Working Document to

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Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V "M. Ytterstad", M/V "Vendla", M/V "Tróndur í Gøtu", M/V "Finnur Fríði" and R/V "Árni Friðriksson", 1 – 31 July 2016

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1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within only four weeks from 1st to 31st of July 2016 on five vessels from Norway (2), Iceland (1), Faroe Islands (1) and Greenland (1). A standardised pelagic trawl swept area method was used to obtain abundance indices and study the spatial distribution of NEA mackerel (*Scomber scombrus*) in relation to other pelagic fish stocks, ecological and environmental factors in the Nordic Seas as in recent years. One of the main objectives is to provide age-disaggregated abundance indices on an annual basis with uncertainty estimates for NEA mackerel applicable as a tuning series in the stock assessment. In 2016 we also aimed at getting acoustical abundance estimation of blue whiting (*Micromesistius poutassou*) and Norwegian spring-spawning (NSS) herring (*Clupea harengus*).

The total swept area biomass index of NEA mackerel in summer 2016 was 10.2 million tonnes distributed over an area of 3.0 million square kilometres in the Nordic Seas. The estimate in 2016 is 2.5 million tonnes higher (32.5%) than in 2015 (7.7 million tonnes), when it was distributed over an area of 2.7 million square kilometres. The 2011-year class contributed with 20% (in numbers) followed by the 2010- and 2014 year classes with 17% each in numbers. The 2012 year class had 11%. Altogether 55% of the estimated number of mackerel was less than 6 years old. The internal consistency plot for age-disaggregated year classes has improved since the benchmark in March 2014 by the inclusion of three more survey years. This is especially apparent for younger ages. There is now good internal consistency for 1-10 years old mackerel, and the internal consistency has also improved between age 5 and 6.

Mackerel was observed in most of the surveyed area, and the zero boundaries were found in the western and the northern areas. The zero boundary was not found to the east in the southern Barents Sea nor in the southeastern areas (towards the North Sea/Shetland). The mackerel was present in higher quantities in the northern, northwestern and western regions including Icelandic and Greenland waters of the surveyed area in 2016 compared to last year.

Acoustical measurements of Norwegian spring-spawning (NSS) gave abundance index of age 4+ of 19.3 billions, corresponding to 6.57 million tonnes. This is comparable to the May (IESNS) survey index in 2016 of 18.3 billions (4.9 million tonnes). The 2004 year class dominated with 23% of the biomass. The NSS herring was mainly found north of the Faroe Islands, to the east and north off Iceland and in the Jan Mayen zone. Low concentrations were found in the central, northern and eastern areas of the Norwegian Sea.

The spatio-temporal overlap between NEA mackerel and NSS herring in July-August 2016 was highest in the south-eastern, southern and south-western 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.

The acoustical measurements and dedicated trawling on deeper registrations provided a robust estimate of blue whiting abundance in Nordic Sea and is considered as an establishment of new time-series possibly applicable for tuning in the analytical stock assessment in the future. The total biomass of blue whiting was estimated to be 2.28 million tonnes (29.8 billion individuals), which is higher than the estimate from IESNS in May-June 2016 (1.55 million tonnes and 20.0 billion individuals) and slightly lower than the estimate from the IBWSS spawning survey in March-April 2016 (2.87 million tonnes and 34.4 billion individuals).

Lumpfish of all sizes were caught in the upper 30 m of the water column practically distributed everywhere within the total surveyed area from west of Cape Farwell in Greenland to southern part of the Barents Sea.

A few North Atlantic salmon were caught mainly in central part and western part of the Norwegian Sea during the IESSNS survey.

The sea surface temperature in July 2016 was 1-2°C warmer than in 2015 throughout most of the surveyed area and also 1-2 °C higher than the long term average for the last 20 years.

The average zooplankton index for the Norwegian Sea was slightly higher in 2016 (8.6 g m^{-2}; n=158), than in 2015 while 50% lower in Icelandic waters (4.2 g m^{-2}; n=56) and Greenlandic waters (7.4 g m^{-2}; n=21).

Opportunistic whale observations were done by the two Norwegian vessels during the survey. Overall 700 marine mammals were observed, substantially higher number of sightings than previous years. Higher densities, including large groups of fin whales, were observed in the northernmost part of the Norwegian Sea

2 Introduction

During four weeks (1st to 31st of July) in 2016, five vessels; the M/V "M. Ytterstad" and M/V "Vendla" from Norway, and M/V "Trøndur i Grøtu" 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 survey with altogether five vessels was conducted within only 4 weeks of survey time in July 2016.

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. Other major pelagic species such as Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) have also been covered, although with less effort. But in 2016 a new primary objective during was to conduct systematic acoustic abundance estimation of both herring and blue whiting. 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 both species during their summer feeding distribution in the Nordic Seas (Utne et al. 2012; Trenkel et al. 2014; Pampoulie et al. 2015).

Opportunistic whale observations were conducted onboard the Norwegian vessels M. Ytterstad and Vendla in order to collect data on distribution and aggregation of marine mammals in relation to potential prey species and the physical environment. 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.

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. Since then, three more years have been added to the time-series, which makes it more robust. In addition, methodological and statistical changes and improvements 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. Details on the survey methods are published in Nøttestad et al. (2016). A preliminary estimate of the abundance of mackerel based on the swept area analyses using the StoX is presented.

3 Material and methods

Coordination of the survey was done during WGWIDE meeting in San Sebastian, Spain, WGIPS meeting in Dublin, Ireland, and by correspondence in spring and summer 2016. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were very calm with exceptionally good survey conditions for all the five vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling.

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 were considered and implemented during the IESSNS survey in July-August 2014 and in the surveys thereafter.

Table 1. Survey effort by each of the five vessels in the IESSNS survey in 2016. *) 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	1/7-31/7	5481	98/82	82	79
Tróndur í Gøtu	4/7- 21/7	2922	45/39	39	38
Finnur Fríði	23/7-31/7	1908	20	20	20
Vendla	1/7-30/7	3813	91/69	70	69
M.Ytterstad	1/7-30/7	3731	87/72	73	72
Total	1/7-31/7	17856	341/262	284	278

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. Trøndur i Gøtu was equipped with a mini SEABIRD SBE 25+ CTD sensor, and M.Ytterstad and Vendla were both equipped with SEABIRD CTD sensors and SAIV CTD sensors. Finnur Fridi operation 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.

All five 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 (M. Ytterstad and Vendla) and 200 µm (Árni Friðriksson, Trøndur i 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).

This year, it was possible to take all planned CTD and plankton stations. The number of stations taken by the different vessels is provided in Table 1.

Light measurements from the mast were done continuously, including during all trawl hauls, on all vessels, except onboard Árni Friðriksson. These data have not yet been analysed and therefore the results are not presented in this report, but will be reported later.

3.2 Trawl sampling

All vessels used the standardized Multpelt832 pelagic trawl (ICES, 2013a; Valdemarsen et al. 2014) 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. The properties of the Multpelt832 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 100 kg (if it was clean catch of either herring or mackerel) to 200 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 1st to 31st of July 2016. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**M. Ytterstad**	**Árni Friðriksson**	**Vendla**	**Tróndur í Gøtu**	**Finnur Fríði**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Tornet/Hampiðjan (55/27)	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	350	350	0
Difference in warp length port/starboard (m)	2-10	3-12	2-10	20-25	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg (decreased to 320 kg)	2×400	2×400	2×500	0
Weight of the groundrope chain (kg)		Tornet 1163kg/Hampiðjan 925 kg		950 kg		
Setback (m)	6 m	6	6 m	6 m	6	+
Type of trawl door	Seaflex adjustable hatches	Jupiter	Seaflex 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 m^2 with 75% hatches	7 m^2	7.5 m^2 with 25% hatches	6 m^2	7 with 50%	+

	(effective 6.5 m^2)		(effective 6.5 m^2)		hatches (effective 6.5 m^2)	
Towing speed (knots)	4.8 (4.5-5.2)	5.0 (3.6-5.4)	4.7 (4.4-5.2)	5.0 (4.7-5.2)	4.8 (4.5-5.1)	+
Trawl height (m)	25-34	26-44 m	26-36	34.8	38-50	+
Door distance (m)	112-128	96-126 m	110-125	108.7	115 (103-125)	+
Trawl width (m)	-	-	-	-	65.3 m	+
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, 10-17 m	5-28, 5-27 m	5-16, 7-18 m	7.8, 7.4	5-15, 6-18 m	+
Headline depth	0 m	0-1 m	0 m	0 m	0-1 m	+
Float arrangements on the headline	Kite +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite + 2 buoys on each wingtip	Kite + 2 buoys on wingtips	Kite + 2 buoys on wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	All weighted	+

Table 3. Summary of biological sampling in the survey from 1.-31. July 2016 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	200/100*	100/50*	150	100
	Herring	200/100*	100/50*	200	100
	Blue whiting	200/100*	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	30	0	0	
Stomach sampling	Mackerel	10	20	10**	
	Herring	10	20	10**	10
	Blue whiting	10	20	10**	10
	Other fish sp.	0	0	0	10
Tissue for genotyping	Mackerel	0		0	0
	Herring	30		0	30

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

Underwater camera observations during trawling

All vessels except onboard RV Árni Friðriksson employed an underwater video camera (GoPro HD Hero 3 or 4 Black Edition, www.gopro.com) or high definition Sony camera in the trawl to observe mackerel behaviour during trawling. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. The goal of the video recordings was to observe and assess: individual and schooling behaviour, escapement from the cod end and through meshes, patchiness and swimming performance of mackerel. No light source was employed with cameras, hence, recordings were limited to day light hours. Video recordings were collected at 20 trawl stations between 200 mm and 400 mm mesh sizes onboard M. Ytterstad and Vendla. Onboard Trøndur i Grøtu video recordings were collected at 4 trawl stations between 1 and 2 m mesth size. Video recordings from a total of 6 trawl stations were taken by M/V Finnur Fridi in Greenland waters. Analyses of the recording material 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 1st and 30st of July 2016 onboard the Norwegian chartered vessels M/V "M. Ytterstad" and M/V "Vendla", respectively. 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 M. Ytterstad and Vendla were calibrated 29th of June 2016 for 18, 38 and 200 kHz. Árni Friðriksson was also calibrated on 12th of April 2016 for the frequencies 18, 38, 120 and 200 kHz, Tróndur í Gøtu was calibrated on 30th June 2016 and Finnur Fríði was calibrated on the 19. July 2016 for 38, 120 and 200 kHz prior to the cruise. 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 1st to 31st of July 2016. M/V Finnur Fridi did collect acoustic data during the survey, but they were not used in the analyses.

	M/V M. Ytterstad	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu	M/V Finnur Fríði
Echo sounder	Simrad EK60	Simrad EK 500	Simrad EK 60	Simrad EK 60	Simrad EK 60
Frequency (kHz)	18, 38, 70, 120, 200	38, 18, 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	8	9	6	8
Upper integration limit (m)	15	15	15	7	Not used
Absorption coeff. (dB/km)	9.9	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	2.425	2.425	2.43	
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)	-21.1	-20.81	-20.6	-20.6	-20.7
TS Transducer gain (dB)	24.87	24.44	23.27	24.29	24.04
s_A correction (dB)	-0.60	-0.63	-0.65	-0.65	-0.61
alongship:	6.89	7.22	7.01	7.12	7.21
athw. ship:	6.87	7.2	7.11	7.19	7.07
Maximum range (m)	500	500 (750 in part of the survey)	500	500	500
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 7.x	Sonardata Echoview 6.x

Multibeam sonar

M/V "M. Ytterstad" 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. The main objective for the continuous sonar recordings was to study the vertical distribution, school geometry and patchiness of the mackerel.

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 and herring. The main adaptation was in the Icelandic-south stratum where it was shortened southwards as the zero line of mackerel distribution had been reached. Temporal survey progression by vessel along the cruise tracks in July 2016 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.

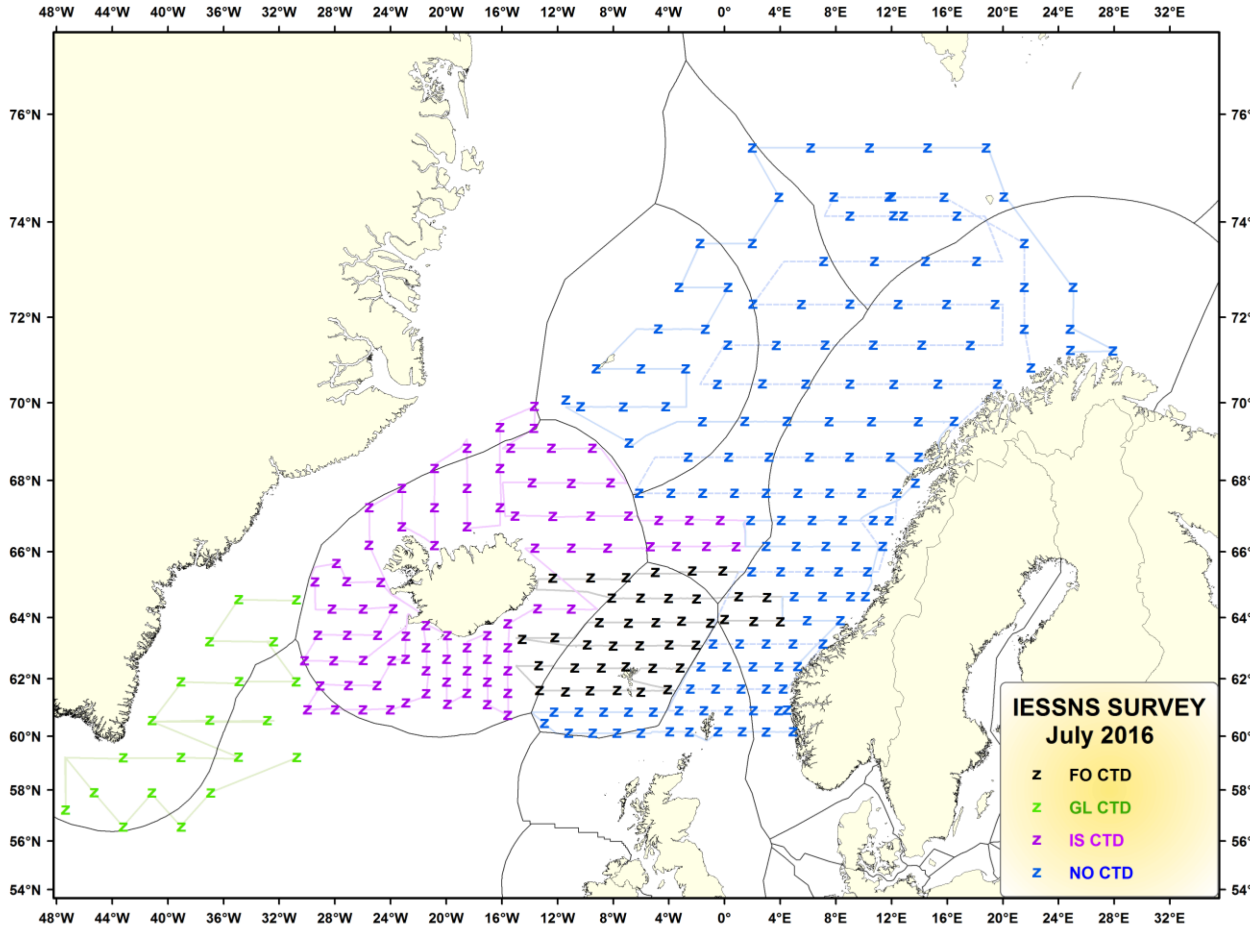


Figure 1. Fixed predetermined trawl stations included in the IESSNS July 2016. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Arni Fridriksson (purple), Tróndur í Gøtu (black), M. Ytterstad and Vendla (blue) and Finnur Fríði (green).

