Working Document to

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Cruise report from the coordinated ecosystem survey (IESSNS) with M/V ”Brennholm”, M/V “Vendla”, M/V “Finnur Fríði” and R/V “Árni Friðriksson” in the Norwegian Sea and surrounding waters, 2 July - 12 August 2014

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Abstract.......... 3
Introduction.......... 4
Material and methods.......... 5
Hydrography and Zooplankton.......... 6
Trawl sampling.......... 6
Underwater camera observations during trawling.......... 8
Acoustics.......... 9
Cruise tracks.......... 11
Swept area index and biomass estimation.......... 12
Results.......... 15
Hydrography.......... 15
Zooplankton.......... 22
Pelagic fish species.......... 25
Mackerel.......... 25
Norwegian spring-spawning herring.......... 36
Discussion.......... 42
Recommendations.......... 44
General recommendations.......... 44
Survey participants.......... 44
Acknowledgements.......... 45
References.......... 45
Annex 1.......... 47
Swept area biomass estimates in the different exclusive economical zones (EEZs).......... 47

Abstract

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 2 July to 12 August 2014 on four vessels from Norway (2), Iceland (1) and Faroes (1). Greenland leased the Icelandic vessel for 12 days to cover the East Greenland area. A standardised pelagic trawl swept area method was used to estimate abundance of NEA mackerel in the Nordic Seas in recent years.

One of the main objectives of the IESSNS is to provide reliable and consistent age-disaggregated abundance indices of NEA mackerel. The WKPELA meeting held at ICES in Copenhagen in February 2014 benchmarked the assessment of mackerel in the Northeast Atlantic (ICES 2014c). It was agreed during the meeting to include age-disaggregated indices for age group 6+ scaled by the coverage each year from the IESSNS into the assessment.

The total swept area estimate of NEA mackerel in summer 2014 was 9.0 million tonnes distributed over an area of 2.45 million square kilometres in the Nordic Seas from about 58°30'N up to 76°10'N and from 22°E on the Norwegian coast to 43°W in the Irminger Sea south of Cape Farewell in Greenland waters. The 2011-year class contributed with 32.0% in number followed by the 2010-year class with 21.1%. The 2007, 2008 and 2009 year classes contributed then to around 11% each. Altogether 66.2% of the estimated number of mackerel was less than 6 years old. The internal consistency plot for age-disaggregated year classes has greatly improved since 2013 especially for younger year classes. There is now good internal consistency between year classes 1-10 years old, except between the less abundant 5 and 6 year old. The improved consistency in younger year classes for NEA mackerel in the IESSNS survey should be taken into consideration by ICES, specifically by including also younger mackerel 1-5 years of age, and not only age 6+ mackerel, into the tuning series as input on abundance of NEA mackerel to the assessment.

Mackerel was observed in most of the surveyed area, and the zero boundaries were found in most areas, except in the southwestern border of the East Greenland zone. Approximately 8% of the mature mackerel sampled during the survey had not yet spawned based on maturity on each trawl haul and all the vessels.

The geographical coverage and survey effort was 2.45 million km2 in 2014 which was very similar to 2013 (2.41 million km2). The area coverage in 2013 and 2014 is larger than previous years mapping from 2007 to 2012.

Norwegian spring-spawning (NSS) herring was measured acoustically during the survey and the total biomass came to 4.6 million tonnes. The 2004 and 2005 year classes were most abundant in the survey. The NSS herring was mainly found in the southwestern and western part of the Norwegian Sea; i.e. from north of the Faroe Islands and to the east and north off Iceland. Small concentrations were found in the northern and eastern areas, while herring was mostly absent in the mid Norwegian Sea. The biomass estimate is considerably lower than from the 2013 survey (8.6 million tonnes). This is partly due to insufficient coverage north of Iceland and west of Jan Mayen, and partly due to the very shallow distribution in the Jan Mayen area, with apparently high proportions of NSS herring being in the acoustic deadzone above the transducers.

The spatio-temporal overlap between NEA mackerel and NSS herring in July-August 2014 was highest in the southern and south-western part of the Norwegian Sea. Herring was most densely aggregated in areas where zooplankton concentrations where high. Mackerel, on the other hand, was found in most of the surveyed area, and in areas with varying zooplankton concentrations.

No deep trawl hauls were taken on acoustic registrations of blue whiting, and acoustic registrations deeper than 200 m were not scrutinized in part of the survey area in 2014. Thus the results of the survey can neither be used to quantify nor map the distribution of blue whiting in the Nordic Seas in the summer 2014.

The surface temperatures in the Nordic Seas in July-August 2014 were generally higher in all areas compared to July-August 2013. The SST anomaly map showed considerably higher average surface temperatures in July 2014 or 1-3°C higher compared to the average temperature in July during the last 20 years. This is thought to be due to the unusual calm weather conditions during this summer.

The average concentration of zooplankton in the Nordic Seas in July-August 2014 was at the same level as in 2013, 8.3 g/m^2 and 8.6 g/m^2, respectively. However, in the western areas, i.e. west of 14 degrees west (Iceland and East Greenland areas), the zooplankton biomass was markedly lower in 2014.

Whale observations were done by the two Norwegian vessels during the survey. The number of marine mammal sightings was generally very low in the central and eastern part of the Norwegian Sea but considerably higher numbers, especially of fin whales, were observed in the northern Norwegian Sea and into the Barents Sea. Many groups of killer whales were observed in central and northern Norwegian Sea feeding on mackerel, whereas fin whales where mainly observed near Jan Mayen, Bear Island and the southwestern part of the Barents Sea and off the coast of Finnmark.

All vessels that participated in the IESSNS 2014 used the same pelagic sampling trawl design (Multpelt 832) and followed the protocol agreed upon in Hirtshals in February 2013 for both rigging and operation (ICES 2013). Systematic underwater video recordings of mackerel swimming behaviour in relation to the catching process were also conducted. Results from those exercises are not available yet.

Introduction

In July-August 2014, four vessels; the chartered trawler/purse seiners M/V "Brennholm" and M/V "Vendla" from Norway, and M/V "Finnur Fríði" from Faroe Islands, and the research vessel R/V "Arni Friðriksson" from Iceland, participated in the joint ecosystem survey (IESSNS) in the Norwegian Sea and surrounding waters. The five weeks coordinated survey from 2nd of July to 11th of August 2014 is part of a long-term project to collect updated and relevant data on abundance, distribution, aggregation, migration and ecology of northeast Atlantic mackerel and other major pelagic species. Major aims of the survey were to quantify abundance, spatio-temporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel in relation to distribution of other pelagic fish species such as Norwegian spring-spawning herring, oceanographic conditions and prey communities. Whale observations were conducted on the Norwegian vessels 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 1990's. Faroe Islands and Iceland have been participating on the joint mackerel-ecosystem survey since 2009, but the Icelandic survey results for 2009 were not included in a joint cruise report that year.

The main objective of the IESSNS survey in relation to quantitative assessment purposes is to provide reliable and consistent age-disaggregated abundance indices of NEA mackerel. WKPELA meeting was held in ICES HQ in Copenhagen from the 21-27 February 2014, to benchmark the assessment of mackerel in the Northeast Atlantic. In the case of NEA mackerel the previous assessment was not considered to give a reliable estimate of the development of the stock, and this assessment was limited by lack of independent age-structured indices. There was an agreement during the benchmark meeting to include age-structured indices on adults from the IESSNS swept-area trawl survey. It was decided that an age-disaggregated time-series for analytical assessment should be restricted to adult mackerel at age 6 years and older for the years 2007, 2010-2013. We furthermore aim to extend the existing time series with annual updates from 2014 on abundance indices from the IESSNS swept-area trawl survey as input to the analytical assessment on NEA mackerel. Based on results on coefficient of correlation from updated internal consistency plots in the age-disaggregated data between year classes when extending the time series, we will test whether younger year classes (2, 3, 4 and 5 year olds) can be included in the age-disaggregated time-series from the IESSNS survey.

It must be noted that even if the IESSNS covers the spatial distribution of blue whiting adequately no dedicated deep trawl hauls were taken on likely acoustic registrations of blue whiting and acoustic registrations deeper than 200m were not scrutinized in part of the survey area. Thus the results of the survey can neither be used to quantify nor map the distribution of blue whiting in the Nordic Seas in the summer 2014.

Material and methods

Coordination of the survey was done by correspondence during the spring and summer 2013 and in relation to the international ICES WKNAMMM workshop in February 2013 in Hirtshals, Denmark and input and recommendations from the mackerel benchmark in February 2014 (ICES 2014c). The participating vessels together with their effective survey periods are listed in Table 1.

In general, the weather conditions were predominantly very calm with good survey conditions for the two Norwegian vessels "Brennholm" and "Vendla" related to oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. The same was the case with the Faroese chartered vessel "Finnur Fridi" experiencing very good weather conditions in Faroese waters. Although "Arni Fridriksson" experienced some bad weather in the northwestern part of the Iceland in the beginning of the survey, and a few days in Greenland waters at the end of the survey the weather conditions did not affect the quality to any extent of the various scientific data collection during the survey for the involved survey vessels. Only a few plankton stations could not be taken due to bad weather.

During this year's survey the special designed pelagic trawl, Multpelt 832, was used by all four participating vessels for the third consecutive year. This trawl is a product of a cooperation of participating institutes in designing and construction of a standardized sampling trawl for this survey in the future for all participants. The work lead by trawl gear scientist John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway, has been in good progress for four years. 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 2013). 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 have further been implemented and improved on all the four vessels involved during the IESSNS survey in July-August 2014.

Table 1. Survey effort by each of the four vessels in the July-August survey in 2014.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton stations
Arni Friðriksson	11/7-12/8	6080	117	117	108
Finnur Fríði	10/7- 21/7	2247	33	33	32
Brennholm	2/7-28/7	4283	77	77	77
Vendla	2/7-28/7	3462	55	54	55
Total	2/7-12/8	16072	282	281	272

Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 2. Arni Fridriksson was equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. Finnur Fríði was equipped with a mini SEABIRD SBE 25+ CTD sensor, and Brennholm and Vendla were equipped with a SAIV SD200 CTD sensor, recording temperature, salinity and pressure (depth) from the surface down to 500 m, or when applicable as linked to maximum bottom depth.

All 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 temperatures continuously near the surface throughout the survey.

Zooplankton was sampled with a WP2-net on all vessels. Mesh sizes were 180 μm (Brennholm and Vendla) and 200 μm (Arni Fridriksson and Finnur Fríði). 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).

The number of stations taken by the different vessels is provided in Table 1. The lower number of plankton stations in comparison to the trawl and CTD stations (e.g. on Árni Friðriksson) is usually due to bad weather preventing plankton sampling.

Trawl sampling

Trawl catches were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. The full biological sampling at each trawl station varied between nations and is presented in Table 2. On Finnur Fríði, trawl hauls were sub-sampled, 100 kg to 300 kg, and the same sample processing protocol follow as used on the other three vessels. Smaller sub-sample (approximately 100 kg) was taken when either mackerel or herring was visible in catch but if both species were in catch a large sub-sample is taken (300 kg).

Table 2. Summary of biological sampling in the survey from 2nd of July to 11th of August 2014 by the four participating countries. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Iceland	Norway
Length measurements	Mackerel	100*	100	100
	Herring	100*	200	100
	Blue whiting	100*	100	100
	Other fish sp.	0	50	25
Weighed, sexed and maturity determination	Mackerel	15	50	25
	Herring	15	50	25
	Blue whiting	15	50	25
	Other fish sp.	10	10*	0
Otoliths/scales collected	Mackerel	15	25	25
	Herring	15	50	25
	Blue whiting	50	50	25
	Other fish sp.	0	0	0
Stomach sampling	Mackerel	10	10	10
	Herring	10	10	10
	Blue whiting	10	10	10
	Other fish sp.	0	0	10*
Tissue for genotyping	Mackerel	210	400	1125

*are also weighted

All vessels used the Multpelt 832 pelagic trawl aimed for further strict standardization of fishing gear used in the survey (see ICES 2013; ICES 2014c). Standardization and documentation/quantification on effective trawl width, trawl depth and catch efficiency was improved according to requests during the mackerel benchmark (ICES 2014c). The most important properties of the Multpelt 832 trawls during the survey and their operation were as shown in Table 3.

Table 3. Trawl settings and operation details during the international mackerel survey in the Nordic Seas in July-August 2014. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	Brennholm	Arni Fridriksson	Vendla	Finnur Fríði	Influence
Trawl producer	Egersund Trawl AS	Tornet/Hampiðjan (50:50)	Egersund Trawl AS	Vónin	0
Warp in front of doors	Dyneema – 32 mm	Dynex-34 mm	Dyneema -32 mm	Dynex – 34mm	+
Warp length during towing	350 m	350 m	350 m	350 m	0
Difference in warp length port/starboard	0-4 m	3-12 m	0-4 m	5-12 m	0
Weight at the lower wing ends	400 kg	400 kg	300 kg	400 kg	0
Setback in metres	6 m	6 m	6 m	6 m	+
Type of trawl door	Seaflex adjustable hatches	Jupiter	Seaflex adjustable hatches	Injector F-15	0
Weight of traw door	2000 kg	2200 kg	1700 kg	2000 kg	+
Area trawl door	9 m² 75% hatches (effective 6.5m²)	7 m²	7.5 m² 25% hatches (effective 6.5m²)	6 m²	+
Towing speed (GPS) in knots	4.8 (4.5-5.2)	5.0 (4.5-5.5)	4.8 (4.5-5.2)	4.9 (4.1-5.1)	+
Trawl height	28-35	27-30	29-35	~ 35	+
Door distance	110-117 m	110-114 m	110-117 m	105-110	+
Trawl width*	-	-	-	-	+
Turn radius	5-8 degrees turn	5-10 degrees turn	5-8 degrees turn	5-10 degrees turn	+
A fish lock in front end of cod-end	Yes	Yes	Yes	Yes	+
Trawl door depth (port and starboard)	5-15, 7-17 m	8-13, 10-15 m	5-15, 8-18 m	5-15 m	+
Headline depth	0-1 m	0-1 m	0-1 m	0-1 m	+
Float arrangements on the headline	Kite +2 buoys on each wing	Kite + 2 buoys on wings	Kite + 2 buoys on each wingtip	Kite + 2 buoys on wings and 1 in middle	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	+

Marine mammal observations

Observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 2nd and 28th of July 2014 onboard the Norwegian chartered vessels M/V "Brennholm" 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.

Underwater camera observations during trawling

All vessels employed an underwater video camera (GoPro HD Hero 3 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 to 40 m or 60 m, and mounted on a small steel frame (approximately 20 cm by 30 cm, weight < 1 kg) with protective bars preventing entanglement of camera in trawl (see Photo 1 and 2). The small and light frame enabled camera employment at many different locations in trawl. The camera was employed inside (except at one station) the trawl where the steel frame was tied to trawl using a rope. It proved a quick and secure method of attaching frame to trawl.

The goal video recordings was to observe and assess: if the fish lock successfully prevents mackerel/herring from escaping the cod end when effective trawl time ends and speed slows below 5 nmi, and escapement of mackerel/herring at meshes from 16 m to 8 cm (Table 9). No light source was employed with camera, hence, recordings were limited to day light hours. Video recordings were collected at 30 % of trawl stations from eleven different locations in the trawl.

Photo 1. GoPro camera inside a waterproof box, mounted on steel frame and ready for employment in trawl on Finnur Fríði.

Photo 2. GoPro camera attached to inside of trawl by fish lock on Finnur Fríði. The steel frame was tied to trawl, at the each corner using a rope.

Acoustics

Multifrequency echosounder

The acoustic equipment onboard Brennholm and Vendla were calibrated 30th of June and 1st of July 2014 for 18, 38, 70, 120, 200 and 333 kHz. Arni Fridriksson was also calibrated on 31st of March 2014 for all frequencies 18, 38, 120 and 200 kHz, whereas Finnur Fridi was calibrated on 9th July 2014 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.

Generally, acoustic recordings were scrutinized on daily basis using the softwares LSSS onboard Vendla, Brennholm and Arni Fridriksson, and Echoview onboard Finnur Friði. 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.

The survey was based on scientific echosounders using 38 kHz frequency as the main frequency for the abundance estimate. Also 200 kHz was used as frequency for acoustic registrations of NEA mackerel. A summary of acoustic settings is given in Table 4.

Acoustic estimates of herring and blue whiting abundance were obtained during the surveys in a same way as e.g. done in the International ecosystem survey in the Nordic Seas in May (ICES 2014a) and detailed in the manual for the surveys (ICES 2014b).

Table 4. Acoustic instruments and settings for the primary frequency in the July/August survey in 2014.

	M/V Brennholm	R/V Arni Friðriksson	M/V Vendla	M/V Finnur Friði
Echo sounder	Simrad EK60	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
Primary transducer	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull
Transducer depth (m)	9	8	9	5
Upper integration limit (m)	15	15	15	12
Absorption coeff. (dB/km)	9.9	10	9.9	9.7
Pulse length (ms)	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
Angle sensitivity (dB)	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-21.1	-20.9	-20.6	-20.7
TS Transducer gain (dB)	24.87	24.64	23.27	24.37
s_A correction (dB)	-0.60	-0.84	-0.65	-0.63
alongship:	6.89	7.31	7.01	7.06
athw. ship:	6.87	6.95	7.11	7.16
Maximum range (m)	500	750	500	500
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 5.1

Multibeam sonar

M/V "Brennholm" and M/V "Vendla" were equipped with the Simrad fisheries sonars SX90 (frequency range: 111.5-115.5 kHz), with a scientific output incorporated which allow the storing of the beam data for post-processing. One of the objectives in this survey was to continue the test of the software module "Processing system for fisheries omni-directional sonar, PROFOS" in LSSS at the Institute of Marine Research in Norway. The first test was done during the 2010 survey, and the basic processing was described in the cruise report (Nøttestad et al., 2010). The PROFOS module is in a late development phase and for this survey, functionalities for school enhancement by image processing techniques and for automatic school detection have been incorporated (Nøttestad et al., 2012; 2013).

