Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE), ICES HQ, Copenhagen, Denmark, 30. August – 5. September 2017

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V ”Kings Bay”, M/V “Vendla”, M/V “Tróndur í Gøtu”, M/V “Finnur Fríði” and R/V “Árni Friðriksson”, 3rd of July – 4th of August 2017

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1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 4 weeks from July 3rd to August 4th in 2017 using five vessels from Norway (2), Iceland (1), Faroe Islands (1) and Greenland (1). The main objective is to provide annual age-disaggregated abundance index, with an uncertainty estimate, for the NEA mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 ICES mackerel benchmark. A standardised pelagic swept area trawl method is used to obtain abundance index and to study the spatial distribution of mackerel in relation to other abundant pelagic fish stocks and to environmental factors in the Nordic Seas, as has been done annually since 2010. Another aim is to construct new time series for blue whiting (*Micromesistius poutassou*) abundance index and for Norwegian spring-spawning (NSS) herring (*Clupea harengus*) abundance index. This is obtained by utilizing standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations.

The mackerel index 2017 increased 13% for biomass and decreased 2 % for abundance (numbers of individuals) compared to the mackerel index in 2016. The most abundant year classes were 2010, 2011, 2012 and 2014 with 19 %, 19 %, 14 % and 15 % (in numbers). The incoming 2016-year class appears abundant and is larger than the 2015-year class. Mackerel cohort internal consistency has improved by adding the 2017 survey data to the time series. Internal consistency is strong for ages 1 to 5 years (r > 0.8) and a fair/good internal consistency for ages 5 to 11 years (r > 0.5), except for 6-7 years old mackerel. The survey coverage area was 2.8 million square kilometres in 2017 which is 7% smaller than in 2016. Mackerel was observed in most of the survey area. Distribution zero boundaries were found in westward areas, in Icelandic and Greenlandic waters, in northward areas near Jan Mayen and Bear Island, and also in northeast areas in the southern Barents Sea.

The NSS herring index in 2017 increased by 2% in numbers, but the biomass declined 10.5% compared to 2016. The acoustic measurements of Norwegian spring-spawning (NSS) herring was dominated by 4 years old (2013-year class) in terms of numbers and biomass. Distribution is age segregated with mature individuals (> 5 years) located at frontal areas north of Iceland, and in the areas east of Iceland and north of Faroe Islands. The recruiting year class (4 years old) was mainly distributed in the north-eastern part of the Norwegian Sea and it contributed with 19% of the total biomass index. The blue whiting index in 2017 decreased by 19 % in numbers and increased by 3.5 % in biomass, compared to 2016 (when excluding the 0-group). The acoustic measurements of blue whiting were dominated by 3-year olds (2014-year class) in terms of both numbers and biomass. Blue whiting was found in the whole survey area that was dominated by warm Atlantic waters, i.e. the Norwegian Sea, east, south and west of Iceland. The spatio-temporal overlap between NEA mackerel and NSS herring in July-August 2017 was highest in the south-eastern, southern and south-western parts of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSS herring in the central and northern part of the Norwegian Sea. Herring was most densely aggregated in areas where zooplankton concentrations where high compared to other regions. Mackerel, on the other hand, was distributed in most of the surveyed area, and in areas with more varying zooplankton concentrations.

Other fish species also monitored are lumpfish and Atlantic salmon. Lumpfish of all sizes were caught in the upper 30 m of the water column. They were practically distributed everywhere within the total surveyed area from west of Cape Farwell in Greenland to western part of the Barents Sea. The largest individuals were consistently found in the north-western and northernmost part of the surveyed area. A total of 36 North Atlantic salmon were caught, mainly in central northern and north-western part of the Norwegian Sea.

Environmental conditions showed moderate changes when comparing 2017 to 2016. Sea surface temperature (SST) in July 2017 was similar to temperatures in July 2016 throughout most of the survey area. The 2017, SST was 1-2 °C higher than the long-term average (20-year mean) in central and northern part of the Norwegian Sea, but similar or colder in southern part of the Norwegian Sea and in southern Icelandic and Greenland waters. In 2017, the average zooplankton index for the Norwegian Sea was slightly lower

(7.6 g m^{-2}; n=158), while the index was approximately 100% higher in Icelandic waters (8.4 g m^{-2}; n=50) and Greenlandic waters (16.5 g m^{-2}; n=25), compared to in 2016.

Opportunistic whale observations were done by M/V “Kings Bay” and M/V “Vendla” from Norway in addition onboard R/V “Árni Friðriksson” from Iceland. Overall >700 marine mammals and 8 species were observed, representing a substantially higher number of sightings compared to previous years.

2 Introduction

During approximately four weeks of survey in 2017, five vessels; the M/V “Kings Bay” and M/V “Vendla” from Norway, and M/V “Tróndur í Gøtu” from Faroe Islands, the R/V “Árni Friðriksson” from Iceland, and the M/V “Finnur Fridi” operating in Greenland waters, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS). The highly coordinated IESSNS survey in space and time was successfully conducted with altogether five vessels participating from 3rd of July to 4th of August 2017.

The main aim of the coordinated IESSNS have been to collect data on abundance, distribution, migration and ecology of Northeast Atlantic mackerel (*Scomber scombrus*) during their summer feeding migration phase in the Nordic Seas, to be used as input to the abundance estimation of mackerel at ICES. Since 2016 we have also conducted systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*). This objective was initiated to provide an additional abundance index for these two stocks because the current indices used in the stock assessments by ICES have shown some unexplained fluctuations (ICES, WGWIDE 2016). It was considered that a relatively small increase in survey effort would accommodate a full acoustic coverage of the adult fraction (spawning stock biomass (SSB)) of both species during their summer feeding distribution in the Nordic Seas (Utne et al. 2012; Trenkel et al. 2014; Pampoulie et al. 2015). The pelagic trawl survey was initiated by Norway in the Norwegian Sea in the beginning of the 1990s. Faroe Islands and Iceland have participated in the joint mackerel-ecosystem survey since 2009 and Greenland since 2013.

Opportunistic whale observations were conducted onboard the Norwegian vessels Kings Bay and Vendla, and the Icelandic R/V Arni Fridriksson in order to collect data on distribution, aggregation and behaviour of marine mammals in relation to potential prey species and the physical environment.

Swept-area abundance indices of mackerel from IESSNS have been used for tuning in the analytical assessment by ICES, WGWIDE, since the benchmark assessment in 2014. A new benchmark assessment on NEA mackerel was performed in January 2017 (ICES 2017). Methodological and statistical changes and improvements have been done in the survey design, inclusion of uncertainty estimates on the age-disaggregated abundance estimations using the StoX have improved the quality and consistency of the NEA mackerel abundance estimates (Olafsdottir et al. 2017, Salthaug et al 2017). Details on the survey methods are published in Nøttestad et al. (2016). The benchmark assessment accepted several changes and improvements from the IESSNS related to abundance of NEA mackerel based on the swept area analyses including using StoX (ICES 2017). The changes involving IESSNS included the following issues (see Olafsdottir et al. 2017):

a) Implement a new stratified approach using the StoX software to calculate mackerel age-segregated index and coefficient of variation (Salthaug *et al.*, 2017),
b) Introduce an annual swept-area age-structured abundance index,
c) Include age-groups 3+ (3-11 years old),
d) Include years 2010 and 2012 onwards (2012-2017),
e) Expand the spatial coverage to include the area from 60 °N northwards (east of longitude -2 W) in the stratified approach (see Nøttestad *et al.*, 2016a).

3 Material and methods

Coordination of the IESSNS survey was done during WGWIDE 2016 meeting in August-September 2016 in Copenhagen, Denmark, WGIPS meeting in January 2017 in Reykjavik, Iceland, and by correspondence in spring and summer 2017. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calm with good survey conditions for all the five vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. The weather in Iceland waters had predominantly foggy conditions, with up to 7 days of stormy weather. The weather in Faroese waters were good with exception of one day. The weather in Greenland waters was fairly good only with a few days of windy conditions. The weather was exceptionally good and calm for the two Norwegian vessels operating in the central and northern part of the Norwegian Sea.

During the IESSNS survey the special designed pelagic trawl, Multpelt 832, has now been applied by all participating vessels since 2012. This trawl is a product of cooperation between participating institutes in designing and constructing a standardized sampling trawl for the IESSNS. The work was lead by trawl gear scientist John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway, and has been the standard for six years now (Valdemarsen et al. 2014). The design of the trawl was finalized during meetings of fishing gear experts and skippers at meetings in January and May 2011. Further discussions on modifications in standardization between the rigging and operation of Multpelt 832 was done during a trawl expert meeting in Copenhagen 17-18 August 2012, in parallel with the post-cruise meeting for the joint ecosystem survey, and then at the WKNAMMM workshop and tank experiments on a prototype (1:32) of the Multpelt 832 pelagic trawl, conducted as a sequence of trials in Hirtshals, Denmark from 26 to 28 February 2013 (ICES 2013a). The swept area methodology was also presented and discussed during the WGISDAA workshop in Dublin, Ireland in May 2013 (ICES 2013b). The standardization and quantification of catchability from the Multpelt 832 pelagic trawl was further discussed during the mackerel benchmark in Copenhagen in February 2014. Recommendations and requests coming out of the mackerel benchmark in February 2014, were considered and implemented during the IESSNS survey in July-August 2014 and in the surveys thereafter. Furthermore, recommendations and requests coming out of the mackerel benchmark in January-February 2017, were carefully considered and implemented during the IESSNS survey in July-August 2017.

Table 1. Survey effort by each of the five vessels in the IESSNS survey in 2017. *) The number of predetermined ("fixed") trawl stations being part of the swept-area stations for mackerel in the IESSNS are shown after the total number of trawl stations.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations/ Fixed stations*)	CTD stations	Plankton stations
Árni Friðriksson	3/7-3/8	5616	91/74	75	72
Tróndur í Gøtu	3/7- 19/7	3167	47/43	31	43
Finnur Fríði	21/7-2/8	2500	18/15	15	16
Vendla	5/7-4/8	5735	91/72	72	72
Kings Bay	5/7-4/8	4969	94/75	76	74
Total	3/7-4/8	21987	341/279	281	277

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Árni Friðriksson was equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. Tróndur í Gøtu was equipped with a mini SEABIRD SBE 25+ CTD sensor, and Kings Bay and Vendla were both equipped with SAIV CTD sensors. Finnur Fridi operating in Greenland waters used a SEABIRD 19+V2 CTD sensor. The CTD-sensors were used for recording temperature, salinity and pressure (depth) from the surface down to 500 m, or to the bottom when at shallower depths.

Some vessels collected and recorded also oceanographic data from the surface either applying a thermosalinograph (temperature and salinity) placed at approximately 6 m depth underneath the surface or a thermograph logging or visualizing temperatures continuously near the surface throughout the survey.

Zooplankton was sampled with a WP2-net on all vessels. Mesh sizes were 180 µm (Kings Bay and Vendla) and 200 µm (Árni Friðriksson, Tróndur í Gøtu and Finnur Fridi). The net was hauled vertically from a depth of 200 m (or bottom depth at shallower stations) to the surface at a speed of 0.5 m/s. All samples were split in two, one half preserved for species identification and enumeration, and the other half dried and weighed. Detailed description of the zooplankton and CTD sampling is provided in the survey manual (ICES 2014b).

Not all planned CTD and plankton stations were taken. The number of stations taken by the different vessels is provided in Table 1.

3.2 Trawl sampling

All vessels used the standardized Multpelt 832 pelagic trawl (ICES, 2013a; Valdemarsen et al. 2014; Nøttestad et al. 2016) for trawling, both for fixed surface stations and for trawling at greater depths to confirm acoustic registrations. Standardization of trawl deployment was emphasised during the survey as in previous years (ICES 2013a; ICES 2014c). Effective trawl width and trawl depth was monitored live by scientific personal and stored on various sensors on the trawl doors, headrope and groundrope of the Multpelt 832 trawl. The properties of the Multpelt 832 trawl and rigging on each vessel is reported in Table 2.

Trawl catch was sorted to the highest taxonomical level possible, usually to species for fish, and total weight per species recorded. The processing of trawl catch varied between nations as the Norwegian, Icelandic and Greenlandic vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting. Sub-sample size ranged from 60 kg (if it was clean catch of either herring or mackerel) to 100 kg (if it was a mixture of herring and mackerel). The biological sampling protocol for trawl catch varied between nations in number of specimen sampled per station (Table 3).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 3rd of July to 4th of August 2017. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Kings Bay**	**Árni Friðriksson**	**Vendla**	**Tróndur í Gøtu**	**Finnur Fríði**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynema – 34mm	Dynex-38 mm	+
Warp length during towing	350	350	350	300-350	350	0
Difference in warp length port/starboard (m)	2-10	3-12	2-10	0-25	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×500	0
Weight of the groundrope chain (kg)						

Setback (m)	6 m	6	6 m	6 m	6	+
Type of trawl door	Seaflex 7,5 m^2 adjustable hatches	Jupiter	Seaflex 7,5 m^2 adjustable hatches	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	2300	2000	+
Area trawl door (m^2)	7.5 with 25% hatches (effective 6.5)	7	7.5 with 25% hatches (effective 6.5)	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots)	4.9 (4.2-5.4)	5.1 (4.6-5.8)	4.9 (4.2-5.7)	4.7 (4.4-4.9)	4.6 (4.5-4.7)	+
Trawl height (m)	30-32	31 (21-39)	24-32	36.5	-	+
Door distance (m)	120-130	122 (110 - 130)	114-131	107.2	107 (100-107)	+
Trawl width (m)-calculated from door distance	69	69	68	61.2	60.7	+
Turn radius	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees BB turn	5-10 degrees turn	+
A fish lock in front end of cod-end	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m)	5-15, 7-18 m	15-28, 1-23	6-18, 7-19 m	7.4, 8.3	-	+
Headline depth	0 m	0-1 m	0 m	0 m	0-1 m	+
Float arrangements on the headline	Kite with fender buoy +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite with fender buoy + 2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite + 2 buoys on wingtips	+
Weighing of catch	All weighted	All weighted except 2 stations where the cod end bursted.	All weighted	All weighed – except 3 large catches estimated	All weighted	+

Table 3. Summary of biological sampling in the survey from 3rd of July to 4th of August 2017 by the five participating countries. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Greenland	Iceland	Norway
Length measurements	Mackerel	100	100/50*	150	100
	Herring	100	100/50*	200	100
	Blue whiting	100	100/50*	50	100
	Other fish sp.	0	25/25*	50	25
Weighed, sexed and maturity determination	Mackerel	25	25	50	25
	Herring	25	25	50	25
	Blue whiting	25	25	50	25
	Other fish sp.	0	0	10	0
Otoliths/scales collected	Mackerel	25	25	25	25
	Herring	25	25	50	25
	Blue whiting	25	25	50	25
	Other fish sp.	0	0	0	0
Fat content	Mackerel	0	50	0	10
	Blue whiting	0	50		
	Herring	0	0	0	
Stomach sampling	Mackerel	5	20	10**	
	Herring	5	20	10**	10
	Blue whiting	5	20	10**	10
	Other fish sp.	0	0	0	10
Tissue for genotyping	Mackerel	0		0	0
	Herring	0		0	30

- *Length measurements / weighed individuals
- **Stomachs sampled at every third station
-

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and escapement from the cod end and through meshes. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. No light source was employed with cameras; hence, recordings were limited to day light hours. Some recordings were also taken during night time when there was midnight sun and good underwater visibility in the upper 30 m of the water column. Video recordings were collected at 50 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm mesh sizes onboard Kings Bay and Vendla. Analyses of the recording material, including behaviour and patchiness of mackerel and NSS herring are underway and will be presented by other means when available.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 3rd of July and 4th of August 2017 onboard M/V "Kings Bay" and M/V "Vendla", respectively. Dedicated marine mammal observations were done onboard R/V "Árni Friðriksson". The priority periods of observing were during the transport stretches from one trawl station to another. Observations were done 24 h per day if the visibility was sufficient for marine mammal sightings. Digital filming and photos were taken whenever possible on each registration from scientists onboard.

3.4 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 3rd of July 2017 for 18, 38 and 200 kHz. Árni Friðriksson was calibrated on 6th of May 2017 for the frequencies 18, 38, 120 and 200 kHz. Tróndur í Gøtu was calibrated on 28th June 2017 for 38 and 200 kHz. Finnur Fríði was calibrated on the 18th July 2017 for 38 kHz prior to the cruise, and 120 and 200 kHz after the cruise at 2nd of August. All vessels used standard hydro-acoustic calibration procedure for each operating frequency (Foote, 1987). CTD measurements were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

Acoustic recordings were scrutinized to herring and blue whiting on daily basis using the post-processing software (LSSS or Echoview, see Table 4 for details of the acoustic settings by vessel). Species were 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.

To estimate the abundance from the allocated NASC-values the following target strengths (TS) relationships were used.

Blue whiting: TS = 20 log(L) – 65.2 dB (rev. acc. ICES CM 2012/SSGESST:01)
Herring: TS = 20.0 log(L) – 71.9 dB

Table 4. Acoustic instruments and settings for the primary frequency from 3rd of July to 4th of August 2017.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu	M/V Finnur Fríði
Echo sounder	Simrad EK60	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 60
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 120, 200	18, 38, 70, 120, 200	38,120, 200	38,120, 200
Primary transducer	ES38B	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	9	10	9	6	8
Upper integration limit (m)	15	15	15	7	Not used
Absorption coeff. (dB/km)	9.8	10.6	9.9	9.8	9.7
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	2.43	2.425	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.90	21.9	21.90	21.9	21.9
2-way beam angle (dB)	-20.6	-20.81	-20.6	-20.6	-20.7
TS Transducer gain (dB)	23.10	24.28	23.27	24.15	23.75
s_A correction (dB)	-0.64	-0.61	-0.65	-0.65	-0.59
alongship:	6.98	7.20	7.01	7.19	7.17
athw. ship:	7.03	7.22	7.11	7.11	7.01
Maximum range (m)	500	500 (750 in part of the survey)	500	500	500 (750 in part of the survey)
Post processing software	LSSS	LSSS v.2.1.0	LSSS	Sonardata Echoview 8.x	Sonardata Echoview 8.x

Multibeam sonar

M/V "Kings Bay" and M/V "Vendla" were equipped with the Simrad fisheries sonar SH90 (frequency range: 111.5-115.5 kHz), with a scientific output incorporated which allow the storing of the beam data for post-processing. Acoustic multibeam sonar data was stored continuously onboard Kings Bay and Vendla for the entire survey from 5th of July to 4th of August 2017. The main objective for the continuous sonar recordings was to study the vertical distribution, school geometry and patchiness of the mackerel and herring in the upper 30-40 m of the water column.