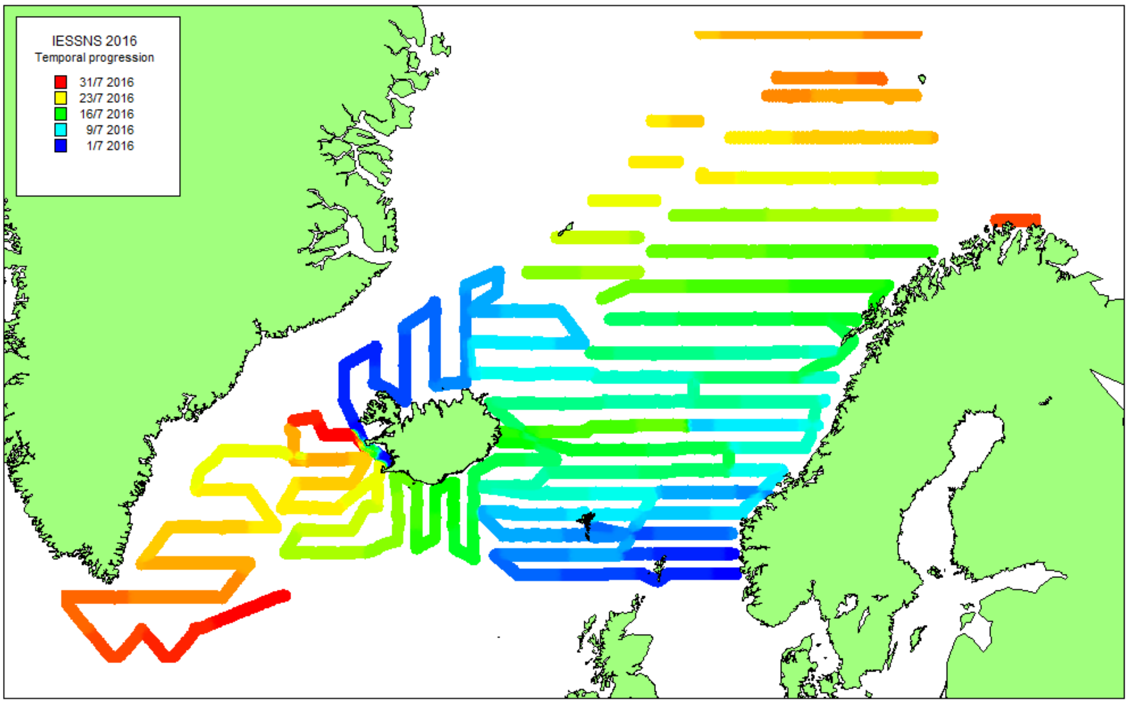


Figure 2. Temporal survey progression by vessel along the cruise tracks in July 2016: blue represents survey start (1 July) progressing to red representing the end of the survey (31 July).

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.

The acoustic biomass estimates of herring and blue whiting were calculated from the StoX software package.

An exploratory run for mackerel was also done using the swept-area option in StoX.

3.6 Swept area index and biomass estimation

The swept area estimate is based on catches in the whole area covered in the survey, or between 56°N and 76°N and 45°W and 28°E. Rectangle dimensions were 2° latitude by 4° longitude as for the calculations in 2015. However, this rectangle size is larger than what was used prior to 2015. Allocation of the biomass to exclusive economic zones (EEZs) was done in the same way as in 2010-2015 (see Annex 1).

The swept area calculations follow the same approach as in previous years. The approach is basically the same as thoroughly presented in Nøttestad et al (2016) without the collapse of strata for precision estimates. 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). The average Mac_D for all hauls within a rectangle are used to calculated the total abundance of mackerel within that rectangle. All rectangles are summarized to get total biomass estimate, and the biomass is split into number-at-age for each rectangle. This is done according to standard allocation of biomass to age according to the length distribution of the sampled fish. As there are spatial differences in length-at-age within the survey area (Ices 2014), four different age-length keys area applied (southern eastern area, northern eastern area, middle area and western area).

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; for trawl door spread all values < 80 m and > 140 m were deleted and for opening vertical spread all values < 20 m and > 50 were deleted. 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	M. Ytterstad	Vendla	Finnur Fríði
Trawl doors horizontal spread (m)					
Number of stations	39	82	72	69	20
Mean	108.7	114	119	117	116
max	114.7	126	127	125	126
min	104.4	96	104	106	103
st. dev.	4.5	4	6	5	8
Vertical trawl opening (m)					
Number of stations	37	75	72	69	20
Mean	34.8	33	31	33	43
max	38.1	44	34	36	50
min	31.8	26	27	28	38
st. dev.	2.9	4	4	4	3.5
Horizontal trawl opening (m) **					
mean	63	65.2	65	66	65.3
Speed (over ground, nmi)					
Number of stations	39	82	72	69	20
mean	5.0	5.0	4.7	4.8	4.8
max	5.2	5.4	5.2	5.3	5.1
min	4.7	3.6	4.1	4.2	4.5
st. dev.	0.12	0.3	0.3	0.3	0.2

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 a 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.

Door	Towing speed (knots)					
spread (m)	4.5	4.6	4.7	4.8	4.9	5
100	57.2	57.7	58.2	58.7	59.2	59.7
101	57.6	58.1	58.6	59.1	59.6	60.1
102	58.1	58.6	59.0	59.5	60.0	60.5
103	58.5	59.0	59.5	59.9	60.4	60.9
104	59.0	59.4	59.9	60.3	60.8	61.3
105	59.4	59.9	60.3	60.8	61.2	61.7
106	59.8	60.3	60.7	61.2	61.6	62.1
107	60.3	60.7	61.2	61.6	62.0	62.5
108	60.7	61.1	61.6	62.0	62.4	62.9
109	61.2	61.6	62.0	62.4	62.8	63.2
110	61.6	62.0	62.4	62.8	63.2	63.6
111	62.0	62.4	62.8	63.2	63.6	64.0
112	62.5	62.9	63.3	63.7	64.0	64.4
113	62.9	63.3	63.7	64.1	64.4	64.8
114	63.4	63.7	64.1	64.5	64.9	65.2
115	63.8	64.2	64.5	64.9	65.3	65.6
116	64.3	64.6	65.0	65.3	65.7	66.0
117	64.7	65.0	65.4	65.7	66.1	66.4
118	65.1	65.5	65.8	66.1	66.5	66.8
119	65.6	65.9	66.2	66.6	66.9	67.2
120	66.0	66.3	66.6	67.0	67.3	67.6

4 Results

4.1 Hydrography

Overall the surface temperatures were generally 1-2°C warmer in the whole Northeast Atlantic in July 2016 compared to the average for the last 20 years based on Sea Surface Temperature (SST) anomaly plot (Figure 3). The temperature in the surface layer from northern North Sea in the south to Barents Sea in the north, and from the Norwegian coast in the east to Greenland in the west was between 1-2°C warmer in July 2016 than the average for the last 20 years (Figure 3). In the central and eastern part of the Norwegian Sea the SST was also 1-2°C warmer than the 20 year average. The waters around Faroe Islands and Iceland also had 1-2°C warmer waters compared to July 2015. South of the Greenland-Scotland ridge the SST was about 1°C lower or at the same level compared to the 20 year average. The surface temperatures were warmer in July 2016 compared to July 2015 (Figure 4), although not as warm as found in July 2014.

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 3 and 4). However, since the anomaly is now based on averages values over whole July, it should give representative results of the surface temperature.

The upper layer (< 30 m depth) was 1-2°C warmer in 2016 compared to 2015 more or less throughout the surveyed area (Figures 5 and 6). The temperature in the upper layer was more than 6°C in more or less throughout the surveyed area covering approximately 3 million km², except along the north-western fringes of the surveyed area 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 2014 and 2015. At all depths there was a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

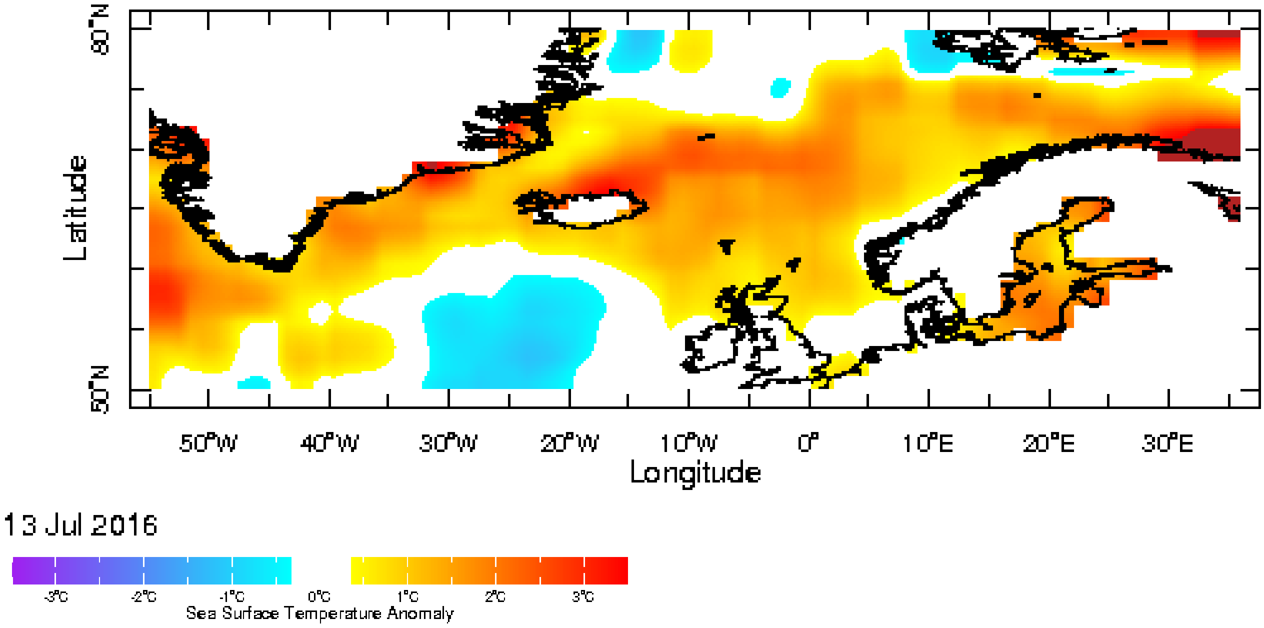


Figure 3. Sea surface temperature anomaly in July (°C; centered for mid July 2016) showing warm and cold conditions in comparison to a 20 year average.

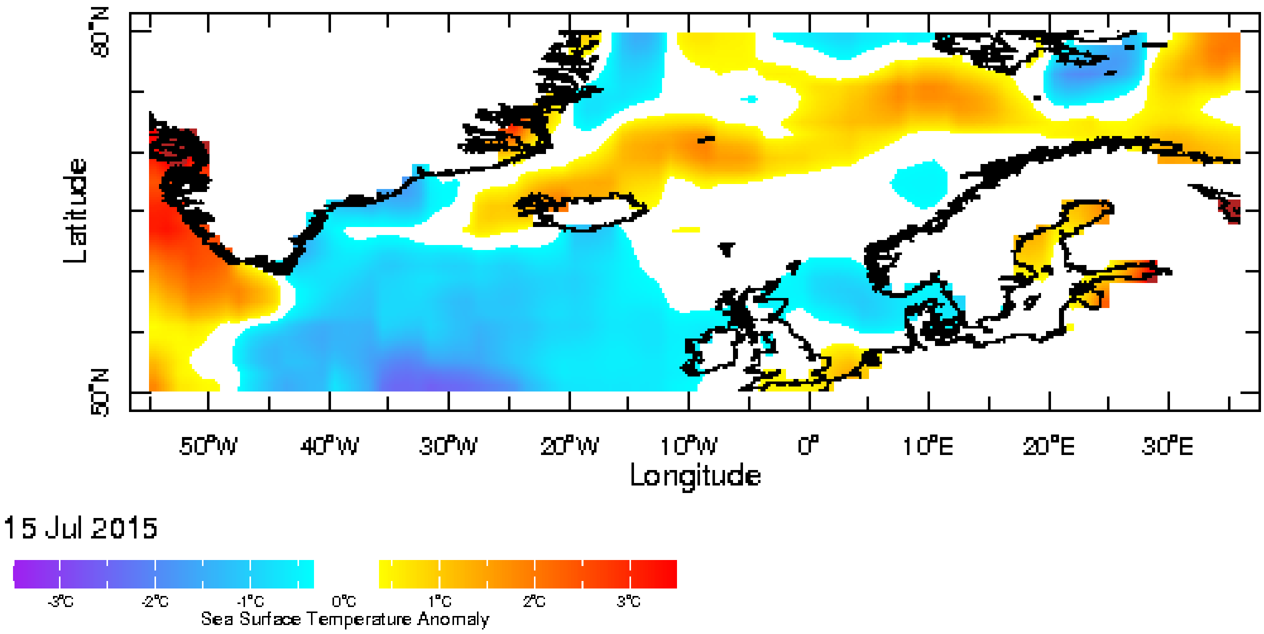


Figure 4. Sea surface temperature anomaly in July (°C; centered for mid July 2015) showing warm and cold conditions in comparison to a 20 year average.