Acoustic doppler current profiler (ADCP)

M/V "Brennholm" are equipped with a scientific ADCP, RDI Ocean surveyor, operating at 75 kHz and/or 150 kHz. The data collected during the survey will be quality checked and used for later analysis.

Intercalibration of Multpelt 832 pelagic trawl

No intercalibration of the Multpelt 832 pelagic trawl was performed during the 2014 survey.

Cruise tracks

M/V "Brennholm", M/V "Vendla", M/V "Finnur Friði" and R/V "Arni Fridriksson" followed predetermined survey lines with pre-selected pelagic trawl stations (Figure 1). An adaptive survey design was also adopted although to a small extent, due to uncertain geographical distribution of our main pelagic planktivorous schooling fish species. The cruising speed was between 10-12.0 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

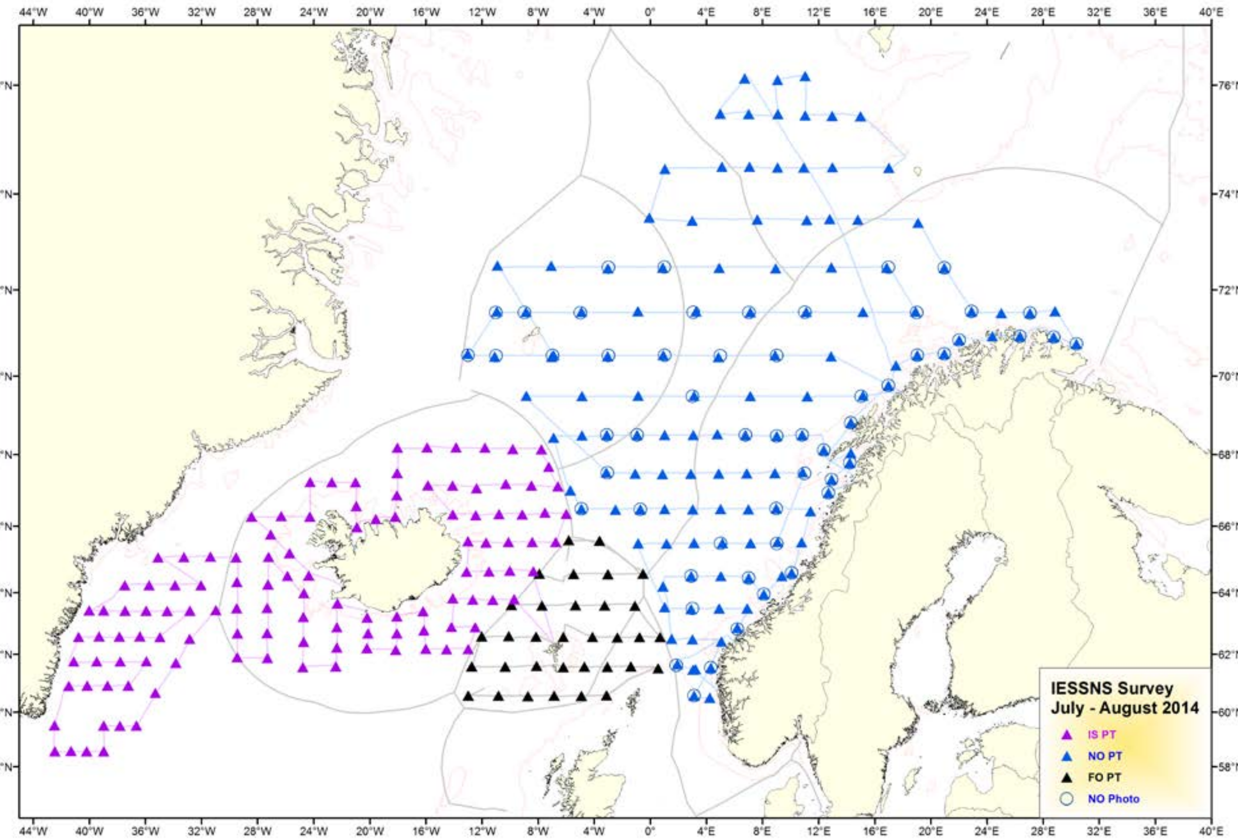


Figure 1. Cruise tracks and pelagic trawl stations shown for M/V "Brennholm" and "Vendla" (Norway) in blue, M/V "Finnur Friði" (Faroe Islands) in black and R/V "Arni Fridriksson" (Iceland/Greenland) in purple within the covered areas of the Norwegian Sea and surrounding waters from 2nd of July to 11th of August 2014.

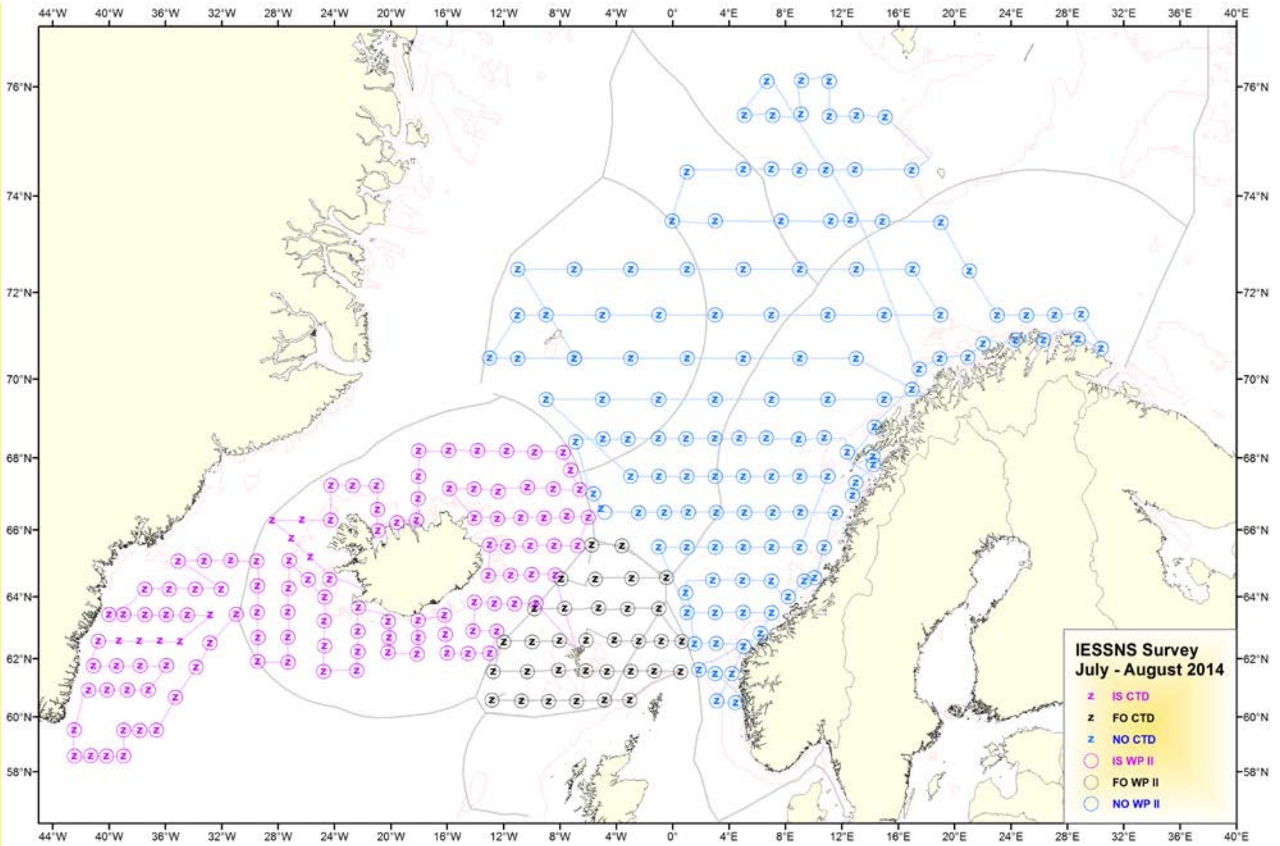


Figure 2. CTD stations (0-500 m) using SEABIRD SBE 37 (Arni Fridriksson) SEABIRD SB 25+ (Finnur Friði) and SAIV SD200 (Brennholm and Vendla) CTD sensors and WP2 plankton net samples (0-200 m depth). These were taken systematically on every pelagic trawl station on all four vessels

Swept area index and biomass estimation

The swept area estimate is based on catches in the whole area covered in the survey, or between 58°N and 77°N and 43°W and 22°E. Rectangle dimensions were 1° latitude by 2° longitude as in the estimates from previous years. Allocation of the biomass to exclusive economic zones (EEZs) was done in the same way as in 2010-2013 (see Annex 1).

In order to calculate a swept area estimate, the horizontal width of the trawl opening is required. It is assumed that no mackerel is distributed below the ground rope (vertical opening of the trawl). Average trawl door spread, vertical trawl opening and tow speed were sampled on each vessel for all stations. Two different kinds of data are available, manually reported values from log books (one value per station) and digitally recorded data from trawl sensors. The digtally recorded data were analysed as follows: Average door spread and vertical opening were calculated for each station, then the average values per station were used to calculate mean, maximum (max), minimum (min) and standard deviation (st.dev.) for each vessel. Horizontal opening of the trawl was calculated by a formula using average values of trawl door horizontal spread and tow speed for each vessel. The results of the measurements and estimations for the four vessels are given in Table 5. Based on these results average horizontal trawl opening used in the swept area calculations was set at the following vessel specific values given as 'Horizontal trawl opening (m)' in Table 5.

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. For Árni Friðriksson, trawl door spread is reported both for log book data and digital trawl sensor data (*). Horizontal trawl opening (**) was calculated using average vessel values for trawl door spread and tow speed (details in Table 6).

	Finnur Fríði	RV Árni Friðriksson		Brennholm	Vendla
Trawl doors horizontal spread (m)					
Number of stations	31*	44*	110	76	56
mean	109*	113*	113	117	117
max	116*	118 *	120	133	127
min	102*	102*	97	100	110
st. dev.	3*	3*	3	4	4
Vertical trawl opening (m)					
Number of stations	27*	110		77	56
mean	35*	31		33	33
max	43*	38		40	41
min	27*	30		24	29
st. dev.	3*	2		2	5
**Horizontal trawl opening (m) ** **					
mean	63	65		65	66
Speed (over ground, nmi)					
Number of stations	33	115		77	56
mean	5	5.0		4.7	4.8
max	5.5	5.4		5.7	6.0
min	4.6	4.5		4.0	4.2
st. dev.	0.2	0.2		0.2	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 for 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

Results

Hydrography

The surface layer in the northeastern part of the North Atlantic was warm in July 2014, as seen from the SST anomaly (one week in mid July 2014 relative to a 20 year average, Figure 3). The SST was more than 3°C warmer north of Iceland and between 2-2.5°C warmer in the central Norwegian Sea. This is in contrast to 2013 when the surface layer was close to the long-term average (Figure 4). The anomaly pattern in 2014 resembles that of 2012 with the exception that in 2012 the Irminger Sea was considerably (more than 3°C) warmer than the average.

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 (< 20 m depth) in the southern and mid area surveyed, i.e. from East Greenland extending to the Norwegian coast, was 1-2°C warmer in 2014 compared to 2013 (Figures 5-6). In the northern part of the surveyed area (Jan Mayen towards the northern Norwegian coast) the temperatures was at the 2013 level (Figures 5-6). One exceptional feature of the upper layer in 2014 is the very low signal of the cold East Icelandic Current (EIC) north of Iceland. The usual cool water of the EIC originating from the East Greenland Current (EGC) extending in a southeasterly direction was very weak (Figures 5-6). The temperature was up to 2°C warmer in the surface portion of the EIC in 2014 compared to 2013. The temperature distribution at 50 m depth was similar to the surface layers but with cooler water (Figure 7).

In the deeper layers (below 100 m depth), however, the hydrographic features in the area were similar to those in 2013, with a very clear signal of the EIC extending progressively farter eastwards with depth, towards the Norwegian coast at 400 m depth (Figures 8-10).

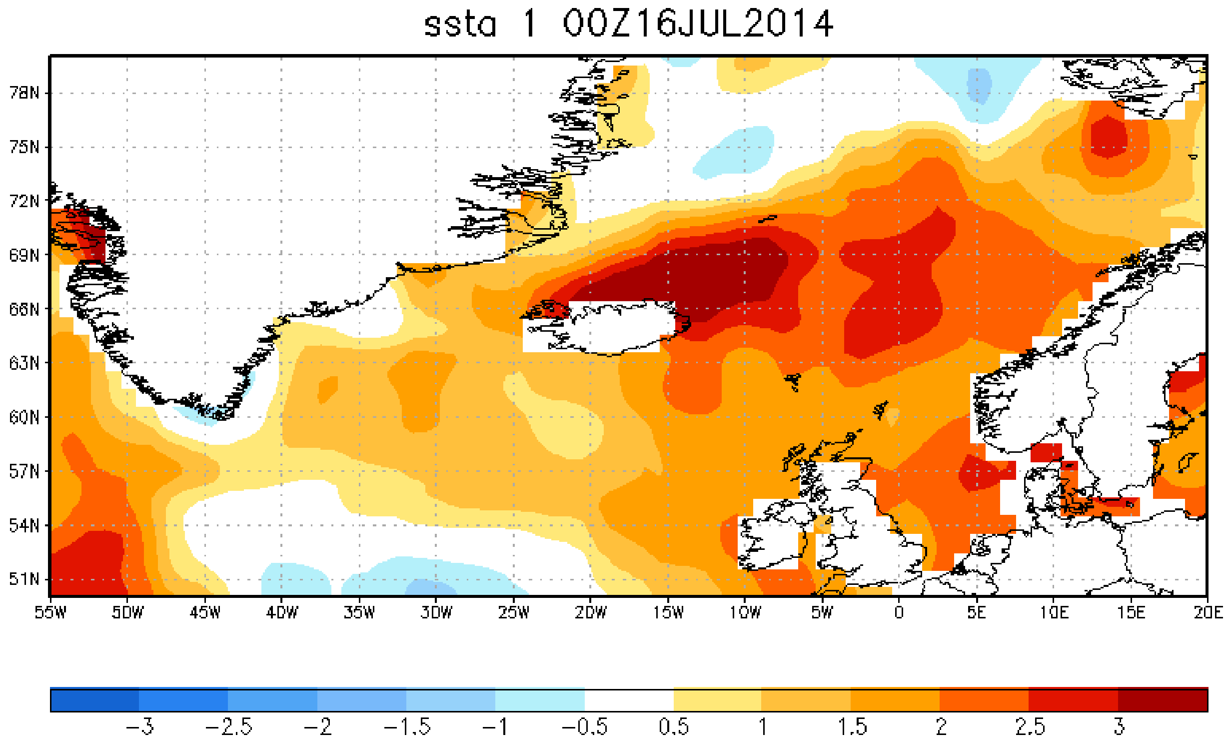


Figure 3. Sea surface temperature anomaly in July (°C; centered for mid July 2014) showing warm and cold conditions in comparison to a 20 year average.

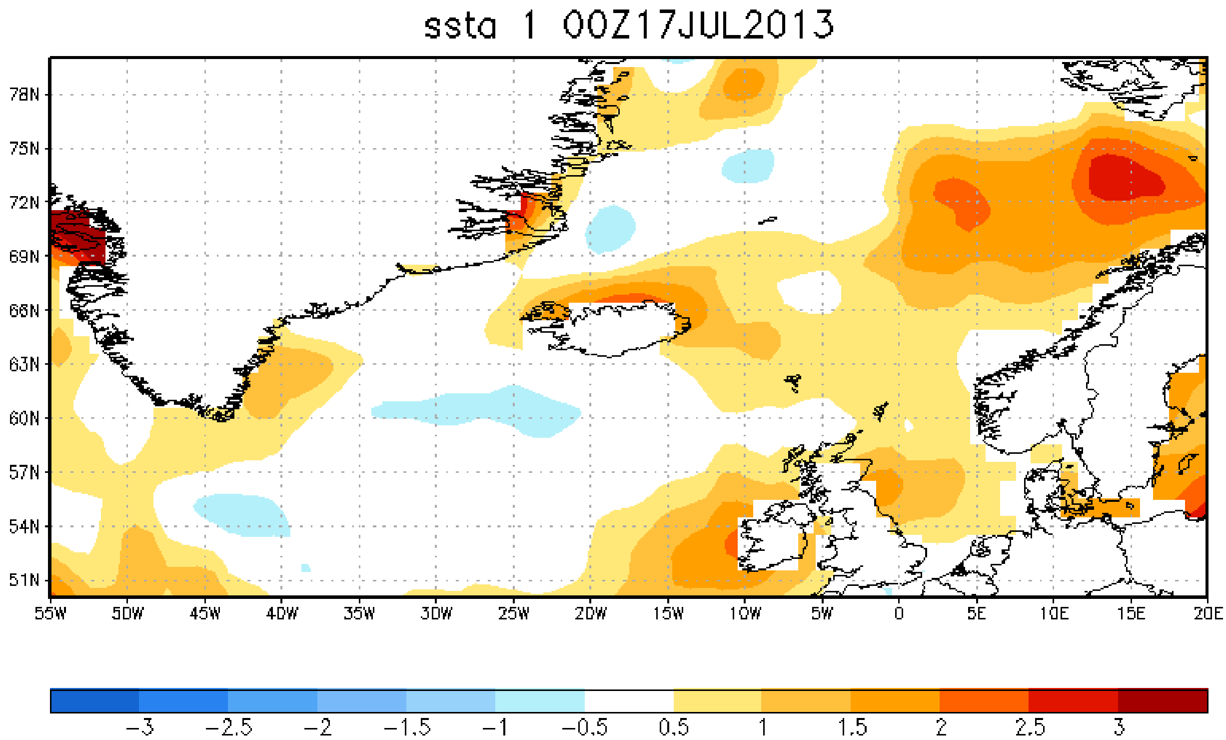


Figure 4. Sea surface temperature anomaly in July (°C; centered for mid July 2013) showing warm and cold conditions in comparison to a 20 year average.