Cruise tracks

The five participating vessels followed predetermined survey lines with pre-selected surface trawl stations (Figure 1). An adaptive survey design was also adopted although to a small extent, due to uncertain geographical distribution of mackerel, herring and blue whiting. The main adaptation was in the Icelandic-south stratum where it was shortened southwards as the zero line of mackerel distribution had been reached. Furthermore, northwest of Iceland, one station and one transect could not be surveyed due to sea ice. Temporal survey progression by vessel along the cruise tracks in July-August 2017 is shown in Figure 2. The cruising speed was between 10-13 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

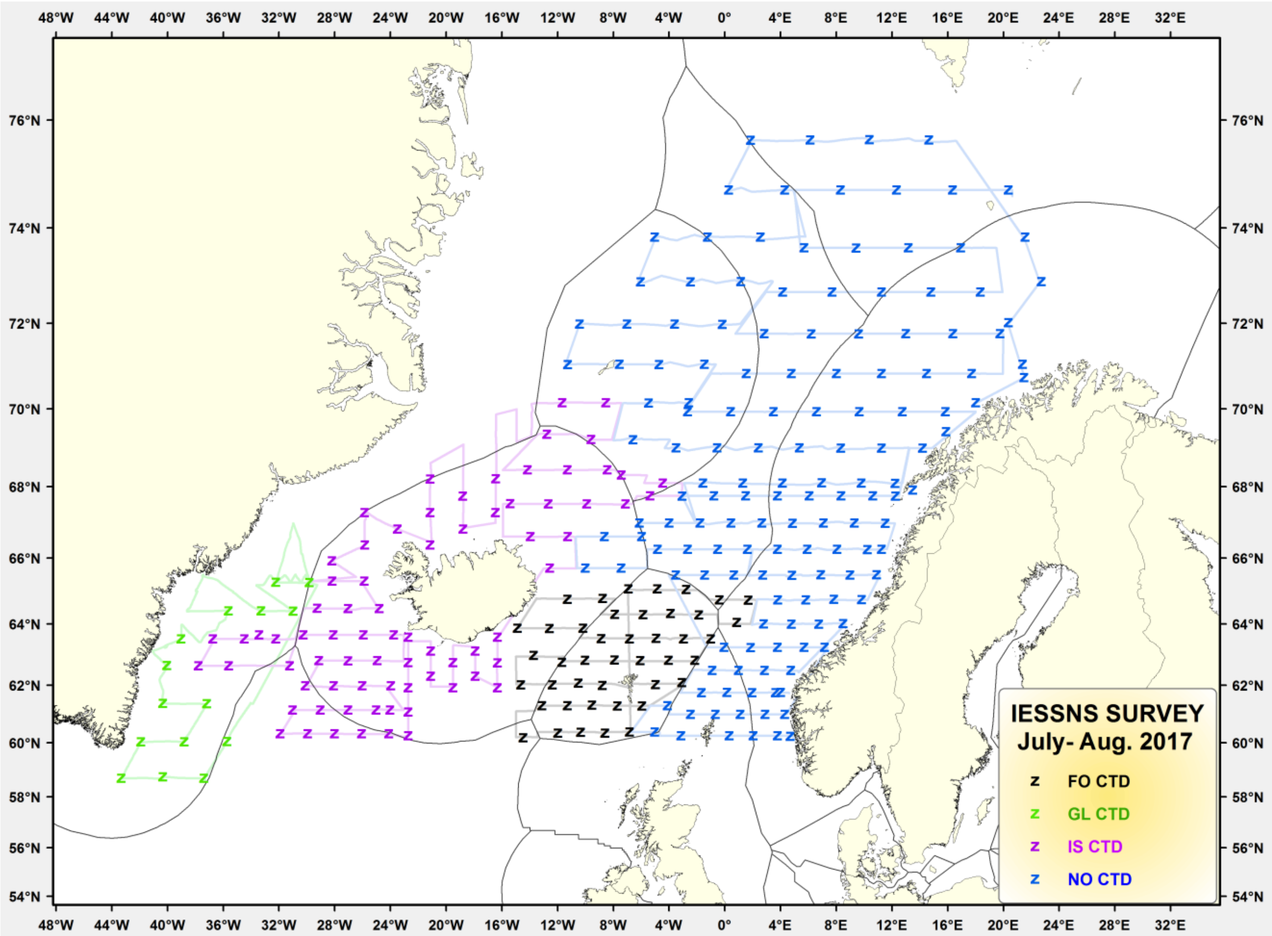


Figure 1. Fixed predetermined trawl stations included in the IESSNS 3rd of July – 4th of August 2017. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue) and Finnur Fríði (green).

In relation to calculating the abundance of NEA mackerel based on the swept area approach, we have designed the survey in different strata (permanent and dynamic strata), (Figure 2). The survey design using different strata is done in order to be able to calculate abundance indices with uncertainty estimates both overall and from each stratum in the software program StoX (see Salthaug et al. 2017).

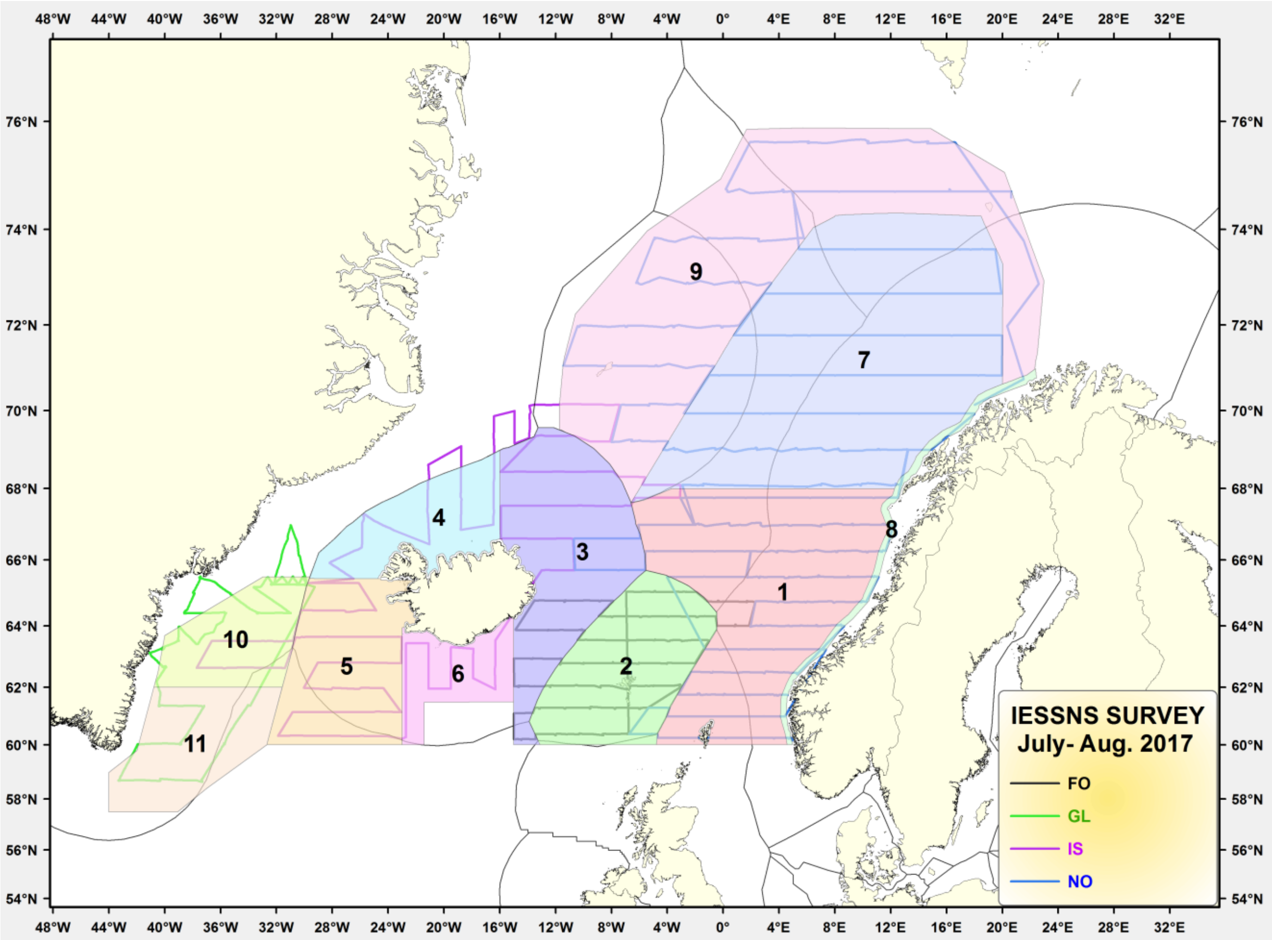


Figure 2. Permanent and dynamic strata used in StoX for the IESSNS 2017 survey. The dynamic strata are: 4, 9 and 11.

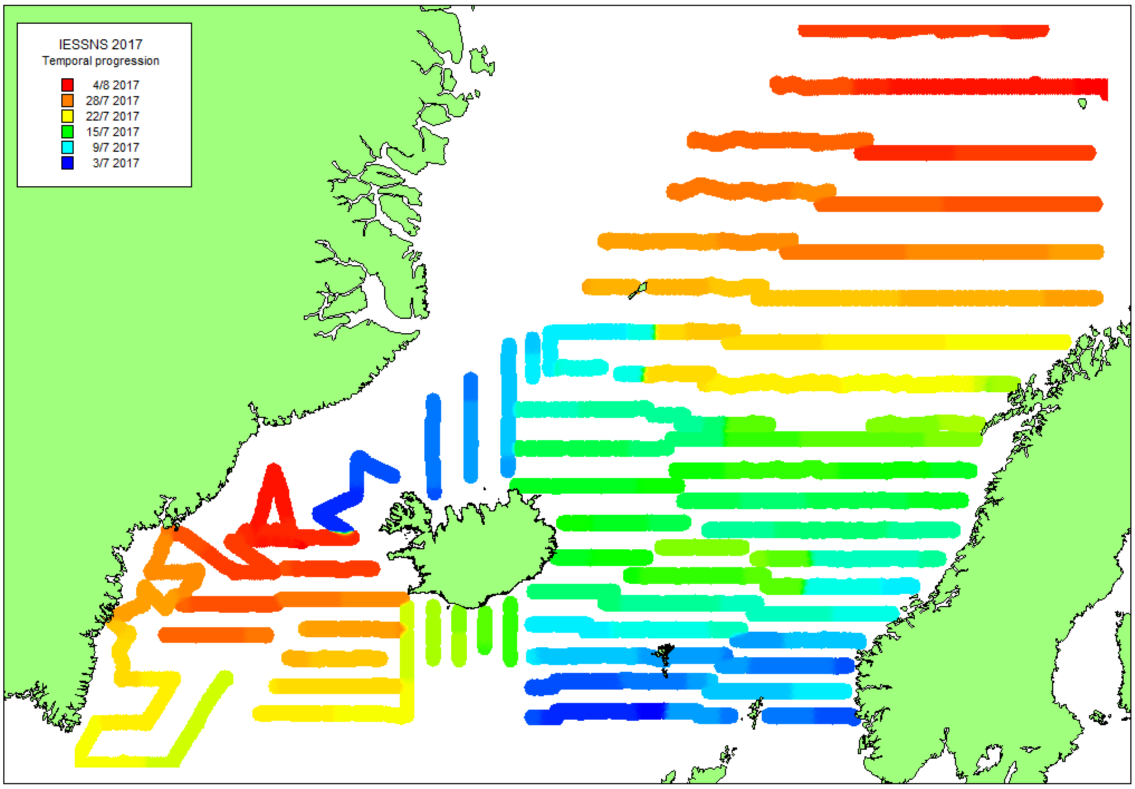


Figure 3. Temporal survey progression by vessel along the cruise tracks in July-August 2017: blue represents survey start (3 July) progressing to red representing the end of the survey (4 August).

3.5 StoX

StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The software, examples and documentation can be found at: http://www.imr.no/forskning/prosjekter/stox/nb-no. The program is a stand-alone application build with Java for easy sharing and further development in cooperation with other institutes. The underlying high-resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high-resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990) is implemented. Mackerel, herring and blue whiting indices were calculated using the StoX software package.

3.6 Swept area index and biomass estimation

The swept area age segregated index is calculated separately for each stratum (see stratum definition in Figure 2). Individual stratum estimates are added together to get the total estimate for the whole survey area which is approximately defined by the area between 57°N and 76°N and 44°W and 22°E.

Average density (Mac_D; kg km^{-2}) is calculated by for each trawl haul with the following formula;

Mac_D = h * d * c

where h (km) is the horizontal opening of the trawl, d is distance trawled (km) and c is the total mackerel catch (kg). The horizontal opening of the trawl is vessel specific, and the average value across all hauls is calculated based on door spread (Table 5 and Table 6).

Table 5. Descriptive statistics for trawl door spread, vertical trawl opening and tow speed for each vessel. Two different kinds of data were analyzed, manually reported values from log books (one value per station) and digitally recorded data from trawl sensors (*). Digitally recorded data were filtered prior to calculations and outliers were excluded. Next, average door spread and vertical opening was calculated for each station, then the average values per station were used to calculate overall mean, maximum (max), minimum (min) and standard deviation (st.dev.) for each vessel. Number of trawl stations used in calculations is also reported. Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (details in Table 6).

	Tróndur í Gøtu	RV Árni Friðriksson	Kings Bay	Vendla	Finnur Fríði
Trawl doors horizontal spread (m)					
Number of stations	39	73	75	72	16
Mean	107.2	122	120	114	107
max	113.0	130	130	131	114
min	98.0	110	125	122	100
st. dev.	3.9	5	10.5	7.8	4.5
Vertical trawl opening (m)					
Number of stations	40	72	75	72	-
Mean	36.5	31	30	28	-
max	39.9	39	32	32	-
min	33.0	21	30	24	-
st. dev.	1.9	3	2	4.5	-
Horizontal trawl opening (m)					
mean	61.2	69	69	68	60.7
Speed (over ground, nmi)					
Number of stations	43	73	75	72	16
mean	4.7	5.1	4.9	4.9	4.6
max	4.9	5.8	5.4	5.7	4.7
min	4.4	4.6	4.2	4.2	4.5
st. dev.	0.11	0.2	0.7	0.8	0.1

Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (Table 6). The estimates in the formulae were based on flume tank simulations in 2013 (Hirtshals, Denmark) where formulas were developed from the horizontal trawl opening as a function of door spread, for two towing speeds, 4.5 and 5 knots:

Towing speed 4.5 knots: Horizontal opening (m) = 0.441 * Doorspread (m) + 13.094

Towing speed 5.0 knots: Horizontal opening (m) = 0.3959 * Doorspread (m) + 20.094

Table 6. Horizontal trawl opening as a function of trawl door spread and towing speed. Relationship based on simulations of horizontal opening of the Multpelt 832 trawl towed at 4.5 and 5 knots, representing the speed range in the 2014 survey, for various door spread. See text for details. This year the towing speed range was extended from 5.0 to 5.2.