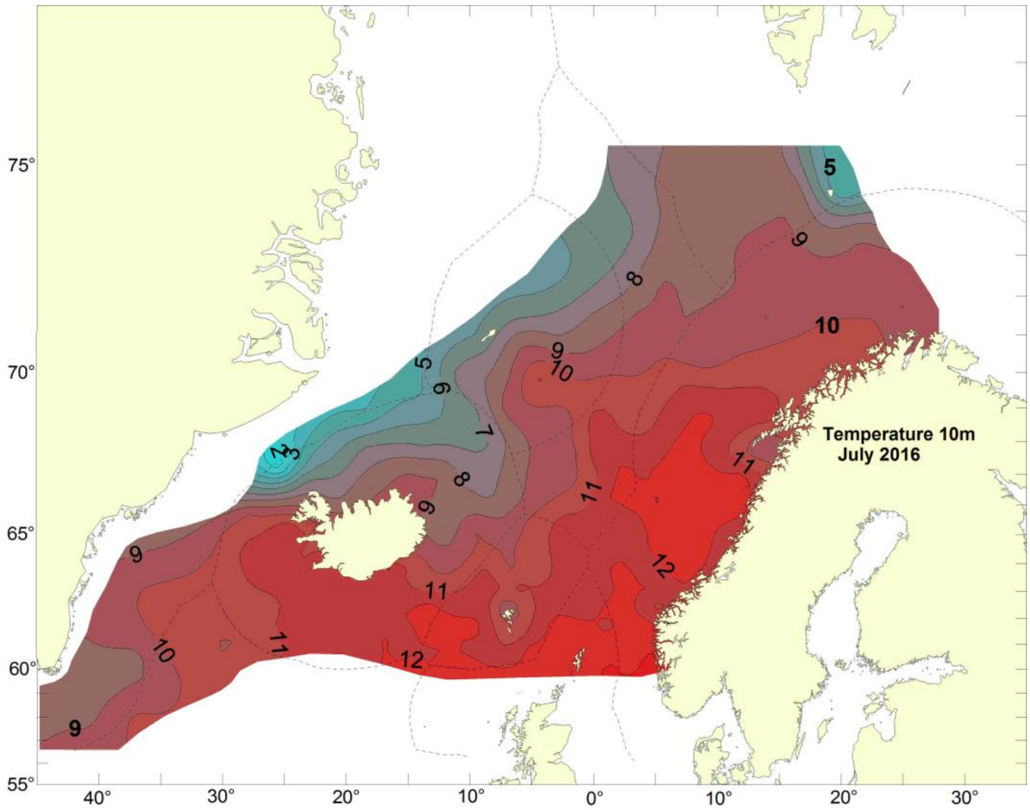


Figure 5. Temperature (°C) at 10 m depth in the Norwegian Sea and surrounding waters in July 2016.

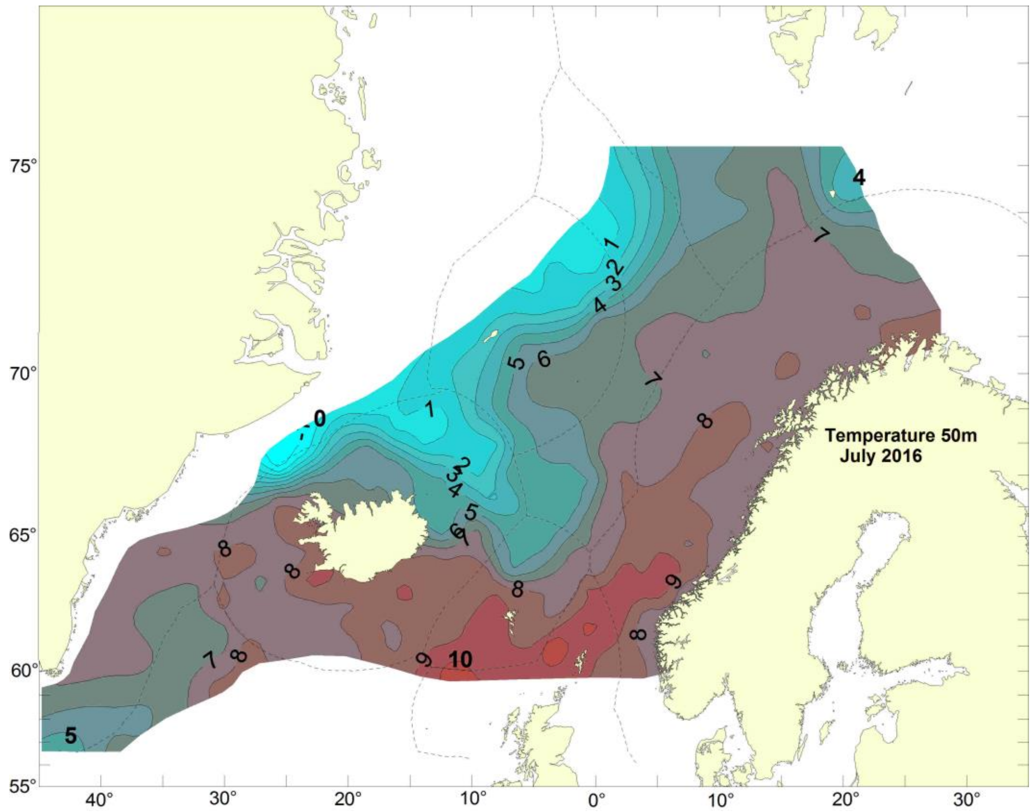


Figure 6. Temperature (°C) at 50 m depth in the Norwegian Sea and surrounding waters in July 2016.

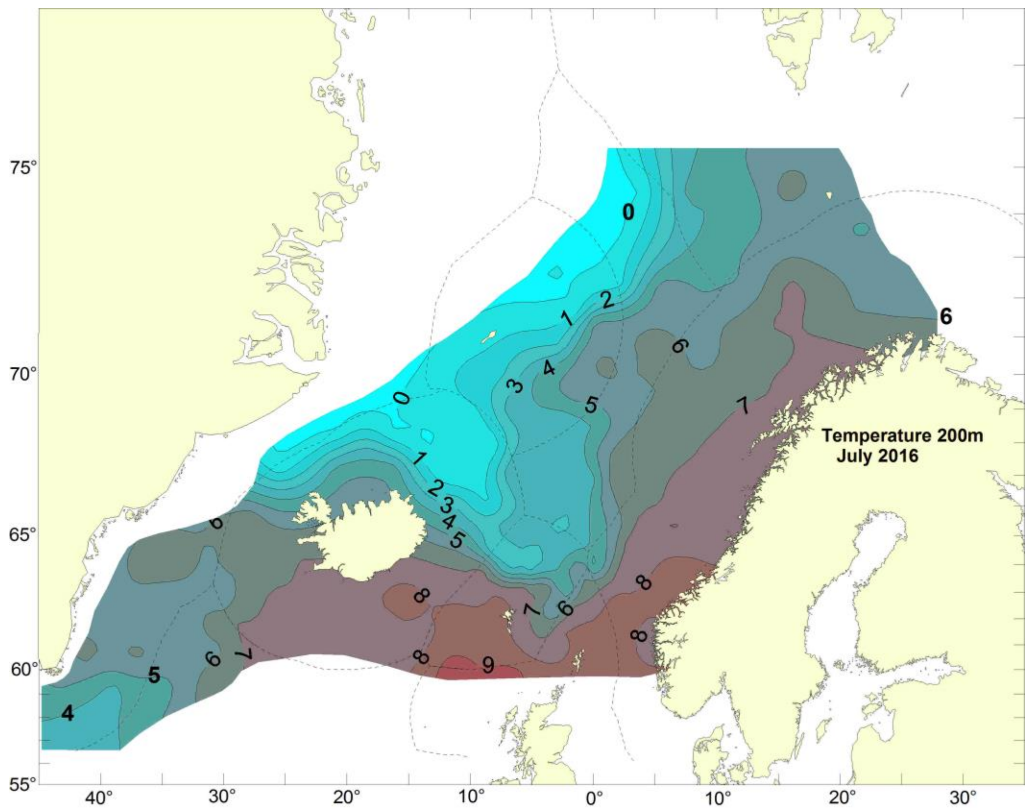


Figure 7. Temperature (°C) at 100 m depth in the Norwegian Sea and surrounding waters in July 2016.

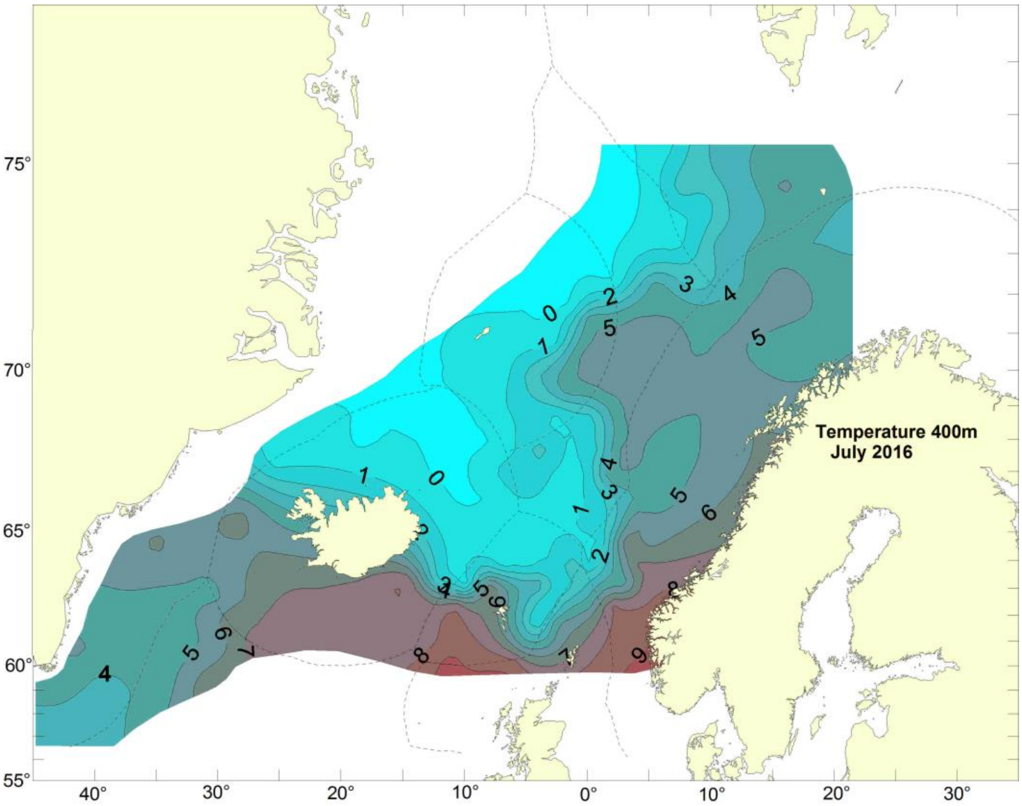
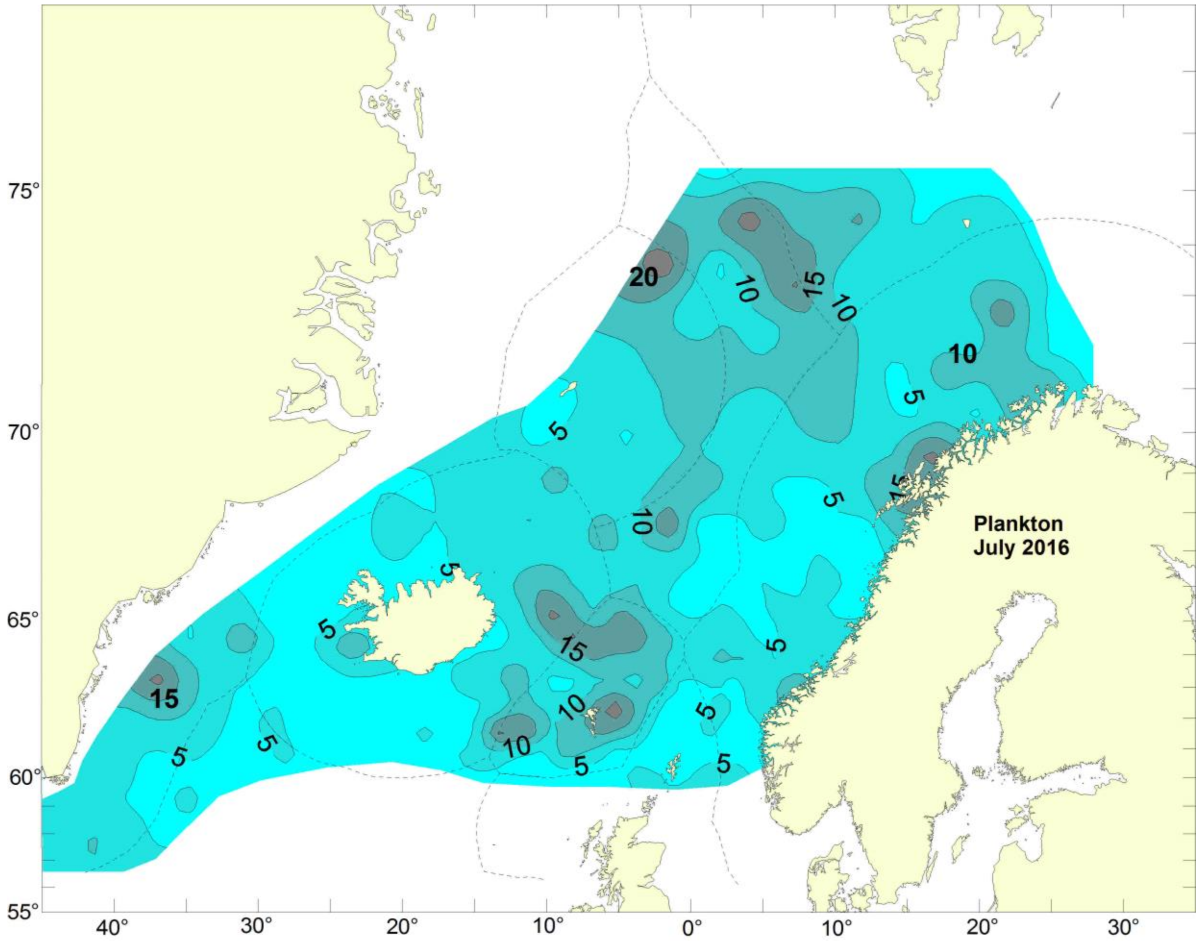


Figure 8. Temperature (°C) at 400 m depth in the Norwegian Sea and surrounding waters in July 2016