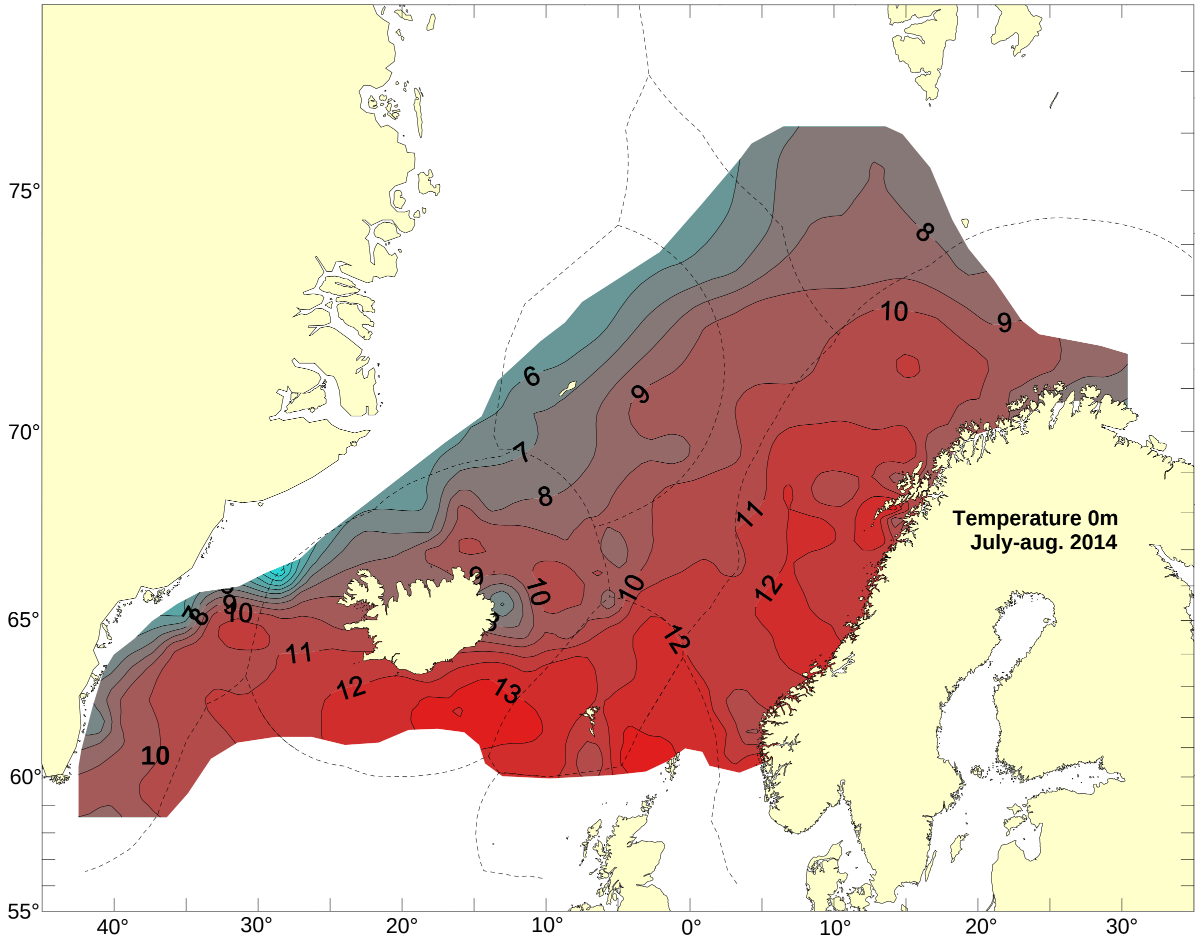


Figure 5. Temperature (°C) at 10 m depth in the Norwegian Sea and surrounding waters in July/August 2014.

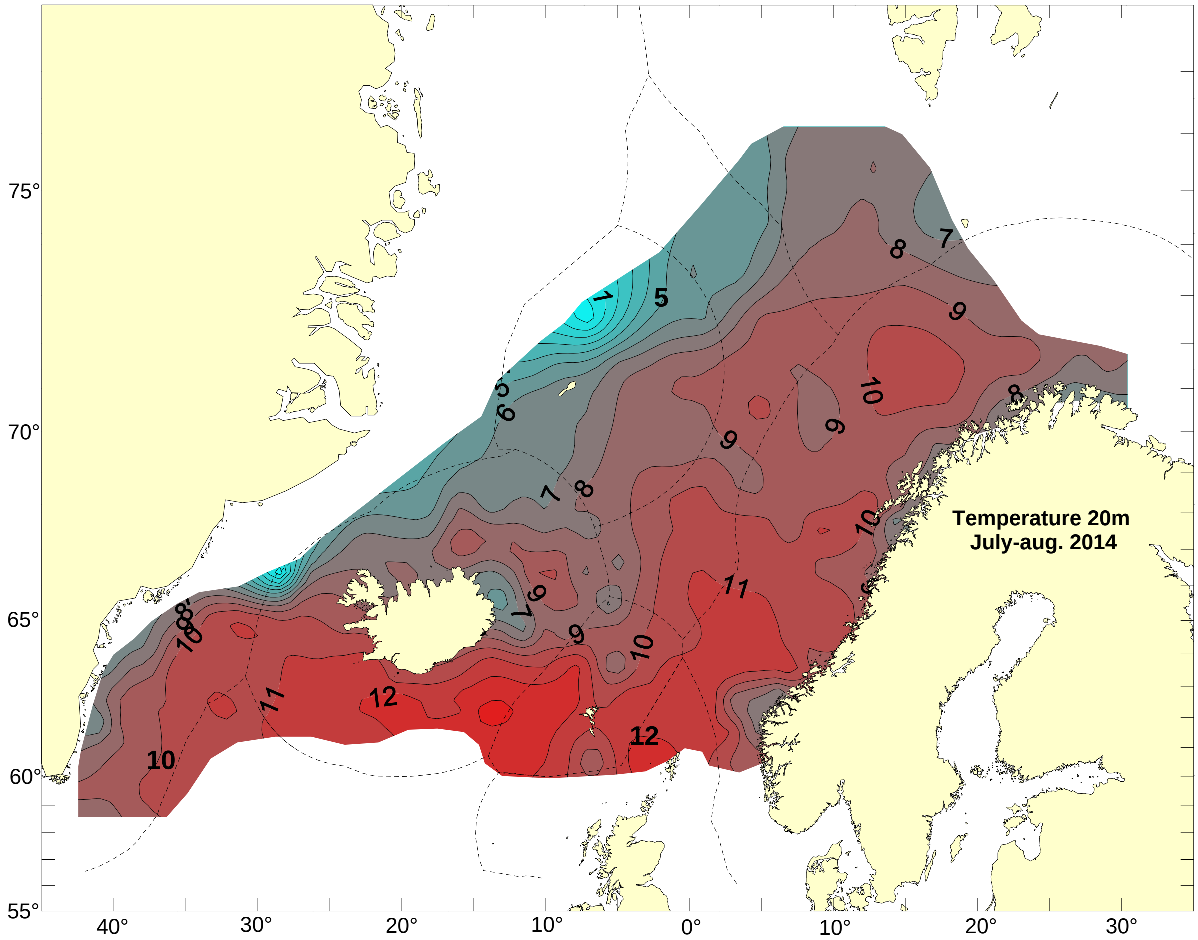


Figure 6. Temperature (°C) at 20 m depth in the Norwegian Sea and surrounding waters in July/August 2014.

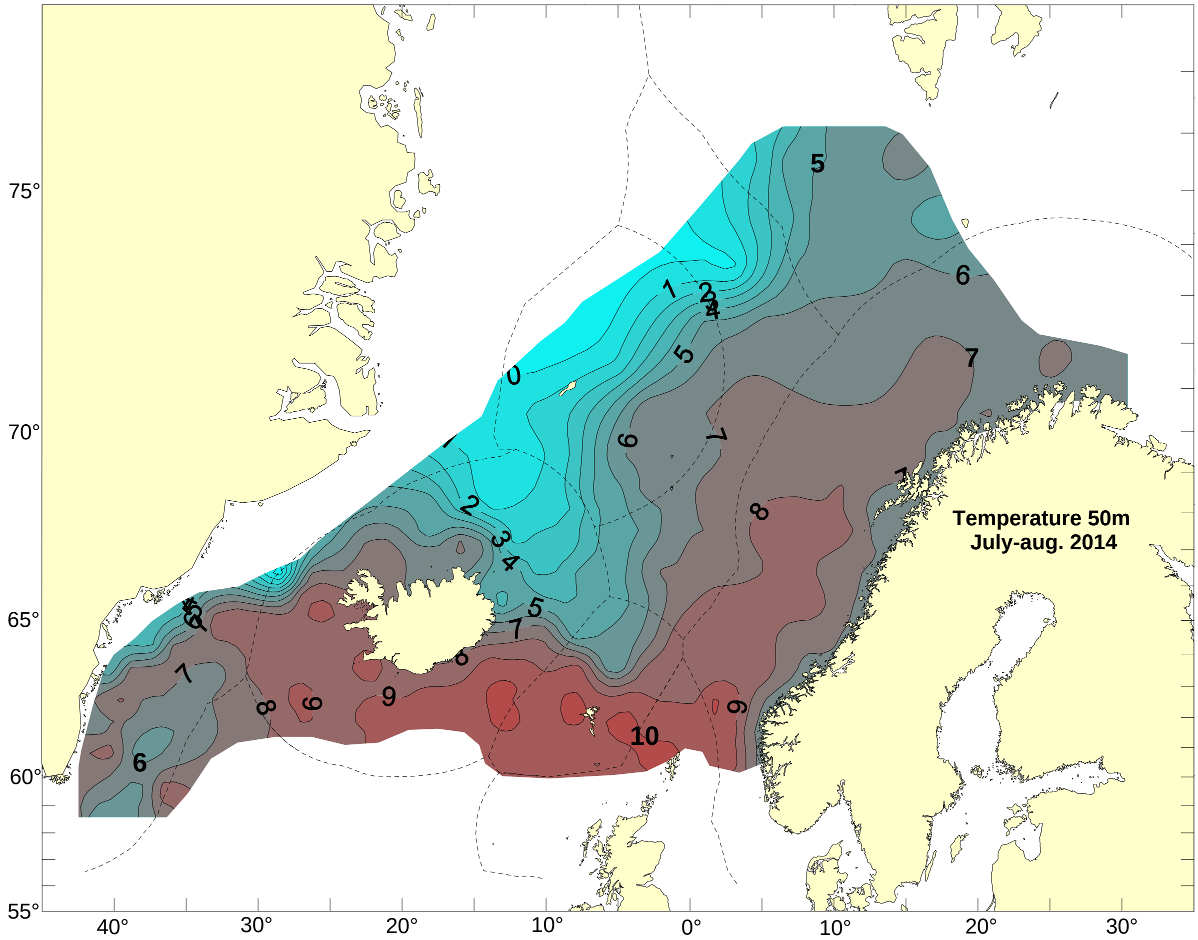


Figure 7. Temperature (°C) at 50 m depth in the Norwegian Sea and surrounding waters in July/August 2014.

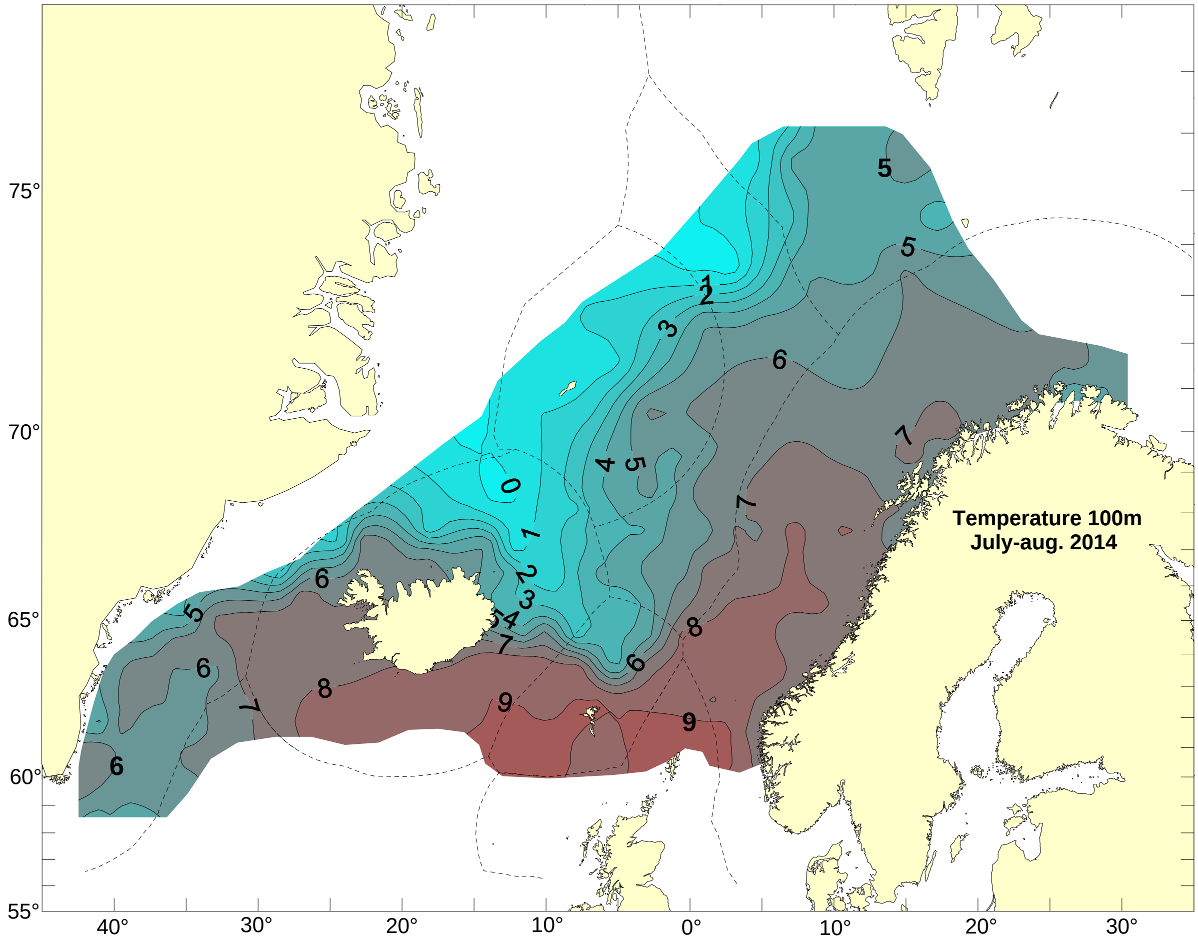


Figure 8. Temperature (°C) at 100 m depth in the Norwegian Sea and surrounding waters in July/August 2014.

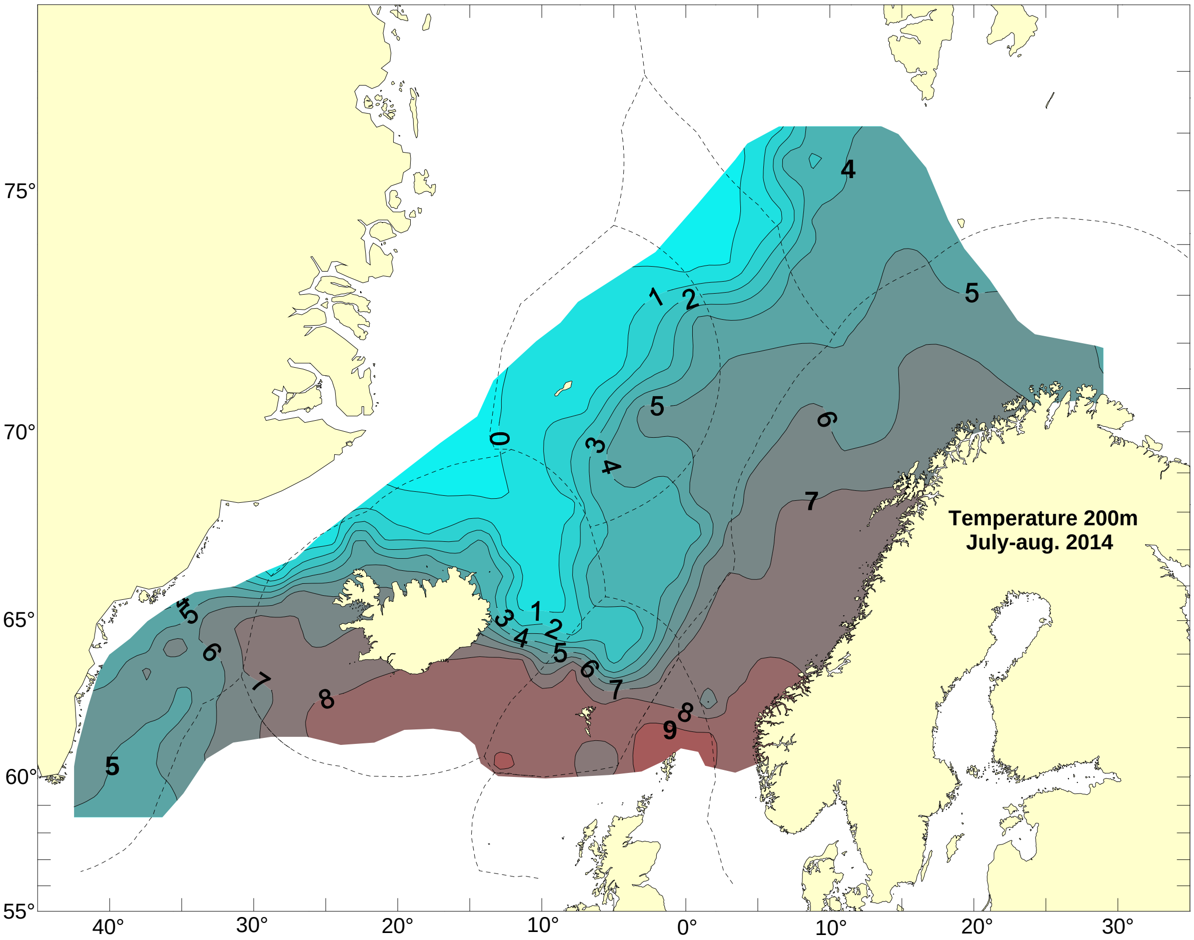


Figure 9. Temperature (°C) at 200 m depth in the Norwegian Sea and surrounding waters in July/August 2014.