Door spread(m)	Towing speed 4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2
100	57.2	57.7	58.2	58.7	59.2	59.7	60.2	60.7
101	57.6	58.1	58.6	59.1	59.6	60.1	60.6	61.1
102	58.1	58.6	59.0	59.5	60.0	60.5	61.0	61.4
103	58.5	59.0	59.5	59.9	60.4	60.9	61.3	61.8
104	59.0	59.4	59.9	60.3	60.8	61.3	61.7	62.2
105	59.4	59.9	60.3	60.8	61.2	61.7	62.1	62.6
106	59.8	60.3	60.7	61.2	61.6	62.1	62.5	62.9
107	60.3	60.7	61.2	61.6	62.0	62.5	62.9	63.3
108	60.7	61.1	61.6	62.0	62.4	62.9	63.3	63.7
109	61.2	61.6	62.0	62.4	62.8	63.2	63.7	64.1
110	61.6	62.0	62.4	62.8	63.2	63.6	64.1	64.5
111	62.0	62.4	62.8	63.2	63.6	64.0	64.4	64.8
112	62.5	62.9	63.3	63.7	64.0	64.4	64.8	65.2
113	62.9	63.3	63.7	64.1	64.4	64.8	65.2	65.6
114	63.4	63.7	64.1	64.5	64.9	65.2	65.6	66.0
115	63.8	64.2	64.5	64.9	65.3	65.6	66.0	66.3
116	64.3	64.6	65.0	65.3	65.7	66.0	66.4	66.7
117	64.7	65.0	65.4	65.7	66.1	66.4	66.8	67.1
118	65.1	65.5	65.8	66.1	66.5	66.8	67.1	67.5
119	65.6	65.9	66.2	66.6	66.9	67.2	67.5	67.9
120	66.0	66.3	66.6	67.0	67.3	67.6	67.9	68.2

4 Results

4.1 Hydrography

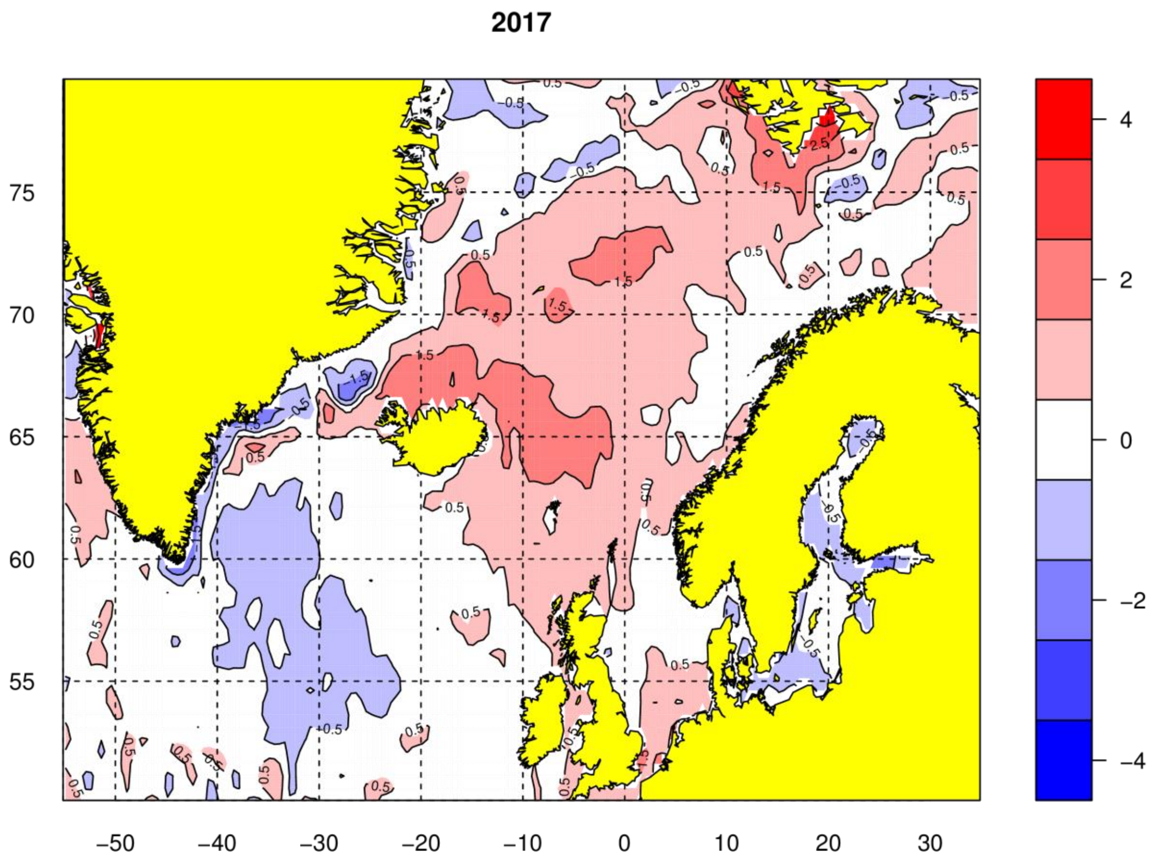
Overall the surface temperatures were generally 1-2°C warmer in the NE part of the Northeast Atlantic in July 2017 compared to the average for 1990-2009 based on Sea Surface Temperature (SST) anomaly plot (Figure 4a). On the other hand, to the SW of the Greenland-Scotland ridge the SST was generally closer to or colder than average especially in the central Irminger Sea.

The surface temperatures were similar in July 2017 compared to July 2016 (Figure 4a or 4b), although not as warm as found in July 2014.

The surface temperatures were generally 0.5-1.5°C warmer in the northern part of the Northeast Atlantic in July 2017 compared to the average for the last 20 years based on Sea Surface Temperature (SST) anomaly plot (Figure 4). The temperature in the surface layer in southern and southeastern part of Greenland waters in the west it was between 0.5-1.5°C colder in July 2017 than the average for the last 20 years (Figure 4). In the eastern part of the Norwegian Sea and along the Norwegian coast the SST was more or less the same as the 20 years average on SST anomaly. Overall in the Northeast Atlantic, the SST was quite similar between July 2016 and July 2017 (Figures 5a, b).

It must be mentioned that the NOAA sea surface temperature measurements (SST) are sensitive to the weather condition (i.e. wind and cloudiness) prior to and during the observations and do therefore not necessarily reflect the oceanographic condition of the water masses in the areas, as seen when comparing detailed features of SSTs between years (Figures 4a, b and 5a, b). However, since the anomaly is now based on the average for the whole month of July, it should give representative results of the surface temperature.

The upper layer (< 30 m depth) was 0.5-1.0°C colder in 2017 compared to 2016 in the northern and north-western part of the surveyed area (Figures 5a and b). The temperature in the upper layer was higher than 6°C in more or less throughout the surveyed area covering approximately 2.8 million km², except along the north-western fringes of the surveyed areas north of Iceland, west of Jan Mayen and north of Bear Island where it was slightly lower. In the deeper layers (50 m and deeper), the hydrographical features in the area were similar to 2015 and 2016. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.



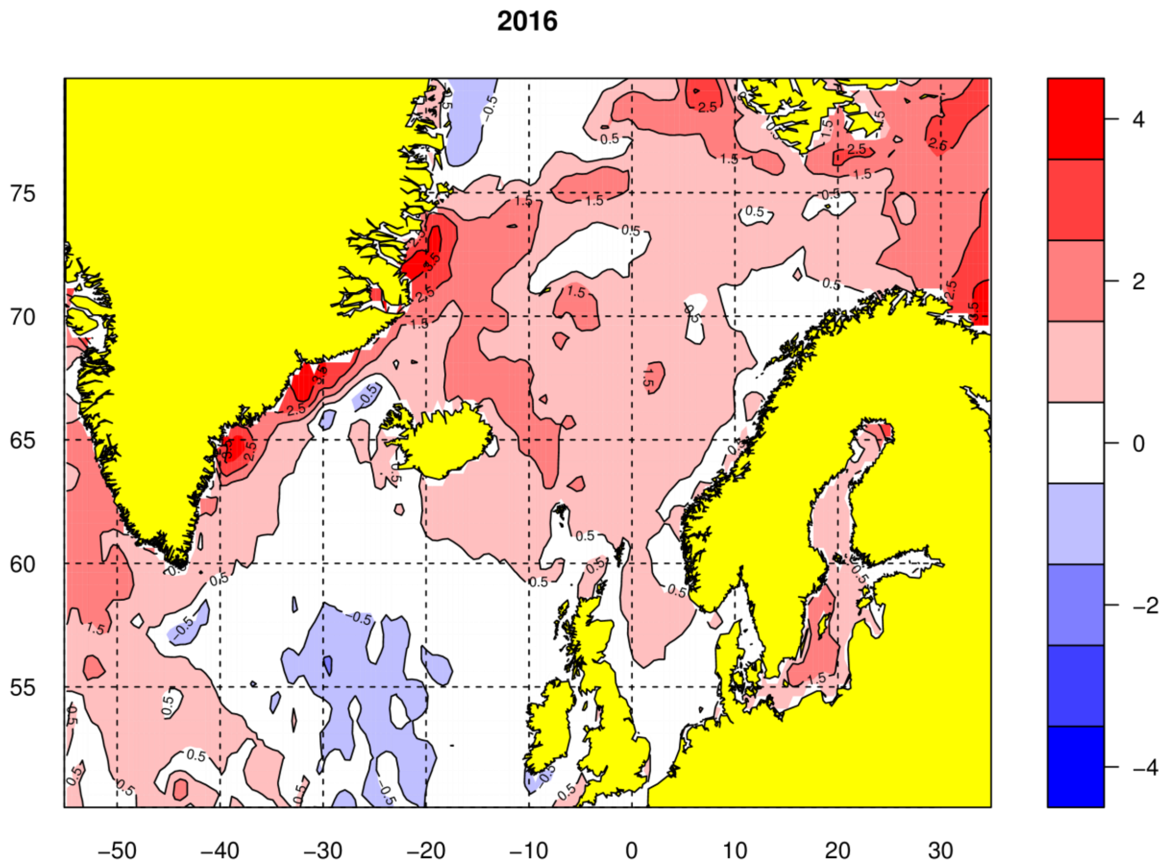
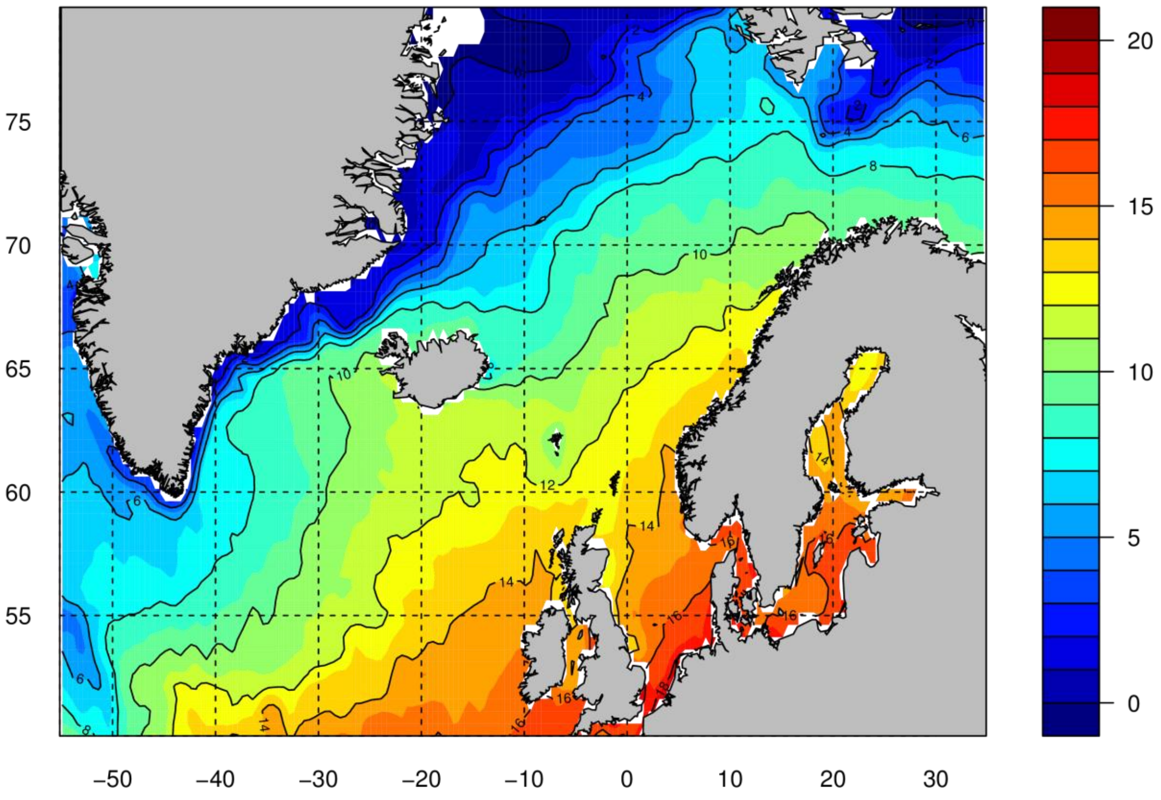


Figure 4. Sea surface temperature anomaly in the North Atlantic for July 2017 (a) and 2016 (b) (°C) showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

2017



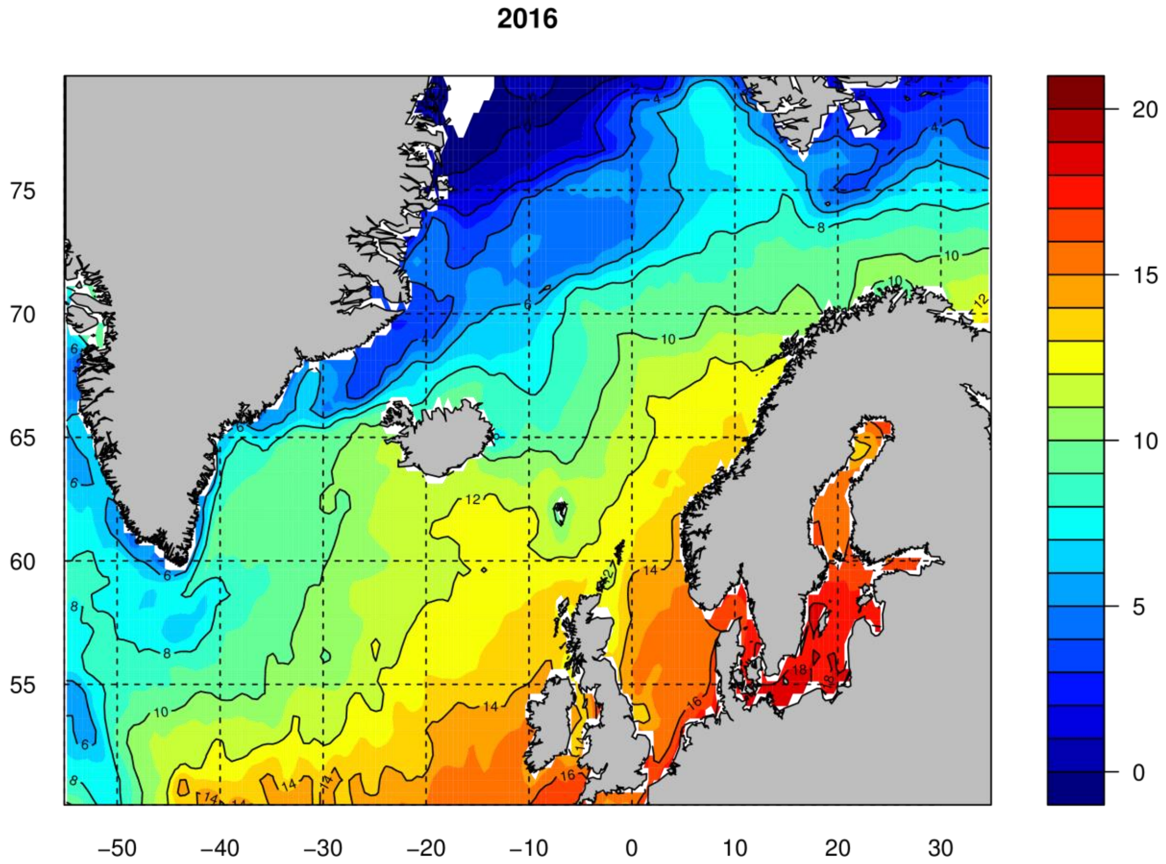


Figure 5. Average sea surface temperature in the North Atlantic for a) July 2017 (°C) and b) July 2016 (°C). Based on daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

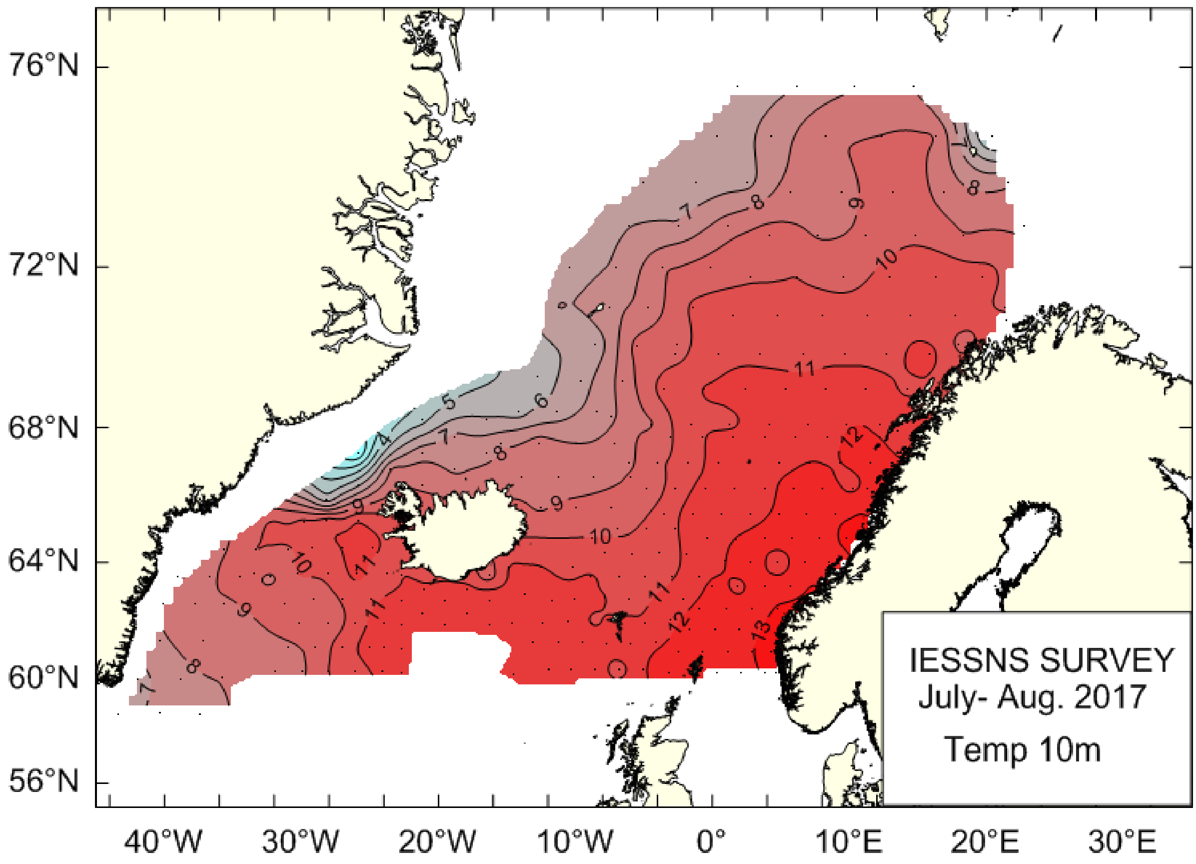

76°N
72°N
68°N
64°N
60°N
56°N
40°W
30°W
20°W
10°W
0°
10°E
20°E
30°E
IESSNS SURVEY
July- Aug. 2017
Temp 10m

Figure 6. Temperature (°C) at 10 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