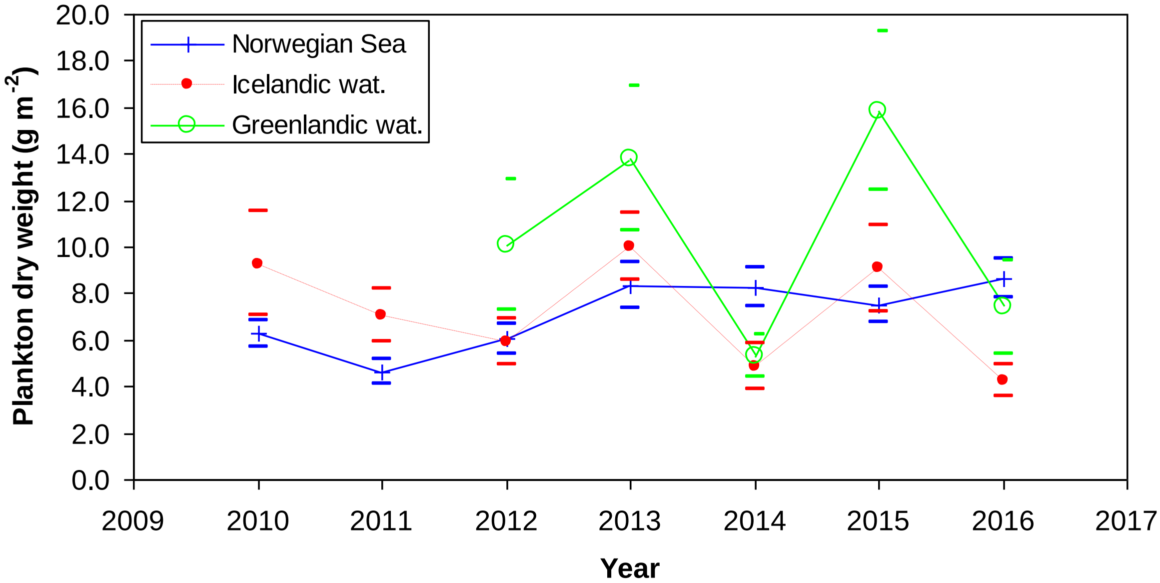
4.2 Zooplankton

The zooplankton biomass was relatively uniform over the whole survey area, with several areas with higher density, according to the dry weight measurements of the WP2 samples (Figure 9a). The average index for the Norwegian Sea was slightly higher in 2016 (8.6 g m^{-2}; n=158), than in 2015 while 50% lower in Icelandic waters (4.2 g m^{-2}; n=56) and Greenlandic waters (7.4 g m^{-2}; n=21) (Figure 9b). This relatively short time-series show more fluctuations and more variability in the Icelandic waters and Greenlandic waters than in the Norwegian Sea, which might in part be explained by both more homogeneous oceanographic condition in the area defined as Norwegian Sea and more sampling stations.

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



(a)



(b)

Figure 9. Zooplankton biomass indices (g dw/m², 0-200 m) (a) in the Norwegian Sea and surrounding waters in July 2016 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/km²) measured with the Multpelt 832 is presented in Figure 10 together with the mean catch rates per 2*4° rectangles. The map is showing large variations in trawl catch rates throughout the survey area from zero to 15 206 kg corresponding to 50 527 kg/km². The mackerel occupied a very wide spatial distribution of 3.0 million km². High density areas were found in the central and north-western part of the Norwegian Sea as well as in southern and western part of Iceland and further west into Greenland waters and international waters south-east of Greenland.

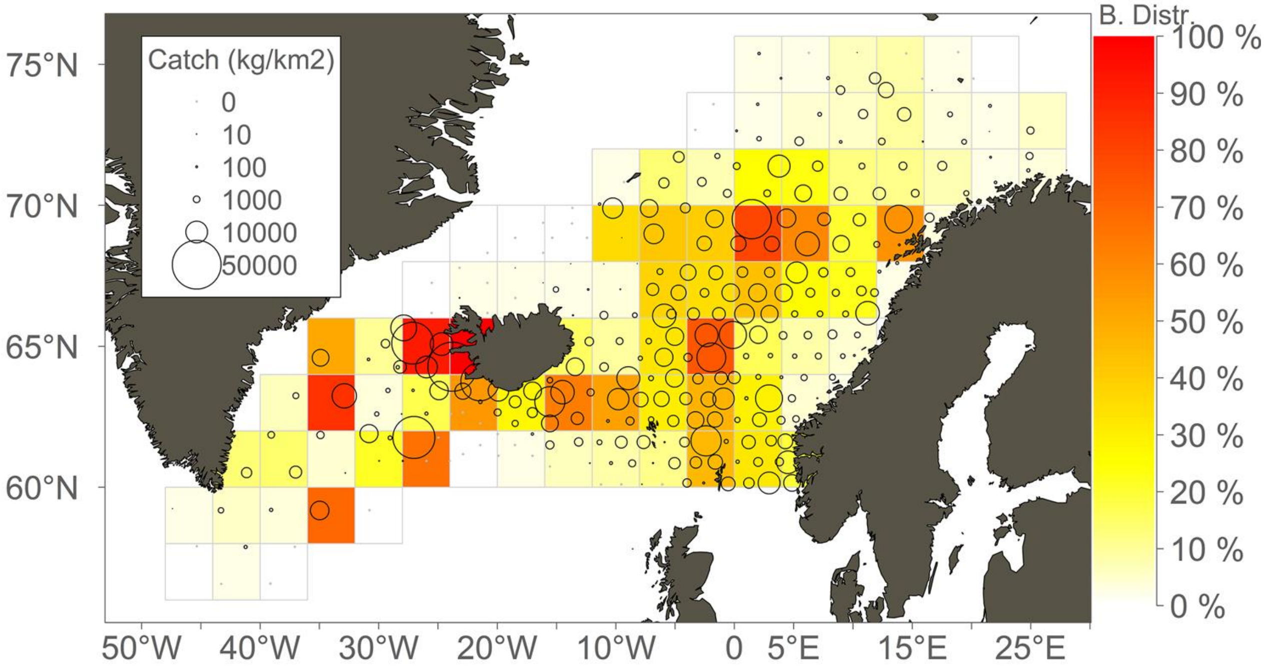


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.). White rectangles indicate zero-observations and yellow-red colour scale represent the biomass distribution (illustrated as cumulative fractions, e.g. the sum of all areas with the colour corresponding to 40% represents 40% of the total biomass in the entire survey).

The length distribution of NEA mackerel during the IESSNS survey showed a pronounced length-dependent distribution pattern both with regard to latitude and longitude. The largest mackerel on average were found in the northernmost (39 cm in length) (including northeast in the Barents Sea) and westernmost (40 cm in length) part of the covered area (Figure 11).

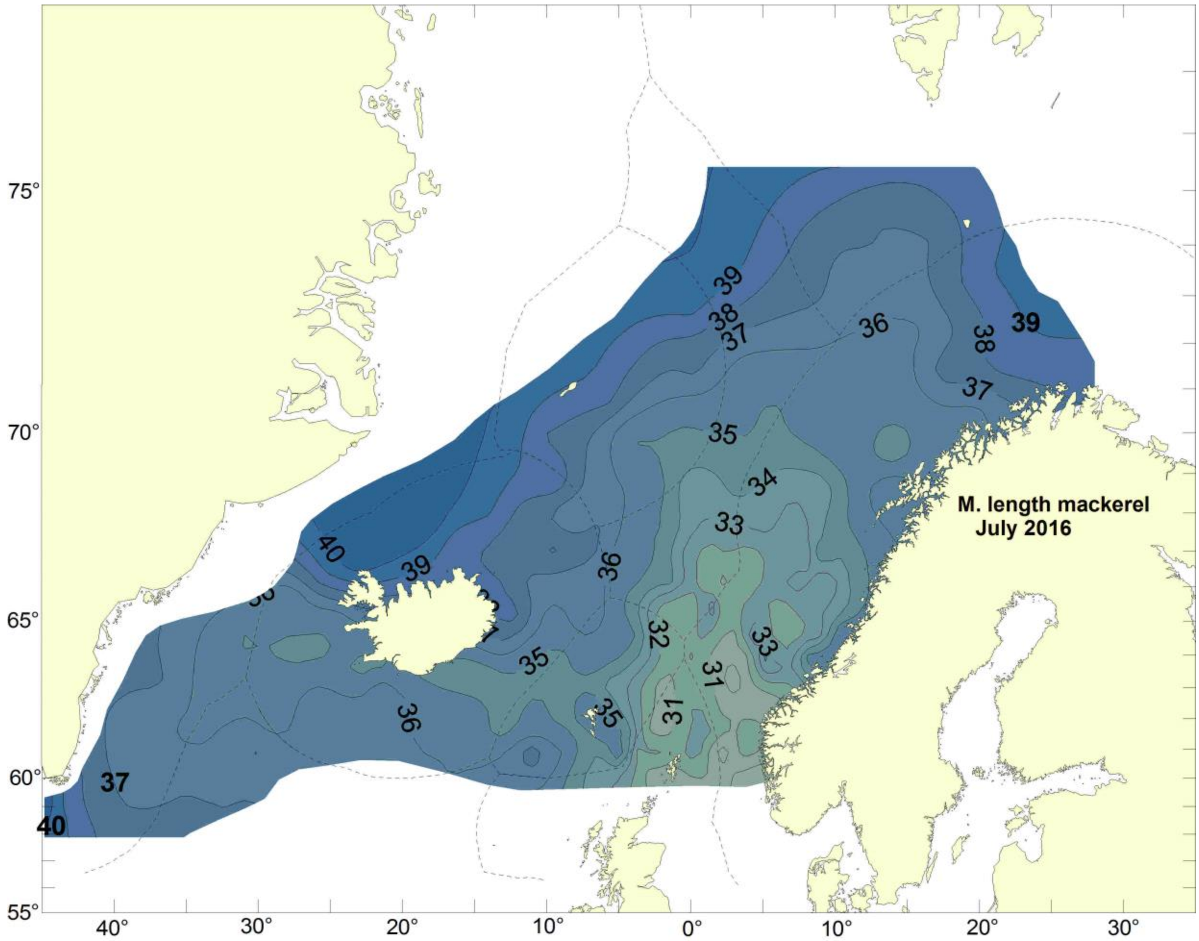


Figure 11. Average length distribution of NEA mackerel from the joint ecosystem survey with the five involved vessels M/V "M. Ytterstad", M/V "Vendla", M/V "Trøndur i Gøtu", R/V "Árni Friðriksson" and M/V "Finnur Fridi" in the Nordic Seas between 1st and 31st of July 2016.

Mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 27 cm to 43 cm in length with the individuals between 28-30 cm, 33-38 cm dominating in the abundance. The mackerel weight (g) varied between 180 to 860 g). The 2014-year class (2 year olds) dominated among juvenile mackerel caught. The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon, lumpsucker) from the joint ecosystem IESSNS survey 2016 in the Nordic Seas according to the catches are shown in Figure 12.

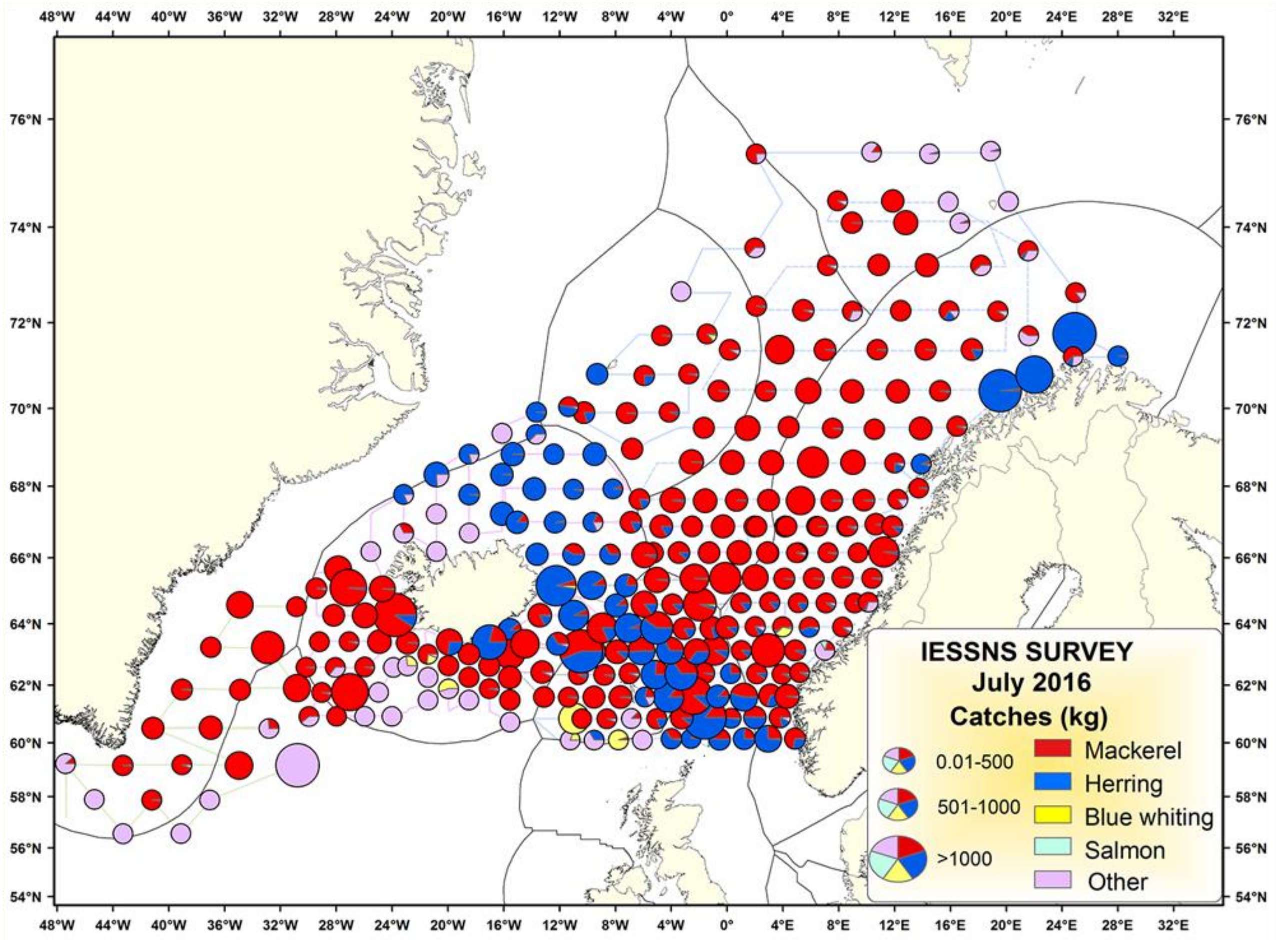


Figure 12. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (turquoise) from joint ecosystem surveys conducted onboard M/V "M. Ytterstad" and M/V "Vendla" (Norway), M/V "Trøndur i Gøru" (Faroe Islands), R/V "Árni Friðriksson" (Iceland) and M/V "Finnur Fridi" (chartered to Greenland) in the Norwegian Sea and surrounding waters between 1st to 31st of July 2016. 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 2016 were based on average density of mackerel within rectangles of 2° latitude and 4° longitude. Mackerel were horizontally distributed over more or less the entire survey area. Compared to last year, there are less mackerel in the eastern region while there are more in the west. The total biomass estimate was 10.23 million tonnes, which is a 33% increase from last year. This is the highest index in the time series, nearly 14 % higher than the previous maximum, which was in 2014. The allocation to different EEZs is given in Annex 1. The total area of rectangles with mackerel is 3.0 million km^2.