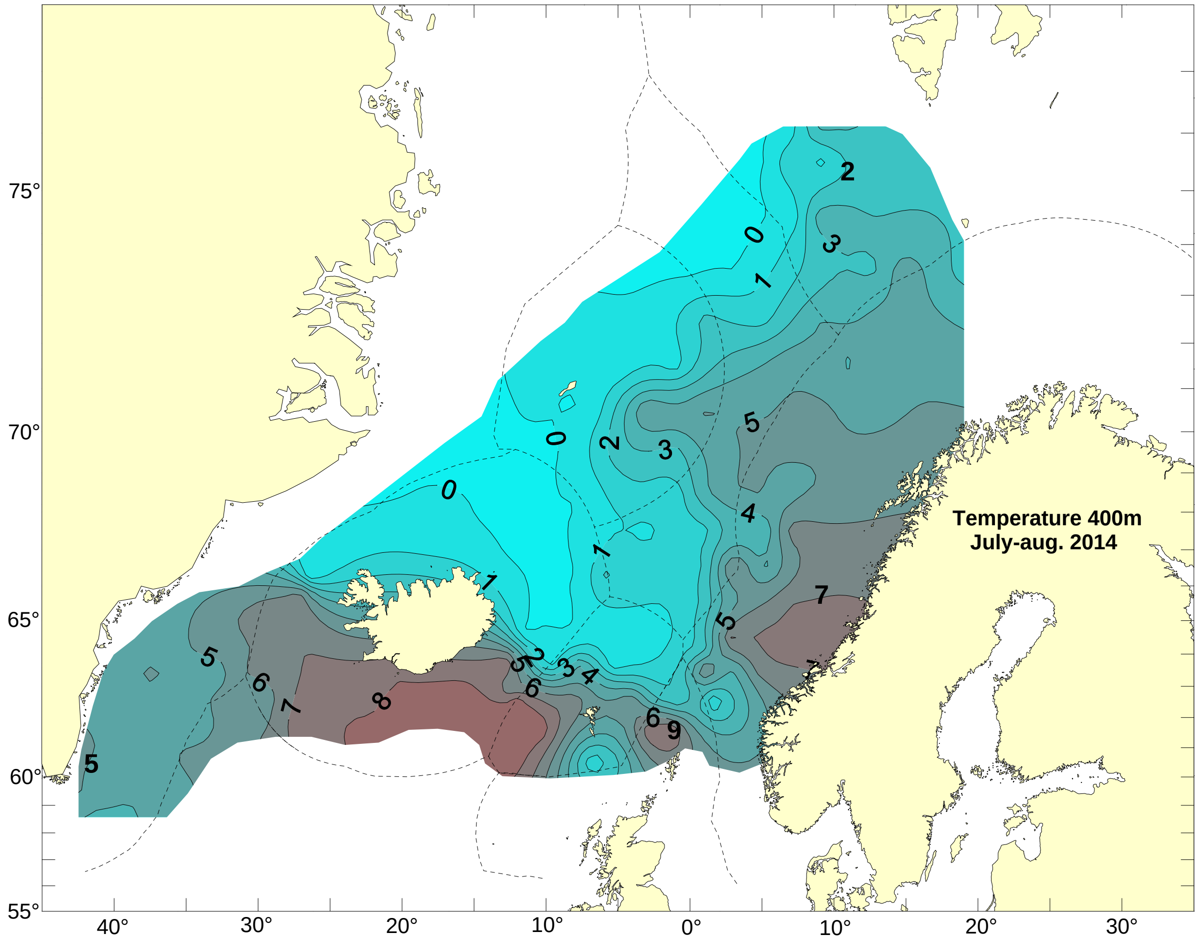


Figure 10. Temperature (°C) at 400 m depth in the Norwegian Sea and surrounding waters in July/August 2014.

Zooplankton

The average plankton biomass in the Norwegian Sea (north of 61°N and between 14°W and 17°E) in July-August was at the same level in 2014 as in 2013 or 8.4 g/m² and 8.2 g/m² respectively (Table 7). This is a substantial increase from 2012 when the average biomass was 6 g/m². The plankton concentrations were high in the northeastern part of the Icelandic area and the northern part of the Faroese area, as in 2013 (Figure 11). However, in 2014 the concentrations in the central part of the Norwegian Sea were higher than in 2013, as well as in the northeastern part (Svalbard area) (Figure 11).

In 2014 the average zooplankton concentration the Icelandic area (between 14°W and 30°W) was only 4.8 g/m², or only half of the biomass observed in 2013 (Table 7).

This year additional and extensive area in East Greenland waters was surveyed. The area was first surveyed in a limited area east of Greenland in 2013 (between 62-66°N). In 2014 this survey was expanded to cover the area from 65°30′ N to 58°30′ N. The average plankton biomass in this area was 13.8 g/m² in 2013 and only 5.3 g/ m² in 2014. This is considerably lower than last year, but the area covered in 2014 was extending much farther south in East Greenland waters, and therefore cannot be compared directly. The level in East Greenland waters is at the same levels as in the Icelandic area. Overall, the impression is that the concentration in the western part of the surveyed area is lower than last year.

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

The increased biomass of zooplankton in the Norwegian Sea is in agreement with the increase that has been observed in the zooplankton biomass in the area in the May survey from 2010 to 2014 (ICES 2014a) after a decade with a decreasing trend in zooplankton biomass. These data need nevertheless to be treated with some care, due to various amounts of phytoplankton between years and areas in the samples influencing the total amount of zooplankton (g dry weight/m^2) which is relevant and valuable as available food for pelagic planktivorous fish.

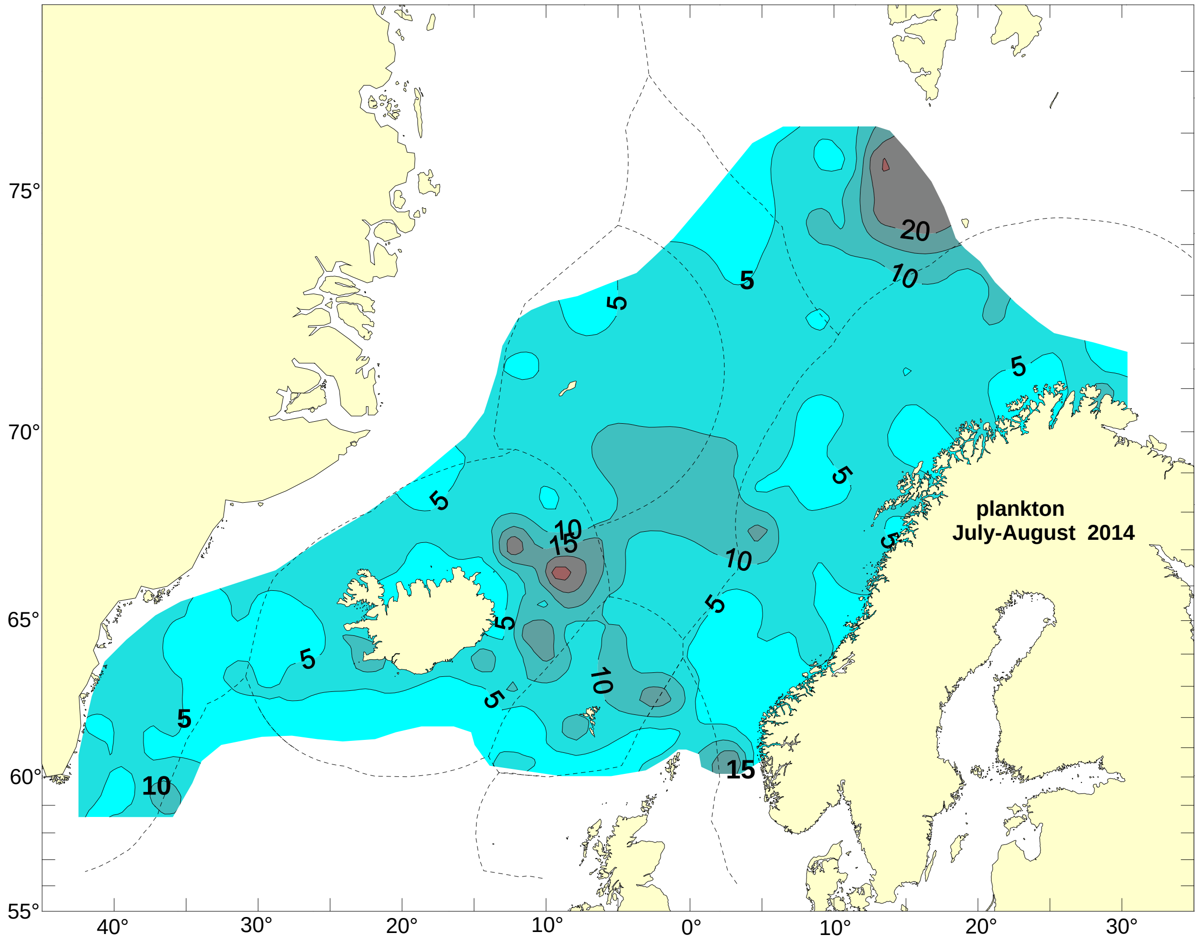


Figure 11. Zooplankton biomass (g dw/m², 0-200 m) in the Norwegian Sea and surrounding waters, 2nd of July -9th of August 2014.

Table 7. The time-series of zooplankton dry weight in IESSNS during 2010 to 2014 for 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). The number of samples is given in parentheses.

	Dry weight of zooplankton (mg/m²)		
Year	Norwegian Sea	Icelandic waters	Greenlandic waters
2010	4911 (167)	9276 (8)*	
2011	4622 (110)	7058 (61)	
2012	6033 (134)	5926 (55)	10086 (2)
2013	8360 (163)	9990 (49)	13787 (14)
2014	8242 (167)	4834 (47)	5308 (33)

*No plankton samples on the Icelandic vessel, only by Norwegian vessel north off Iceland.

Pelagic fish species

Mackerel

The total mackerel catches (kg) taken during the joint mackerel-ecosystem survey with the Multpelt 832 quantitative sampling trawl is presented in standardized rectangles in Figure 12. The map is showing different concentrations of mackerel from zero catch to more than 5000 kg.

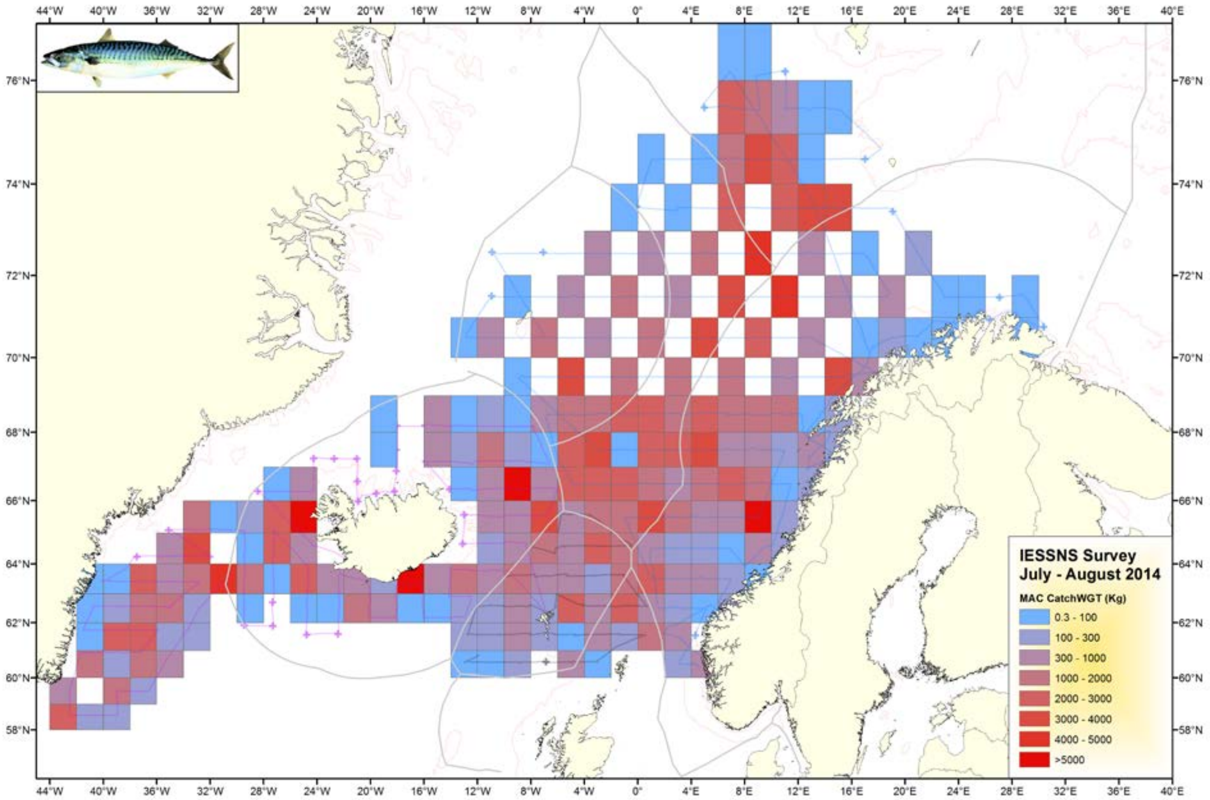


Figure 12. Catches of mackerel in kg represented in standardized rectangles. Light blue represents small catches (0.3-100 kg), while dark red represents catches of more than 5000 kg mackerel after 30 min standardized towing with the Multpelt 832 pelagic trawl. Vessel tracks are shown as continuous lines. Trawl stations are marked as small crosses for each vessel. Empty rectangles surrounded by three or more were interpolated in the calculations on biomass/abundance and density indices.

The length distribution of NEA mackerel during the joint ecosystem survey showed a pronounced length-dependent distribution pattern both with regard to latitude and longitude. The largest mackerel were found in the northernmost and westernmost part of the covered area in July-August 2014 (Figure 13).

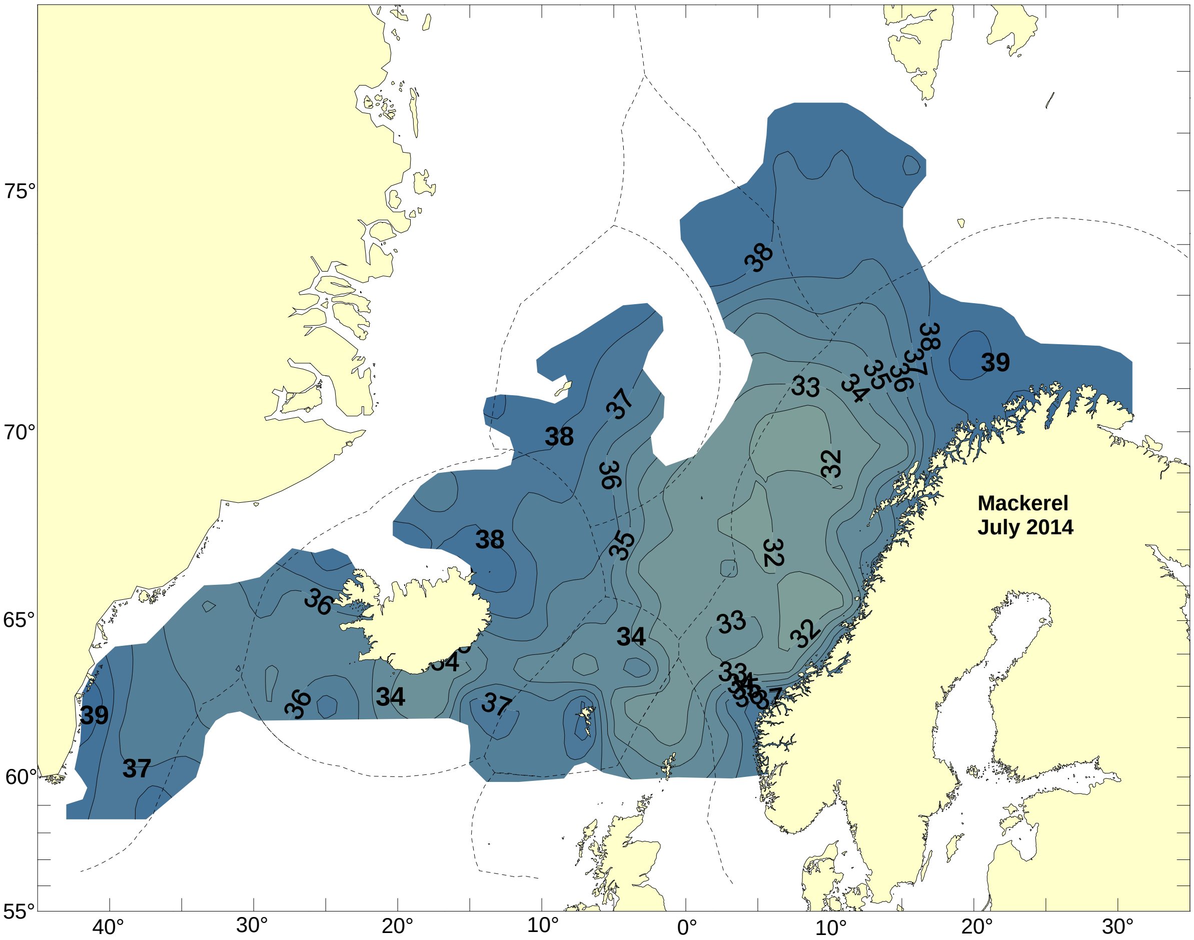


Figure 13. Average length distribution of NEA mackerel from the joint ecosystem survey with M/V "Brennholm", M/V "Vendla", M/V "Finnur Friði" and R/V "Arni Fridriksson" in the Norwegian Sea and surrounding waters between 2nd of July and 12th of August 2014.

