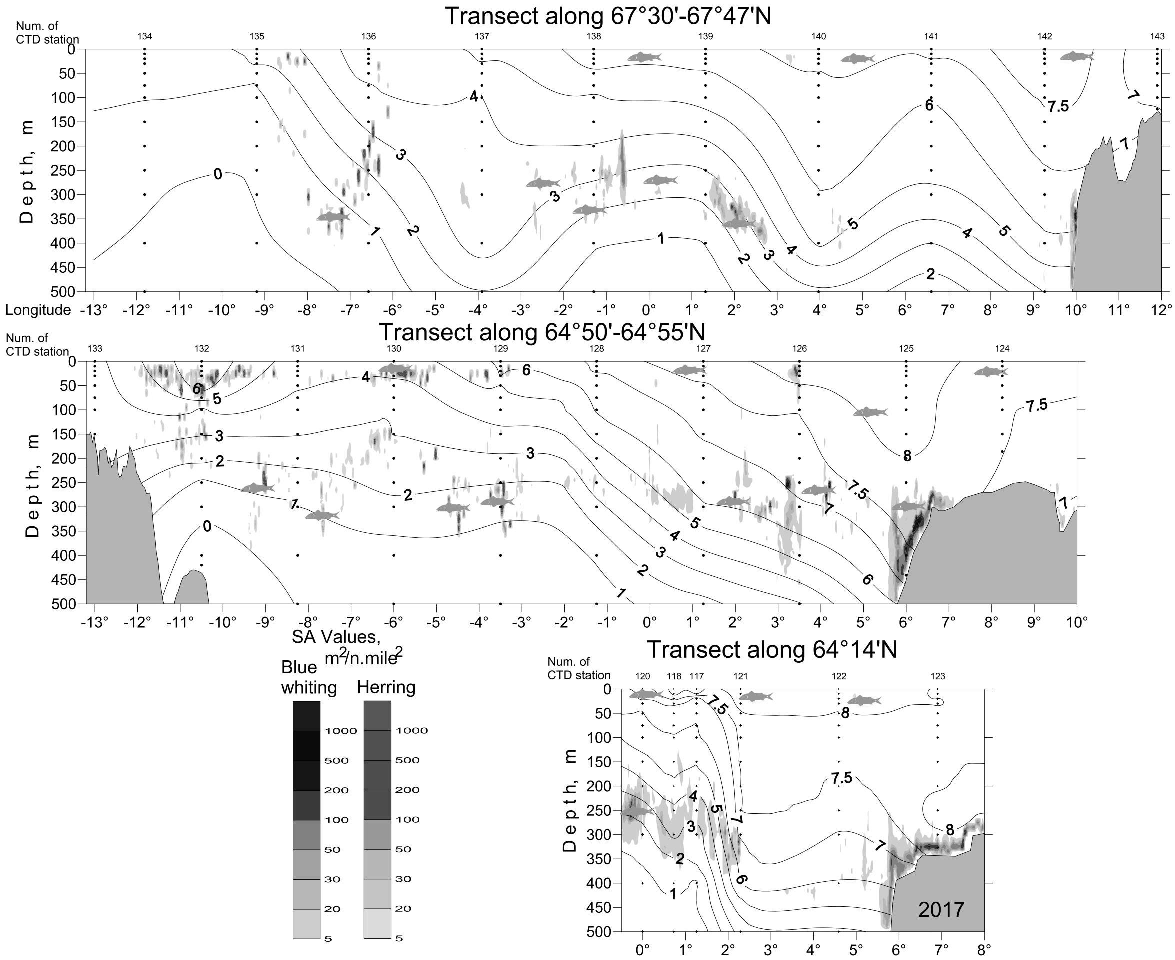


Figure 21. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2017, and one short transect in close to the Norwegian coast covered by "G.O. Sars".

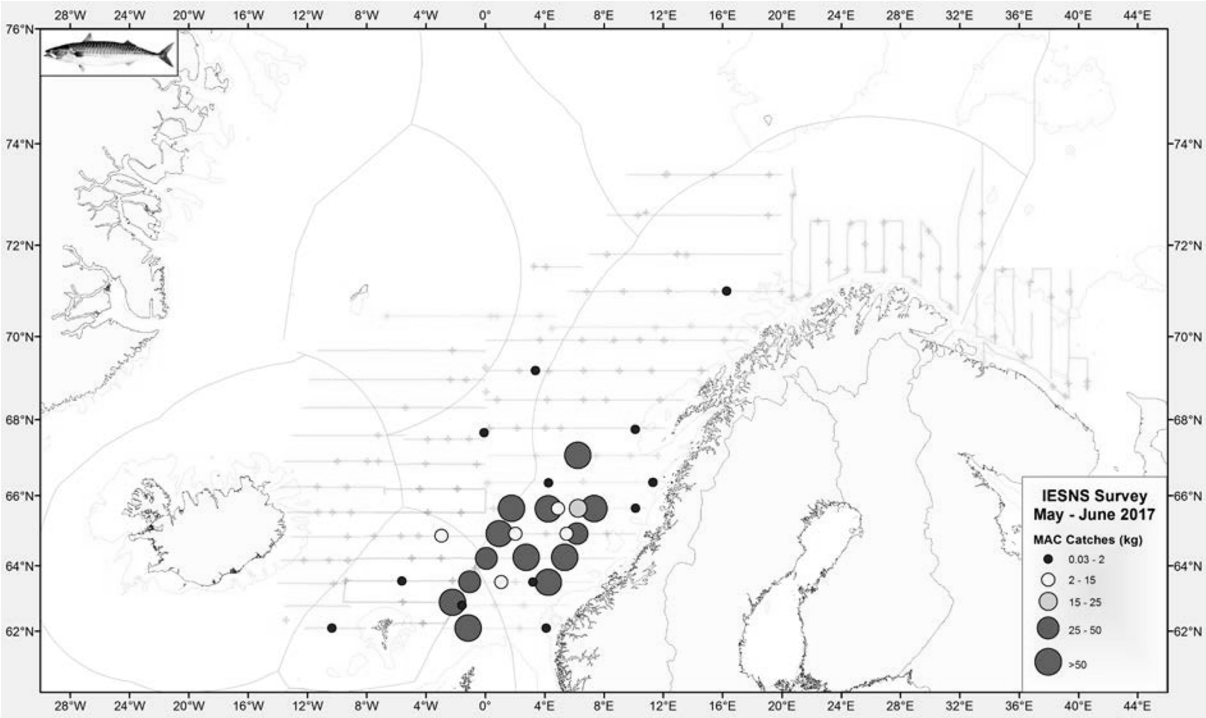


Figure 22. Distribution of hauls containing mackerel and the catch size in the 2017 IESNS.