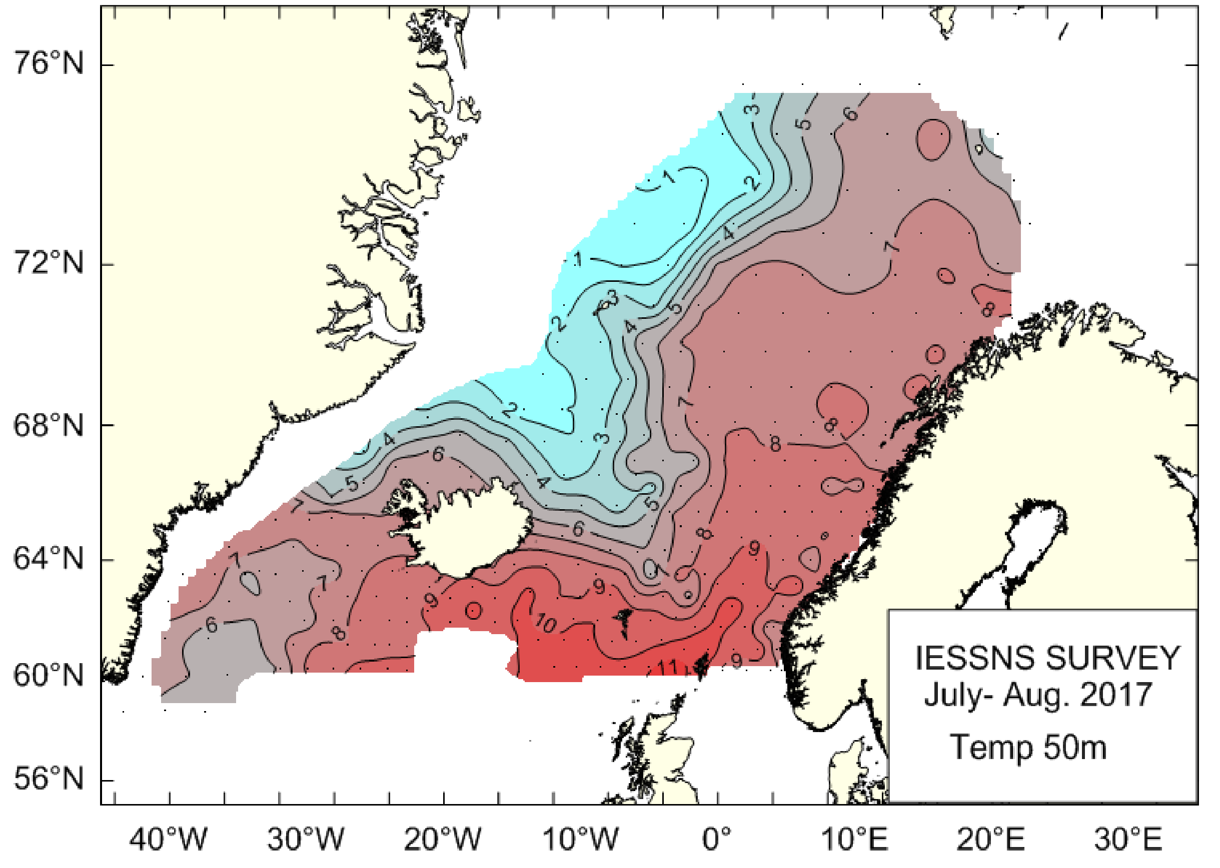


Figure 7. Temperature (°C) at 50 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

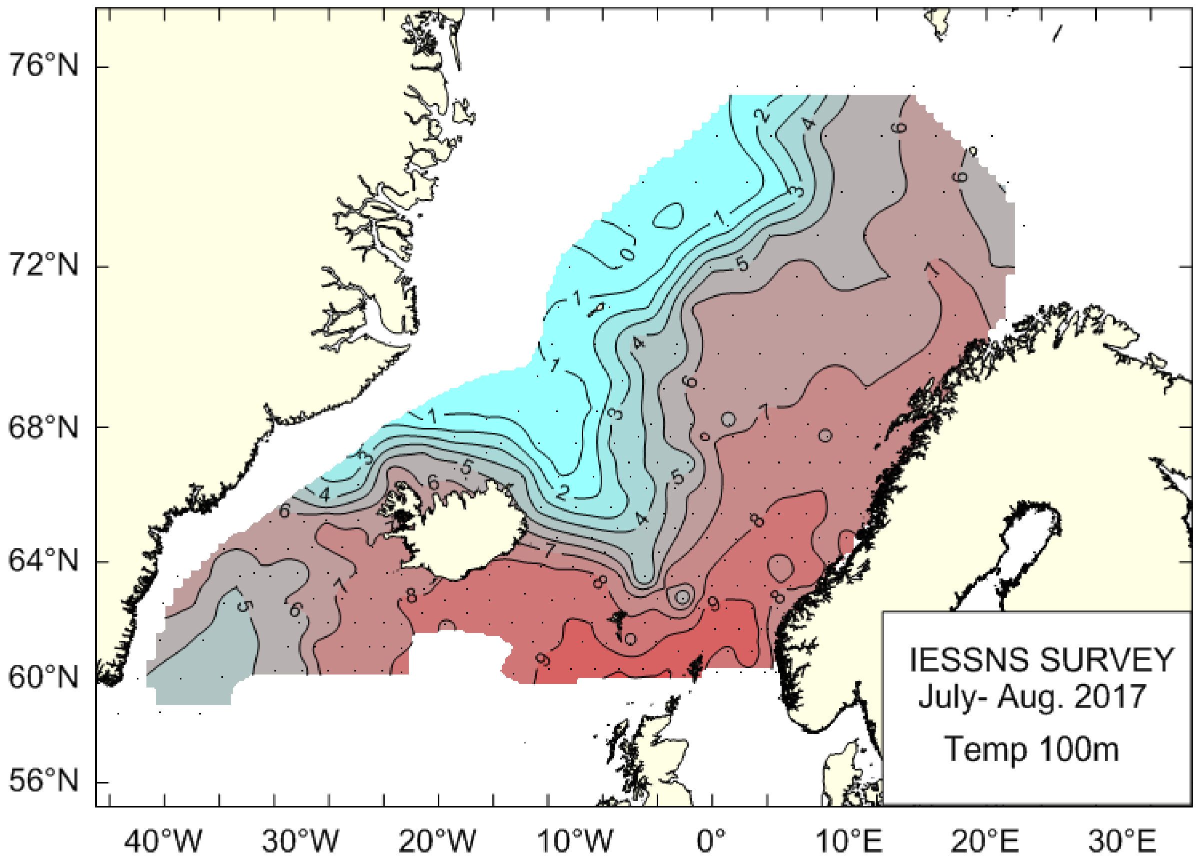

IESSNS SURVEY
July- Aug. 2017
Temp 100m
76°N
72°N
68°N
64°N
60°N
56°N
40°W
30°W
20°W
10°W
0°
10°E
20°E
30°E

Figure 8. Temperature (°C) at 100 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

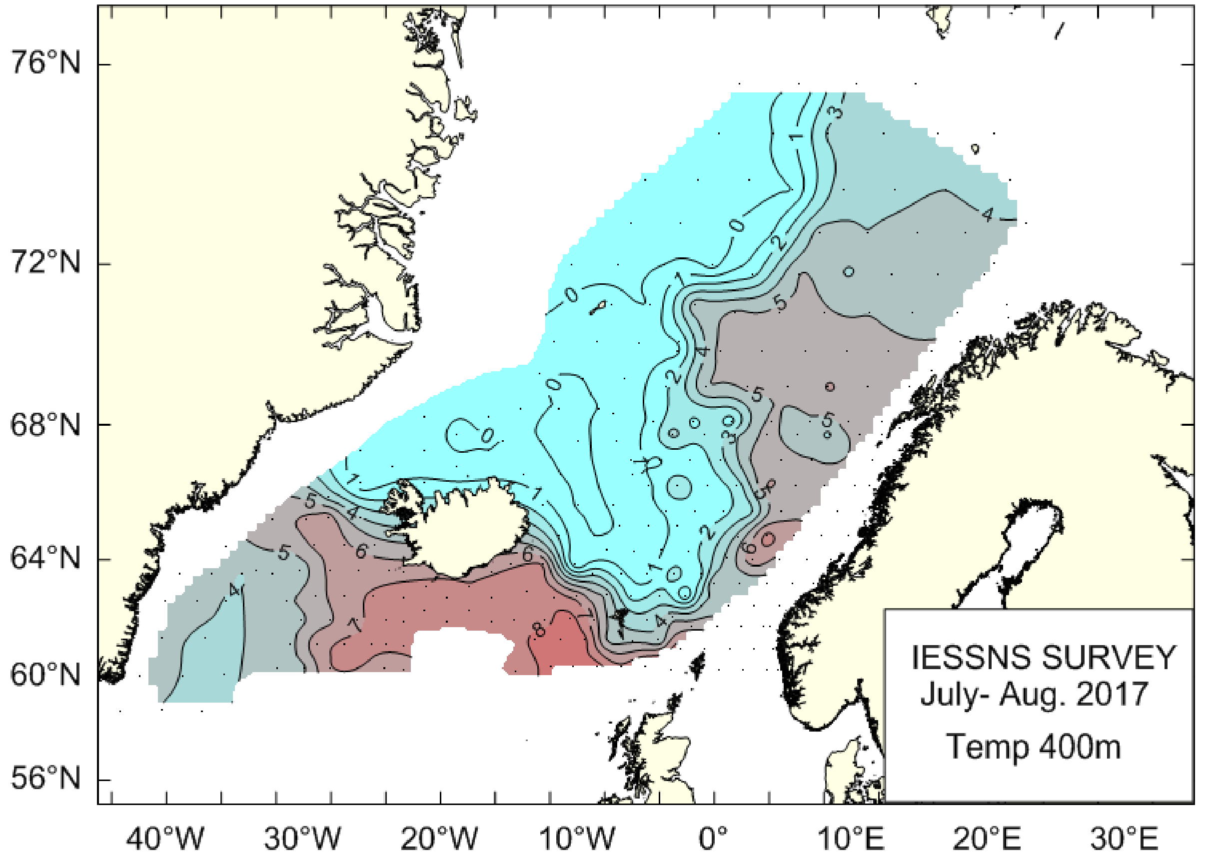
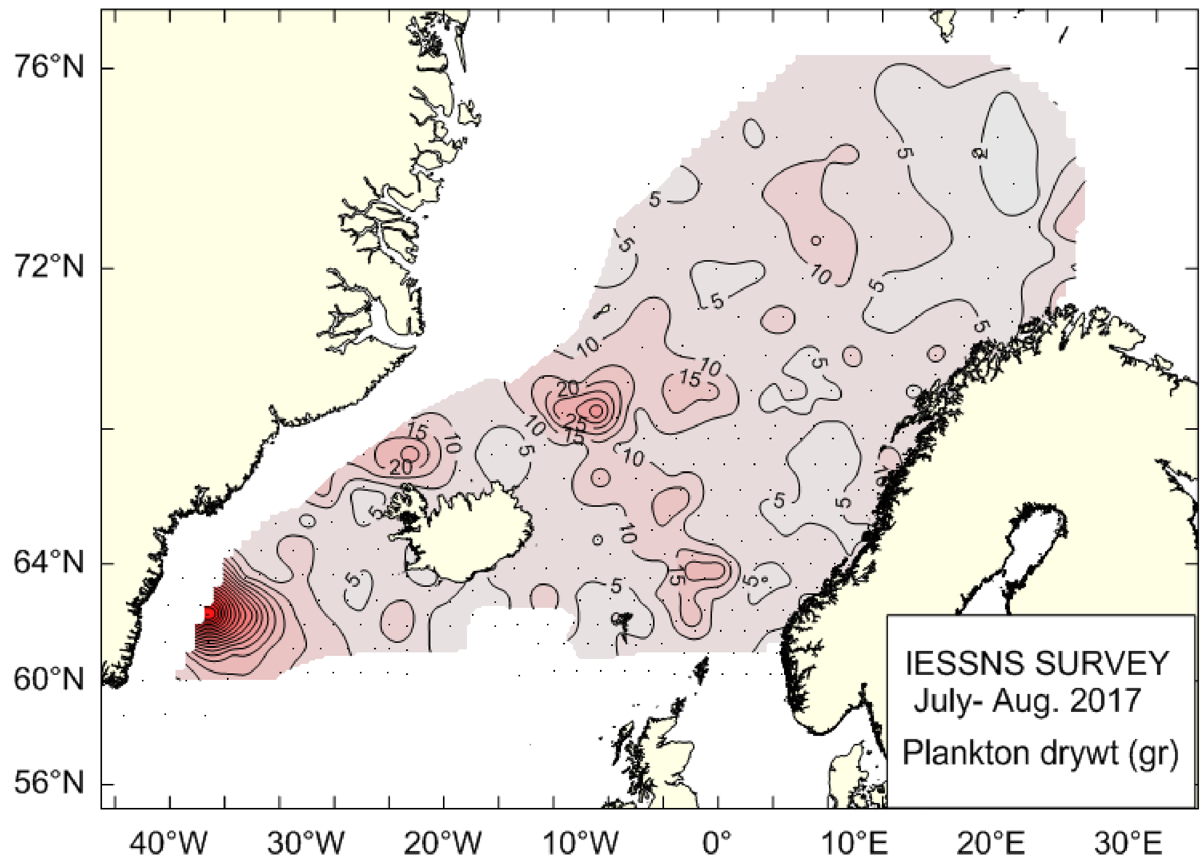


Figure 9. Temperature (°C) at 400 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

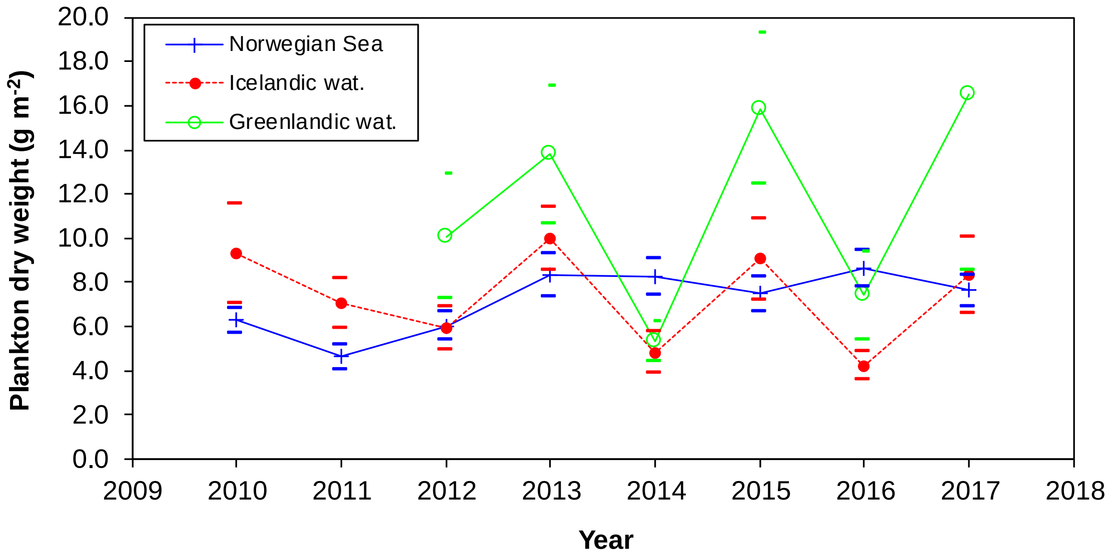
4.2 Zooplankton

The zooplankton biomass was relatively uniform over the whole survey area. Biomasses between 1-10 g m^{-2} dominated the picture in the Norwegian Sea, whereas Iceland waters had higher biomasses 5-15 g m^{-2} and Greenland waters with the highest plankton biomasses 5- > 40 g m^{-2}. Some areas had very high densities, especially in eastern Greenland waters off the coast, according to the dry weight measurements from the WP2 samples (Figure 10a). The average index for the Norwegian Sea was slightly lower in 2017 (7.6 g m^{-2}; n=179), than in 2016 (GIVE THE 2016 VALUE HERE) while approximately 100% higher in Icelandic waters (8.4 g m^{-2}; n=50) and Greenlandic waters (16.5 g m^{-2}; n=25) (Figure 10b). This relatively short time-series show much more pronounced fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to in the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea and more sampling stations. Iceland and Greenland waters fluctuate a lot, however, they fluctuate in the same way from one year to the next (Figure 10b).

The zooplankton samples for species identification have not been examined in detail.



(a)



(b)

Figure 10. Zooplankton biomass indices (g dw/m², 0-200 m) (a) in the Norwegian Sea and surrounding waters in July-August 2017 and (b) time-series for three areas or Norwegian Sea (between 17°E and 14°W and north of 61°N), Icelandic waters (between 14°W and 30°W) and Greenlandic waters (west of 30°W).

4.3 Mackerel

The mackerel catch rates by trawl station (kg/km^2) measured with the Multpelt 832 is presented in Figure 11 together with the mean catch rates per 1*2° rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 30 tonnes, corresponding to 94 tonnes/km^2 on average. The mackerel occupied a very wide spatial distribution of 2.8 million km^2. High density areas were found in the central and north-eastern part of the Norwegian Sea as well as in south-eastward and westward of Iceland and further west into the adjacent part of Greenland waters.