The total survey index for number-at-age is 27 billion individuals. The dominating age groups are 2, 5 and 6 year olds, which are the 2014, 2011 and 2010 year classes (Figure 13) and they contributed to 55% of the total biomass estimate.

The indices used for NEA mackerel stock assessment in WGIWIDE are the number-at-age indices for age 6 to 10 year (Table 7) divided by the spatial distribution of these ages which was 2.34 mill. km^2..

The internal consistency plot for age-disaggregated year classes (Fig. 20) has improved since the benchmark in 2014 by the inclusion of three more survey years (2014, 2015 and 2016). This is especially apparent for younger ages (1-5 years), where the year-to-year correlation is now between 0.80 and 0.97, somewhat higher than the 5-10 years old mackerel (0.47 to 0.73). The internal consistency of the oldest mackerel (10+) is poor, ranging from -0.22 to 0.85 which likely reflects the difficulties in aging old mackerel and their relatively low number in the catches.

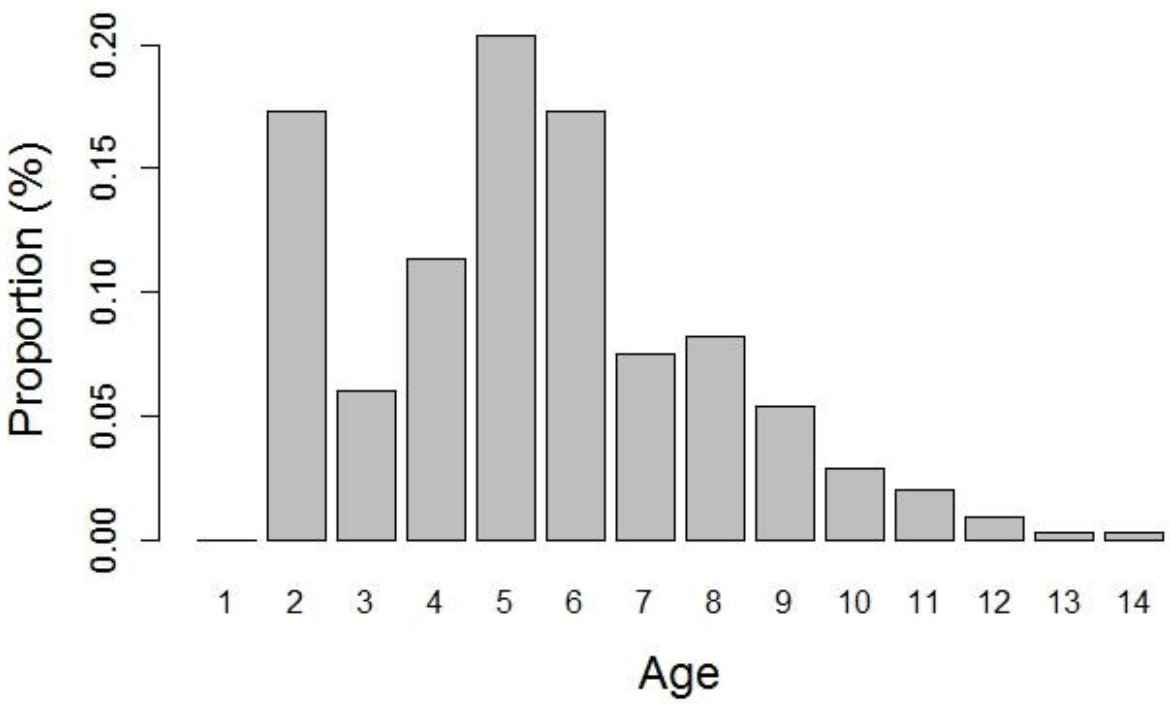


Figure 13. Age distribution in proportion (0.00-1.00) of Northeast Atlantic mackerel in the IESSNS 2016.

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	4.68	1.63	3.06	5.50	4.67	2.04	2.23	1.47	0.77	0.56	0.26	0.09	0.09	27.06
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	92	235	328	361	371	399	445	463	479	495	501	503	533	546	411
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	1.11	0.54	1.11	2.07	1.87	0.91	1.03	0.7	0.39	0.28	0.13	0.05	0.05	10.24

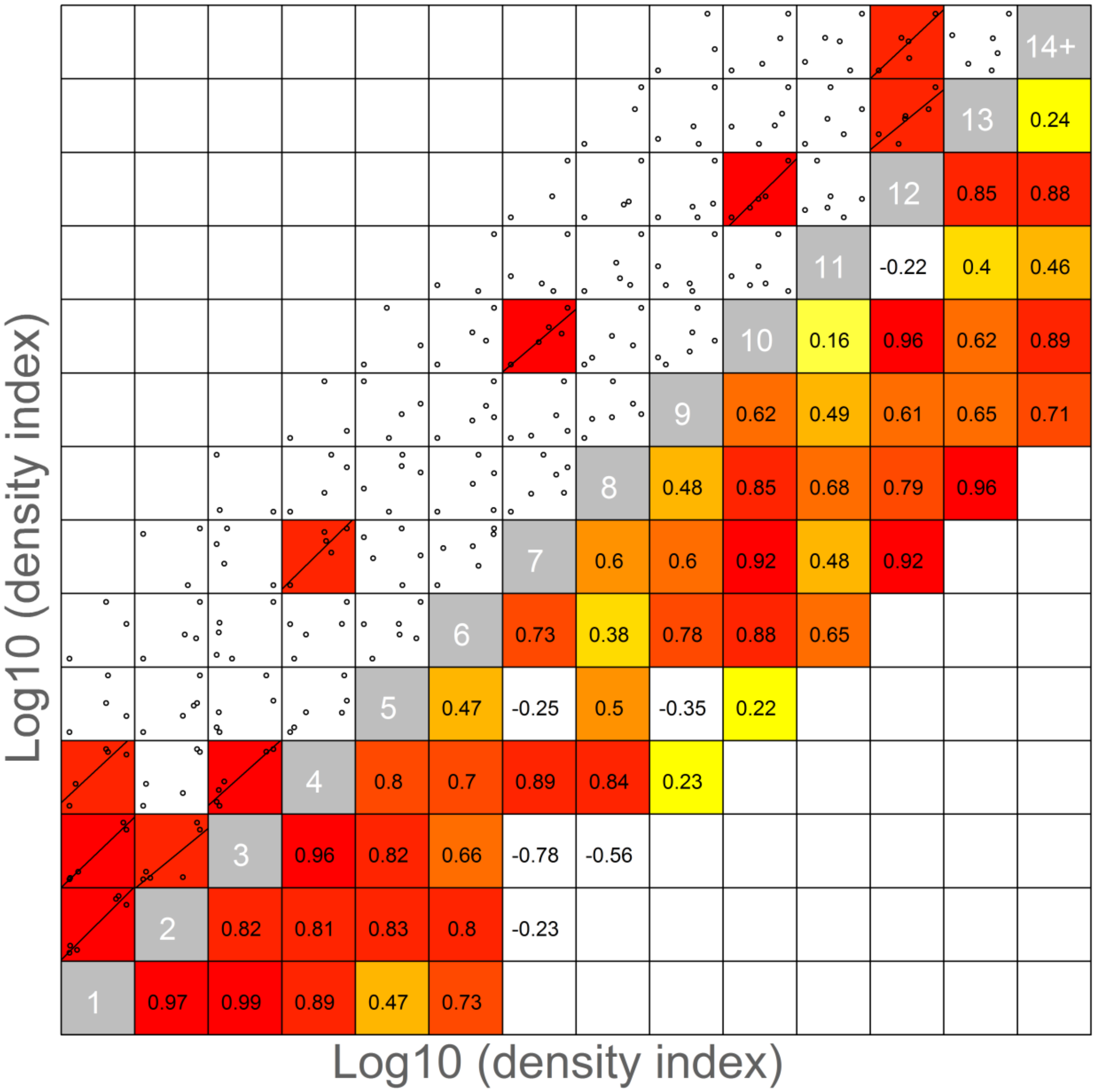


Figure 14. Internal consistency of mackerel density index. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations ($p<0.05$) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

Multibeam sonar recordings

Multibeam sonar recordings were conducted and recorded onboard the two Norwegian vessels M. Ytterstad and Vendla. The mackerel schools detected were of small size predominantly with low density and appearing more as individual fish or loose aggregations. They were detected swimming in the upper 5-30 m of the water column throughout the day. However, within large proportions of the mackerel distribution areas based on the Multpelt trawling we could only detect any mackerel on the multibeam sonars (Simrad SH90 and Simrad SX90) when the mackerel were swimming in more concentrated shoals and aggregations. 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 including multi-frequency echosounder and high and low frequency multibeam sonars. We could sometimes detect nothing or very little on the sonars but still got medium to high catches of mackerel during surface trawling with the Multpelt 832 pelagic sampling trawl, also suggesting very dispersed mackerel concentrations.

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 and east and north of Iceland (Figure 15). Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring. Also herring to the west in Icelandic waters (west of 14°W south of Iceland and west of 24°W north of Iceland) 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 12 year old herring (year classes 2004) in terms of numbers and biomass (Table 8). This year class contribute 23% to the total biomass in the Norwegian Sea. The total number of herring recorded in the Norwegian Sea was 20.2 billion in 2016 and the total biomass was 6.75 million tonnes. Number by age, with uncertainty estimates, for NSS herring during IESSNS in July 2016 is shown in Figure 16.

Table 8. IESSNS 2016 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 (Excluded: 5,6)

SpecCat: SILDG03

LenGrp	age Unknown	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
2-3	2388	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2388	-	-
8-9	2585	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2585	-	-
9-10	21165	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21165	117.9	5.57
10-11	46841	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46841	338.7	7.23
11-12	10617	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10617	94.0	8.86
12-13	-	3053	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3053	42.7	14.00
13-14	-	18320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18320	338.9	18.50
14-15	-	16030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16030	327.5	20.43
17-18	779	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	779	28.8	37.00
19-20	-	1559	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1559	81.8	52.50
22-23	-	639	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	639	67.1	105.00
23-24	-	-	2109	412	-	-	-	-	-	-	-	-	-	-	-	-	-	2520	299.4	118.79
24-25	-	-	9170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9170	1220.8	133.13
25-26	-	-	16949	62924	3269	-	-	-	-	-	-	-	-	-	-	-	-	83142	12543.7	150.87
26-27	-	-	20014	178739	26016	4796	-	-	-	-	-	-	-	-	-	-	-	229565	39097.4	170.31
27-28	-	-	16134	178367	105622	20662	62841	-	508	1524	-	-	-	-	-	-	-	385657	73713.4	191.14
28-29	-	-	26340	81339	220922	31833	30534	79120	19652	5700	3103	9308	-	-	518	-	-	508369	111168.8	218.68
29-30	-	-	47260	29857	133473	237901	225109	65419	65334	53947	99046	7673	7673	2792	-	1861	-	977345	236844.8	242.33
30-31	-	-	-	86678	73796	323498	119490	184577	384811	91788	94253	14543	4529	2013	1510	503	5183	1387172	367701.8	265.07
31-32	-	-	-	68365	36453	211536	189073	150544	171712	56760	46344	28903	42806	-	5183	2741	20431	1030850	294710.2	285.89
32-33	-	-	-	72213	29892	267117	112390	93312	77074	51577	68961	51941	-	2089	16226	-	-	842790	257427.7	305.45
33-34	-	-	-	-	17315	296541	250871	325246	112499	17213	32533	15514	46541	-	3878	-	-	1118149	359389.0	321.41
34-35	-	-	-	-	-	188375	299084	609293	229896	163557	266406	241283	320515	35420	32667	1068	-	2387563	823701.8	345.00
35-36	-	-	-	-	-	36909	291651	343894	299559	484086	656047	582945	1664536	322945	22723	28966	7206	4741467	1698922.5	358.31
36-37	-	-	-	-	-	-	57911	137195	122739	269389	538210	799644	1378143	592708	115958	31091	13706	4056693	1511822.2	372.67
37-38	-	-	-	-	-	10512	-	-	42548	68310	118625	400705	578343	312987	143429	92698	46370	1814526	715680.6	394.42
38-39	-	-	-	-	-	-	-	-	-	-	30950	34253	133140	122819	135482	21242	-	477887	200560.2	419.68
39-40	-	-	-	-	-	-	-	-	-	-	-	-	14287	66442	-	6123	-	86852	37657.6	433.58
40-41	-	-	-	-	-	-	-	-	-	-	-	-	5170	-	10724	-	-	15894	7589.5	477.50
41-42	5170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5170	-	-
TSN(1000)	89547	39602	137975	758893	646757	1629678	1638955	1988599	1526332	1263851	1954476	2186711	4195684	1460213	488298	186294	92895	20284760	-	-
TSB(1000 kg)	579.5	858.1	25424.6	155698.2	148608.5	454539.7	503232.9	640454.1	490911.1	431627.6	685789.0	798891.7	1559906.7	557877.3	191479.3	72040.5	33570.0	-	6751488.9	-
Mean length (cm)	11.62	13.96	27.32	28.13	28.85	31.53	32.41	33.19	32.82	34.31	34.64	35.50	35.64	36.27	36.57	36.54	35.13	-	-	-
Mean weight (g)	7.30	21.67	184.27	205.16	229.77	278.91	307.05	322.06	321.63	341.52	350.88	365.34	371.79	382.05	392.14	386.70	361.37	-	-	333.00