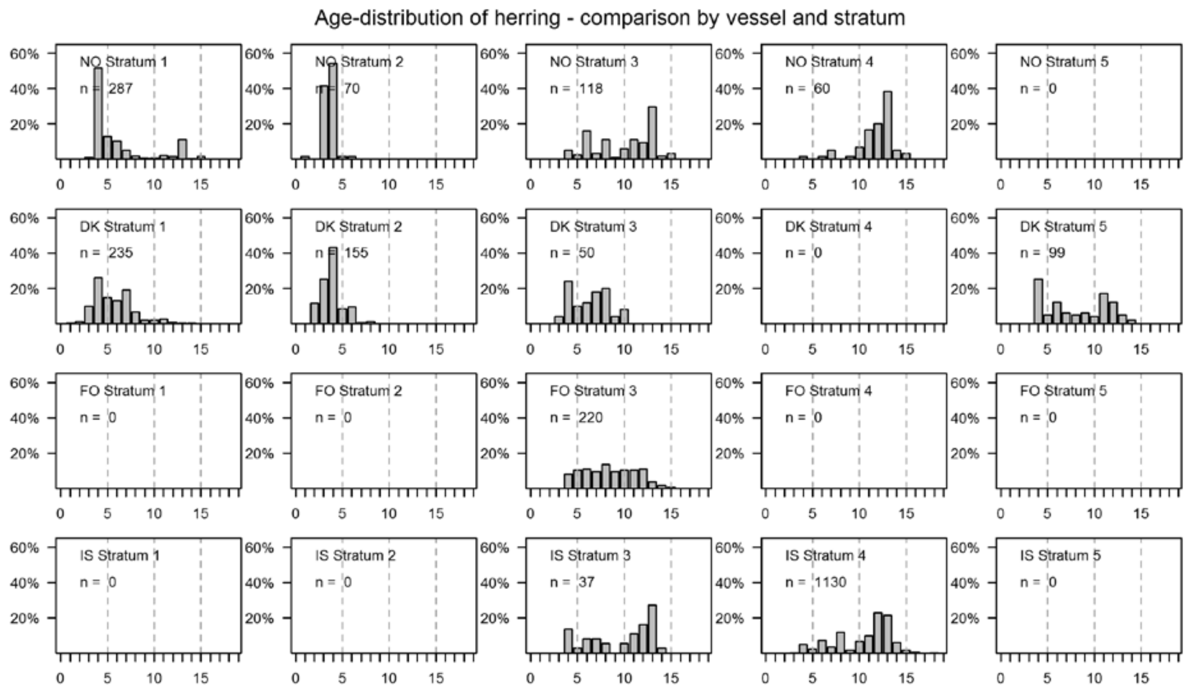


Figure 23. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2017. The strata are shown in Figure 3.

Appendix 1

School observations using omni directional fisheries sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2017

Héctor Peña
Marine ecosystem acoustic group
Institute of Marine research, Bergen, Norway

Introduction

In acoustic trawl surveys on pelagic schooling species, the down-looking narrow beam echosounder is the standard tool used for estimation of fish abundance. An important bias in this method is occurs when fish are distributed in the acoustic blind zone of the echosounder, i.e. between the sea surface and the far field of the transducer. When transducers are mounted in a drop keel below the vessels hull, the blind zone can extend up to 15 m below sea surface. Another source of bias, is the avoidance of the fish aggregations to the approaching surveying vessel, either by swimming away from the vessel track or by diving (De Robertis and Handegard, 2012).

Omni directional fisheries sonar are multibeam acoustic systems using horizontal beams in a 360 deg fan around the vessel alternated with vertical beams in a 180 deg fan. The horizontal beams can be electronically steered, being able to measure the fish aggregations in the upper layers up to the sea surface, at long distances (i.e. kilometers) from the vessel. Similarly, the vertical beams can be steered to form a vertical fanpointing in any direction,in most cases perpendicular to the vessel track, sampling the entire water column, at both sides of the vessel. These technical characteristics, together with the high availability of these instruments in most research and commercial fishing vessels, make omni sonars a potential tool to investigate the blind zone and avoidance bias of the echo sounder sampling.

Efforts from the Norwegian Institute of Marine Research, over last 5 years have allowed the development of calibrationmethods and data processing of omni sonars for single school investigations and from systematic surveys for abundance estimation. In this report, we present the results of an investigation looking at the use of the omni sonars as a tool to identify and quantify the level of bias of the echosounder estimates.

The objectives of the present work are: i) present a new methodology using vertical beams from omni sonars to investigate the presence of schools in the echo sounder blind zone, ii) compare sonar and echo sounder measurementsin the blind zone, and use results as an indicator of bias in echo sounder estimates.

Methods

Data preparation

Low frequencyomni sonar Simard SU90 onboard R/V "G. O. Sars" was calibrated following in Macaulay et al.'s guidelines(2016) prior the start of the survey, on May 3 in Bergen'sharbor. Calibration parameters were computed and applied to the stored data during post-processing. Data was collected continuously all throughout the survey and Raw files where stored in external USB hard drives.

