Working Document to

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Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V ”Brennholm”, M/V “Eros”, M/V “Christian í Grótinum” and R/V “Árni Friðriksson”, 1 July - 10 August 2015

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Executive summary

The international ecosystem summer survey in the Nordic Seas (IESSNS) was performed during 1 July to 10 August 2015 on four vessels from Norway (2), Iceland (1) and Faroes (1). Greenland chartered the Icelandic vessel for 12 days to cover the East Greenland area. A standardised pelagic trawl swept area method was used to obtain abundance indices and study the spatial distribution NEA mackerel 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.

The total swept area biomass index of NEA mackerel in summer 2015 was 7.7 million tonnes distributed over an area of 2.7 million square kilometres in the Nordic Seas. The estimate in 2015 is 1.3 million tonnes lower than in 2014 (9.0 million tonnes), when it was distributed over an area of 2.4 million square kilometres. The 2011-year class contributed with 28% of numbers followed by the 2010-year class with 22%. The 2012 year class had 12% in number. Altogether 71% 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 2014 by the inclusion of two more survey years. This is especially apparent for younger ages. There is now good internal consistency for 1-10 years old mackerel, except between age 5 and 6.

Mackerel was observed in most of the surveyed area, and the zero boundaries were found in the large majority of areas. The mackerel had a more patchy distribution in July-August 2015 based on the trawl catches compared to previous years. The mackerel were also present in smaller quantities in the northernmost and westernmost regions of the surveyed area compared to the last few years.

Norwegian spring-spawning (NSS) herring was measured acoustically during the survey and the abundance index of age 4+ came to 22.7 billions, which is comparable to the May survey index in 2015 of 20.3 billions. The 2004, 2005 and 2009 year classes were most abundant in the survey. The NSS herring was mainly found 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 had low concentrations in the central part of the Norwegian Sea.

The spatio-temporal overlap between NEA mackerel and NSS herring in July-August 2015 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.

Blue whiting was not prioritized during this IESSNS survey, hence no trawling was conducted on acoustic registrations of blue whiting. Additionally, acoustic registrations were limited to the upper 200 m 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 2015.

Lumpfish of all sizes were caught in the upper 30 m of the water column practically distributed everywhere within the total surveyed area. North Atlantic salmon, represented as postsmolt, grilse and adults, were mainly caught in central part of the Norwegian Sea during the IESSNS survey.

The SST in July-August 2015 was 1-2°C colder compared to 2014 throughout the surveyed area. The SST was close to the long term average for the last 20 years. This is in contrast to the generally increasing SST observed during last decade for most of the area, particularly in the Irminger Sea area.

The average concentration of zooplankton in the Norwegian Sea in July-August 2015 was slightly lower than in 2014, or 7.2 g/m^2 compared to 8.1 g/m^2 in 2014. West and south of Iceland and in east Greenlandic waters the average concentrations were higher than in 2014.

Dedicated whale observations (North Atlantic Sighting Survey (NASS)) were performed on the Icelandic vessel for the entire survey. These data are not available yet. Opportunistic whale observations were done by the two Norwegian vessels during the survey. Higher densities of especially fin whales, humpback whales and white beaked dolphins were observed off the coast of Finnmark and into the southern part of the Barents Sea.

Introduction

In July-August 2015, four vessels; the chartered trawler/purse seiners M/V "Brennholm" and M/V "Eros" from Norway, and M/V "Christian í Grótinum" from Faroe Islands, and the research vessel R/V "Árni Friðriksson" from Iceland, participated in the joint ecosystem survey (IESSNS) in the Norwegian Sea and surrounding waters. The vessel M/V "Birtingur" from Iceland had been chartered to participate on the IESSNS survey on behalf of Greenland, and cover part of Greenland waters in the western regions, but due to engine breakdown at the start of the survey it was not possible for "Birtingur" to participate. "Árni Friðriksson" then had to take over and conduct six of the planned stations in Greenland waters appointed initially to M/V "Birtingur". The five week coordinated survey from 1st of July to 10th of August 2015 is part of a long-term project to annually collect data on abundance, distribution, aggregation, migration and ecology of northeast Atlantic mackerel (*Scomber scombrus*) 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 (*Clupea harengus*), oceanographic conditions and prey communities. Dedicated whale observations were conducted on the Icelandic research vessel as part of the 2015 North Atlantic Sighting Survey. Opportunistic 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 1990s. Faroe Islands and Iceland participated in the joint mackerel-ecosystem survey since 2009.