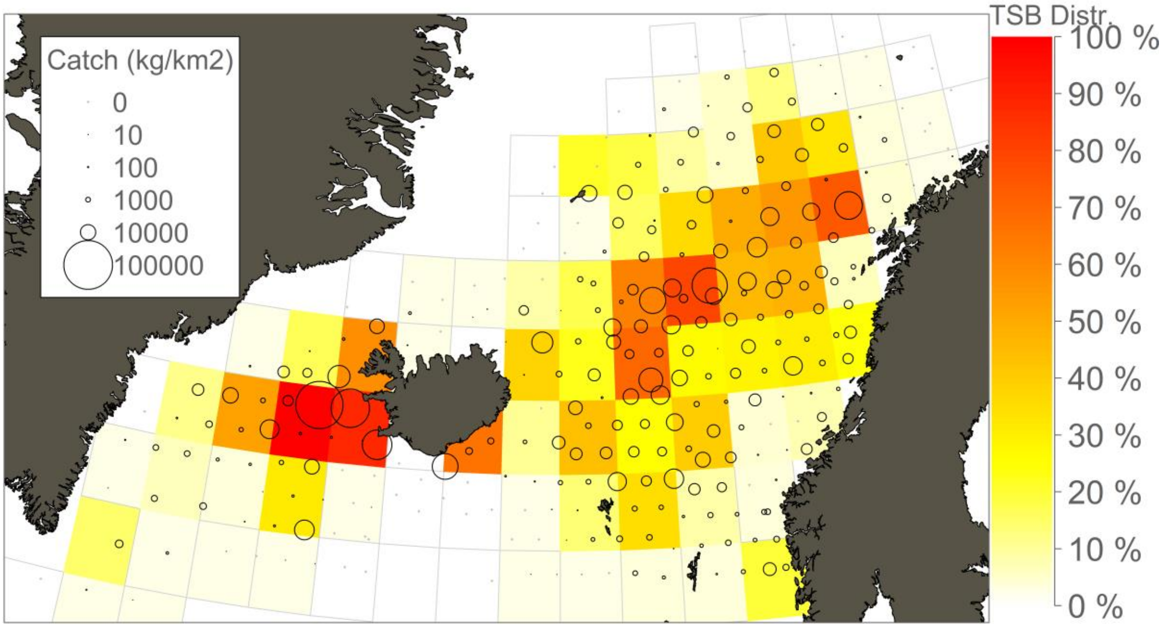


Figure 11. Mackerel catch rates by Multpelt 832 pelagic trawl haul (circle areas represent catch rates in kg/km^2) overlaid on mean catch rates per standardized rectangles (1° lat. x 2° lon.). White rectangles indicate zero-observations and yellow-red colour scale represent the biomass distribution (illustrated as cumulative fractions, e.g. the sum of all areas with the colour corresponding up to 40% represents 40% of the total biomass in the entire survey).

The length distribution of NEA mackerel during the IESSNS 2017 showed a pronounced length- dependent distribution pattern both with regards to latitude and longitude. The largest mackerel on average were found in the northernmost (39 cm in length) including northeast in the entrance to the Barents Sea, and westernmost (38 cm in length) part of the covered area (Figure 12).

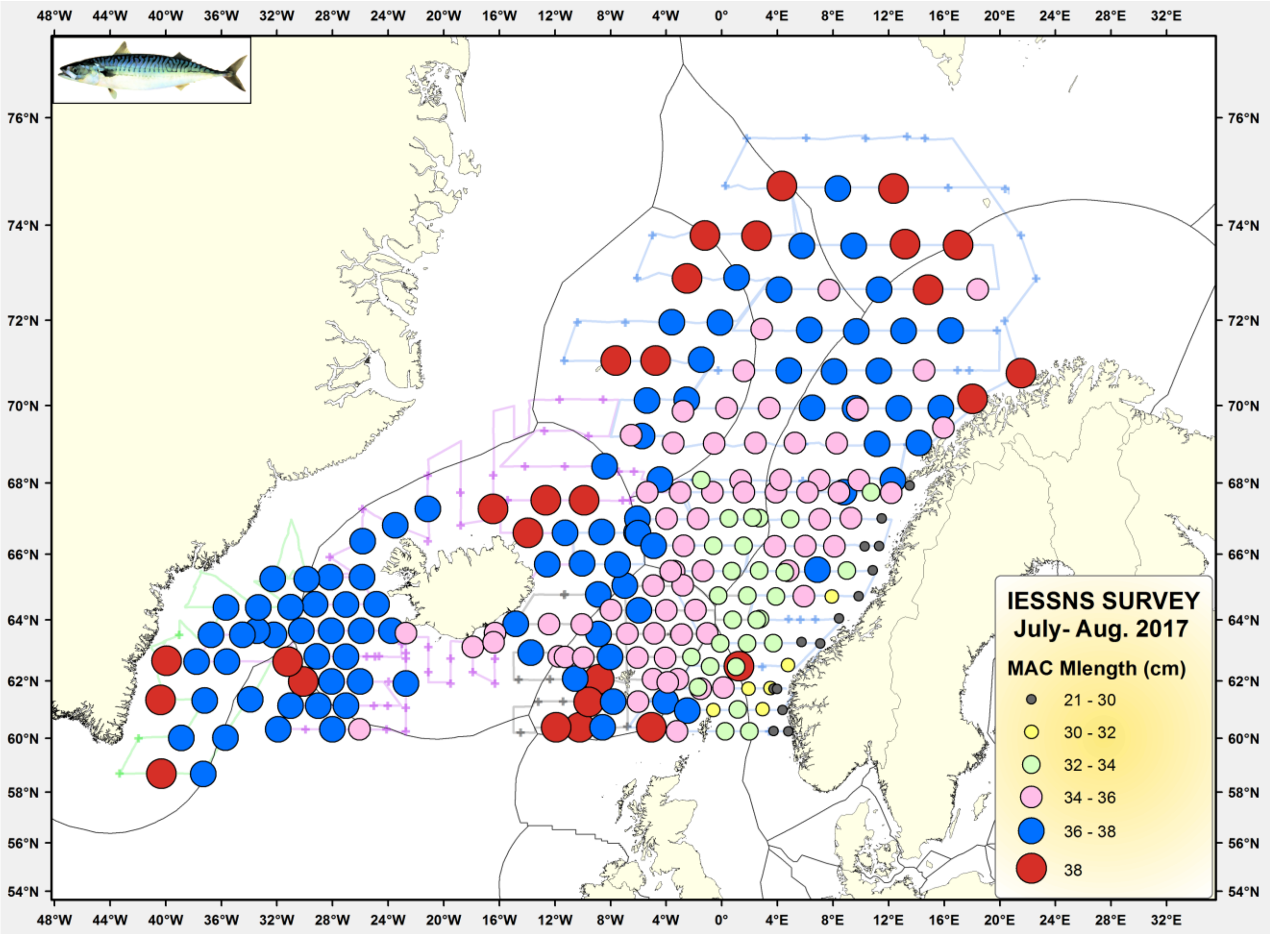


Figure 12. Average length distribution of NEA mackerel from the joint ecosystem survey with the five involved vessels M/V "Kings Bay", M/V "Vendla", M/V "Trøndur i Gøtu", R/V "Árni Friðriksson" and M/V "Finnur Fridi" in the Nordic Seas between 3rd of July and 4th of August 2017.

Mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 21.7 to 40.1 cm in length. The average length was 35.1 cm. The individuals between 28-30 cm and 33-38 cm dominated in numbers and biomass. The mackerel weight (g) varied between 89 to 599 g and was 418 g on average. The 2016-year class (1-year old) dominated among juvenile mackerel caught. The 2016 year-class was dominating the catches along the Norwegian coast from Bergen in south to Lofoten area in the north. The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon, lumpsucker) from the joint ecosystem IESSNS survey 2017 in the Nordic Seas according to the catches are shown in Figure 13.

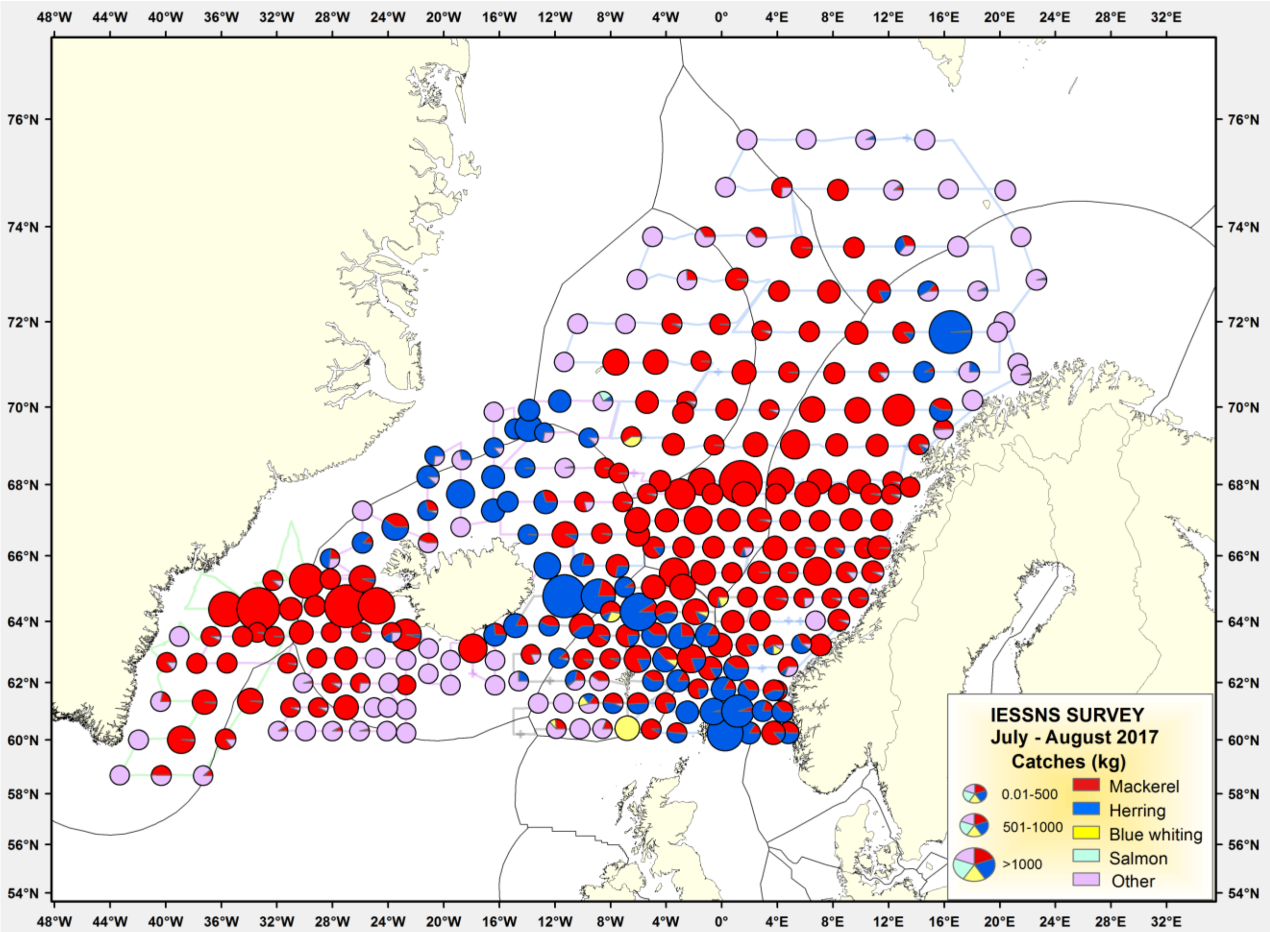


Figure 13. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (turquoise) from joint ecosystem surveys conducted onboard M/V "Kings Bay" and M/V "Vendla" (Norway), M/V "Trøndur i Gøtu" (Faroe Islands), R/V "Árni Friðriksson" (Iceland) and M/V "Finnur Fridi" (chartered to Greenland) in the Norwegian Sea and surrounding waters between 3rd of July and 4th of August 2017. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass in July 2017 were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX (version 2.4). Mackerel were horizontally distributed over more or less the entire survey area. The total swept area biomass index of NEA mackerel in summer 2017 is the highest biomass index in the time series and increased with 13% compared to in summer 2016, whereas the abundance index in 2017 was 2 % lower than in 2016. The survey coverage area was 2.8 million square kilometres in 2017. The most abundant year classes were 2010, 2011, 2012 and 2014 with 19, 19, 14 and 15 % (in numbers). The incoming 2016-year class appear promising and are higher than the 2015-year class.

The total survey index for number-at-age is 24 billion individuals. The dominating age groups are 3, 6 and 7 years old, which are the 2014, 2012, 2011 and 2010-year classes (Figure 14) and they contributed to 67% of the total abundance estimate.

The indices used for NEA mackerel stock assessment in WGIWIDE are the number-at-age indices for age 3 to 11 year (Table 7).

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2017 by the inclusion of one more survey year (Figure 15). This is especially apparent for 5 to 11 years old mackerel. There is now a strong internal consistency for ages 1 to 5 years, and a fair/good internal consistency for ages 5 to 11 years.

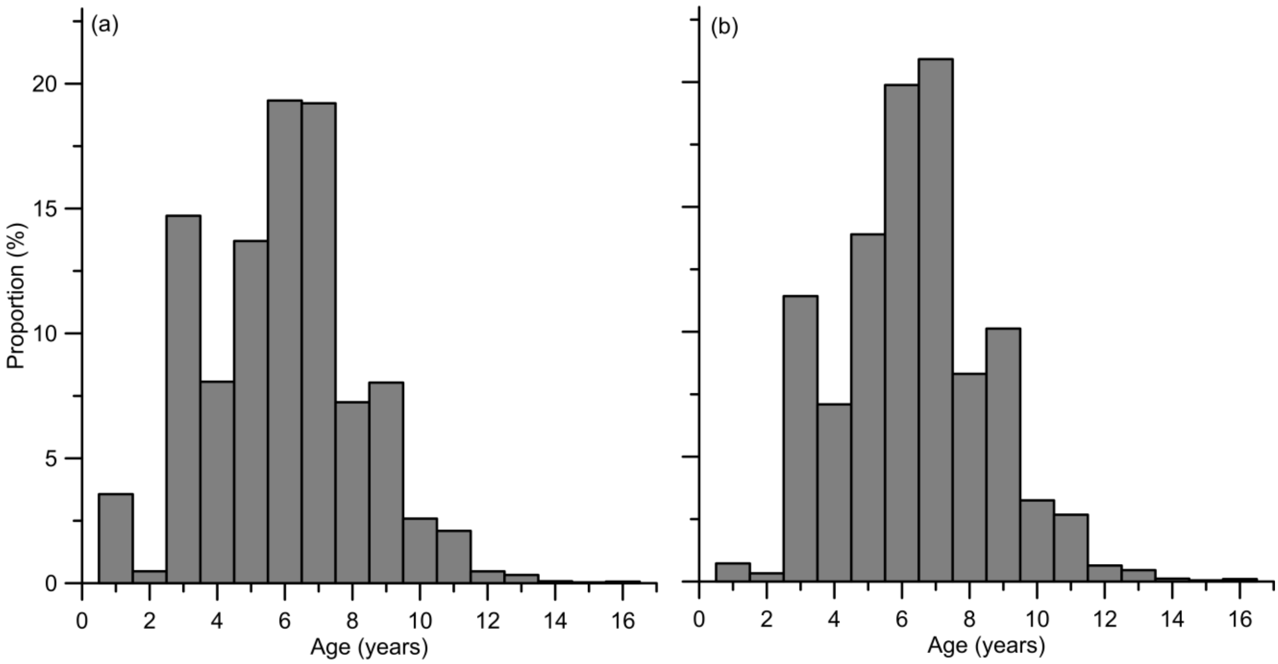


Figure 14. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in the IESSNS 2017.

Table 7. Time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (g) per age and (c) estimated biomass at age (million tonnes).

a)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot N
2007	1.33	1.86	0.90	0.24	1.00	0.16	0.06	0.04	0.03	0.01	0.01	0.00	0.01	0.00	5.65
2010	0.03	2.80	1.52	4.02	3.06	1.35	0.53	0.39	0.20	0.05	0.03	0.02	0.01	0.01	13.99
2011	0.21	0.26	0.87	1.11	1.64	1.22	0.57	0.28	0.12	0.07	0.06	0.02	0.01	0.00	6.42
2012	0.50	4.99	1.22	2.11	1.82	2.42	1.64	0.65	0.34	0.12	0.07	0.02	0.01	0.01	15.91
2013	0.06	7.78	8.99	2.14	2.91	2.87	2.68	1.27	0.45	0.19	0.16	0.04	0.01	0.02	29.57
2014	0.01	0.58	7.80	5.14	2.61	2.62	2.67	1.69	0.74	0.36	0.09	0.05	0.02	0.00	24.37
2015	1.20	0.83	2.41	5.77	4.56	1.94	1.83	1.04	0.62	0.32	0.08	0.07	0.04	0.02	20.72
2016	<0.01	4.98	1.37	2.64	5.24	4.37	1.89	1.66	1.11	0.75	0.45	0.20	0.07	0.07	24.81
2017	0.86	0.12	3.56	1.95	3.32	4.68	4.65	1.75	1.94	0.63	0.51	0.12	0.08	0.04	24.22

b)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	W
2007	133	233	323	390	472	532	536	585	591	640	727	656	685	671	512
2010	133	212	290	353	388	438	512	527	548	580	645	683	665	596	469
2011	133	278	318	371	412	440	502	537	564	541	570	632	622	612	467
2012	112	188	286	347	397	414	437	458	488	523	514	615	509	677	426
2013	96	184	259	326	374	399	428	445	486	523	499	547	677	607	418
2014	228	275	288	335	402	433	459	477	488	533	603	544	537	569	441
2015	128	290	333	342	386	449	463	479	488	505	559	568	583	466	431
2016	95	231	324	360	371	394	440	458	479	488	494	523	511	664	367
2017	86	292	330	373	431	437	462	487	536	534	542	574	589	626	425

c)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot B
2007	0.18	0.43	0.29	0.09	0.47	0.09	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.00	1.64

2010	0.00	0.59	0.44	1.42	1.19	0.59	0.27	0.20	0.11	0.03	0.02	0.01	0.01	0.00	4.89
2011	0.03	0.07	0.28	0.41	0.67	0.54	0.29	0.15	0.07	0.04	0.03	0.01	0.01	0.00	2.69
2012	0.06	0.94	0.35	0.73	0.72	1.00	0.72	0.30	0.17	0.06	0.03	0.01	0.00	0.00	5.09
2013	0.01	1.43	2.32	0.70	1.09	1.15	1.15	0.56	0.22	0.10	0.08	0.02	0.01	0.01	8.85
2014	0.00	0.16	2.24	1.72	1.05	1.14	1.23	0.80	0.36	0.19	0.05	0.03	0.01	0.00	8.98
2015	0.15	0.24	0.80	1.97	1.76	0.87	0.85	0.50	0.30	0.16	0.04	0.04	0.02	0.01	7.72
2016	<0.01	1.15	0.45	0.95	1.95	1.72	0.83	0.76	0.53	0.37	0.22	0.10	0.04	0.04	9.11
2017	0.07	0.03	1.18	0.73	1.43	2.04	2.15	0.86	1.04	0.33	0.28	0.07	0.05	0.03	10.29