Mackerel caught in the pelagic trawl hauls on the four vessels varied from 24 cm to 46 cm in length with the individuals between 30-33 cm and 35-38 cm dominating in the abundance. The mackerel weight (g) varied between 180 to 820 g (Figure 14). Very few juvenile mackerel were caught in 2014.

The spatial distribution and overlap between the major pelagic fish species from the joint ecosystem survey in the Nordic Seas according to the catches are shown in Figure 15.

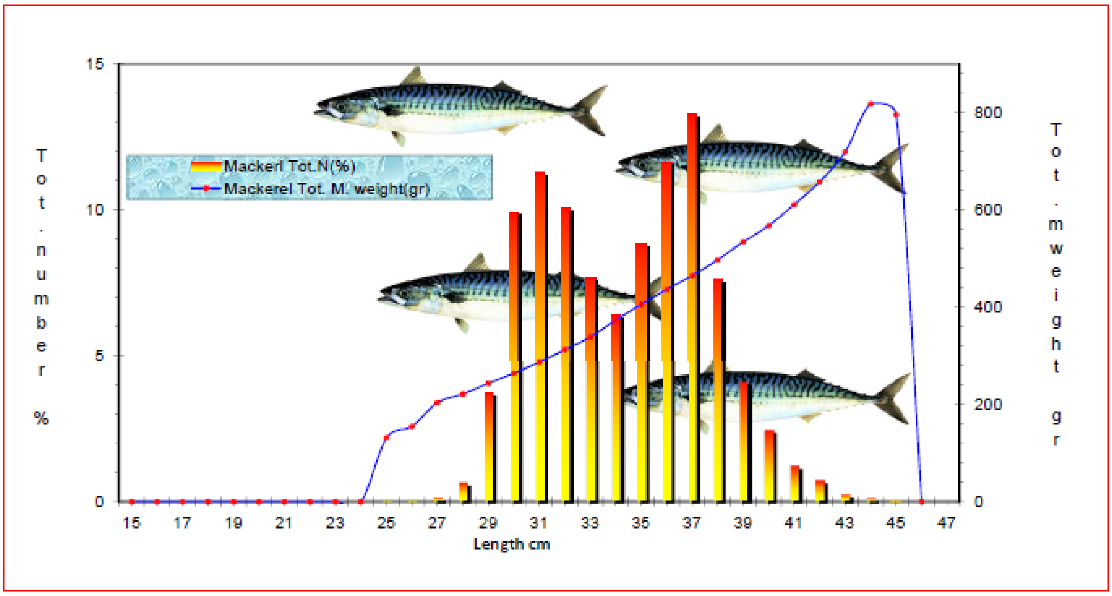


Figure 14. Length (cm) and weight (g) distribution in percent (%) for mackerel sampled in the trawl catches. Note that these values are not weighed with catch or area size and can therefore divide from the estimation of length distribution in the stock (not provided).

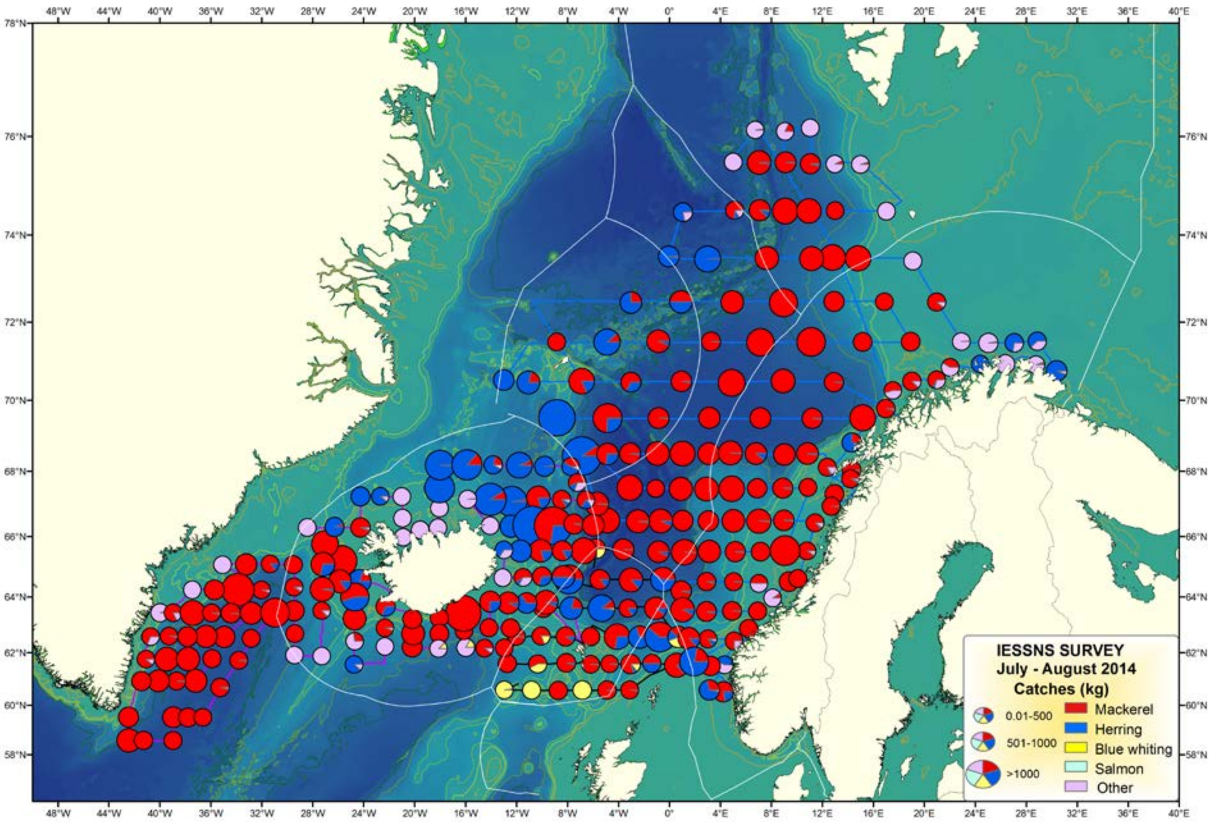


Figure 15. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) from joint ecosystem surveys conducted onboard M/V "Brennholm" and M/V "Vendla" (Norway), M/V "Finnur Friði" (Faroe Islands) and R/V "Arni Fridriksson" (Iceland) in the Norwegian Sea and surrounding waters between 2nd of July and 12th of August 2014. 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-August 2014 were based on average catches of mackerel within rectangles of 1° latitude and 2° longitude and measurements of horizontal opening of the trawls (Table 5), which gave catch indices (kg/km²; Fig. 16). An interpolation for rectangles not covered on the edges of area covered was only done for those that had adjacent rectangles with one or more tows on three or four sides. Total number of rectangles interpolated was 38 (Fig. 17). The interpolation was done by taking the average values of all adjacent rectangles. The swept area estimates for the different rectangles is shown in Fig. 17 and in a different graphical way in Fig. 18. The total biomass estimate came to 9.0 million tons, which was allocated to the different EEZs as in previous years (Annex 1). This estimate was based on the standard method using the average horizontal trawl opening by each participating vessel (around 65 m, see Table 5). A further assumption was that all mackerel inside the trawl opening are caught, i.e. no escape through the meshes.

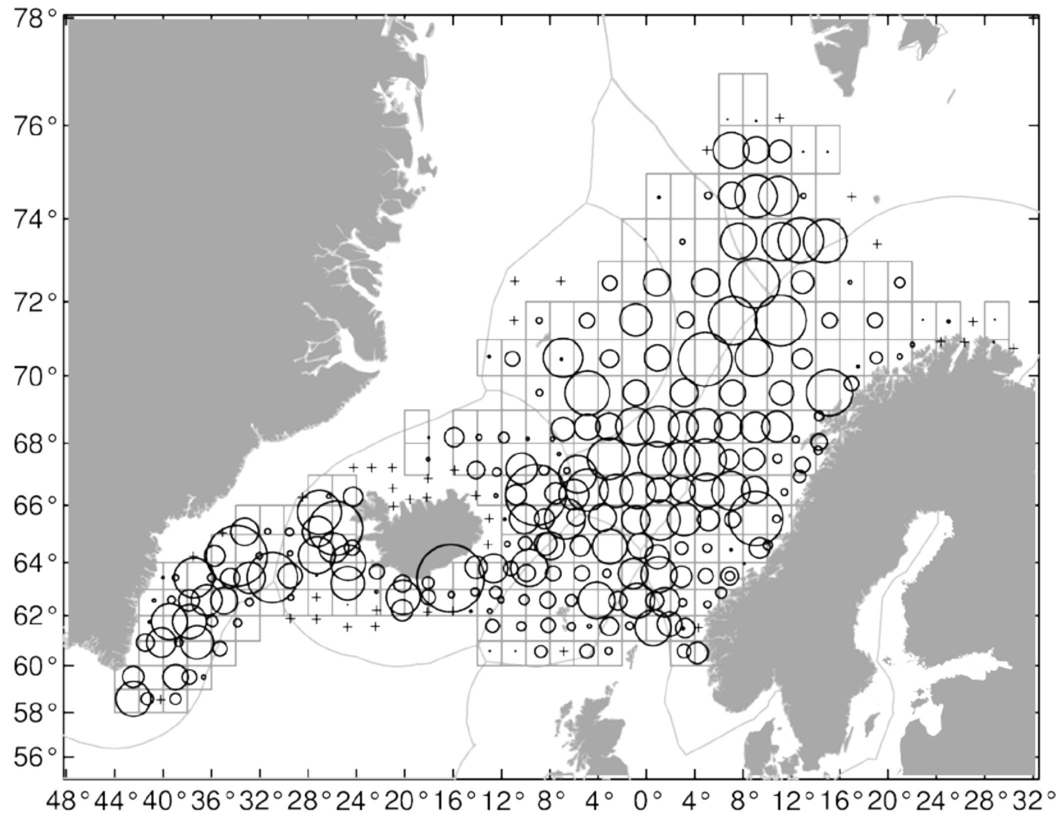


Figure 16. Stations and catches of mackerel in July/August 2014 where the circles size is proportional to square root of catch (kg/km²) and stations with zero catches are denoted with +.

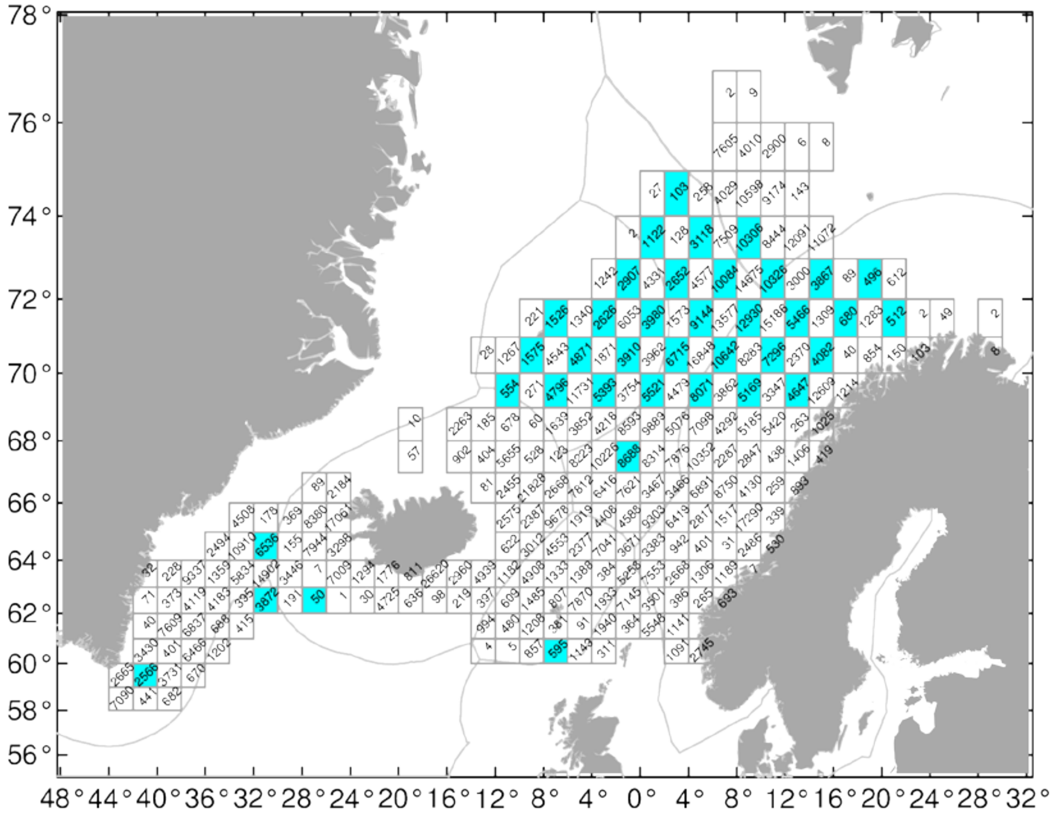


Figure 17. Standardized mackerel catch rates (kg/km²) in 1° lat. by 2° lon. rectangles from swept area estimates in July/August 2014 where interpolated rectangles are denoted with blue shading.

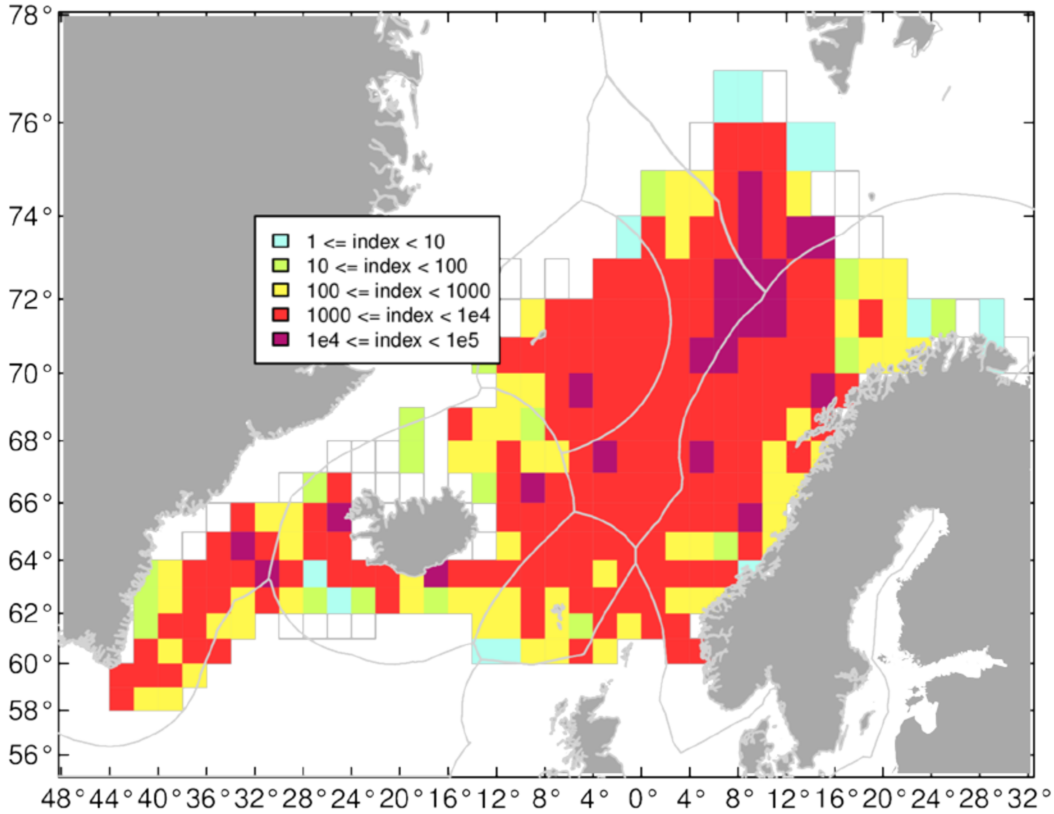


Figure 18. Standardized mackerel catch rates (kg/km²) for mackerel in the July/August 2014 survey represented graphically. Colouring of levels is the same as in the 2013 IESSNS survey report (Nøttestad et al. 2013).

Age-disaggregated indices from IESSNS obtained using the swept-area methodology were first estimated and introduced in the Benchmark assessment of the mackerel stock in 2014 (Nøttestad et al. 2014). The same methodology was used now and the series updated with the 2014 data to be used in the analytical assessment of the stock (Table 8). The 2014 results show that 2011-year class contributed with 32.0% in number followed by the 2010-year class with 21.1% (Fig. 19). The 2007, 2008 and 2009 year classes contributed then to around 11% each. Altogether 66.2% of the estimated number of mackerel was less than 6 years old. The consistency between years for the different age groups is shown in Fig. 20. A good consistency was observed for all age groups from age 1-10, except for age 5. That might be explained by that the 2009 year class (age 5) is a rather weak and has a similar low strength in abundance as the 2008 year class (age 6) providing low contrast in the consistency plot, compared to many of the surrounding very strong year classes (2005, 2006, 2010, 2011), and could be more difficult to track over time compared to the much stronger year classes within the mackerel stock.