Sonar operating at 26 kHz was synchronized with the SIMRAD EK80 echo sounders to avoid acoustic interference, with the latter set as the master. Sonar settings were optimized for sampling the surface layers between surface and 80 m, with alternated horizontal and vertical beams, at higher ping rate possible of ca. 1 Hz. The 64 horizontal beams were set to a 7 deg tilt, with a range from 0 to 450 m. The 64 vertical beams were set in direction perpendicular to the vessel track, with a 180 deg fan, with a range of 450 m from the vessel. In addition, the noise filter was disabled during the data collection because it affects the raw data.

Data recorded withthe vertical beam number 3 (counting from surface) on both port side and starboard side were converted to echo sounder EK80 raw file format in LSSS (Korneliussen et al,. 2016) using the module Processing system for omni directional fisheries sonar (Profos).

The data between 5 and 80 m range from the vessel were individually scrutinized by beamusing the standard echo sounder postprocessing tools in LSSS. A threshold of -60 dB was used to keep only scatters which correspond to schools. Note that all schools from sonar data were not categorized as species, allocation that was done during the data analysis based in the pelagic trawl data and personal communication with the cruise leader.Data was stored into LSSS database at range channels of 10 m and 1 nmi distance along the vessel track by beam.

The data from the vertical beams was converted from range from the vessel to a depth range below sea surface, by using sonar transducer depth, sonar beam tilt angle and beam width. A schematic representation of one vertical beam and the parameters considered are presented in Figure 1.

The data from the echosounder correspond to the scrutinized EK80 data at 38 kHz done onboard during the survey. In the scrutinized echosounder data, the acoustic category herring was used, but no allocation of acoustic data was done to mackerel. Data was stored in channels of 10 m and 1 nmi distance along the vessel track

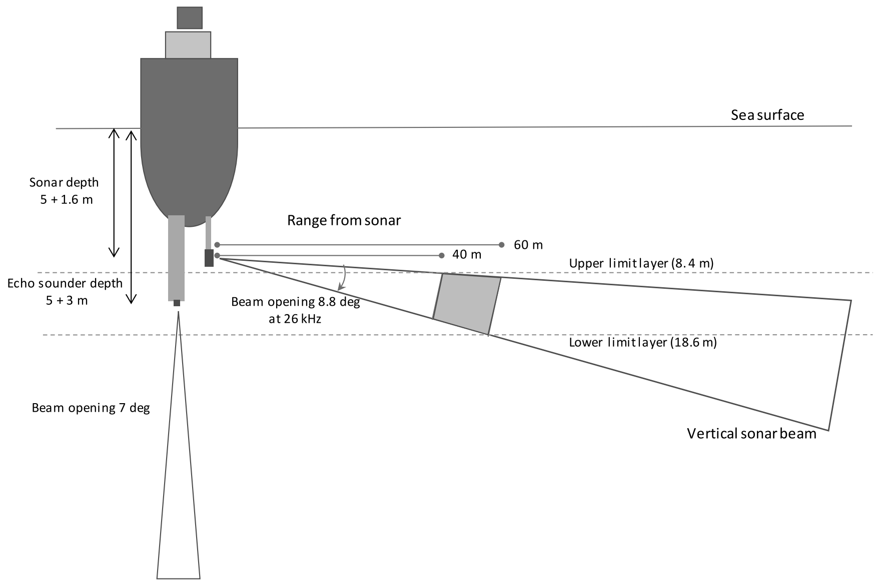


Figure 1. Section view of vessel with schematic description of one vertical beam from SU90 sonar. During operation sonar transducer is lowered 1.6 m below the vessel hull (at 5 m). Also, is included the drop keel where the echosounder transducers are mounted 3 me below vessel hull.

Sonar vertical beam data is displayed in Profos as a half circle with the vessel in the center, with upper beam (at both sides) pointing straight along the depth of the sonar transducer, i.e. 6.6. m for R/V "G.O. Sars"(Figure 2).

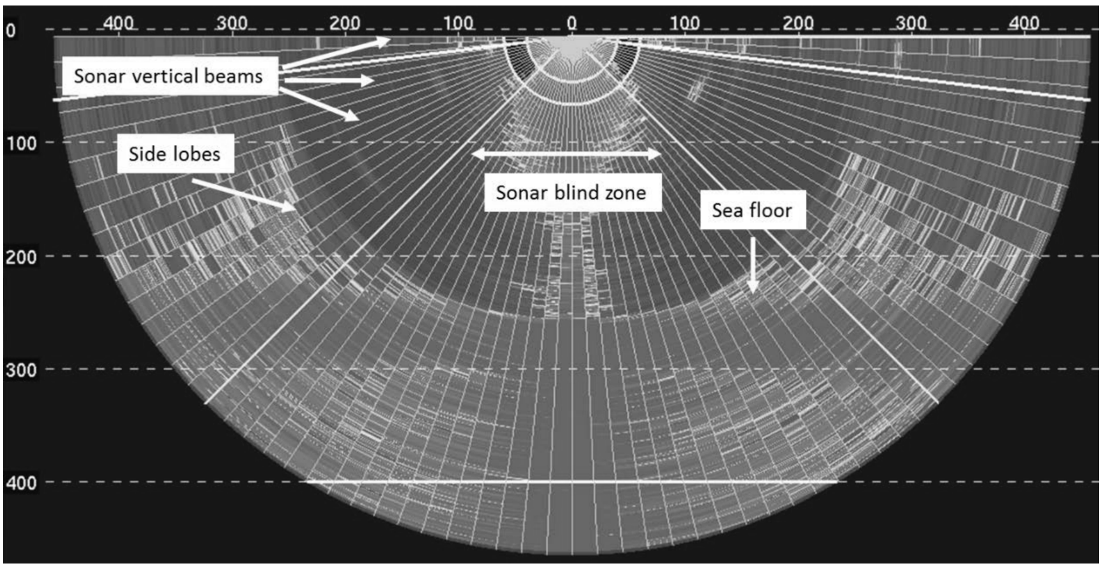


Figure 2. Image of one ping of the complete fan of the vertical beams of the SU90 sonar. A total of 64 beams are displayed up to a range from 0 to 450 m (vessel in 0 m range). This sonar has a cylindrical transducer without acoustic elements pointing directly downwards, therefore, no beams are pointing in that direction generating a sonar blind zone.