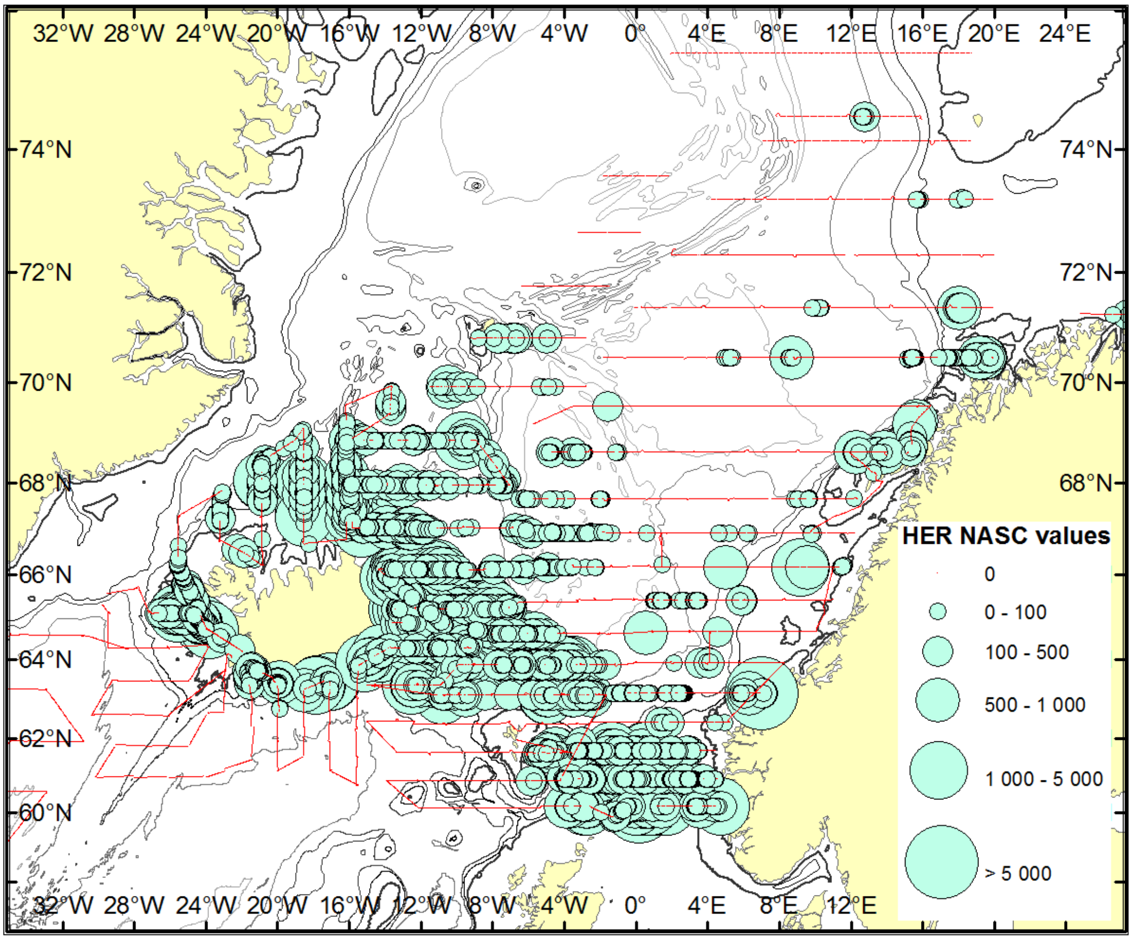


Figure 15. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring, North Sea herring (north of 62°N) and Icelandic summer-spawning herring (west of 14°W south of Iceland and west of 25°W north of Iceland) along the cruise tracks in IESSNS in July 2016.

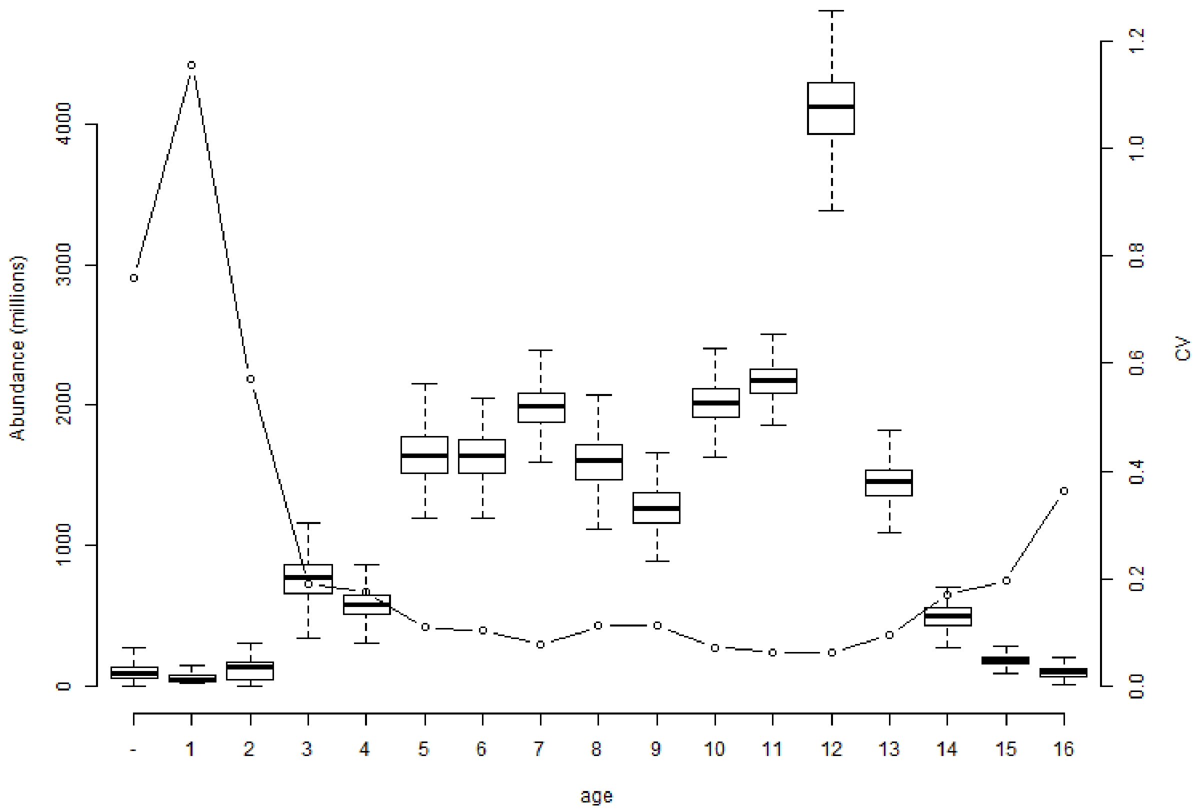


Figure 16. Number by age for NSS herring during IESSNS in July 2016. R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.5 Blue whiting

The blue whiting was distributed in the entire survey area with exception of the far western and northwestern part. The highest s_A-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 south of Iceland. The main concentrations were observed both in connections with the continental slopes in the eastern and the southern part of the Norwegian Sea (Figure 17). 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 2016 was 2.3 million tons (Table 9), which is approximately 0.8 million tonnes higher than what was observed in the IESNS in May. The stock estimate in number for 2016 is 30 billion. Age two is dominating the estimate (41% of the biomass and 38% by number). Number by age, with uncertainty estimates, for blue whiting during IESSNS in July 2016 is shown in Figure 18.

Table 9. IESSNS 2016 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

	age																		
LenGrp	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
10-11	64138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64138	534.5	8.33
11-12	1334076	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1334076	11969.1	8.97
12-13	1398214	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1398214	15274.2	10.92
13-14	769659	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	769659	10621.3	13.80
14-15	215854	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	215854	3810.1	17.65
15-16	25655	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25655	487.5	19.00
16-17	61259	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61259	1464.3	23.90
18-19	-	63234	53900	-	-	-	-	-	-	-	-	-	-	-	-	-	117134	4465.6	38.12
19-20	-	349126	17967	-	-	-	-	-	-	-	-	-	-	-	-	-	367093	13181.5	35.91
20-21	-	1091958	73642	-	-	-	-	-	-	-	-	-	-	-	-	-	1165600	57525.9	49.35
21-22	-	1788335	359802	8983	-	-	-	-	-	-	-	-	-	-	-	-	2157121	127255.6	58.99
22-23	-	1726223	1216251	672338	95232	-	-	-	-	-	-	-	-	-	-	-	3710044	248946.6	67.10
23-24	-	539807	3521303	969622	437473	-	-	-	-	-	-	-	-	-	-	-	5468205	412198.1	75.38
24-25	-	35672	2798864	654107	619098	188638	-	-	-	-	-	-	-	-	-	-	4296379	358098.7	83.35
25-26	-	14461	2122408	517209	508981	230729	16838	-	-	-	-	-	-	-	-	-	3410625	311701.6	91.39
26-27	-	1278	740044	386214	277258	69133	64124	24499	-	-	-	-	-	-	-	-	1562549	161589.3	103.41
27-28	-	-	235055	492958	248898	203973	54319	43829	-	-	-	-	-	-	-	-	1279032	149990.0	117.27
28-29	-	-	212989	317873	120071	184572	60231	42162	-	-	-	-	-	-	-	-	937897	120103.0	128.06
29-30	-	-	20027	133832	119789	40644	14399	-	57595	-	-	-	-	-	-	-	386284	52655.9	136.31
30-31	-	-	-	98694	82136	63617	55385	-	-	-	-	-	-	-	-	-	299832	46015.3	153.47
31-32	-	-	-	40297	18656	41636	5726	10021	-	-	22748	-	-	-	-	-	139084	21627.7	155.50
32-33	-	-	-	2786	41142	56124	9117	-	48037	-	16011	-	-	-	-	-	173217	33230.1	191.84
33-34	-	-	-	-	9726	38045	-	8589	-	-	47986	-	14189	-	-	-	118536	23253.9	196.18
34-35	-	-	-	-	10021	-	31500	2863	-	8008	-	15750	-	-	-	2863	71006	14628.0	206.01
35-36	-	-	-	-	-	-	6288	37800	-	-	-	18900	2863	49427	-	-	115279	30494.0	264.52
36-37	-	-	-	-	-	-	4843	-	18900	-	-	-	-	18900	5726	-	48369	12870.6	266.09
37-38	-	-	-	-	-	-	-	17969	34506	-	17969	-	-	-	-	-	70445	18704.4	265.52
38-39	-	-	-	-	-	-	-	-	4843	-	-	-	-	-	-	-	4843	1375.4	284.00
39-40	-	-	-	-	-	21057	-	21057	-	-	-	-	-	-	-	-	42113	15266.0	362.50
41-42	-	-	-	-	-	-	-	-	12828	-	-	-	-	-	-	-	12828	3668.7	286.00
TSN(1000)	3868857	5610095	11372252	4294911	2588479	1138166	322770	208789	176709	8008	104714	34650	17052	68327	5726	2863	29822369	-	-
TSB(1000 kg)	44160.8	327458.7	933640.3	410073.8	257167.2	140314.9	41598.0	39360.9	34818.7	1145.2	20071.0	8390.0	3824.9	18763.4	1514.6	704.3	-	2283006.7	-
Mean length (cm)	12.27	21.44	24.00	24.97	25.53	27.45	28.91	31.30	33.45	34.25	33.26	34.55	33.60	35.30	36.38	34.50	-	-	-
Mean weight (g)	11.41	58.37	82.10	95.48	99.35	123.28	128.88	188.52	197.04	143.00	191.67	242.14	224.31	274.61	264.50	246.00	-	-	76.55

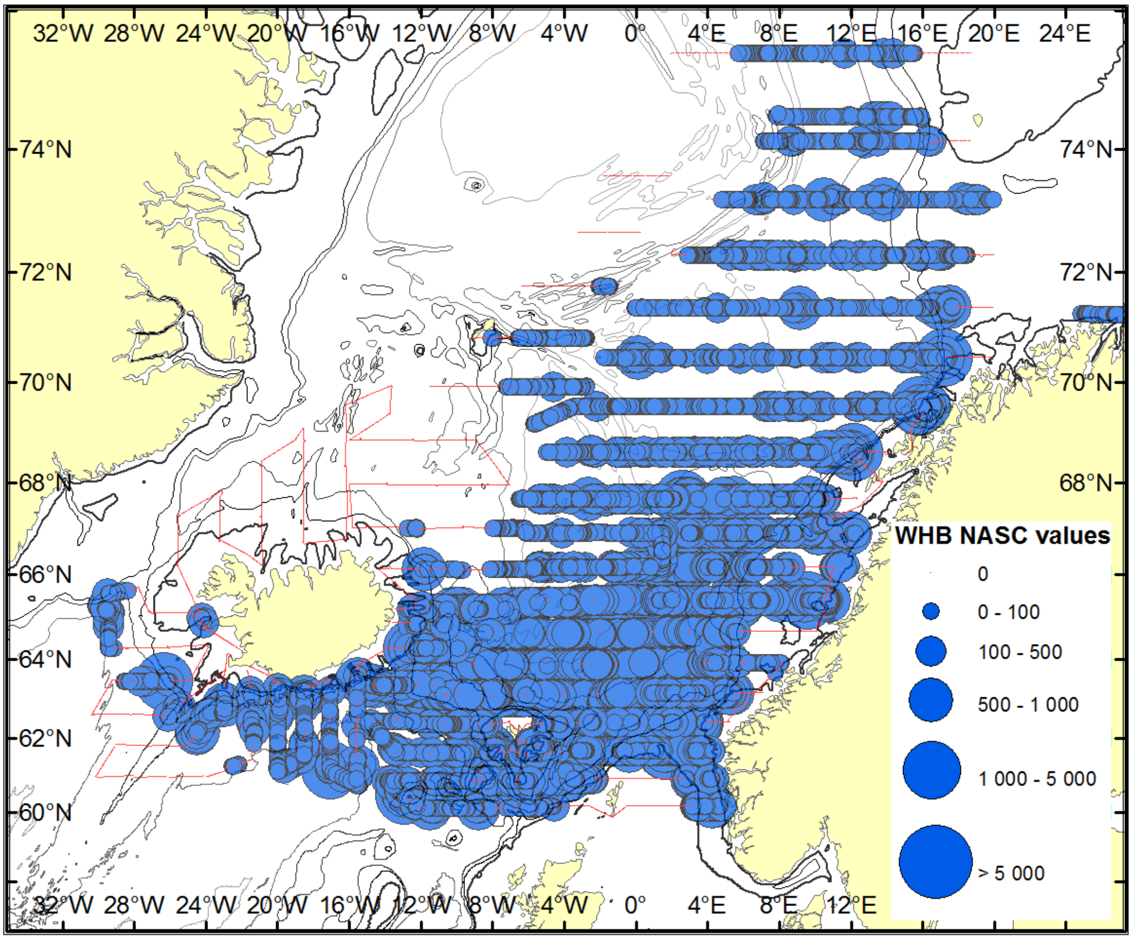


Figure 17. The s_A/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS in July 2016.