The main objective of the IESSNS survey in relation to quantitative assessment 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 back then that an age-disaggregated time-series for analytical assessment should be restricted to adult mackerel at age 6 years and older. New data and results from the IESSNS mackerel-ecosystem surveys in July-August 2014 and 2015 providing a longer time series (2007, 2010-2015) used for swept area abundance estimation on NEA mackerel. In addition, methodological and statistical changes and improvements in the survey design, age-disaggregated abundance estimations on the total biomass and on different age-groups including uncertainty estimates have improved the quality and consistency of the NEA mackerel abundance estimation. A manuscript entitled "Quantifying changes in abundance, biomass and spatial distribution of Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) in the Nordic Seas from 2007 to 2014", based on swept area data and results from IESSNS surveys has been accepted for publication in ICES Journal of Marine Science. A preliminary run estimating the abundance of NEA mackerel by swept area analyses using the newly developed software program StoX was conducted by scientists at the Institute of Marine Research in Norway. A direct comparison between socalled "banana shape" (curved) pelagic trawl towing at the surface and "straight forward" trawl towing where performed in Norwegian, Icelandic and Greenland waters during the IESSNS survey in July-August 2015.

The Norwegian Spring Spawning (NSS) herring, in addition to other herring populations within the survey area, were mapped using acoustic methodology including standardized line transects. NSS herring was scrutinized using the primary echosounder frequency of 38 kHz. The abundance estimation on NSS herring was conducted using the program Beam in similar way as conducted during the International Ecosystem Spring Survey in the Nordic Sea (IESNS) in May-June 2015. It must be noted that even if the IESSNS covers the spatial distribution of blue whiting adequately very few deep trawl hauls were taken on likely acoustic registrations of blue whiting and acoustic registrations deeper than 200 m 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 2015. This situation is similar as for the IESSNS in the summer 2014.

Material and methods

Coordination of the survey was done during an international meeting in Reykjavik, Iceland in April 2015 and by correspondence in spring and summer 2015. The participating vessels together with their effective survey periods are listed in Table 1. One additional ship, M/S *Birtingur* was chartered, staffed and equipped by the Greenlandic Institute of Natural Resources. However, the engine of M/S *Birtingur* failed and the ship had to abort the survey. This led to less survey effort in SW Greenland and western international waters than planned.

In general, the weather conditions were calm with good survey conditions on the Norwegian vessels "Brennholm" and "Eros" for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. Nevertheless some days onboard Brennholm and Eros had somewhat unfavourable conditions, although not hampering any scientific activities. The same was the case on the Faroese vessel "Christian í Grótinum" which experienced good weather conditions except for two days. "Árni Friðriksson" also experienced some windy days, in the southern part of Iceland in the beginning of the survey, but the adverse conditions did not affect the quality of the various scientific data collected during the survey to any extent.

During the survey the special designed pelagic trawl, Multpelt 832, was used by all four participating vessels for the fourth consecutive year. 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 in good progress and improved steadily for five years now. 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 have further been implemented and improved on all the four vessels involved during the IESSNS survey in July-August 2014 and in July-August 2015. Working documents and scientific manuscripts have been written on swept area abundance estimation of NEA mackerel, survey design as well as standardization and improvements on the survey methodology based on the pelagic trawling with the Multpelt 832 sampling trawl (Nøttestad et al. accepted for publication in ICES Journal of Marine Science).

Table 1. Survey effort by each of the four vessels in the IESSNS survey in 2015.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton stations
Árni Friðriksson	6/7-10/8	7166	92	92	92
Christian í Grótinum	3/7- 19/7	2969	43	40	40
Brennholm	3/7-28/7	4395	52	52	52
Eros	1/7-28/7	4511	48	47	47
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. Árni Friðriksson was equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. Christian í Grótinum was equipped with a mini SEABIRD SBE 25+ CTD sensor, and Brennholm and Eros were equipped with SEABIRD CTD sensors. 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 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 Eros) and 200 μm (Árni Friðriksson and Christian í Grótinum). 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 were done during all trawl hauls. These data have not yet been analysed and therefore the results are not presented in this report, but will be reported later.

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 Christian í Grótinum, trawl catches were sub-sampled - 100 kg (if it was clean catch of either herring or mackerel) to 200 kg (if it was a mixture of herring and mackerel); otherwise the same sample processing protocol was followed as on the other three vessels.