Acoustic data from beam 3 from (port and starboard side) was selected from a range between 40 to 60 m from the vessel, which corresponds to a depth range between 8.4 and 18.6 m. This depth range is inside the echosounder blind zone (Figure 3). A comparison between the area scattering NASC from this depth layer from the vertical beam and the EK80 echo sounder data was computed for both transects.

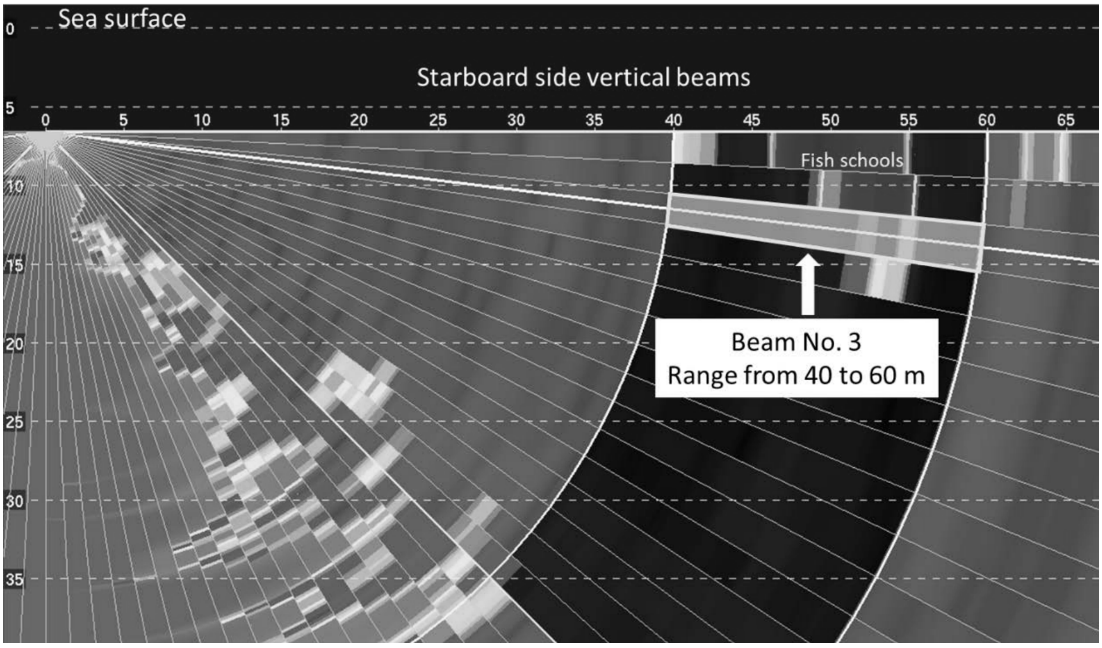


Figure 3. Detail of the vertical beams directed to starboard side. Beam 3 is indicated with a yellow polygon, with upper and lower borders derived from ideal beam shape, and proximal and distal borders by the 40 and 60 m ranges, respectively. Inside this range from the vessel, is possible to observe a fish school (squares colored between yellow and red) distributed from the surface up to beam 4.

A detailed inspection of the echo sounder and sonar data was done to identify those periods when weather conditions were adverse, and large amount of air bubbles were swept below the sea surface reaching up to 20 m. Sonar acoustic data from these periods were excluded from both single schools and vertical beams processing.

Due to time constrains, two transects were processed at the time the submission of the current report, and the results are presented here. Transect centered in latitude 65°N from the coast of Norway to Iceland at the beginning of the survey from 8 to 13 of May, and transect centered in 70°N off the coast of Tromsø, from 22 to 26 May, both transects with sailing direction East to West.

Analyses

To investigate the presence of fish in the echo sounder blind zone, a combined analysis of the data from the sonar vertical beams and the scrutinized data from the EK80 echo sounder was conducted.

Area scattering (NASC) from the sonar and echosounder data were exported as LSSS database outputsand processed in software R (R Core Team, 2015). First, an analysis of the consistency between NASC measurements of beam 3 from port and starboard side, by t-test and linear correlation. For comparing the sonar and echosounder, data were split by transects and plot along the vessel track.

Results

Sonar data storing during most of the survey was adequate, with only reduced periods when the sonar stopped operating and some data was lost before the system was restarted. Data storing rate was 2 GB per hour, with a total of 1.3 TB for the whole survey for R/V "G. O. Sars". A sonar log was completed indicating the more relevant features encounter, i.e. presence of school, bad weather conditions, etc. Also, a daily quality control of the raw data was done loading some files into the post processing system Profos ensuring that all basic information was stored in the files (i.e. navigation, transmission power, etc.).
An example of echo sounder and sonar data along a transect is presented in Figure 4. As both sources of acoustic data contain GPS and synchronized time, simultaneous visualization is possible, and facilitates the interpretation of the sonar data and the school segmentation process.