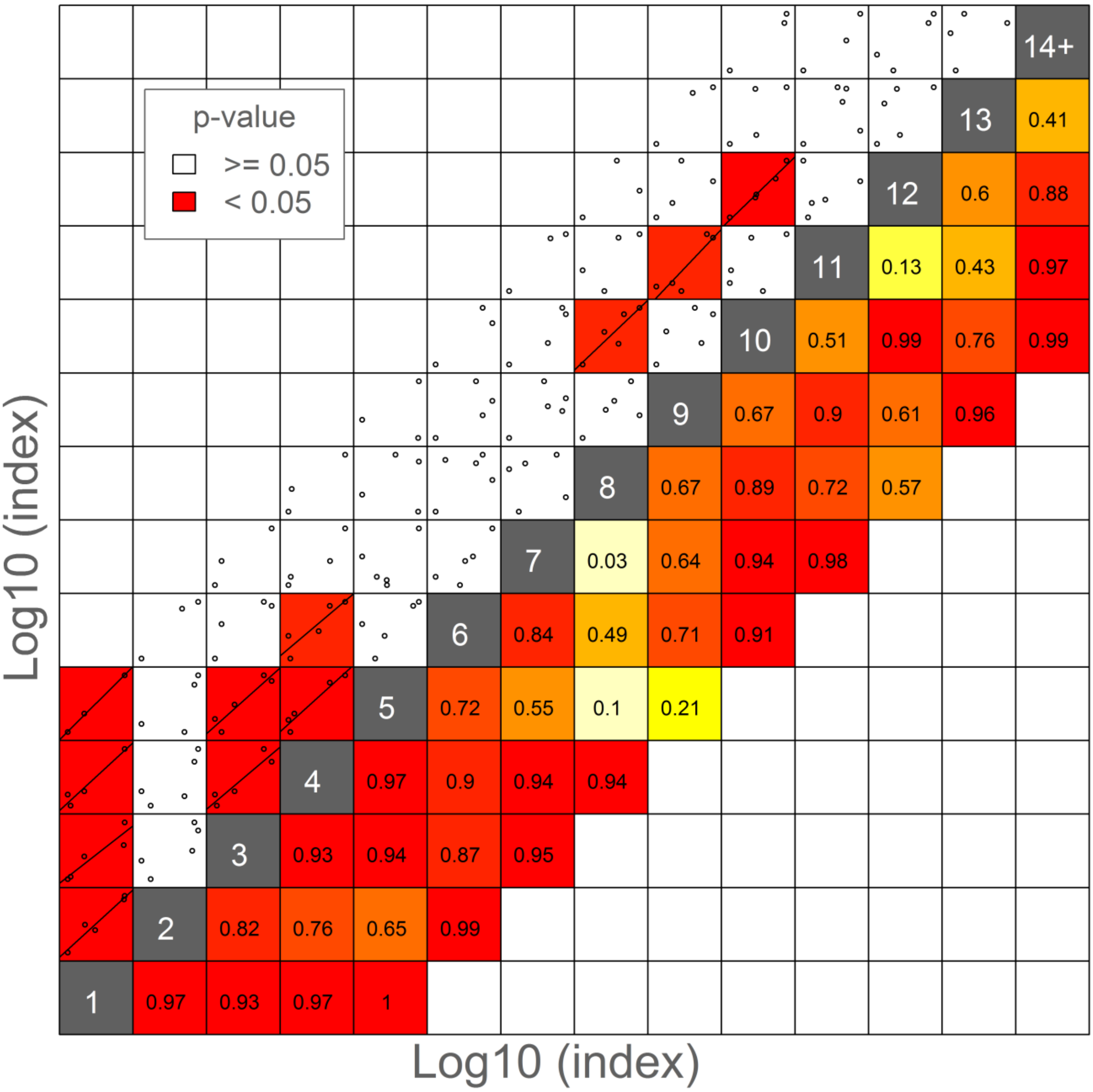


Figure 15. Internal consistency of mackerel density index. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations ($p<0.05$) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

Multibeam sonar recordings

Multibeam sonar recordings were conducted and recorded continuously onboard the two Norwegian vessels M/V "Kings Bay" and M/V "Vendla". The mackerel schools detected were of variable size predominantly with medium density. In some areas, the mackerel schools appeared more as individual fish or loose aggregations, where they were not visible neither on the multibeam sonars (Simrad SH90 and Simrad SX90), nor the echosounder frequencies. They were detected swimming in the upper 5-40 m of the water column throughout the day. Some school were detected below the vertical depth of the Multpelt 832 trawl to approximately 30 m depth. Even if we maximized the ping rate on both the multibeam sonars and multi-frequency echosounders including an array of frequencies from 18 to 333 kHz, the mackerel were practically invisible for the multibeam sonars as well as for the multifrequency echosounders. The main reason is probably due to very loose aggregations/shoals close to the surface thereby providing extremely low detection probability on any acoustic instrumentation. Sometimes nothing or very little was detected on the sonars but still medium to high catches of mackerel were caught, suggesting very dispersed mackerel concentrations. In 2017 we also had several situations where we could observe large amount of schools at the surface with sonars and visual means, but only caught small amounts of mackerel, due to active avoidance of the mackerel.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded mainly in the southern and western part of the Norwegian Sea basin, north of the Faroes and east and north of Iceland (Figure 16). Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring while the herring closer to the Faroes south of 62°N were Faroese autumn spawners. Also herring to the west in Icelandic waters (west of 14°W south of Iceland and west of 24°W north of Iceland, not shown on the map) were allocated to a different stock, Icelandic summer-spawners. The abundance of NSSH in the eastern and northeastern part of the area surveyed were lower and consisted mainly of younger and smaller fish than in the western part. The 0-boundary of the distribution of the adult part of NSS herring was considered to be reached in all directions.

The NSS herring stock is dominated by 4-years old herring (year classes 2013) in terms of numbers and biomass (Table 8). This year class is mainly distributed in the northeastern part of the Norwegian Sea and it contributes 19% to the total biomass. The total number of herring recorded in the Norwegian Sea was 20.6 billion in 2017 and the total biomass was 5.88 million tonnes. Number by age, with uncertainty estimates, for NSS herring during IESSNS in July 2017 is shown in Figure 17.

Table 8. IESSNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian Spring Spawning herring based on calculation in StoX.

```
Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: SILDG03
```

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	21	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
3-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	201	201	-	-
4-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68397	68397	-	-
6-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	256490	256490	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	170993	170993	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-10	59147	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59147	315.4	5.33
10-11	50457	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50457	378.4	7.50
11-12	136402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	136402	1307.9	9.59
12-13	355553	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	355553	4816.1	13.55
13-14	383473	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	383473	6319.9	16.48
14-15	159167	17685	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	176852	3590.1	20.30
15-16	37338	56007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93345	2259.0	24.20
16-17	9751	58506	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68257	2106.2	30.86
17-18	15389	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15389	528.4	34.33
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	7920	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7920	448.5	56.62
20-21	-	18629	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18629	1345.2	72.21
21-22	9699	28394	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38093	3550.3	93.20
22-23	-	40368	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40368	3950.5	97.86
23-24	-	10173	19574	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29747	3214.1	108.05
24-25	-	1611	260359	1074	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	263045	30927.3	117.57
25-26	-	-	212385	1939	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	214324	27947.5	130.40
26-27	-	8370	285480	20073	899	1798	-	-	-	-	-	-	-	-	-	-	-	-	-	316620	46643.9	147.32
27-28	-	-	239377	209150	6589	37718	879	879	-	-	21705	-	-	-	-	-	-	-	-	516297	91045.9	176.34
28-29	-	-	128662	468655	8769	51785	2192	-	26683	6671	-	11674	-	-	-	-	-	-	-	705092	149805.2	212.46
29-30	-	-	68123	1217364	213716	52681	16915	43955	21459	2844	5060	-	-	2174	-	-	-	-	-	1644293	385292.3	234.32
30-31	-	-	48004	1711722	257960	163748	105431	146789	36047	91958	24954	14247	37430	-	-	-	-	-	-	2638289	683813.8	259.19
31-32	-	-	14999	669782	240701	276164	75237	187041	236224	64046	14396	1803	1353	-	-	-	-	-	-	1781746	512964.5	287.90
32-33	-	-	-	179778	164262	244784	211815	199898	164359	70227	63012	64904	-	-	-	-	-	-	-	1363039	438313.1	321.57
33-34	-	-	-	26330	120602	199942	102097	117456	26704	112389	68228	69281	88365	-	26704	-	-	-	-	958098	339260.5	354.10
34-35	-	-	-	38835	42105	114423	160181	291473	111608	103202	83554	125169	145045	19253	-	-	-	-	-	1234849	449380.7	363.92
35-36	-	-	-	31075	-	30272	82236	479029	159563	287383	450808	264361	221082	49526	1109	-	-	-	-	2056442	754143.0	366.72
36-37	-	-	7799	-	-	15124	58784	274260	206195	349368	648398	461976	655694	112215	5619	3989	-	5199	-	2804621	1069276.8	381.26
37-38	-	-	-	-	-	-	-	53288	33303	28907	255151	342890	780999	31985	105920	1259	21452	-	-	1655152	663213.4	400.70
38-39	-	-	-	-	-	-	-	-	-	14365	17534	36788	258188	56554	400	-	-	-	-	383829	165573.5	431.37
39-40	-	-	-	10008	-	-	-	-	-	-	-	5679	19035	22733	26910	-	5679	-	-	90046	36754.7	408.18
40-41	-	-	-	-	-	-	-	-	-	-	-	2315	4629	-	-	-	6944	-	-	13888	6437.3	463.52
TSN(1000)	1216376	247662	1284763	4585786	1055603	1188440	815767	1794067	1022146	1131359	1652800	1401088	2211822	294441	166662	5248	34075	5199	496081	20609383	-	-
TSB(1000 kg)	19003.1	14609.2	202903.9	1114380.3	296986.4	368022.2	272000.6	629533.8	346447.9	403868.4	616834.9	528783.6	870327.9	115766.5	68530.8	1989.5	12682.4	2252.1	-	-	5884923.3	-
Mean length (cm)	12.66	18.44	26.45	29.95	31.07	31.73	32.91	33.79	33.41	34.35	35.37	35.57	36.22	36.43	36.70	36.30	38.10	36.00	6.43	-	-	-
Mean weight (g)	15.62	58.99	157.93	243.01	281.34	309.67	333.43	350.90	338.94	356.98	373.21	377.41	393.49	393.17	411.20	379.11	372.19	433.15	-	-	-	292.59

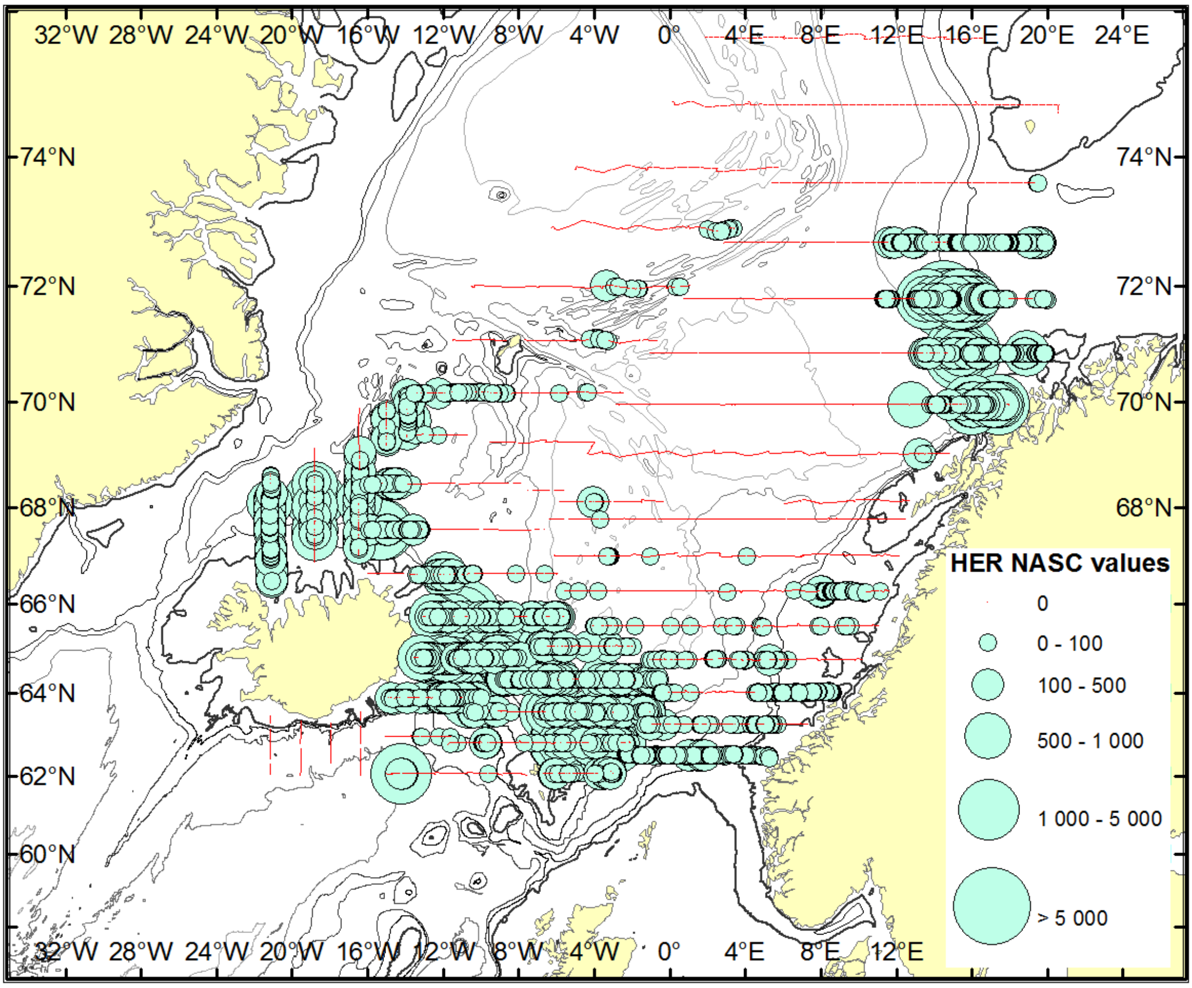


Figure 16. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring north of 62ºN and east of 22 ºW, along the cruise tracks in IESSNS in July-August 2017. South and west of this area the herring observed are other stocks, i.e. Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

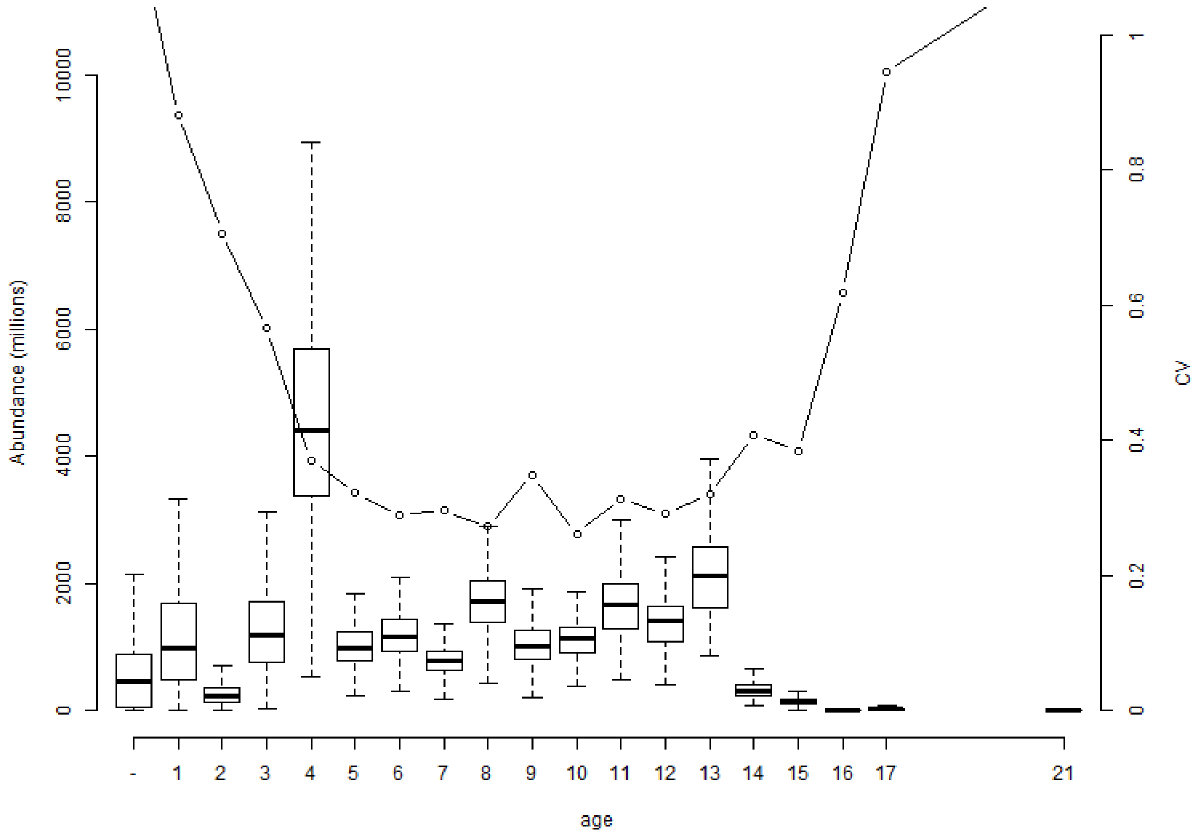


Figure 17. Number by age for NSS herring during IESSNS in July-August 2017. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.5 Blue whiting

The blue whiting was distributed in the entire survey area with exception of the area north of Iceland and in the southern Greenland area. The highest sA-values were observed in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands as well as southwest of Iceland. Some extremely high sA -values were seen south of the Faroe Islands and samples showed that this was 0-group concentrations. The main concentrations of older fish were observed both in connections with the continental slopes in the eastern and the southern part of the Norwegian Sea (Figure 18). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during the IESSNS survey in 2017 was 2.7 million tons (Table 9), which is an increase compared to 2016 when the estimated index was 2.28 million tons. The stock estimate in number for 2017 is 45.4 billion compared to 29.8 billion in 2016. However, when excluding the 0-group, age three is dominating the estimate (46% of the biomass and 48% by number) and the total abundance index (age 1+) decreased from 25.9 in 2016 to 22.3 billion this year, a decrease of approx. 14%. Number by age, with uncertainty estimates, for blue whiting during IESSNS in July 2017 is shown in Figure 19.