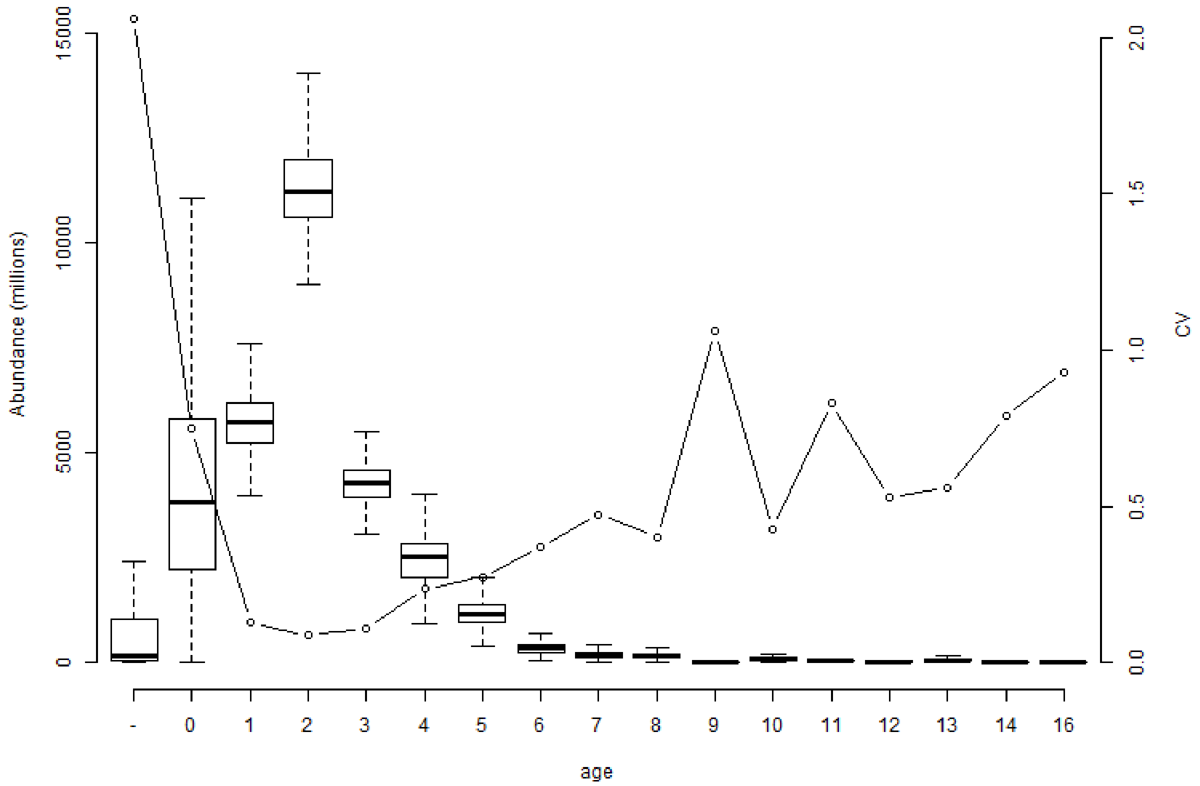


Figure 18. Number by age with uncertainty for blue whiting during IESSNS in July 2016. R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 80% of trawl stations in July 2016 onboard the five vessels (Figure 24). There was occurrence of lumpfish all the way from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Lumpfish was present at majority of stations north of 66°N, whereas lumpfish was scarcer south of 65°N south of Iceland, in Faroese waters and northern UK waters. Of note, total trawl catch at each trawl station were processed on board Árni Friðriksson, M. Ytterstad, 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). However, it is unlikely that larger catches of lumpfish would have gone unnoticed by crew during sub-sampling of catch on Trøndur i Gøtu. 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.

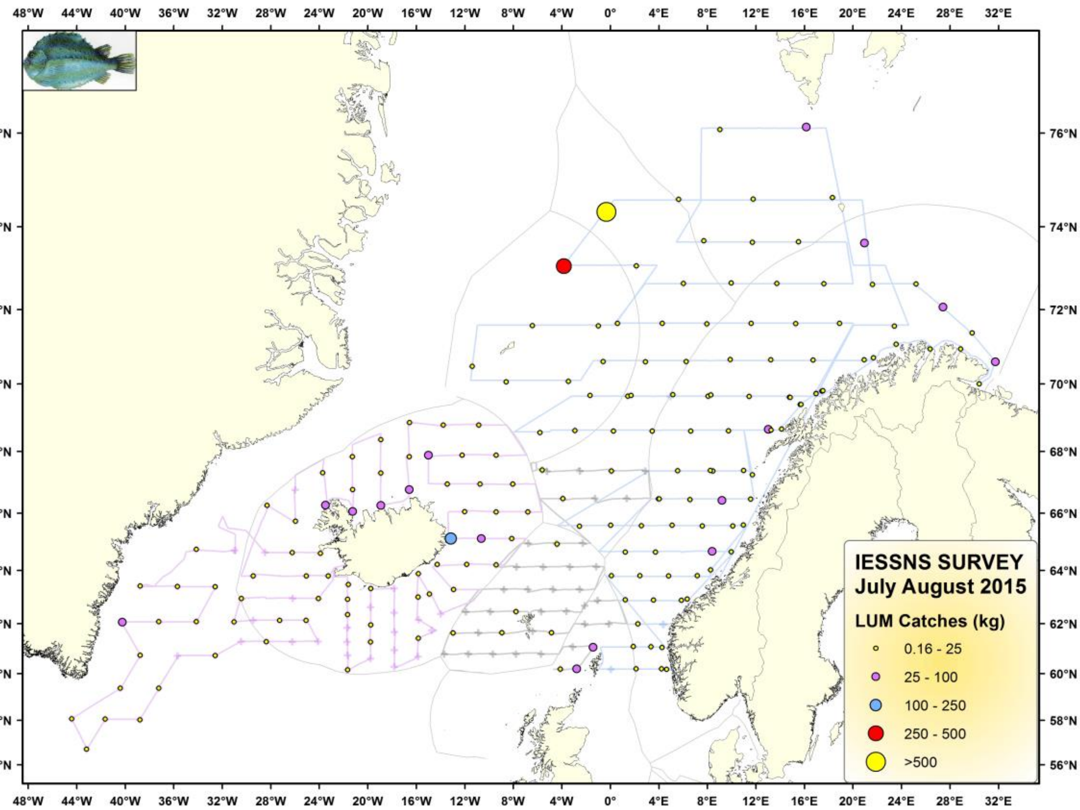


Figure 19. Lumpfish catches at surface trawl stations during the IESSNS survey in July 2016.

Salmon (*Salmo salar*)

North Atlantic salmon (*Salmo salar*) were caught in 28 stations both in coastal and offshore areas in the upper 30 m of the water column with the Multpelt 832 pelagic sampling trawl, during the 2016 IESSNS survey. The salmon weight ranged from 80 gram to > 5 kg in size, dominated by salmon weighing between 100 gram and 1 kg. The length of the salmon ranged from 18 cm to 75 cm, with a large majority of the salmon <30 cm in length.

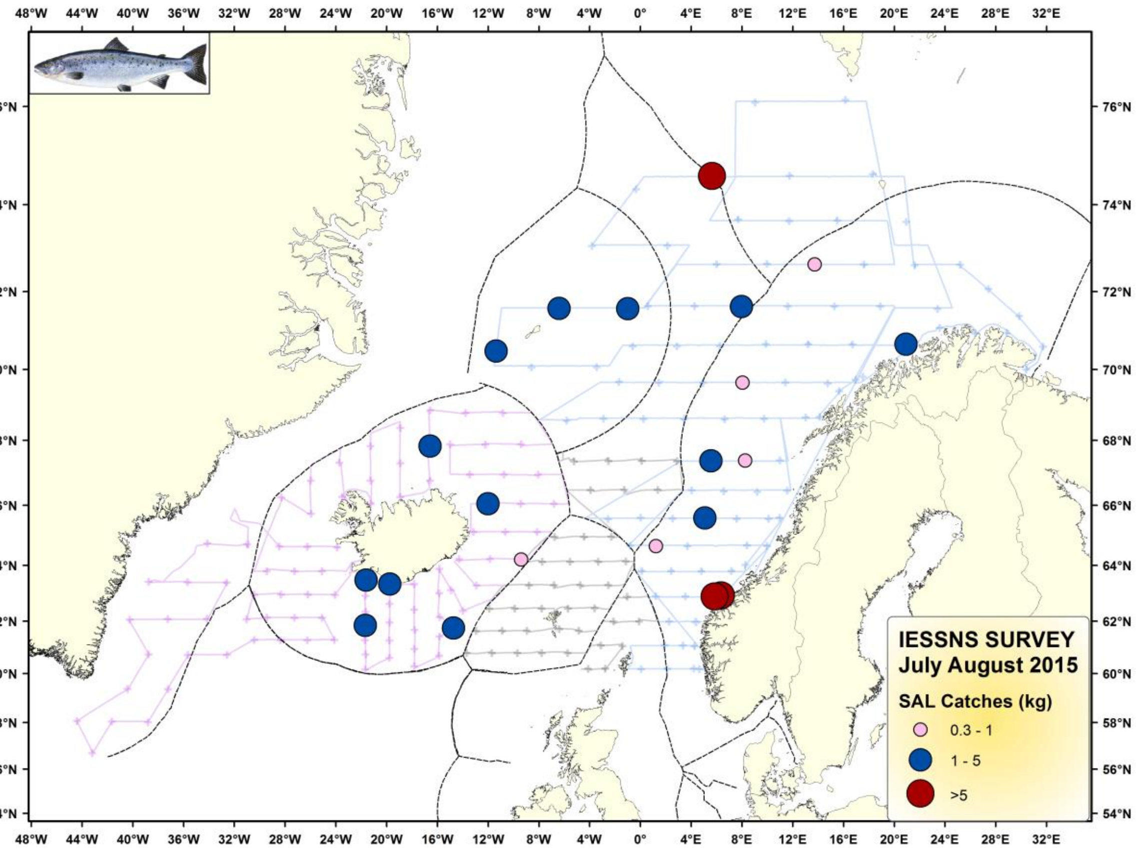


Figure 20. Catches of salmon at surface trawl stations during the IESSNS survey in July 2016.

4.7 Marine Mammals

Totally 700 marine mammals and 8 different species were observed onboard the two Norwegian vessels M/V "M. Ytterstad" and M/V "Vendla" from 1st to 30th of July 2016 (Figure 26). Altogether 5 groups of killer whales were found mostly in the eastern and western part of the Norwegian Sea in close association with mackerel. The species included fin whales, minke whales, humpback whales, pilot whales, killer whales, sperm whales, white-sided dolphins and white beaked dolphins. High densities of especially large groups of fin whales as well as some humpback whales were observed in the northern part of the Norwegian Sea, off the coast of Finnmark and into the southern part of the Barents Sea (Figure 26). Few marine mammals were sighted in the southern and central part of the Norwegian Sea (Figure 26).

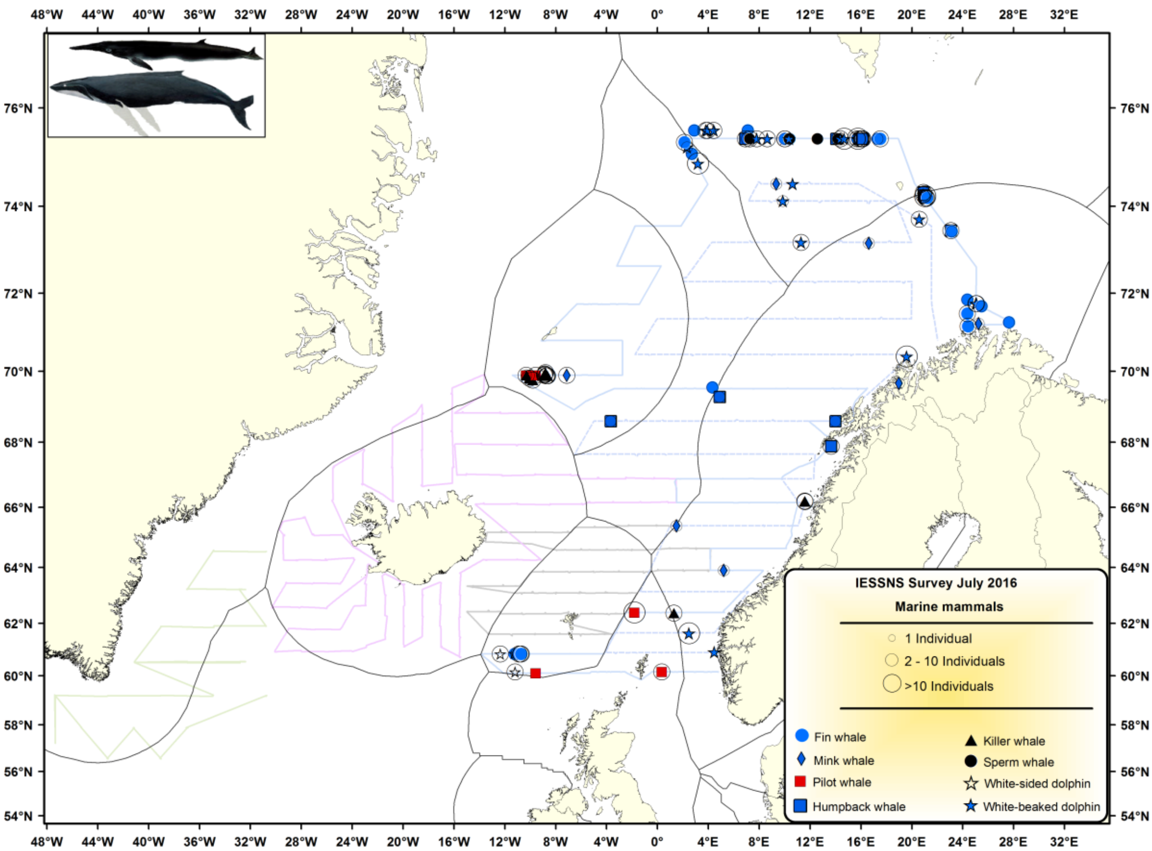


Figure 21. Overview of all marine mammals sighted onboard M/V "Vendla" and M/V "Ytterstad" in the Norwegian Sea and surrounding waters in July 2016.