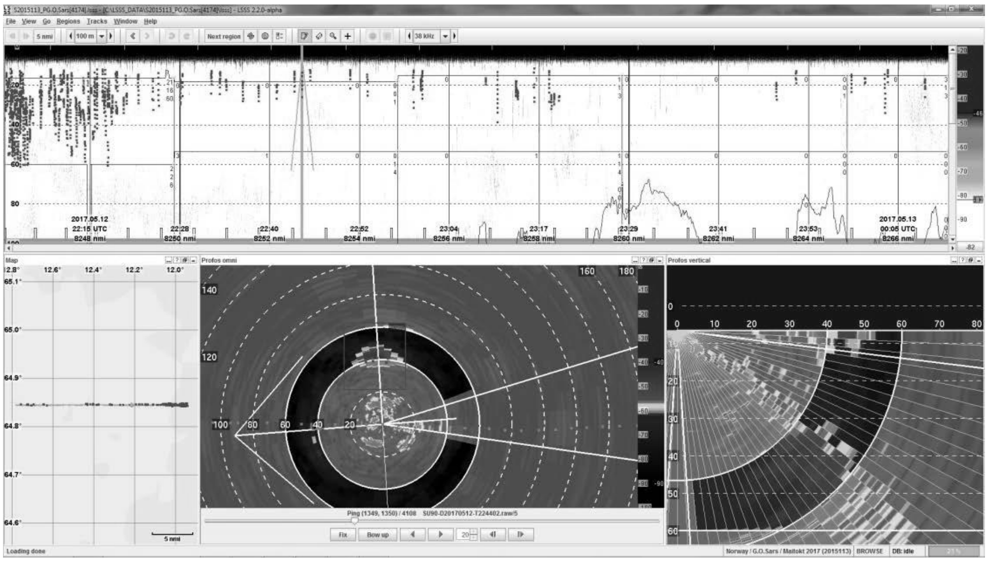


Figure 4. Screen dump from post processing system LSSS, showing ca. 18 nmi of EK80 data from 38 kHz (upper panel) and a map with the position of the transect (bottom left panel). The horizontal beams of the SU90 sonar from one ping zoomed to a range of 180 m with the vessel in the center and an arrow pointing West in sailing direction (center bottom panel). In the same panel and up from the vessel position is observed a colored oval shape (green to red) which correspond to a school in a range between 35 to 50 m from the vessel, marked with a red square. The vertical beams from the starboard side of the vessel, set as a fan across the vessel track, show the same school detected for at least 4 vertical beams at 40 m range, from the surface up to a depth of ca. 15 m.

Sonar data quality

During adverse weather conditions, sonar data is also affected by the large amount of bubbles present in the upper 30 m. As the primary objective of tis report was to investigate the echo sounder blind zone, data from both horizontal and vertical beams was discarded during these periods, because of the inability to discriminate between school and bubble scatters, in the uppermost beams. An example of this adverse conditions is showed in Figure 5.

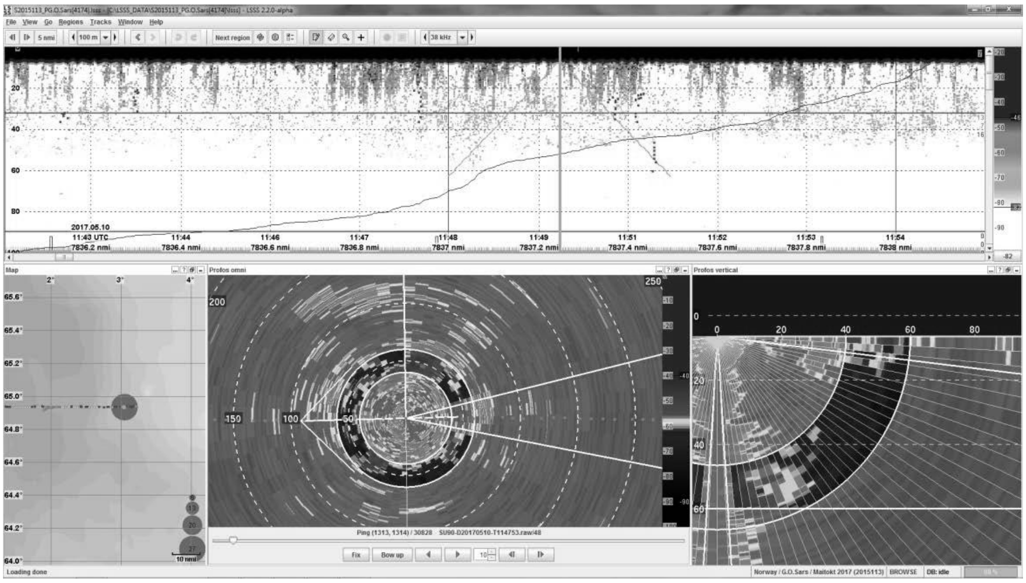


Figure 5. Figure showing acoustic data during adverse weather conditions. EK80 data show rather strong backscatters from the surface up to 30 m product of air bubbles swept down the sea surface (top panel). In the horizontal sonar beams, these bubbles are observed as strong scatters (colors orange to red) almost homogenously distributed up to a range of 150 m from the vessel (central bottom panel). In a zoom of the vertical beams display, the bubble layers are observed as a continuous strong echoes from the surface up to 20 m depth, from the vessel up to 60 m range (right bottom panel).

Consistency between sonar beams

A comparison between area scattering values of beam 3 from port and starboard side for both transects was analyzed (Figure 6). The aggregated transect data showed higher values from port side (p-value = 1.02e-05, mean NASC port = 17.8 m^2 nmi^{-2}, mean NASC starboard = 27.2 m^2 nmi^{-2}). A priori was expected similar NASC values from both sides, and the difference encountered can be explained by the sailing direction East to West in both transects. Although the sonar beams are electronically stabilized, results indicates that beams at both sides of the vessel are not sampling the same depth ranges, and a prevalent vessel roll angle occurs that is not compensated. A comparison of the same beams at different sailing directions will be done later.

Although this difference, measurements from both sides are highly correlated and provide an indication of the presence and relative abundance of school scatters in this layer. We have chosen arbitrary the data from starboard side to be compared with the echo soundermeasurements.

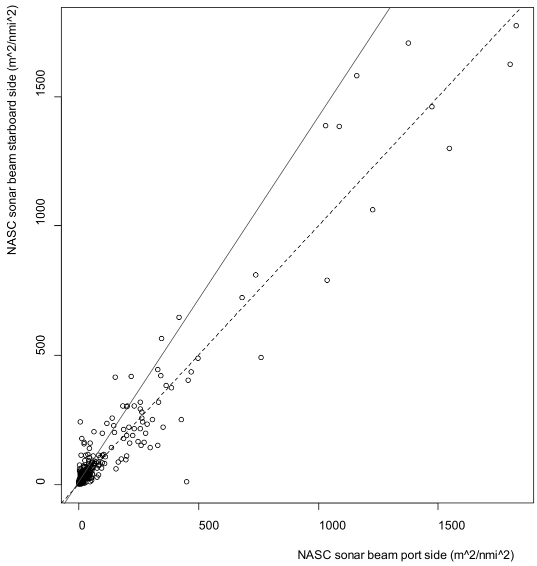


Figure 6. Area scattering NASC values of beam 3 from port and starboard side, for a depth layer between 8.4 and 18.6 m. Red line indicates the linear regression and the black dashed line, the 1:1 curve.