Table 9. IESSNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX.

```
Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: KOLMULE
```

LenGrp	age 0	1	2	3	4	5	6	7	8	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
11-12	-	-	-	-	-	-	-	-	-	-	166730	166730	-	-
12-13	3181768	-	-	-	-	-	-	-	-	-	-	3181768	38929.9	12.24
13-14	4926126	-	-	-	-	-	-	-	-	-	-	4926126	76628.6	15.56
14-15	10924214	-	-	-	-	-	-	-	-	-	-	10924214	202098.0	18.50
15-16	4105096	-	-	-	-	-	-	-	-	-	-	4105096	92091.0	22.43
16-17	-	-	-	-	-	-	-	-	-	-	250096	250096	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	29699	-	-	-	-	-	-	-	-	-	29699	1151.8	38.78
20-21	-	78565	34339	-	-	-	-	-	-	-	-	112905	4967.3	44.00
21-22	-	158104	97447	-	-	-	-	-	-	-	-	255551	14176.2	55.47
22-23	-	696065	96499	24905	32951	-	-	-	-	-	-	850420	57980.5	68.18
23-24	-	1210347	709899	261920	10539	-	-	-	-	-	-	2192706	172693.5	78.76
24-25	-	362568	1480435	1080685	129617	5741	-	-	-	-	-	3059046	270135.6	88.31
25-26	-	17327	1482295	2957036	61490	14891	-	-	-	-	-	4533039	436287.1	96.25
26-27	-	3917	1412002	2681029	223971	-	30307	-	-	-	-	4351225	465045.5	106.88
27-28	-	-	356903	1942397	589950	40551	-	-	-	-	-	2929801	348851.3	119.07
28-29	-	1667	55223	924963	420473	83283	23234	-	-	-	-	1508844	195848.3	129.80
29-30	-	-	26894	248806	395101	97077	24473	-	-	-	-	792351	113468.6	143.20
30-31	-	-	9511	110677	300411	76606	63386	-	-	-	-	560591	87024.1	155.24
31-32	-	-	2994	66315	123690	102618	35267	-	-	-	-	330883	56797.3	171.65
32-33	-	-	-	4019	-	102820	36524	-	-	-	-	143363	25215.3	175.89
33-34	-	-	-	-	12444	49850	18622	-	-	-	-	80916	15652.8	193.45
34-35	-	-	-	-	-	-	-	-	24668	24693	-	49361	11434.0	231.64
35-36	-	-	-	-	-	-	-	18129	-	-	-	18129	4525.3	249.62
36-37	-	-	-	-	-	-	18179	-	-	-	-	18179	4859.0	267.29
37-38	-	-	-	-	-	-	-	-	-	-	6308	6308	1907.5	302.40
38-39	-	-	-	-	-	-	-	-	-	-	6464	6464	1764.7	273.00
39-40	-	-	-	-	-	-	-	-	-	-	6464	6464	1797.0	278.00
41-42	-	-	-	-	-	-	-	-	-	-	6076	6076	2236.1	368.00
TSN(1000)	23137203	2558261	5764440	10302753	2300636	573437	249991	18129	24668	24693	442138	45396350	-	-
TSB(1000 kg)	409747.4	183222.4	548339.6	1111371.3	299418.8	87941.5	39860.4	4525.3	5853.5	5580.6	7705.2	-	2703566.0	-
Mean length (cm)	13.98	22.90	24.99	26.13	27.93	30.12	30.49	35.33	34.12	34.00	15.51	-	-	-
Mean weight (g)	17.71	71.62	95.12	107.87	130.15	153.36	159.45	249.62	237.29	226.00	304.41	-	-	60.11

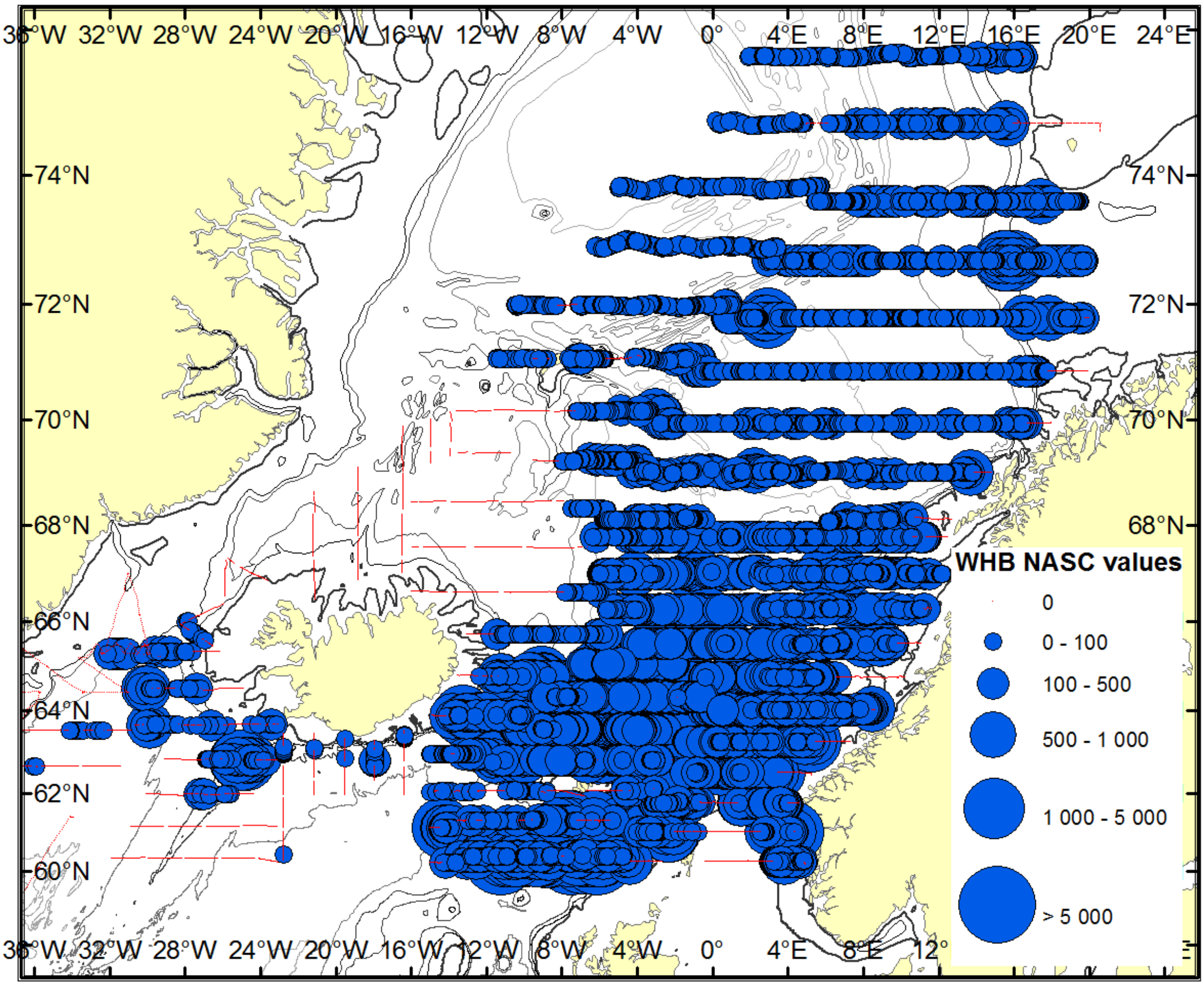


Figure 18. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS in July-August 2017.

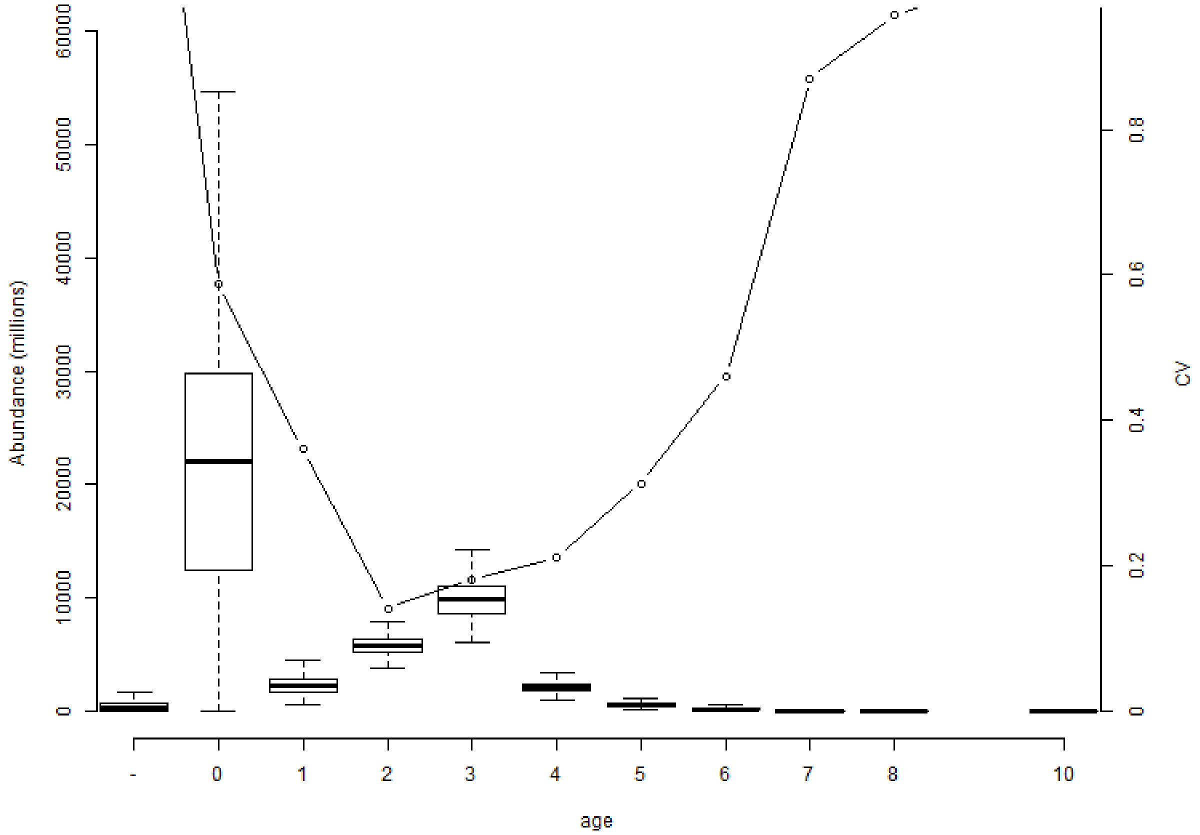


Figure 19. Number by age with uncertainty for blue whiting during IESSNS in July-August 2017. R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 70% of trawl stations in July 2017 (Figure 20) and where lumpfish was caught, 70% of the catches were <10kg. Lumpfish was distributed across the entire survey area, from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Of note, total trawl catch at each trawl station were processed on board Árni Friðriksson, Kings Bay, Vendla and Finnur Fríði, whereas a subsample of 100 kg to 200 kg was processed onboard Trøndur i Gøtu in Faroese waters. Therefore, small catches (< 10 kg) of lumpfish might be missing from the survey track of Trøndur i Gøtu (black crosses in Figure 20).

Abundance was greatest north of 66°N, and lower south of 65°N south of Iceland, in Faroese waters and northern UK waters. The zero line was not hit to the north, northwest and southwest of the survey so it is likely that the distribution of lumpfish extends beyond the survey coverage. The length of lumpfish caught varied from 5 to 57 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups. Generally, the mean length and mean weight of the lumpfish was highest in the coastal waters and along the shelf edges in southwest, west, and northwest, and lowest in the central Norwegian Sea.

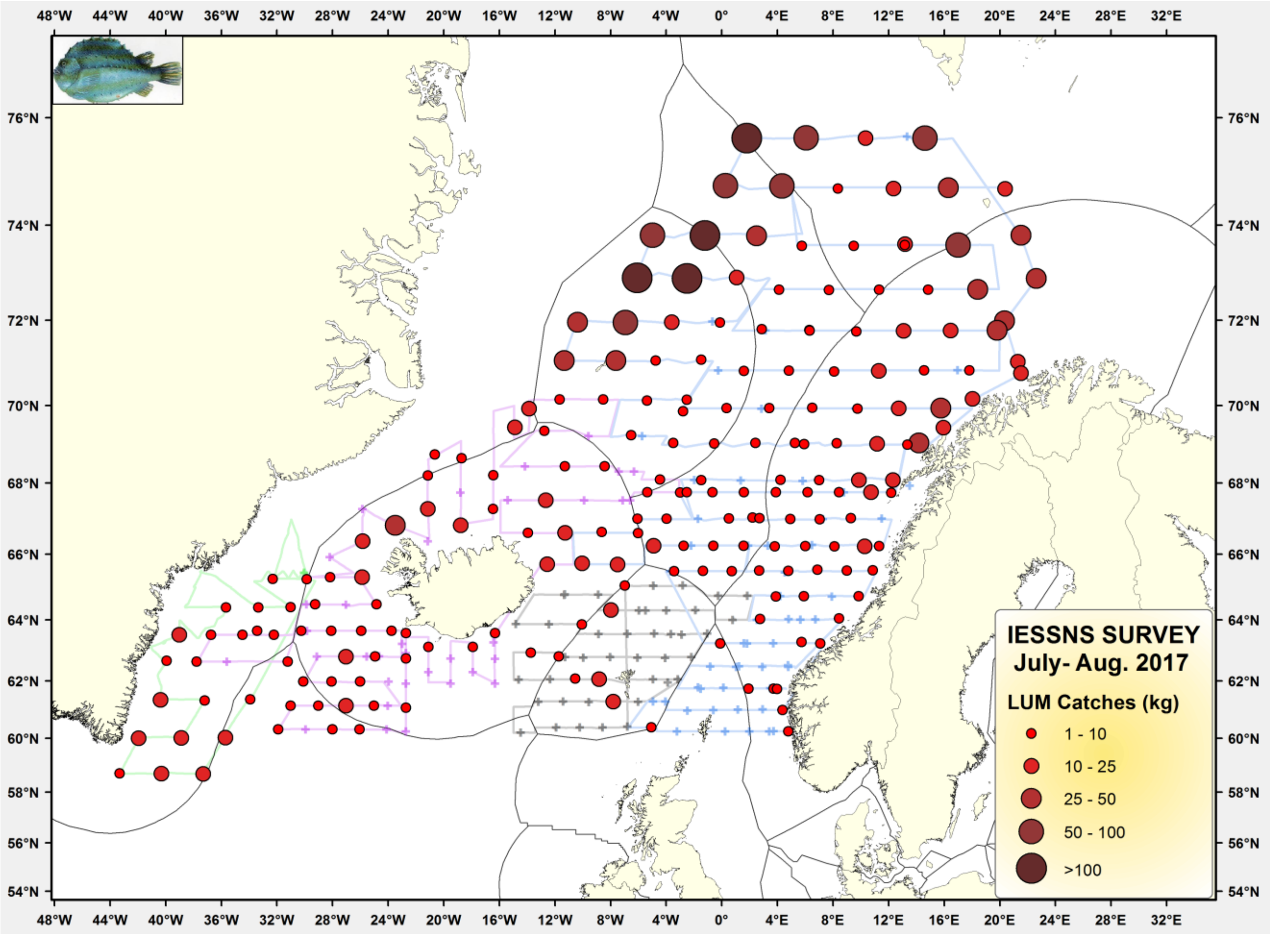


Figure 20. Lumpfish catches at surface trawl stations during the IESSNS survey in July-August 2017.

Salmon (*Salmo salar*)

A total of 36 North Atlantic salmon (*Salmo salar*) were caught in 21 stations both in coastal and offshore areas in the upper 30 m of the water column during the 2017 IESSNS survey (Figure 21). The salmon ranged from 0.11 kg to 5.25 kg in weight, dominated by salmon weighing between 110 gram and 1 kg. The length of the salmon ranged from 24 cm to 61 cm, with a large majority of the salmon <30 cm in length.