5 Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 1-31 July 2016 by five vessels from Norway (2), Iceland (1), Faroes (1), and Greenland (1). The survey coverage was comparable to previous years and the same protocol was followed (ICES 2014b). 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 bottom trawl surveys run for many demersal stocks. In addition to the surface trawling, CTD, zooplankton sampling and marine mammals sightings are also parts of the IESSNS. Deep water trawling aimed on acoustic registrations were undertaken for the first time in the 2016 survey by all the vessels to identify species and size distribution for acoustic estimation of blue whiting and herring. This attempt was considered successful and the 2016 survey therefore provides abundance estimation of three pelagic fish stocks, i.e. mackerel, blue whiting and Norwegian spring-spawning herring.

The total swept area biomass index of mackerel in summer 2016 was the highest in the time-series, or 10.2 million tonnes distributed over an area of 3.0 million km^2, which gives an average density of 3.4 tonnes/km^2. The average density increased therefore from 2015 (2.9 tonnes/km^2) but is lower than in 2013 and 2014 (~3.6 tonnes/km^2). The 33% increase in biomass indices between 2015 and 2016 can partly be explained by addition of the 2014 year class (11% of the biomass), but also by a lower estimate in 2015 than from the years before. As such, the 2016 estimate is more along the 2014 and 2013 estimates for most of the year classes prior to 2012 (Table 7). This is also reflected in improvements of the internal consistency among the age-disaggregated abundance indices (Figure 14). The reason for the low estimates in 2015 is unknown, but as mentioned in last year's report (ICES 2015), it could be a consequence of both adult and juvenile mackerel being outside of the survey area (e.g. in the North Sea and north and west of the British Isles), or less fishable during surface trawling due to different behaviour including possible higher patchiness compared to previous years. Furthermore, this emphasize the necessity to cover the potential distribution areas further south (in the North Sea and west of the British Isles) as a part of IESSNS and recommended below.

The results indicate that the 2014 year class is strong, as it is the third highest in number in the IESSNS time-series for age 2 (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 year class. The 2015 year class was on the other hand hardly seen in the 2016 survey.

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2014 by the inclusion of three more survey years. This is especially apparent for younger ages. There is now fair/good internal consistency for 1-10 years old mackerel (see Nøttestad et al. 2016b). The improved consistency for young NEA mackerel in the IESSNS survey should be taken into consideration by ICES WGWIDE, specifically by including estimates of younger mackerel 1-5 years of age, and not only age 6+ mackerel, from the IESSNS survey into the assessment of NEA mackerel abundance. This is also important since altogether 55% of the estimated number of mackerel was less than 6 years old and are therefore not used in current assessment.

The overlap between mackerel and NSS herring in July 2016 was highest in the south-western part of the Norwegian Sea (Faroe and east Icelandic area) according to the catch compositions in the survey (Figure 15). The spatio-temporal overlap between mackerel and herring in 2016 was similar to that in both 2014 and 2015. 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 furthermore known to go with the flow and take advantage of the dominating Atlantic current (Nøttestad et al. 2016a).

This year's survey was better synchronized in time and was conducted over a shorter period than before (Figure 1). This was in harmony to recommendations put forward in last year's report on the timing and duration of the survey that the survey period should be four weeks with mid-point around 20 July. The main argument for this time frame, 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.

In the IESSNS 2016 two acoustic biomass estimates were calculated using the newly developed StoX software, one for Norwegian spring-spawning herring and one for blue whiting. The survey plans were accommodated to include these two species in addition to mackerel. It was recommended by ICES (WGWIDE) to try to build up new abundance indices of NSS herring and blue whiting in addition to the indices obtained from the IESNS (herring) survey in May. The group considered the two biomass estimates to be of good quality, especially the blue whiting estimates was considered to be of higher quality than the similar estimate from the IESNS survey in May, since the coverage was better in July and by then also a larger part of the stock is likely to have migrated north and being found within the survey area. Consequently, the group recommends that blue whiting should be included in future IESSNS in order to build up a new time series index to be used in the biomass estimation of blue whiting in ICES (WGWIDE).

The acoustic abundance index of Norwegian spring-spawning herring was 20.2 billions corresponding to 6.75 million tonnes (Table 8). The abundance estimate of herring from the May survey was 21.9 billions corresponding to 5.4 million tonnes (ICES 2016/WGWIDE). The abundance estimates are slightly higher in July as compared to May while the biomass index was one third higher in July. This increase in biomass can be explained by the expected weight gain of herring during the feeding season from May to July (Homrum et al. 2016).

The acoustic abundance index of blue whiting was 29.8 billions corresponding to 2.3 million tonnes (Table 9). This is higher than the figure from the May survey in 2016. The acoustic abundance estimate of blue whiting in May 2016 was 20.0 billions corresponding to 1.55 million tonnes (ICES 2016/WGWIDE). However, in May a southern limit for the spatial coverage was a 62 degrees north while in the July survey it was 60 degrees north. Thus a higher proportion of the stock was covered during July than in May, and this is part of the discrepancy in the indices from the two periods. The acoustic estimate of blue whiting during the spawning season in March-April 2016 (IBWSS) was 34.4 billions, corresponding to 2.87 million tonnes (ICES 2016/WGWIDE), which is higher than the acoustic estimate during the IESSNS in July 2016. The IESSNS may underestimate larger blue whiting in the Norwegian Sea and surrounding waters during summer, due to low densities of larger individuals and thereby difficult to scrutinize dispersed concentrations of blue whiting acoustically in deep waters when they are feeding.

The obtained zooplankton biomass indices in this year's survey (Figure 9) were in a good agreement with the results of the IESNS survey in May (ICES, 2016), where slight increase in zooplankton was also observed in the Norwegian Sea and 50% reduction in the areas west of 2°W and northeast of Iceland (different definition of areas than in IESSNS). The latter can be compared to 50% reduction in Icelandic and Greenlandic waters from 2015 to 2016 in IESSNS. These plankton indices, however, needs to be treated with some care due to various amounts of phytoplankton species/groups between years and areas in the samples influencing the total amount of zooplankton, which is of relevance when considering available food for pelagic planktivorous fish.

The swept-area estimate was as in previous years based on the standard method using the average horizontal trawl opening by each participating vessel (ranging from 61 to 67 m; Table 5), assuming that all mackerel inside the trawl opening are caught, i.e. no escape through the meshes. Further, that no mackerel is distributed below the trawl. Uncertainties in such a method include e.g. possible escape of fish through the meshes leading to an underestimation of the estimate. If, on the other hand, mackerel is herded into the trawl paths by the trawl doors and bridles, the method overestimates the abundance. The swept-area method used currently consider all fish inside the trawl-opening to be caught in the cod-end. Further work on trawl capture efficiency will be undertaken in IESSNS.

6 Recommendations

Recommendation	**To whom**
The survey period should be restricted to maximum 4 weeks. The mid-point of the survey should be around 20 July each year to leave sufficient time for data analysis before report delivery at WGWIDE.	Norway, Faroe Islands, Iceland, Greenland
Research should be conducted to find the optimal timing of the survey in relation to i) precision of stock estimates and ii) ecological information (such as the widest distribution of the species which is not covered by other surveys such as spawning surveys).	Norway, Faroe Islands, Iceland, Greenland
Increase the survey effort in Greenlandic and international waters in the western part of the survey area by (i) decreasing the distance between standard trawl stations and (ii) extending the acoustic survey transects further towards land to cover the shelf edge where the blue whiting is known to be.	Greenland
Estimate the relationship between sampling distance and index precision.	Norway, Faroe Islands, Iceland,

	Greenland
The new additional goal of the 2016 IESSNS of obtaining acoustical indices of blue whiting and Norwegian spring-spawning herring was considered successful. Therefore the survey group recommends it to be continued in the IESSNS 2017, with as much effort as needed to cover the three pelagic stocks simultaneously and adequately in the Nordic Seas.	Norway, Faroe Islands, Iceland, Greenland
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
The age disaggregated indices from IESSNS are considered to give a valid signal of year class sizes from age 1-10 as indicated by the consistency plots. It is therefore recommended that WGWIDE explore using the entire time and age series of biomass estimates from the IESSNS survey in the analytical assessment of the mackerel stock.	WGWIDE
We recommend that observers collect sighting information of marine mammals and birds on all vessels.	Norway, Faroe Islands, Iceland, Greenland

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10 Annex 1

Swept area biomass estimates in the different exclusive economical zones (EEZs)

Allocation of the total swept area estimate of mackerel biomass to exclusive economic zones (EEZs) given in Table A1 was done in R with a selection of spatial packages (see 'Task View: Spatial' on http://cran.r-project.org). These included notably 'rgeos' for polygon clipping, and package 'geo' (http://r-forge.r-project.org), i.e. for rectangle manipulation and graphical presentation (R Development Core Team 2014, Bivand and Rundel 2014, Björnsson et al. 2014). EEZs in the Northeast Atlantic were taken from shape files available on http://marineregions.org (low resolution version, downloaded in late 2012 as: World_EEZ_v7_20121120_LR.zip).

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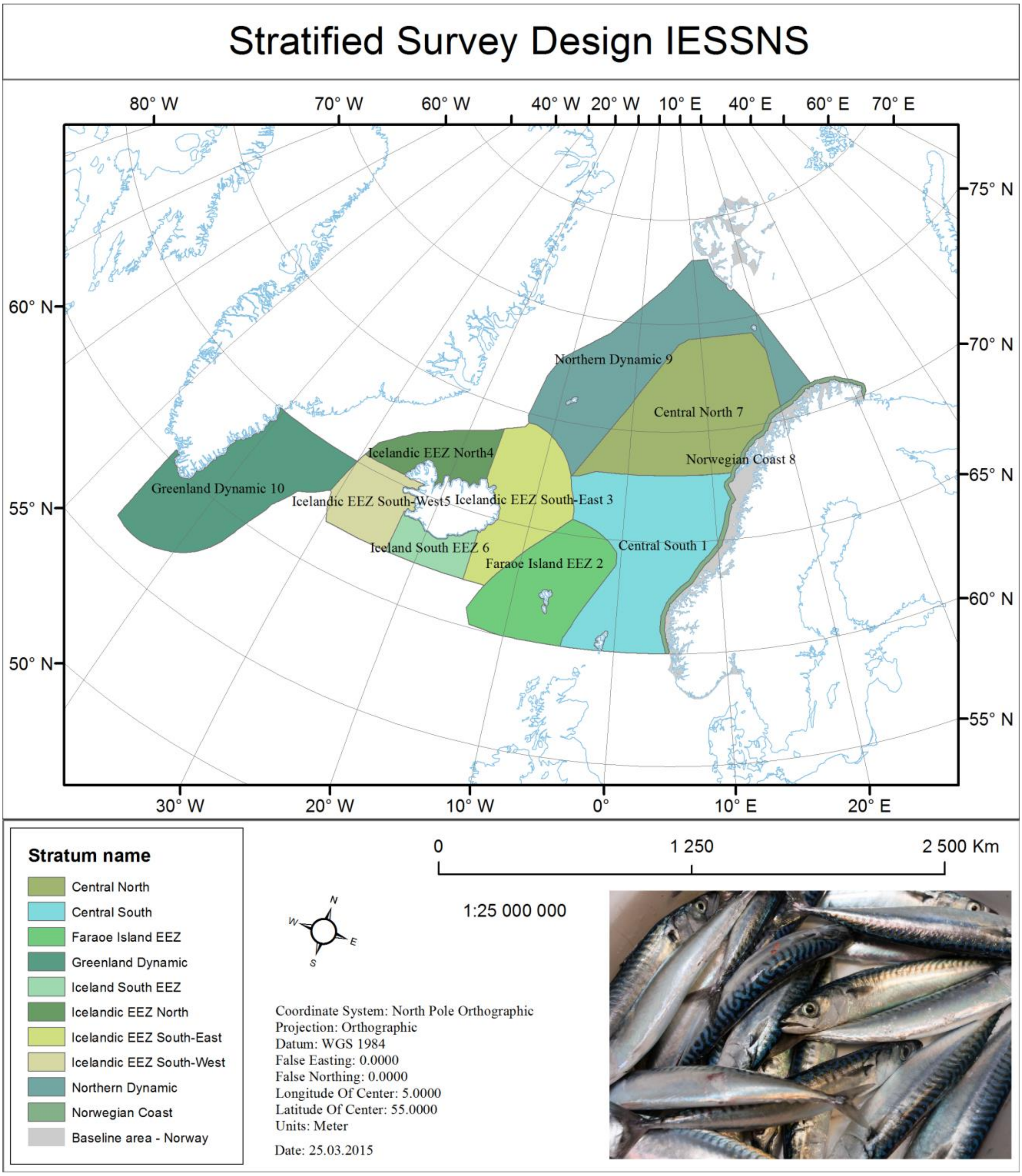
Table A1. Swept area estimates of NEA mackerel biomass in the different Exclusive Economic Zones (EEZs) according to the international coordinated ecosystem (IESSNS) survey in July 2016. Area calculated from rectangles where mackerel was present.

EEZ/Int area	Area (1000' km)	Biomass (1000' tonnes)	Biomass %
EU	101	401	3.92 %
Norway	726	1843	18.01 %
Iceland	644	3134	30.63 %
Faroese	268	949	9.27 %
Jan Mayen	205	663	6.48 %
International north	280	1356	13.25 %
International west	212	734	7.17 %
Greenland	424	1026	10.03 %
Spitzbergen	141	127	1.24 %
Total	3001	10233	100.00 %

11 Annex 2


Stratified Survey Design IESSNS
80° W
70° W
60° W
40° W
20° W
10° E
40° E
60° E
70° E
75° N
70° N
65° N
60° N
55° N
60° N
55° N
50° N
30° W
20° W
10° W
0°
10° E
20° E
Northern Dynamic 9
Central North 7
Norwegian Coast 8
Icelandic EEZ North4
Greenland Dynamic 10
Icelandic EEZ South-West5
Icelandic EEZ South-East 3
Central South 1
Iceland South EEZ 6
Faraoe Island EEZ 2
Stratum name
Central North
Central South
Faraoe Island EEZ
Greenland Dynamic
Iceland South EEZ
Icelandic EEZ North
Icelandic EEZ South-East
Icelandic EEZ South-West
Northern Dynamic
Norwegian Coast
Baseline area - Norway
0
1 250
2 500 Km
1:25 000 000
N
W
E
S
Coordinate System: North Pole Orthographic
Projection: Orthographic
Datum: WGS 1984
False Easting: 0.0000
False Northing: 0.0000
Longitude Of Center: 5.0000
Latitude Of Center: 55.0000
Units: Meter
Date: 25.03.2015