Echosounder and sonar data comparison

The NASC values,in the upper layer between 8 and 19 m depth, along transect at 65°N showed almost continuous school scatters from 10°E to 4°E (Figure 7). To the East no data was available due to bad weather conditions. Around 0°and up to 3°W, more and stronger NASC values were found. Along this sailed distance two surface pelagic trawls confirmed that scatters observed in the sonar data correspond to mackerel. In this same region, no herring was allocated to the EK80 data, except for a few data points around 4°E, which matches the slight increase in the NASC values from the sonar. West from 5°W, another two pelagic trawl indicated the presence of herring in the surface layer above 50 m. From 9°W to about 7°W, high NASC values were measured both by sonar and echosounder. However, in the last part of the transect,close to Iceland, no herring was allocated in the echosounder data, while high values were measured in the sonar.

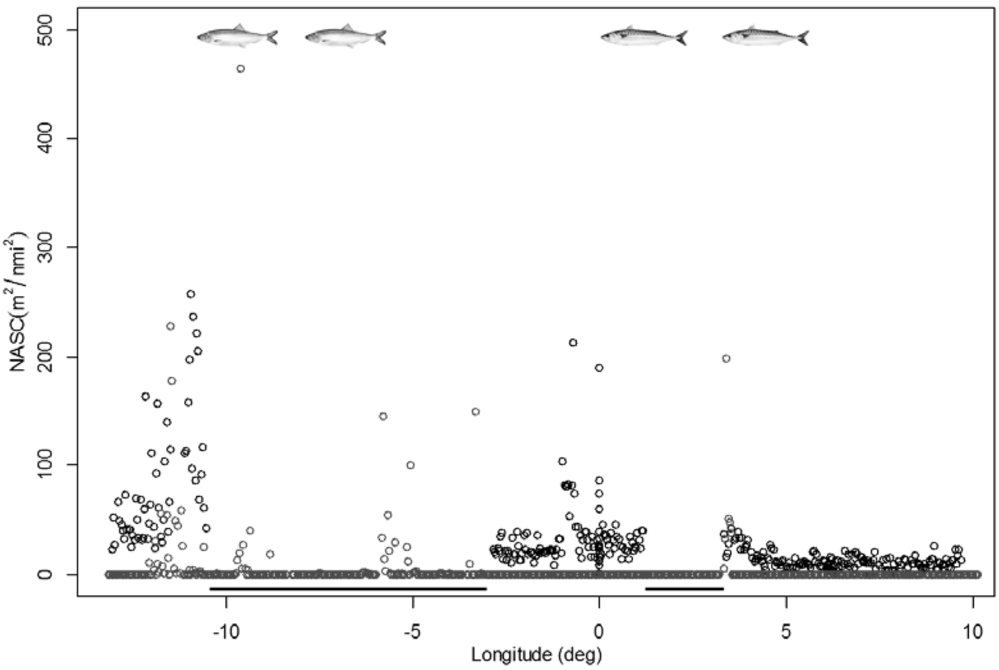


Figure 7.Area scattering along transect centered in 65°N. NASC values from sonar vertical beam (red circles) and echosounder data (black circles). Also indicated the longitude where pelagic trawl stations were made and predominant species (i.e. mackerel and herring). Black continuous line above the X axis indicate periods where sonar data was excluded from the analysis due to bad weather conditions.

Along the transect in the northern region, centered in 70°N, three pelagic trawls indicated the dominance of herring in the surface layer (Figure 8). From the East until about 12°E, high values of NASC were measured by sonar and echosounder in the upper layer between 8 and 17 m depth, reflecting the presence of herring schools in this region. From about 8°E to the East, sonar measurements indicated the presence of herring schools in the upper layer, but no NASC allocation for this species was done in the echo sounder data, except for 1 value (i.e. 1 nmi integrated value) close to the end of the transect.

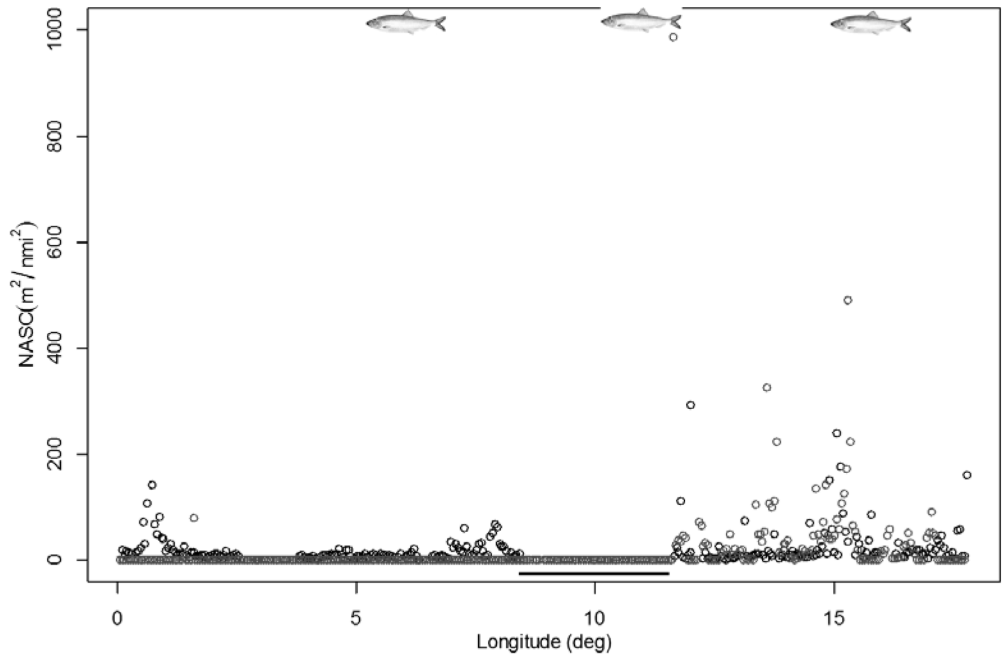


Figure 8. Area scattering along transect centered in 70°N. NASC values from sonar vertical beam (red circles) and echosounder data (black circles). Also indicated longitude where pelagic trawl stations were made and predominant species (i.e. herring). Black continuous line above the X axis indicate periods where sonar data was excluded from the analysis due to bad weather conditions.