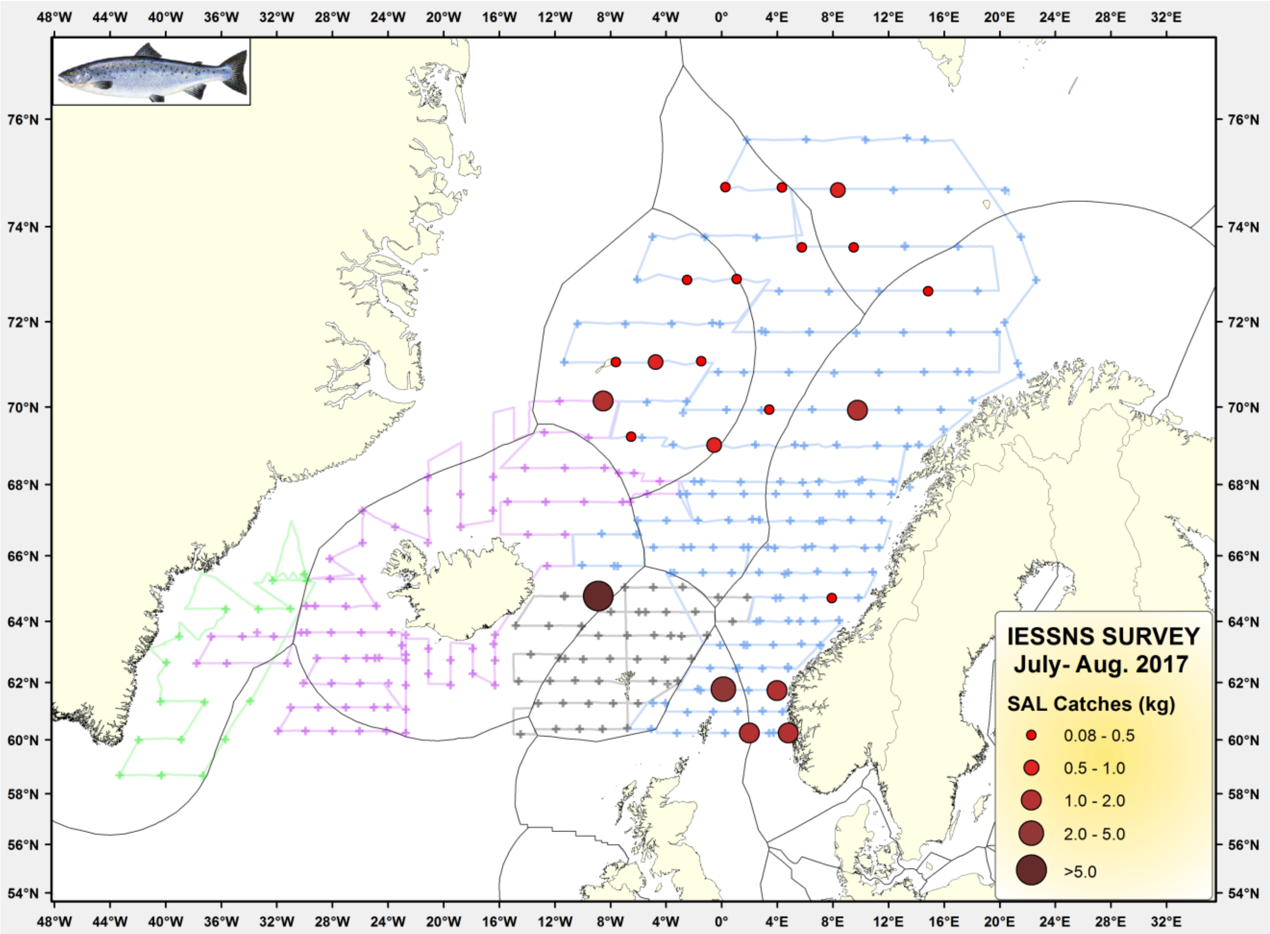


Figure 21. Catches of salmon at surface trawl stations during the IESSNS survey in July-August 2017.

Capelin (*Mallotus villosus*)

Capelin was caught in the trawl on 22 stations from along the cold front at the edge of the mackerel distribution from Cape Farewell, via Denmark Strait, North of Jan Mayen to the Barents Sea around Bear Island (Figure 22).

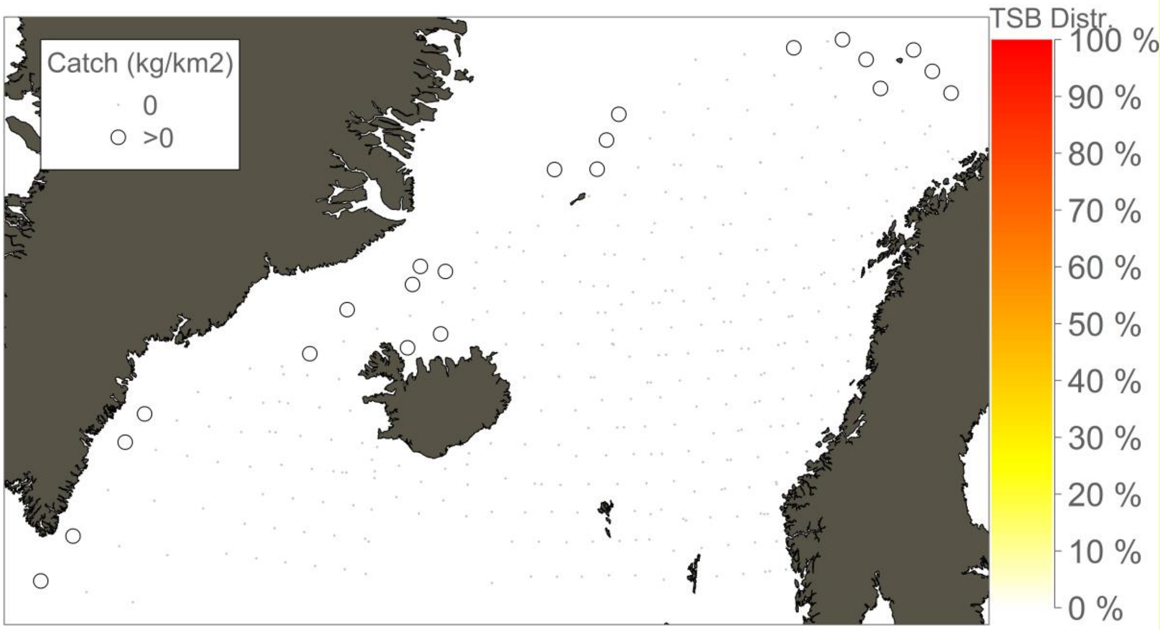


Figure 22. Presence of capelin in surface trawl stations during the IESSNS survey in July-August 2017.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Kings Bay" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland during 3rd of July - 4th of August 2017 (Figure 23). Overall >700 marine mammals and 8 species were observed. Altogether 174 individuals were observed onboard R/V "Árni Friðriksson" whereas >500 individuals were observed onboard M/V "Kings Bay" and M/V "Vendla". We had substantially higher number of sightings in 2017 than previous years, both due to the inclusion of Icelandic data, but also due to more sightings onboard the two Norwegian vessels. The Icelandic sightings were dominated of humpback whales (27), pilot whales (24), sperm whales (14), fin whales (13) and minke whales (12). Only one single small pod of two killer whales was observed during the survey. It has to be mentioned that there were long periods with rather thick fog and thereby low visibility, reducing the sighting probability for marine mammals in Iceland waters during most of the survey period. The opposite situation was evident for the two Norwegian vessels with practically flat sea and excellent visibility during the entire survey period. The species found in the Norwegian part of the survey in the Norwegian Sea and along the Norwegian coast included; fin whales, minke whales, humpback whales, pilot whales, killer whales, sperm whales, white-sided dolphins and white beaked dolphins. Altogether 15 pods consisting of 115 individual killer whales were found, mostly in the central and western part of the Norwegian Sea in close association with mackerel onboard the two Norwegian vessels. High densities of especially large groups of white beaked and white sided dolphins were observed in the northern part of the Norwegian Sea (Figure 23). Small groups of fin whales as well as some humpback whales were also dominating in northern part of the Norwegian Sea feeding on juvenile fish and capelin. Few marine mammals were sighted in the southern and central part of the Norwegian Sea (Figure 23).

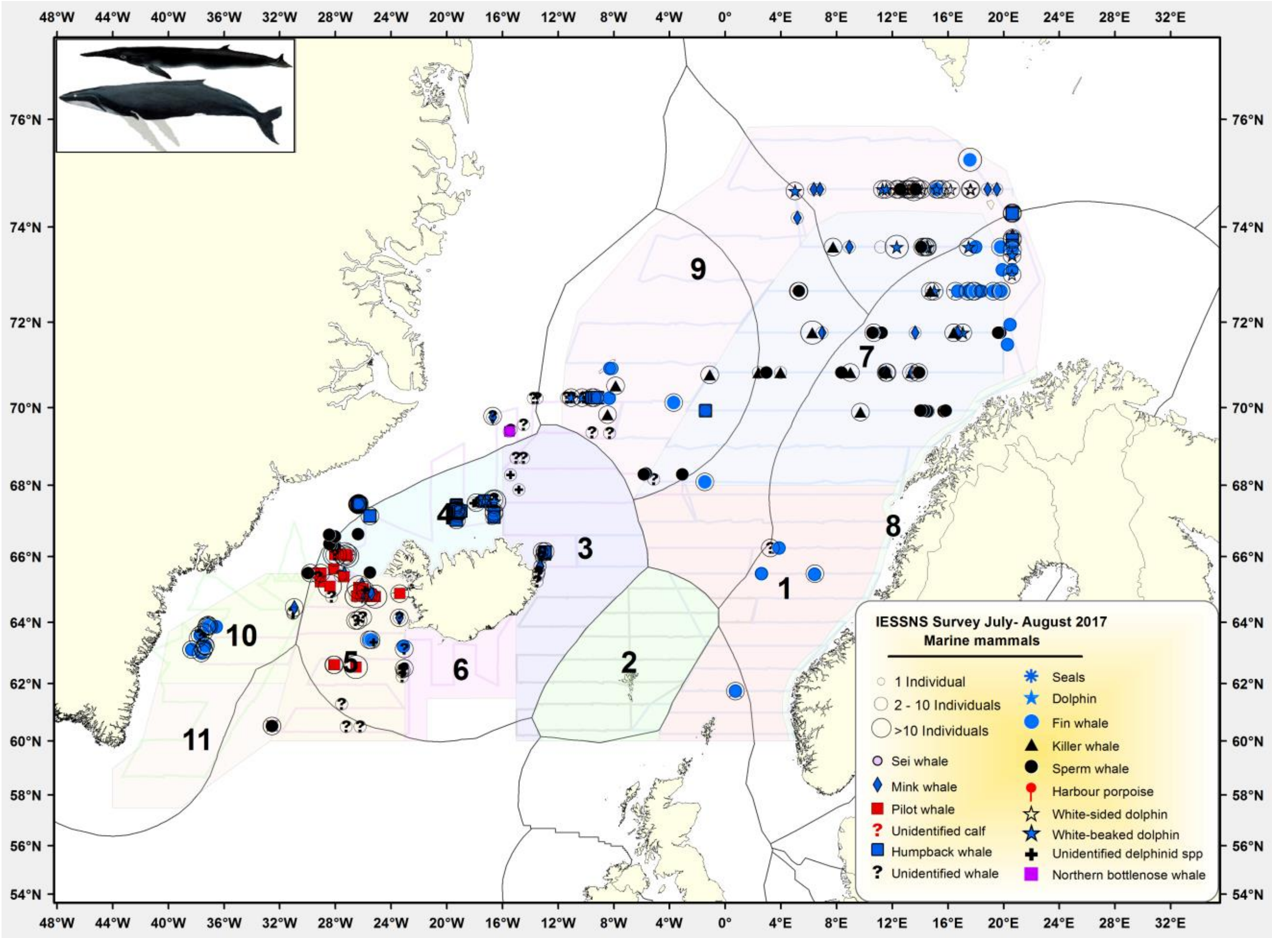


Figure 23. Overview of all marine mammals sighted onboard M/V "Vendla", M/V "Kings Bay" and R/V "Árni Friðriksson" in the Norwegian Sea and surrounding waters in July-August 2017.

5 Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 3rd of July – 4th of August 2017 by five vessels from Norway (2), Iceland (1), Faroes (1), and Greenland (1). The survey coverage slightly smaller than in previous year. A major part of the survey is a standardised surface trawling at predefined locations, which has been used for a swept area abundance estimation of NEA mackerel since 2007, although not in all years. The method is analogous to swept area bottom trawl surveys run for many demersal stocks. In addition to the surface trawling, CTD, zooplankton sampling and marine mammal sightings are also parts of the IESSNS. Deep water trawling aimed on acoustic registrations were undertaken by all vessels for the second time in the 2017 IESSNS survey to identify species and size distribution for acoustic estimation of blue whiting and Norwegian spring-spawning herring. The attempts have been considered successful both in 2016 and 2017, so we are now creating a new time series for abundance estimation and biomass indices for blue whiting (north of 60°N) and Norwegian spring-spawning herring. The IESSNS therefore provides abundance indices of three pelagic fish stocks, i.e. NEA mackerel, blue whiting and Norwegian spring-spawning herring.

The total swept area biomass index of mackerel in 2017 was the highest in the time-series, and was 13 % higher than in 2016, whereas number of individuals was lower in 2017 compared to 2016 by 2 %. The mackerel was distributed over an area of approximately 2.6 million km^2, which gives an average density of 3.9 tonnes/km^2. The average density is the highest in the entire time series. The 13 % increase in biomass indices from 2016 to 2017 can partly be explained by addition of the strong 2014-year class (15 % of the biomass).

The results seem to confirm the observation from the IESSNS 2016 that the 2014-year class is strong (Table 7). The size of the year class is still poorly determined but could be, according to these results, at similar level as the big 2010 and 2011-year classes. The 2016-year class also look promising.

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2017 by the inclusion of one more survey year. This is especially apparent for 5 to 11 years old mackerel. There is now a strong internal consistency for ages 1 to 5 years, and a fair/good internal consistency for ages 5 to 11 years.

The spatio-temporal overlap between mackerel and herring in 2017 was similar to that in both 2015 and 2016. However, the overlap in 2017 was highest in the south-eastern, southern and south-western part of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSS herring in the central and northern part of the Norwegian Sea, mainly because of very limited amounts of herring in this area (Figure 15). Herring concentrations were highest in areas where zooplankton concentrations where high. Mackerel, on the other hand, was distributed in most of the surveyed area, also in areas with more varying zooplankton concentrations. In the areas where herring and mackerel overlap an inter-specific competition for food between the species can be expected. According to Langøy *et al.* (2012), Debes *et al.* (2012), and Oskarsson *et al.* (2015) the herring may suffer in this competition, the mackerel had higher stomach fullness index than herring and the herring stomach composition is different from previous periods. Langøy et al. (2012) and Debes et al. (2012) also found that mackerel target more prey species compared to herring and mackerel may thus be a stronger competitor and more robust in periods with low zooplankton abundances. Mackerel is known to utilize the dominating Atlantic currents for transportation norhtward (Nøttestad et al. 2016a).

This year's survey was very well synchronized in time and was conducted over a relatively short period given the large spatial coverage (Figure 1). This was in harmony to recommendations put forward in last year's report that the survey period should be around four weeks with mid-point around 20 July. The main argument for this time period, was to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year.

The acoustic abundance index of Norwegian spring-spawning herring was 20.6 billion corresponding to 5.88 million tonnes (Table 8). The abundance estimate of herring from the 2016 survey was 20.2 billion corresponding to 6.75 million tonnes, i.e. a reduction of approx. 10.5% in terms of biomass this year. However, the abundance (number of individuals) increased by approx. 2% due to the immigration of the 2013-year class. The distribution of this year class differs from the older fish since most of them are found in the northeastern part of the survey area. Older fish dominates in the western and southwestern part and the 2004-year class is still the most dominant year class in this area. Over all the 2004-year class is second most abundant both in terms of biomass and numbers.

The acoustic abundance index of blue whiting was 45.4 billion corresponding to 2.7 million tonnes (Table 9). The abundance estimate of blue whiting from the 2016 survey was 29.8 billion corresponding to 2.3 million tonnes, i.e. an increase of approx. 17% in terms of biomass. The abundance increased with approx. 52% and this is due to some strong registrations of 0-group south of the Faroe Islands. Some concentrations of 0-group were also seen in the same area last year and it seemed that these schools were mainly fish concentrated by fin whales feeding. The biomass index was close to threefold the estimate from May indicating that blue whiting are moving back to the Norwegian Sea to feed after the spawning migration in the spring.

The group considered the two acoustic biomass estimates of herring and blue whiting to be of good quality in the 2017 IESSNS.

The overall obtained zooplankton biomass indices in this year's survey (Figure 9) were in line with the results of the IESNS survey in May (ICES, 2017). There were, nevertheless, differences in areas where the high-density of plankton biomasses were located from May to July 2017. There was a substantial increase in zooplankton biomasses in parts of Icelandic and Greenland waters from July 2016 to July 2017. In the central and northern Norwegian Sea a slight decrease in zooplankton biomasses was observed from July 2016 to July 2017. These plankton indices, however, needs to be treated with some care due to various amounts of phytoplankton species/groups available to the zooplankton between years and areas. Further, the zooplankton estimate is only a snapshot of the standing stock biomass, not of the actual production in the area, which complicates spatio-temporal comparisons.

The swept-area estimate was as in previous years based on the standard swept area method using the average horizontal trawl opening by each participating vessel (ranging from 61 to 69 m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

6 Recommendations

Recommendation	To whom
Perform statistical power analyses of the historic data, to optimize the survey (station distance vs. patchiness in different areas).	Norway, Faroe Islands, Iceland, Greenland, EU
Encourage EU to join the IESSNS survey in order to obtain an even better synoptic and to include the southern part of the mackerel distribution during summer. Develop a method that can sample the mackerel representatively in the North West European shelf Seas south of the present survey area. Investigate the horizontal distribution and abundance of mackerel and if standardized trawling in the surface (0-30 m) can be used to measure the abundance of mackerel in the North West European shelf Seas south of the present survey area.	EU
We recommend that observers collect sighting information of marine mammals and birds on all vessels.	Norway, Faroe Islands, Iceland, Greenland, EU
In planning for IESSNS 2018, all vessels should aim for planning surface trawls in a straight path in addition to the predefined curved path surface trawl stations, to get enough replicates to evaluate if there are differences in catchability between straight and curved tows. The needed number of extra trawls should be calculated in a power analysis.	Norway, Faroe Islands, Iceland, Greenland, EU
The guidelines for trawl performance should be revised to reflect realistic values.	Norway, Faroe Islands, Iceland, Greenland, EU
Criteria should be established for discarding trawl stations when trawl performance is not good enough.	Norway, Faroe Islands, Iceland, Greenland, EU
A scrutinizing workshop to train all participant in analysing blue whiting and herring backscatter.	Norway, Faroe Islands, Iceland, Greenland.

Scientific personal should observe all surface trawling live from the bridge and specifically observe that headline is in surface, door spread is optimal and that trawl speed is recorded.	Norway, Faroe Islands, Iceland, Greenland.
The stratum south of Iceland (number 6 is not dynamic, it is permanent and the whole stratum should be surveyed.	Iceland

7 Survey participants

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8 Acknowledgements

We greatly appreciate and thank skippers and crew members onboard M/V "Kings Bay", M/V "Vendla", M/V "Trøndur i Grøtu", M/V Finnur Fríði and R/V "Árni Friðriksson" for outstanding collaboration and practical assistance during the joint mackerel-ecosystem IESSNS cruise in the Nordic Seas from 3rd of July to 4th of August 2017.

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