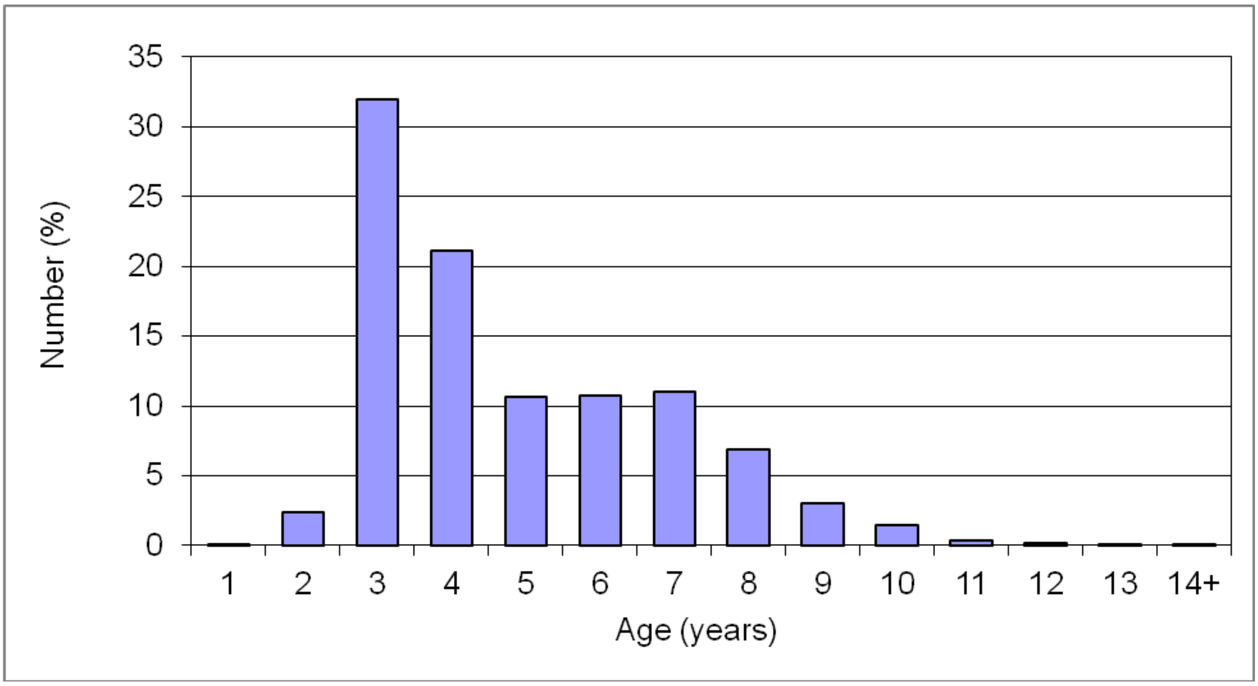


Figure 19. Age distribution in percent (%) of Atlantic mackerel scaled to the total catches, in the Norwegian Sea and surrounding waters from 2nd of July to 12th of August 2014.

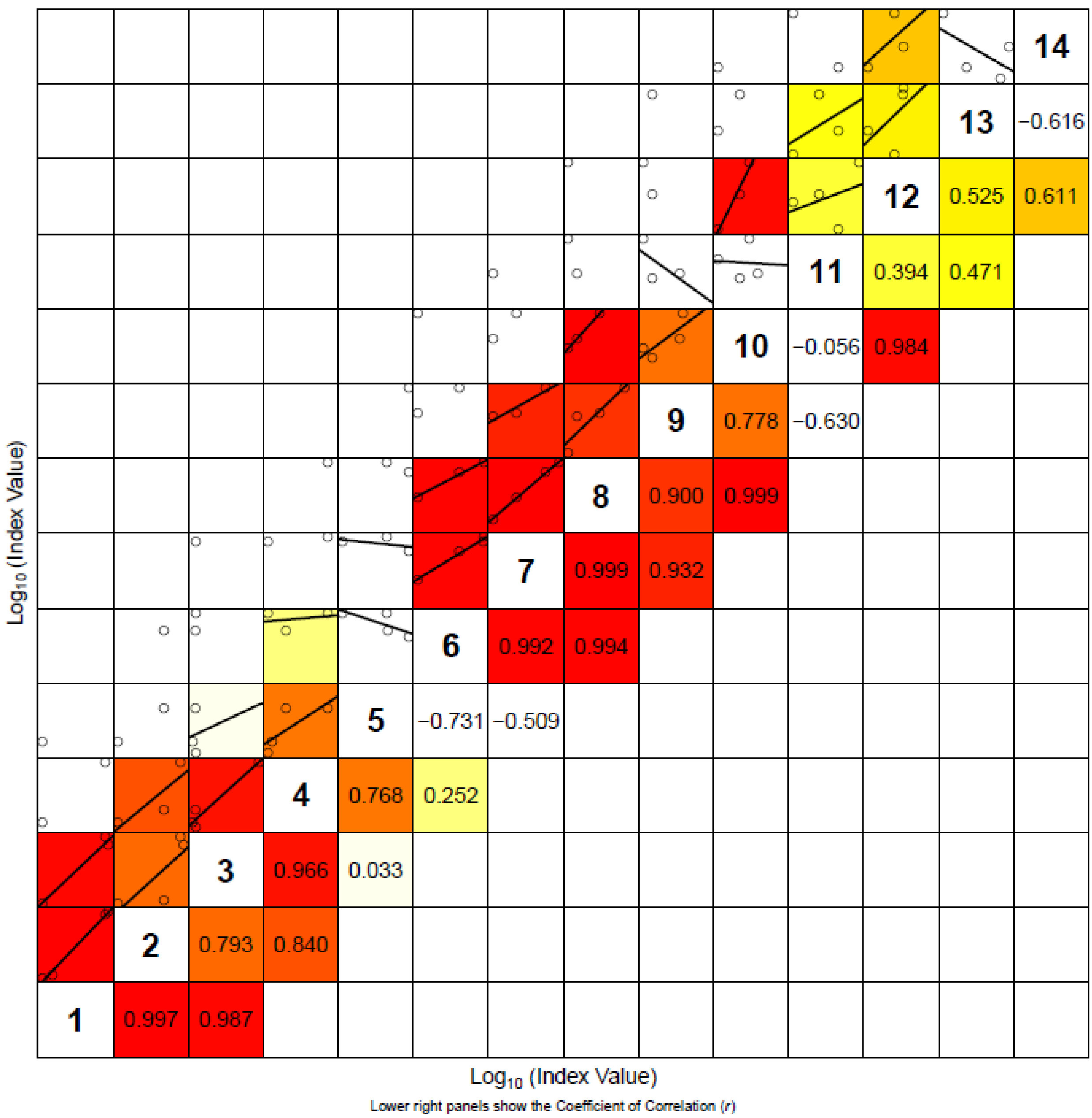


Figure 20a. Consistency plot of mackerel from the July/August 2014 survey (IESSNS).

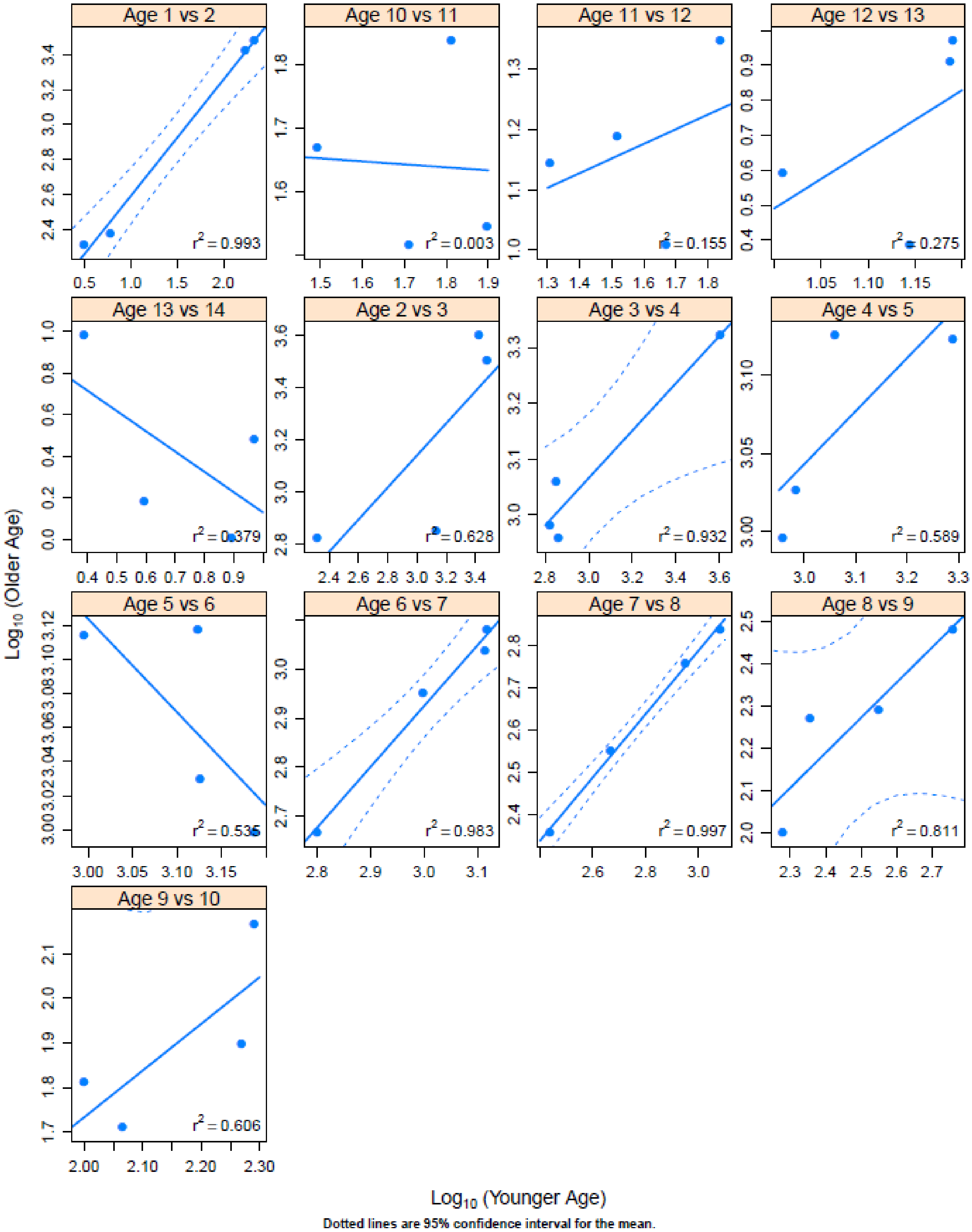


Figure 20b. Consistancy plot (Log_{10} transformed on the x- and y axis) for each year class 1-14+. The correlation is given as r^2 for each year class. Dotted lines are 95% confidence interval for the mean.

Table 8. Time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel, (b) survey area covered where each age class is observed, and (c) swept-area density index (km^{-2}), which is applied in the analytical assessment of mackerel (limited to age 6+).

(a) Number of individuals (billions)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Habitat range (mill. km^2)
2007	1.331	1.861	0.896	0.238	1.000	0.16	0.055	0.039	0.029	0.011	0.009	0.003	0.011	0.002	0.99
2010	0.019	2.768	1.485	3.954	3.123	1.277	0.555	0.385	0.236	0.063	0.041	0.031	0.016	0.005	1.75
2011	0.209	0.251	0.861	1.103	1.616	1.211	0.564	0.276	0.121	0.062	0.057	0.017	0.011	0.001	1.20
2012	0.497	4.991	1.223	2.111	1.822	2.415	1.642	0.652	0.342	0.119	0.067	0.019	0.006	0.006	1.50
2013	0.064	7.776	8.987	2.137	2.906	2.874	2.679	1.266	0.451	0.192	0.161	0.042	0.008	0.022	2.41
2014	0.008	0.579	7.795	5.138	2.605	2.624	2.673	1.686	0.739	0.360	0.086	0.054	0.020	0.004	2.45

(b) Area covered where an age class is observed (km2)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)
2007	0.832	0.832	0.832	0.832	0.832	0.830	0.831	0.829	0.820	0.847	0.865	0.720	0.834	0.788
2010	6.128	2.059	2.052	2.034	2.032	2.028	2.030	2.027	2.032	2.034	2.023	2.002	2.050	2.039
2011	1.217	1.216	1.218	1.217	1.217	1.217	1.216	1.219	1.212	1.208	1.223	1.220	1.182	0.992
2012	2.330	1.892	1.846	1.845	1.842	1.842	1.844	1.842	1.842	1.838	2.041	1.861	2.463	1.974
2013	10.748	2.596	2.255	2.224	2.175	2.209	2.228	2.210	2.313	2.438	2.344	2.730	2.048	2.302
2014	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450	2.450

(c) Density index (millions per km^2)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)
2007	1.599	2.236	1.077	0.286	1.202	0.193	0.066	0.047	0.035	0.013	0.010	0.004	0.013	0.003
2010	0.003	1.345	0.724	1.944	1.537	0.630	0.273	0.190	0.116	0.031	0.020	0.015	0.008	0.002
2011	0.172	0.206	0.707	0.907	1.328	0.995	0.464	0.226	0.100	0.051	0.047	0.014	0.009	0.001
2012	0.213	2.637	0.663	1.144	0.989	1.311	0.890	0.354	0.186	0.065	0.033	0.010	0.002	0.003
2013	0.006	2.995	3.985	0.961	1.336	1.301	1.202	0.573	0.195	0.079	0.069	0.015	0.004	0.010
2014	0.003	0.236	3.182	2.097	1.063	1.071	1.091	0.688	0.302	0.147	0.035	0.022	0.008	0.002

Underwater camera observations

Video recordings have not been quantitatively analysed. However, all recordings have been qualitatively evaluated with regards to research questions stated for employment of camera at each trawl location (Table 9). Quantitative analysis is here defined as viewing of video tape at recorded speed (no stopping and zooming in on details, etc), and writing down comments on fish abundance, swimming direction and escapement. The results of qualitative analysis are that the fish lock is successful in preventing mackerel from escaping the cod end when the towing ends and trawl speed declines to values below 5 knots. Trawl mesh sizes from 8 cm to 16 m were observed. The only location reporting escapement of fish was at the 4 m mesh, herring was confirmed escaping but the video recordings need more detailed analysis before escapement of mackerel can be confirmed.

Table 9. Location of video camera in trawl, number of stations camera was employed and type of video tape analyses completed to date for each vessel. All vessels used a GoPro camera and Árni Friðriksson also used high definition Sony camera. All analyses are qualitative not quantitative.

Vessel	Location of camera	Number of stations	Qualitative results
Finnur Fríði	Junction of 9cm/18cm meshes: facing codend	3	Mackerel swam in direction of towing and no escapement observed. Herring falling back towards cod-end, hence, not swimming with trawl.
	Fish lock: facing codend	5	Negligible amount of mackerel observed escaping but large numbers observed trapped in cod-end by the fish lock at the end of effective tow time.
	Headline	2	Turbulence, no fish observed.
Brennholm	8 m meshes: facing trawl opening	29	No escapement of mackerel observed.
Vendla	8 m meshes: facing trawl opening	27	No escapement of mackerel observed.
Árni Friðriksson	Fish lock: facing codend or trawl opening	5	No escapement of mackerel observed.
	16 m mesh	3	Lots of turbulence.
	4 m mesh	2	Lots of escaping fish observed, herring confirmed escaping but no mackerel confirmed escaping, needs further analysis.
	2 m mesh	4	Fish observed swimming in direction of trawling, and possible escapement of fish observed in 1 of 4 stations.
	40 cm mesh	1	Few fish seen.
	20 cm mesh	1	Mackerel swam direction of trawl, avoided panels and no escaping observed.
	8 cm mesh (mounted outside trawl)	1	No fish observed.
	Headline	1	No fish observed.
	Footrope	1	No fish observed.

Multibeam sonar recordings

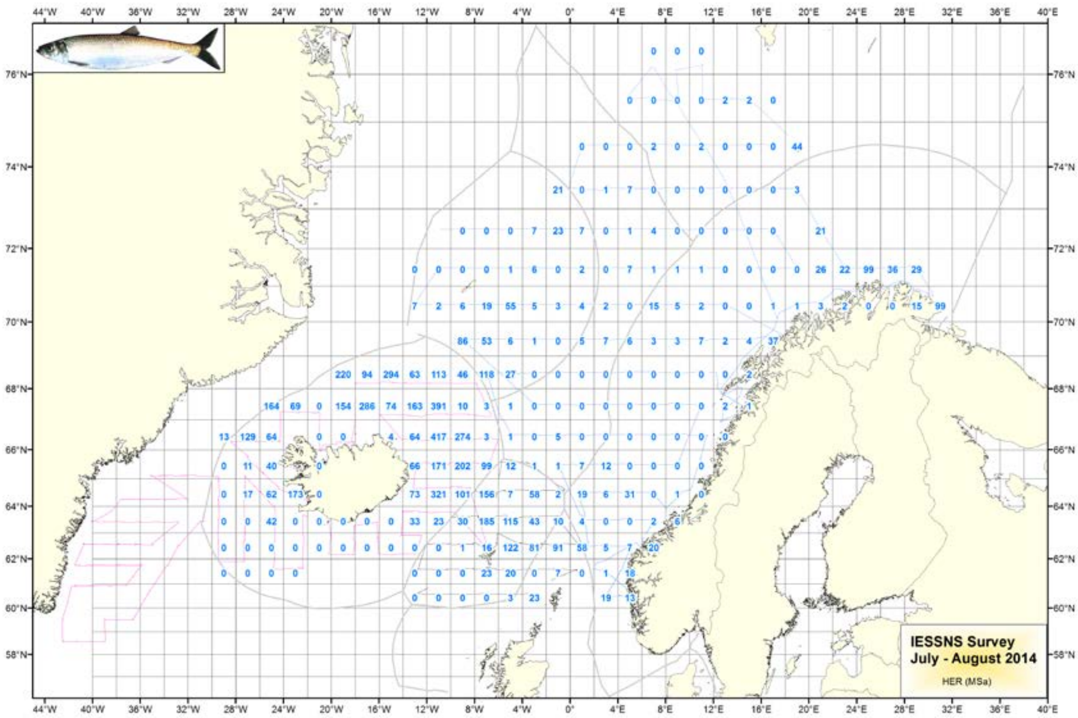
The mackerel schools detected were of small size, predominantly with low density and appeared in the upper 20-30 m of the water column throughout the day, on Simrad SH80 and Simrad SX90 operated within large geographical areas. Only small and loose mackerel schools were recorded on the multibeam sonars at all onboard M/V "Brennholm" and M/V "Vendla". Further quantitative sonar analyses on NEA mackerel will be done in the months ahead. Even if we maximized the ping rate on both the multibeam sonars and multi-frequency echosounders, the mackerel were practically invisible for the multibeam sonars. 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.

Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSS) was recorded in the eastern part of the area surveyed. The western boundary of its distribution was at 14°W south of Iceland and 20°W north of Iceland. The herring observed west of these boundaries belonged to the Icelandic summer-spawning herring according to trawl samples. The acoustic values indicated that NSS herring had the highest density in the western periphery of its distribution, or north of the Faroes and east and north of Iceland (Figure 21). The concentrations were low in the northern and eastern areas, and herring was relatively absent from the mid Norwegian Sea. The periphery of the distribution of NSS herring towards north were probably not reached between 20°W and 8°E, as in the years 2012 and 2013 (Figure 21 and 15).

The biomass estimate of NSS herring came to 4.6 million tons in July-August 2014 based on the acoustic recordings using the primary frequency of 38 kHz and the biological measurements of herring caught in the trawl tows. Herring was in the surface waters in most area feeding and possibly above the transducer (acoustic dead zone) and therefore not fully represented in the acoustic measurements.

(a)



(b)

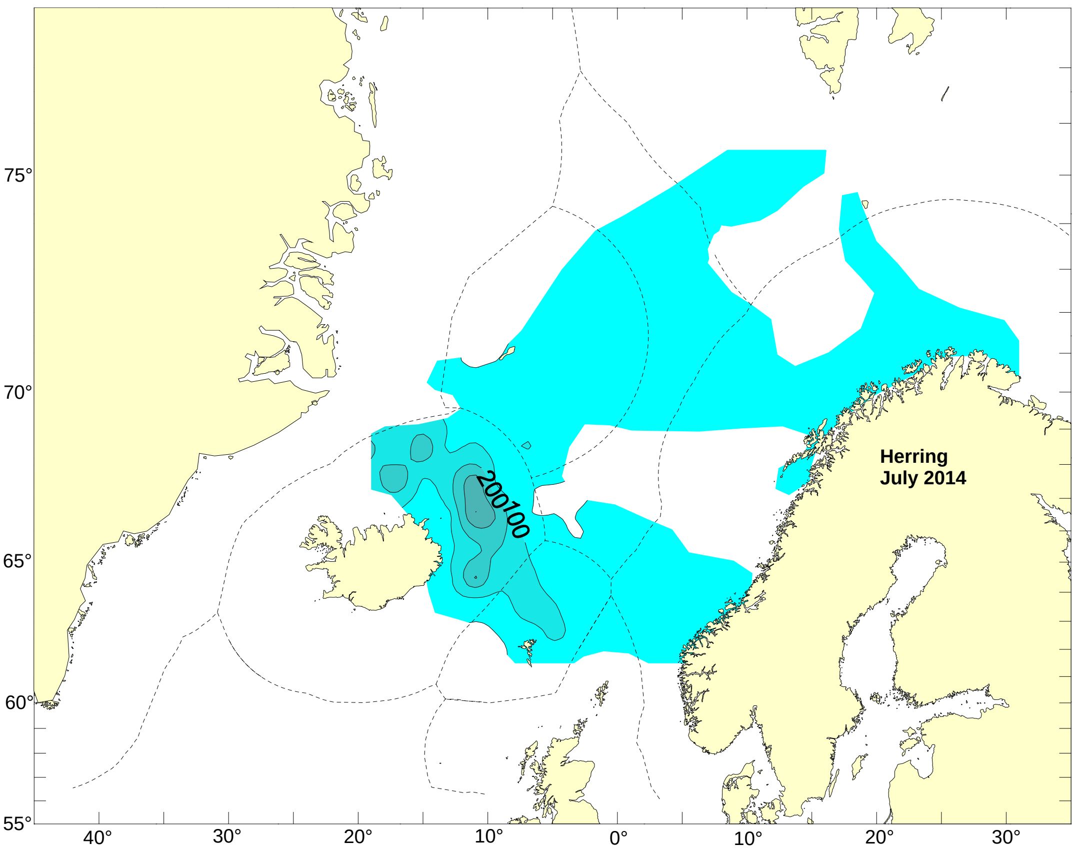


Figure 21. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise track, 2nd of July to 12th of August 2014 (a) within a rectangles and (b) shown on a contour plot.

Norwegian spring-spawning herring had a length distribution from 18-39 cm with a peak at 35 cm and weighed mean length of 33.4 cm. The weighed mean weight was 329.6 g

The age distribution in NSS herring shows dominance of the 2004 year class with about 22% in numbers of the acoustic estimate, followed by the 2005 year class (16%) (Figure 22).

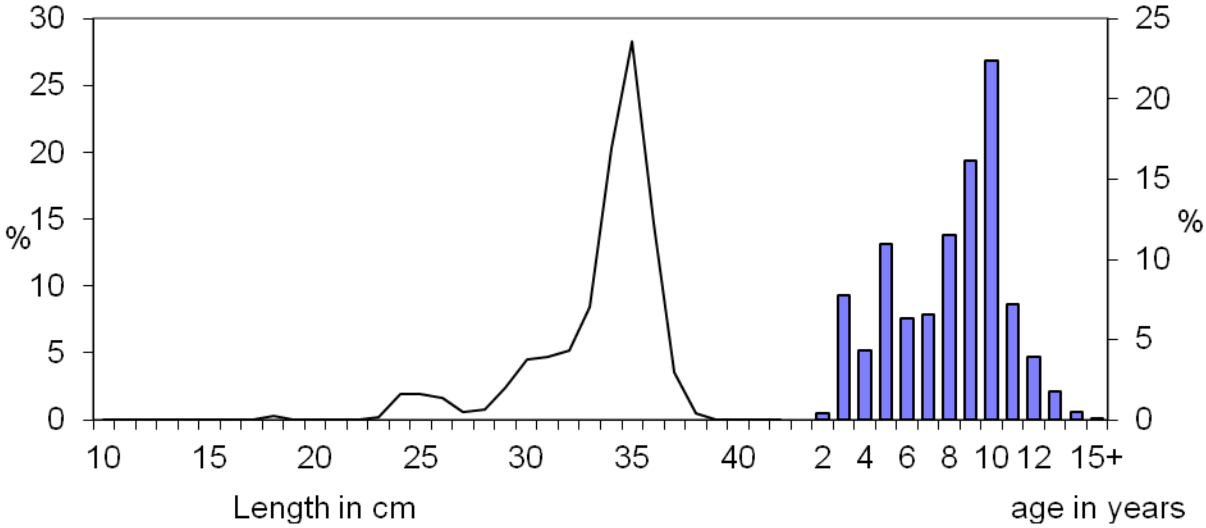


Figure 22. Age and length distribution of Norwegian spring-spawning herring from 2nd to July 11th August 2014.

The length distribution measured on herring showed overall a pronounced length dependent migration pattern, with the largest individuals (>35 cm) swam furthest west and northwest (Figure 23). The large herring observed on the west side of Iceland were Icelandic summer-spawners and the large herring in the Lofoten area were Norwegian autumn-spawners, which are, different from the Icelandic summer-spawners assessed with NSS herring.

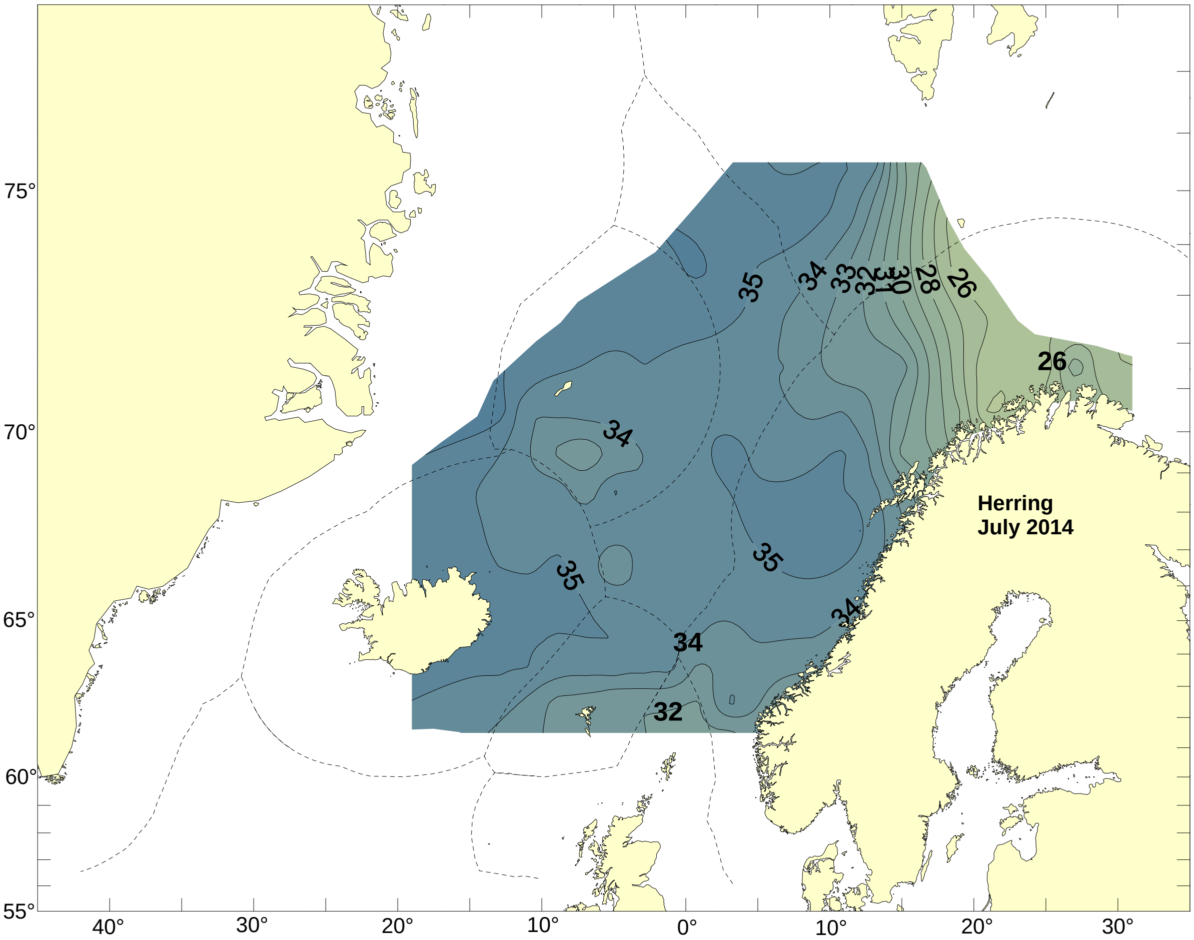


Figure 23. Length distribution of Norwegian spring-spawning herring during the coordinated ecosystem survey 2nd of July to 12th of August 2014.

Blue whiting

No results are presented for blue whiting in 2014 because no dedicated deep trawl hauls were taken on acoustic registrations of blue whiting. See an explanation in the Introduction chapter.

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in 69 % of trawl stations (Fig. 24). Of stations with mackerel present, 60 % of stations had catches < 10 kg. The other 40s% of stations had catches from 25 kg to 95 kg. There was a north-south pattern in lumpfish occurrence. Lumpfish was present at majority of stations north of 65°N, whereas lumpfish was scarce south of 65°N, excluding Greenland waters. Of note, total trawl catch at each trawl station were processed on board Árni Friðriksson, Brennholm and Vendla whereas a subsample of 100 kg to 300 kg was processed on Finnur Fríði. Therefore, small catches (< 10 kg) of lumpfish might be missing from the survey track of Finnur Fríði (black crosses). However, it is unlikely that larger catches of lumpfish would have gone unnoticed by crew during sub-sampling of catch on Finnur Fríði.

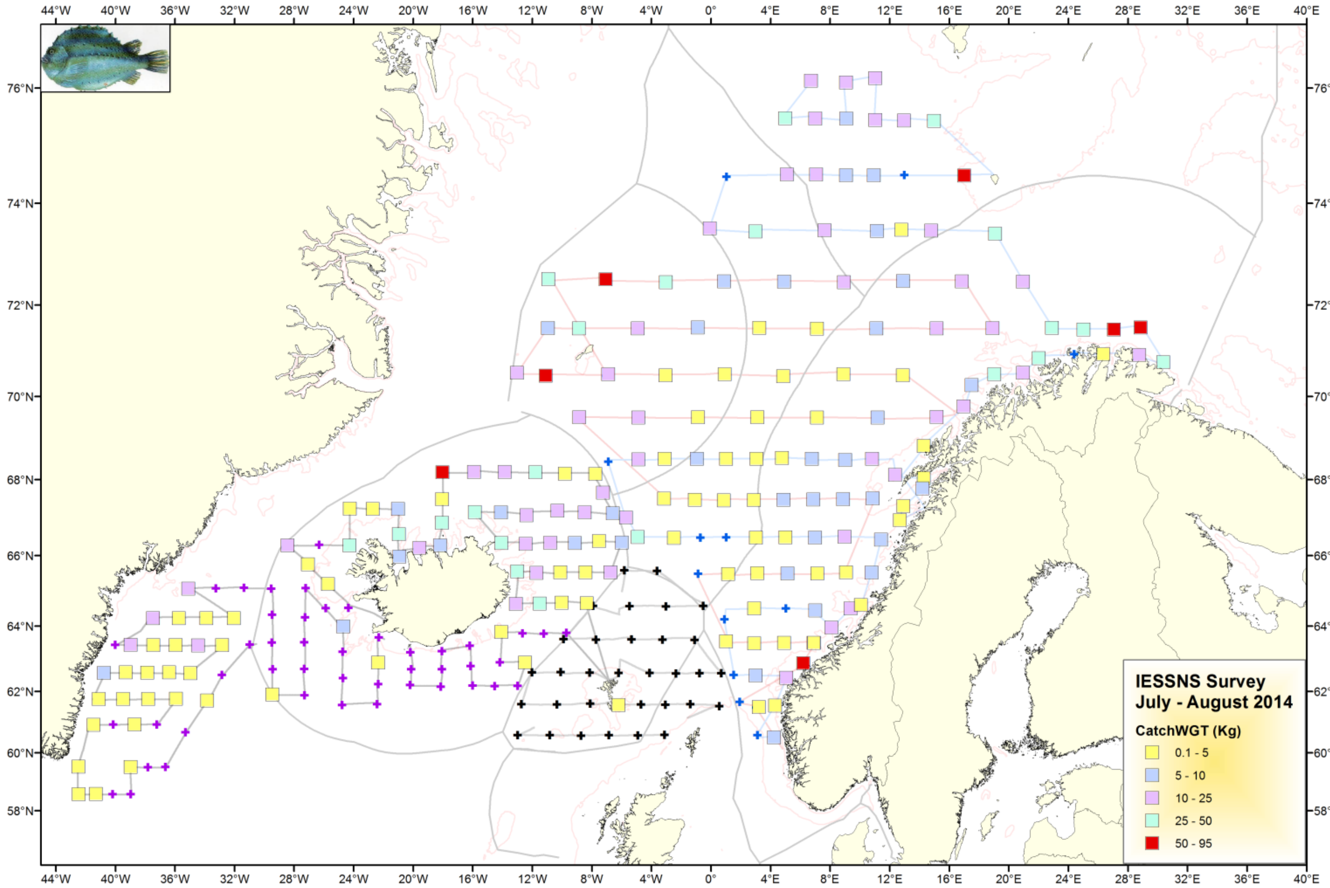


Figure 24. Lumpfish catches at surface trawl stations during the IESSNS survey in July and August 2014.

Marine Mammal Observations

Totally 227 marine mammals and 8 different species were observed onboard M/V "Brennholm" and M/V "Vendla" from 2nd to 28th of July 2014. Altogether 13 groups of killer whales with average group size of 6.6 individuals (N=86, stdev = 8.9) were found in the central and northern part of the Norwegian Sea in close association with small widely distributed shoals of NEA mackerel. A total number of 7 sightings of 9 minke whales were observed east just south of Jan Mayen, in outer part of Vestfjorden and in the central and northern part of the Norwegian Sea. Altogether 10 sightings of 15 fin whales where found concentrated in the northeastern part of the Norwegian Sea and along the coast of Finnmark, just south of Jan Mayen and between Bear Island and Svalbard. Altogether 12 groups of white beaked dolphins with average group size of 7.9 individuals (stdev = 5.2) appeared together with the fin whale observations and in several groups south of Bear Island. Only 2 sightings of 3 humpback whales were mainly found in the northern part of the Norwegian Sea. Very few marine mammals were sighted in the southern part of the covered area including the northern part of the North Sea, and central Norwegian Sea south of 67°N (Figure 25).