Discussion

This report presents a rather simple and fast approach to process vertical beams from sonar data, comparable to the amount of time required to process the echosounder data.

In the present work, sonar data from vertical Beam 3 was analyzed. Beams with a higher tilt (i.e. Beam 1 and 2) were not used because of presence of surface reflection scatters during part of the survey with adverse weather conditions. However, in days with calm seas, the upper beams provided valuable data that will be analyzed later.

The transformation of the sonar data from range along a vertical beam to depth was done using theoretical computations based in transducer location and beam geometry. At the rather short ranges of the sonar data (40 to 60 m), is not expected any ray bending, therefore we estimate that the depth computed is accurate.

Unexpected higher NASC values from the vertical beam pointing to starboard side may indicate a non-random vessel roll when sailing East to West, with the consequent sampling of different depth layerswith respect to the beam pointing to port side. More work is needed to confirm this hypothesis.

The comparison between the sonar and the echosounder data for a depth interval between 8 and 18 m, indicated a general good agreement in some periods of the two transects analyzed. However, in the western end of transect along 65°N close to Iceland, no herring was allocated to the echosounder data, when the sonar measurements indicated the contrary. More dramatic is the difference found in the northern transect, centered in 65°N, where in about 8 deg in longitude (ca. 150 nmi) no herring was allocated to the depth layer analyzed. These results may indicate an underestimation of the herring abundance from the echo sounder measurements, in the specific regions where data was processed. The next step is to investigate methods for the quantification of this underestimation.

References

De Robertis, A. and Handegard N. O., 2012. Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review- ICES Journal of Marine Science, 70: 34–45.

Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., & Eliassen, I. K. (2016). Acoustic identification of marine species using a feature library. Methods in Oceanography, 17, 187-205.

Macaulay, G. J., Vatnehol, S., Gammelsæter, O. B., Peña, H and Ona, E. 2016. Practical calibration of ship-mounted omni-directional fisheries sonars. Methods in Oceanography, 17: 206-220

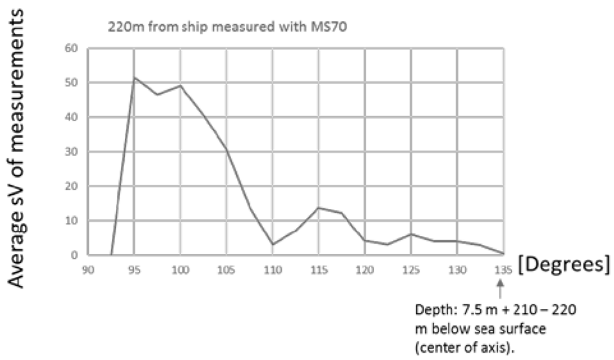
Peña, H., Handegard, N. O. and Ona, E. 2013. Feeding herring schools do not react to seismic air gun surveys. – ICES Journal of Marine Science, 70: 1174–1180.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Appendix 2

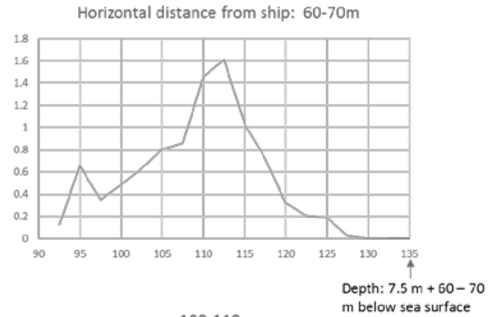
School observations using scientific multibeam sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2017

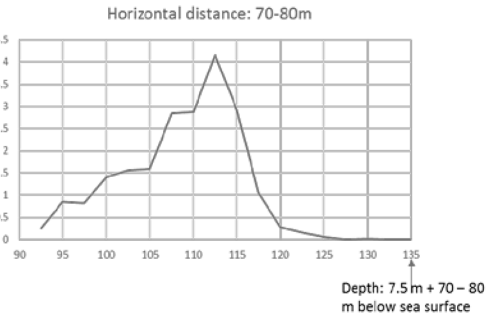
Rolf Korneliussen
Marine ecosystem acoustic group
Institute of Marine research, Bergen, Norway

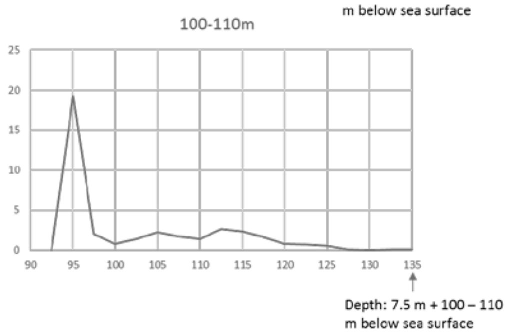


90 degrees means that center of upper fan is horizontal. Center of MS70 transducer is 7.5 m below surface. The three uppermost fans will hit the surface at varying ranges in calm weather, and even more in bad weather. Average all days until 2017.05.23, the weather was mostly good. At 210 – 220 m, the two uppermost beams has hit the surface already, and the upper edge of the third uppermost beam is approaching the surface, while its centre is pointing 5 degrees down. Note that Data was only stored with MS70 down to 180 m

Thus, it is measured fish that may be «at» the surface, but the sonar resolution cannot tell if the fish is on the surface or 40 m below the surface. The center of the beam is 25 m below the surface.

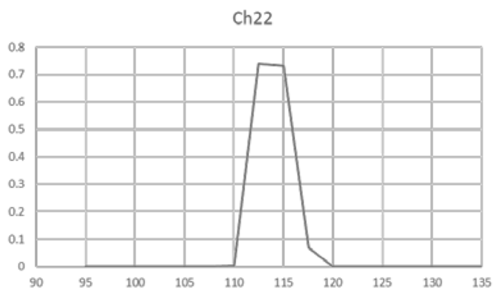




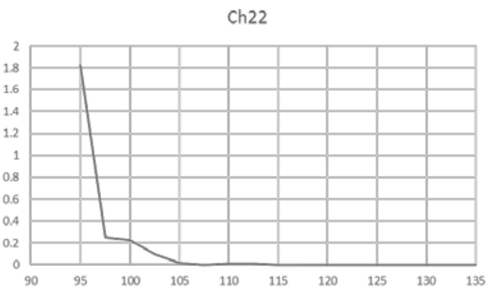


Notice that the s_V is larger at larger distances

All days until 2017.05.23, herring



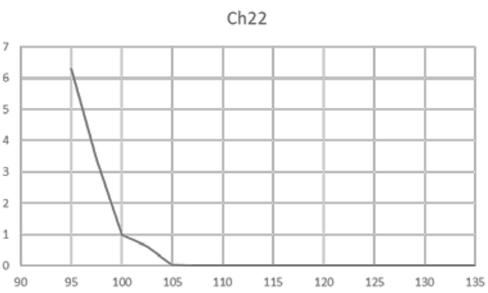
2017.05.07



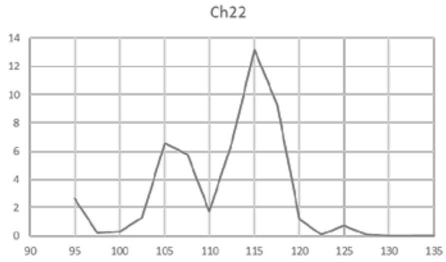
2017.05.08

2017.05.09: Essentially no herring

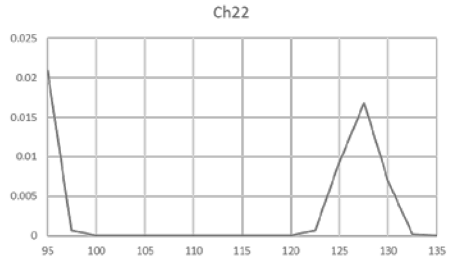
2017.05.10: Essentially no herring



2017.05.11

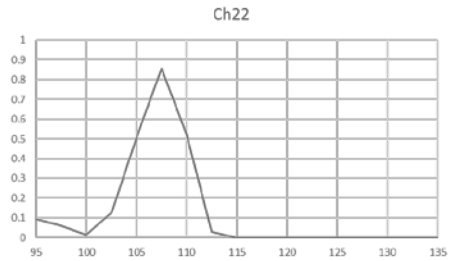


2017.05.12

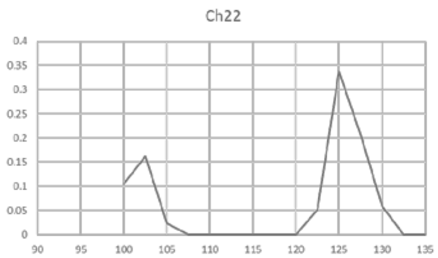


2017.05.14

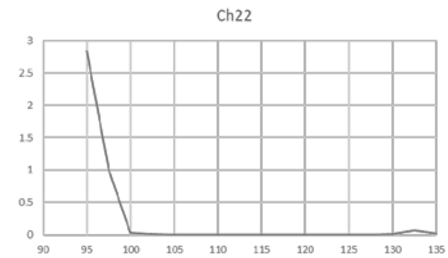
2017.05.15 no PROMUS data



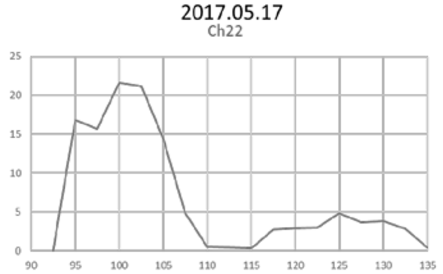
2017.05.16



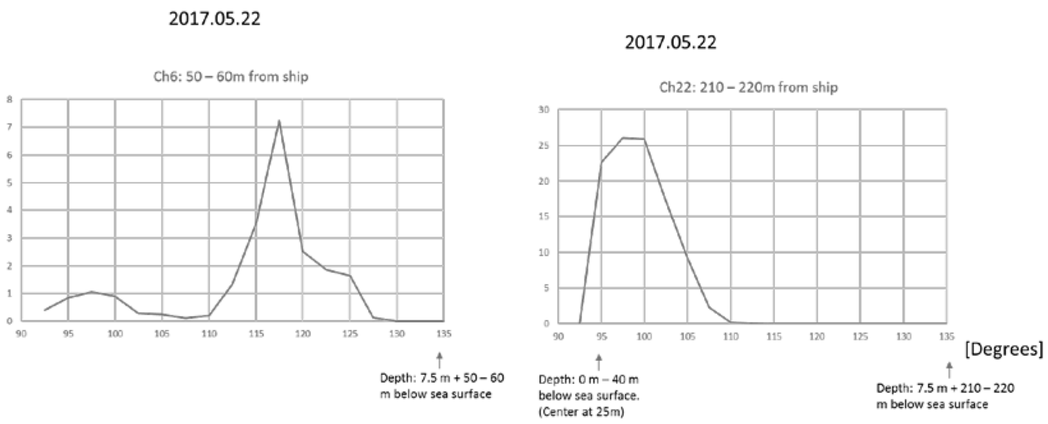
2017.05.17



2017.05.20



2017.05.21



2017.05.22 is the part of the stock close to the Norwegian coast. The depth distribution here is representative for herring close to the Norwegian coast.