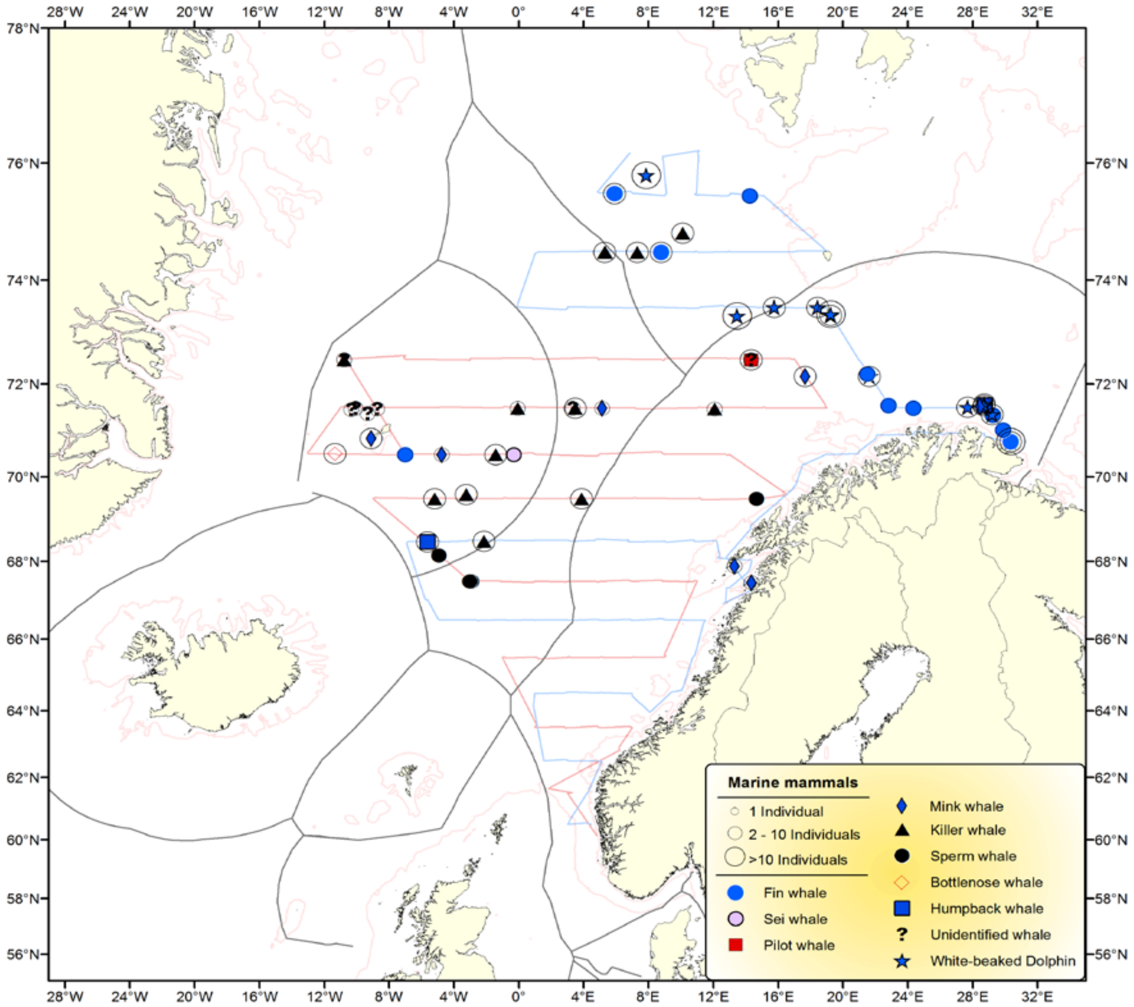


Figure 25. Overview of all marine mammals sighted onboard M/V "Brennholm" and M/V "Vendla" in the Norwegian Sea and surrounding waters from 2nd to 28th of July 2014. No marine mammal sightings were done onboard the Icelandic and Faroese vessels.

Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 2 July to 12 August 2014 by four vessels from Norway (2), Iceland (1) and Faroese (1), beside that the Icelandic vessel was rented by Greenland to cover Greenlandic waters. In this year the survey coverage was extended further into Greenlandic waters than in previous years. Furthermore, the area south of 60°N in the eastern part was not covered, including the northern part of North Sea, as in 2013. Otherwise the survey is 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 the various bottom trawl surveys run for many demersal stocks.

The total swept area estimate of mackerel in summer 2014 was 9.0 million tonnes based on a coverage of more than 2.45 million square kilometres in the Nordic Seas from about 58 degrees up to 76 degrees north and from the Norwegian coast in east and west to the Greenlandic continental shelf. This represents average density of 3.66 tonnes/km^2 which is almost identical to last year's estimate of 3.65 tonnes/km^2. Mackerel was distributed over most of the surveyed area, and the zero boundaries for mackerel were not reached towards south and east in the Greenland waters, west of the southernmost tip of Greenland (Cape Farwell) and towards south in the southeastern part of the survey area.

The 2011-year class contributed with 32.0% in number followed by the 2010-year class with 21.1%. The 2007, 2008 and 2009 year classes contributed then to around 11% each. Altogether 66.2% of the estimated number of mackerel was less than 6 years old. The overlap between mackerel and NSS herring 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), which is similar to 2013 and 2012. However, the overlap is less pronounced now than in the previous two years. 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*. (2012) 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.

The biomass index of Norwegian spring-spawning herring of 4.6 million tonnes is only 53% of the biomass index in July/August 2013 (8.6 million tonnes). There are two likely explanations for the drop in the biomass index in 2014. First, the survey did probably not cover the whole distribution area of the stock, especially north of Iceland between 20°W and 8°E, as in 2012 and 2013 (Figure 21 and 15). Secondly, there is a strong indication that herring were in the acoustic dead-zone above the transducer or in the surface 10-15m. An example is the Jan Mayen area where the trawl catches at surface was high (Figure 15) but the acoustic registrations were low (Figure 21).

The surface temperatures in the Nordic Seas in July-August 2014 were generally higher in all areas compared to July-August 2013. The SST anomaly map showed considerably higher average surface temperatures in July 2014 or 1-3°C higher compared to the average temperature in July during the last 20 years. This is thought to be due to the unusual calm weather conditions during this summer.

The concentrations of zooplankton was at the same level in 2014 as in 2013 (8.6 g dry weight/m^2 in July-August 2013 to 8.3 g/m^2 in July-August 2014) after more than a decade of decreasing trend in plankton concentrations.

During the 2014 survey, light intensity was measured to meet a request from the mackerel benchmark (ICES 2014c). The request was to use solar elevation angle as measure of daytime instead of a simple two state parameter as used at the benchmark, to test possible diel effects on catch rates of mackerel. A further request was to compare weather conditions (wind and wave height) in relation catch rates.

Environmental data were collected on all vessels during the 2014 IESSNS and results will be reported to the next mackerel benchmark.

Whale observations were done by the two Norwegian vessels during the survey. The number of marine mammal sightings was generally very low in the central and eastern part of the Norwegian Sea but with considerable higher numbers of especially fin whales in the northern Norwegian Sea and into the Barents Sea. Groups of killer whales were mostly observed in central Norwegian Sea, whereas fin and humpback whales where mainly observed near Jan Mayen, Bear Island and the southwestern part of the Barents Sea and off the coast of Finnmark.

The swept-area estimate was as in previous years based on the standard method using the average horizontal trawl opening by each participating vessel (around 65 m), 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 internal consistency plot for age-disaggregated year classes has improved since 2013 especially for younger year classes. There is now good internal consistency for year classes 1-10 years old, except for age 5. The reason for the low consistency around age 5 is unknown. However, the 2009 year class (age 5) is a rather weak year class and has a similar low strength in abundance as the 2008 year class (age 6) providing low contrast in the consistency plot, compared to many of the surrounding very strong year classes (2005, 2006, 2010, 2011), and could be more difficult to track over time compared to the much stronger year classes within the mackerel stock.

The improved consistency in younger year classes for NEA mackerel in the IESSNS survey should be taken into consideration by ICES WGWIDE, specifically by including also younger mackerel 1-5 years of age, and not only age 6+ mackerel, into the tuning series as input on abundance of NEA mackerel to the assessment.

Since altogether 66.2% of the estimated number of mackerel was less than 6 years old and the internal consistency plot for younger year classes has greatly improved in 2014, the value of the assessment would improve considerably by including these consistent and valid density indices for all year classes 1-14+ years old as input data series to the assessment.

Recommendations

General recommendations

Recommendation	To whom
Increase the survey effort in Greenlandic and international waters in the western part of the survey area to cover the NEA mackerel stock completely during the summer feeding.	Greenland
Develop a method that can sample the mackerel representatively in the North West European shelf Seas south of 58.5N, where mackerel tend to dive under surface trawls to cover the NEA mackerel stock completely during the summer feeding.	EU
The age disaggregated indices from IESSNS are considered to give a valid signal about year class sizes from age 1-10 as indicated by the consistency plots (Fig. 20). Therefore it is recommended that WGWIDE consider extending the tuning data from the survey to include younger age groups in the future analytical assessment of the mackerel stock.	WGWIDE
We recommend that observers collect sighting information of marine mammals and birds on all vessels.	Norway, Faroe Island, Iceland, Greenland

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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). Figure A1 shows the steps taken in establishing the framework. The shapefiles did not include the outlines of the EEZ of Svalbard, these were taken from a text file used in NEAFC work (pers. comm. Þorsteinn Sigurðarson, MRI, Iceland). A slight discrepancy between the two is shown in Figure A2, but it was left for later to correct this and get authoritative EEZ boundaries according to international agreements.

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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-August 2014. Area calculated from rectangles where mackerel was present. Note that area calculations in the 2013 were incorrect (included covered rectangles without mackerel).

Exclusive economic zone / international area	Area (in thous. km²)	Biomass (in thous. tonnes)	Biomass (%)
EU	78	226	2.5
Norwegian	640	2267	25.2
Icelandic	478	1593	17.7
Faroese	268	549	6.1
Jan Mayen	222	732	8.2
International north	275	1759	19.6
International west	52	83	0.9
Greenland	335	1164	13.0
Spitzbergen	105	611	6.8
Total	2453	8984	100.0

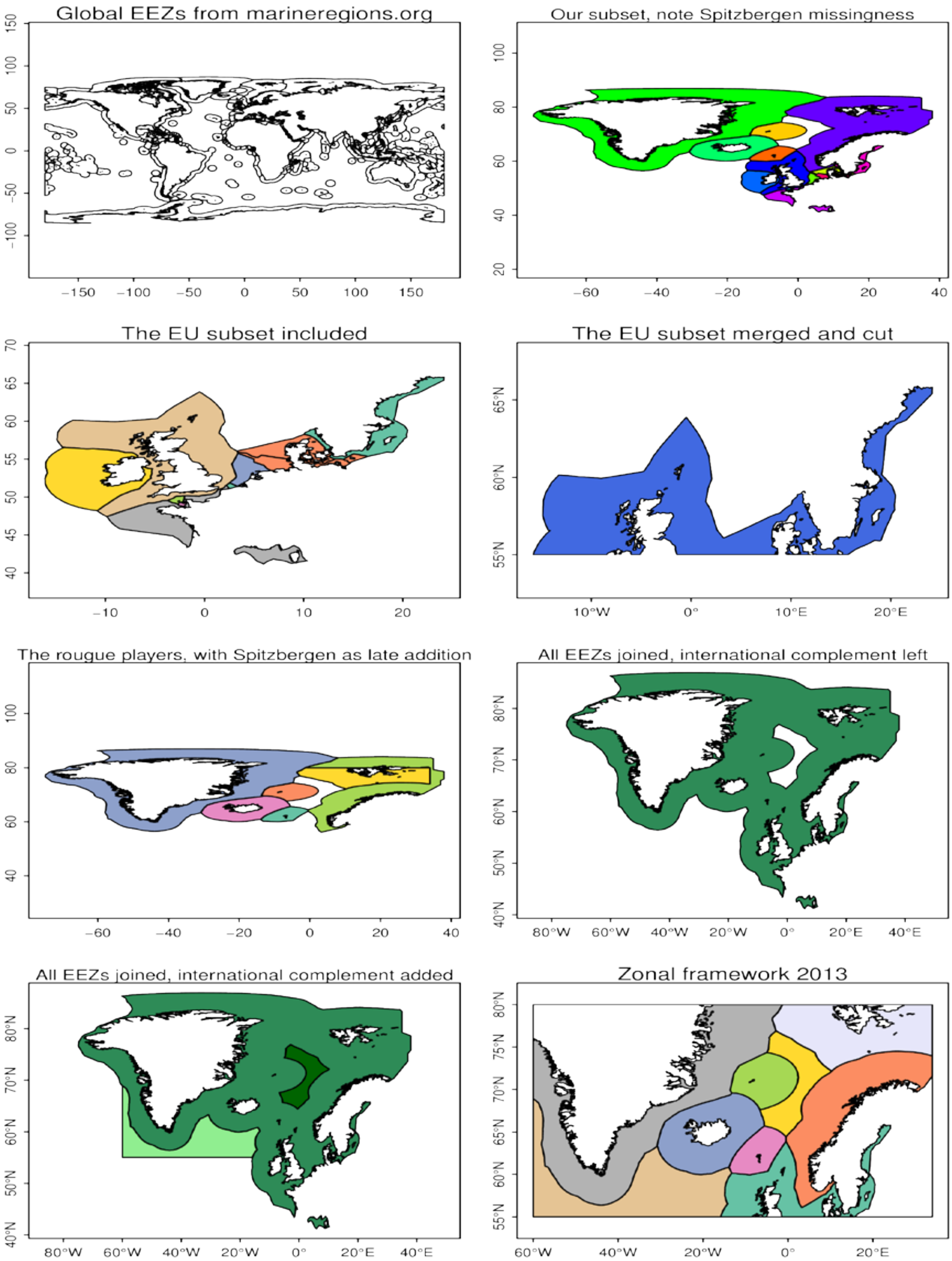

Figure A1. Zonal framework developed and used in 2013, extended and used again in 2014.

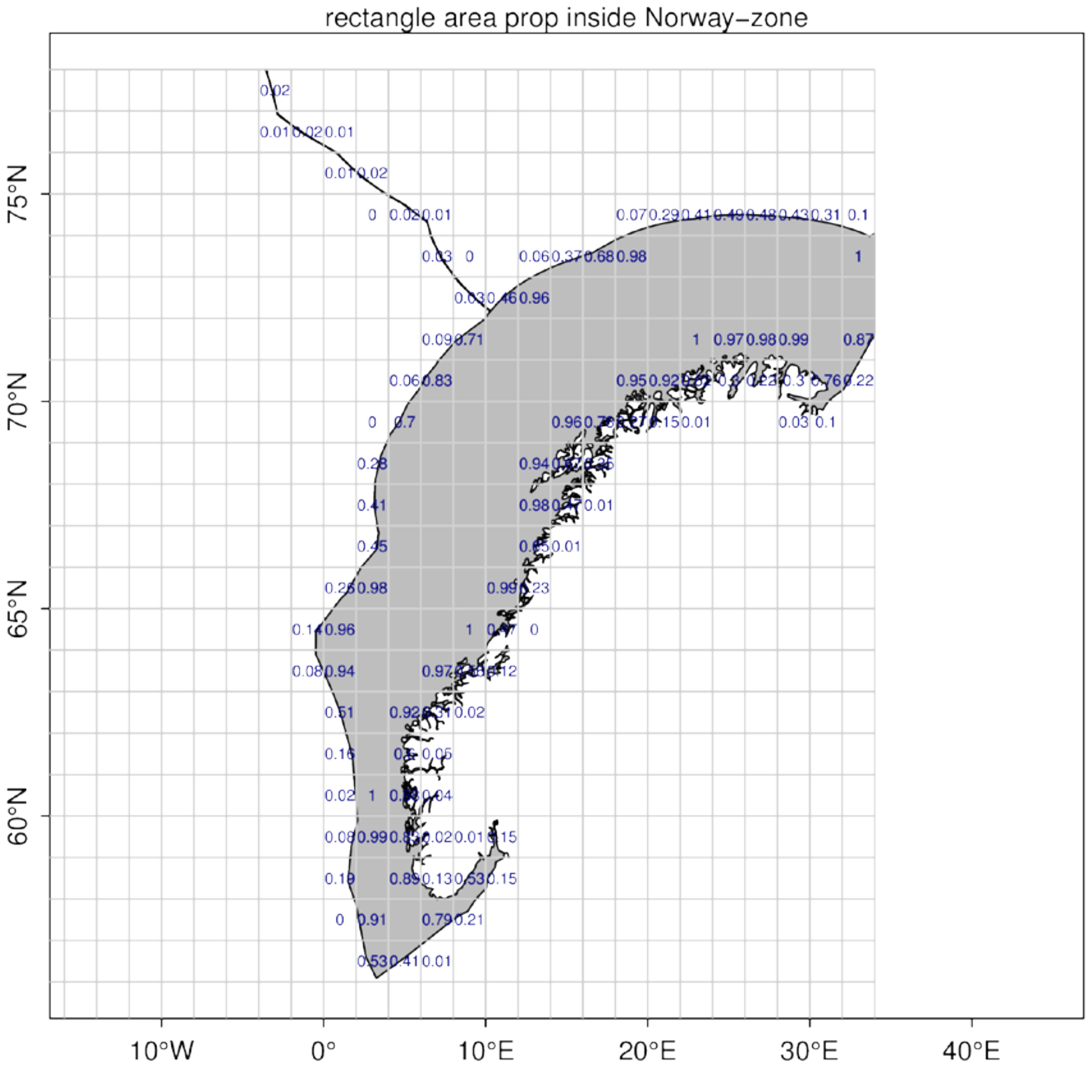

Figure A2. Sea area rectangle (1° latitude by 2° longitude) proportions within the Norway EEZ. The 'outgrowth' is due to discrepancy between the text file used for the Spitzbergen EEZ (pers. comm. Þ. Sigurðsson, MRI, from NEAFC work) and the Norway EEZ according to low-resolution shapefile on htpp://marineregions.org.