All vessels used the Multpelt 832 pelagic trawl and continued and improved standardization of fishing gear and deployment was emphasised in the survey (see ICES 2013a; ICES 2014c; Valdemarsen et al. (submitted manuscript); Rosen et al. (submitted manuscript)). Standardization and documentation/quantification of 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 and their rigging during operation on the survey for participating vessels are given in Table 3.

Table 2. Summary of biological sampling in the survey from 1July – 10 August 2015 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	200/100*	150	100
	Herring	200/100*	200	100
	Blue whiting	200/100*	50	100
	Other fish sp.	0	50	25
Weighed, sexed and maturity determination	Mackerel	20	50	25
	Herring	20	50	25
	Blue whiting	50	50	25
	Other fish sp.	0	10	0
Otoliths/scales collected	Mackerel	20	25	25
	Herring	20	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	0	350	900
	Herring	50	50	

*200 length measurements. 100 are also weighed

Table 3. Trawl settings and operation details during the international mackerel survey in the Nordic Seas in July-August 2015. 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**	**Árni Friðriksson**	**Eros**	**Christian í Grótinum**	**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	Dynema – 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	170 kg	300 kg	400kgSB 500kgPS	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 m^2 75% hatches (effective 6.5m^2)	7 m^2	7.5 m^2 25% hatches (effective 6.5m^2)	6 m^2	+
Towing speed (GPS) in knots	4.8 (4.5-5.2)	4.9 (3.4-5.4)	4.8 (4.5-5.2)	4.5 (3.3-5.3)	+
Trawl height	28-35	27-30	29-35	36-52	+
Door distance	110-117 m	110-114 m	110-117 m	104-113	+
Trawl width*	-	-	-	-	+
Turn radius	5-10 degrees turn	5-10 degrees turn	5-10 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)	10-18, 10-17 m	8-13, 10-15 m	5-12, 7-14 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 wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	+

Marine mammal observations

Dedicated whales observations were conducted onboard R/V "Árni Friðriksson" during the entire surveys from 6th of July until 10th of August 2015. Opportunistic observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 1st and 28th of July 2015 onboard the Norwegian chartered vessels M/V "Brennholm" and M/V "Eros", 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 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 about 20 % of trawl stations onboard Brennholm and Eros. Onboard Christian í Grótinum video recordings were collected at 15% of trawl stations and on a total of 15 trawl stations taken by RV Árni Friðriksson. Analyses of the recording material are underway and will be presented by other means when available.

Acoustics

Multifrequency echosounder

The acoustic equipment onboard Brennholm and Eros were calibrated 29th of June 2015 for 18, 38 and 200 kHz. Árni Friðriksson was also calibrated on 10th of April 2015 for the frequencies 18, 38, 120 and 200 kHz and Christian í Grótinum was calibrated on 29-30th June 2015 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 Eros, Brennholm and Árni Friðriksson, and Echoview onboard Christian í Grótinum. 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.

For acoustic abundance estimation of the NSS herring stock 38 kHz was used as the main frequency while it was 200 kHz for the NEA mackerel. However, it has to be noted that acoustic data collected on mackerel have substantial limitations as it is conducted now, due to different reasons, including the low target strength of mackerel and the distribution of the majority of the mackerel in the acoustic dead zone shallower than the face of the acoustic transducers with or without a drop keel installed in the hull. A summary of acoustic settings is given in Table 4.

Acoustic estimates of herring 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 2015.

	M/V Brennholm	R/V Árni Friðriksson	M/V Eros	M/V Chr. í Grótinum
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	9.9
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	26.44
s_A correction (dB)	-0.60	-0.84	-0.65	-0.66
alongship:	6.89	7.31	7.01	7.07
athw. ship:	6.87	6.95	7.11	7.06
Maximum range (m)	500	500 (750 in Greenlandic waters)	500	500
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 6.x

Multibeam sonar

M/V "Brennholm" and M/V "Eros" 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 within large areas of the Norwegian coast, Norwegian Sea and southern part of the Barents Sea during the survey will be quality checked and used for later analysis.

Cruise tracks

M/V "Brennholm", M/V "Eros", M/V "Chr. í Grótinum" and R/V "Árni Friðriksson" 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 our main pelagic planktivorous schooling fish species. The main adaptation was in the Icelandic-south stratum where it was extended southwards to determine the zero line of mackerel distribution. The cruising speed was between 10-12.0 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

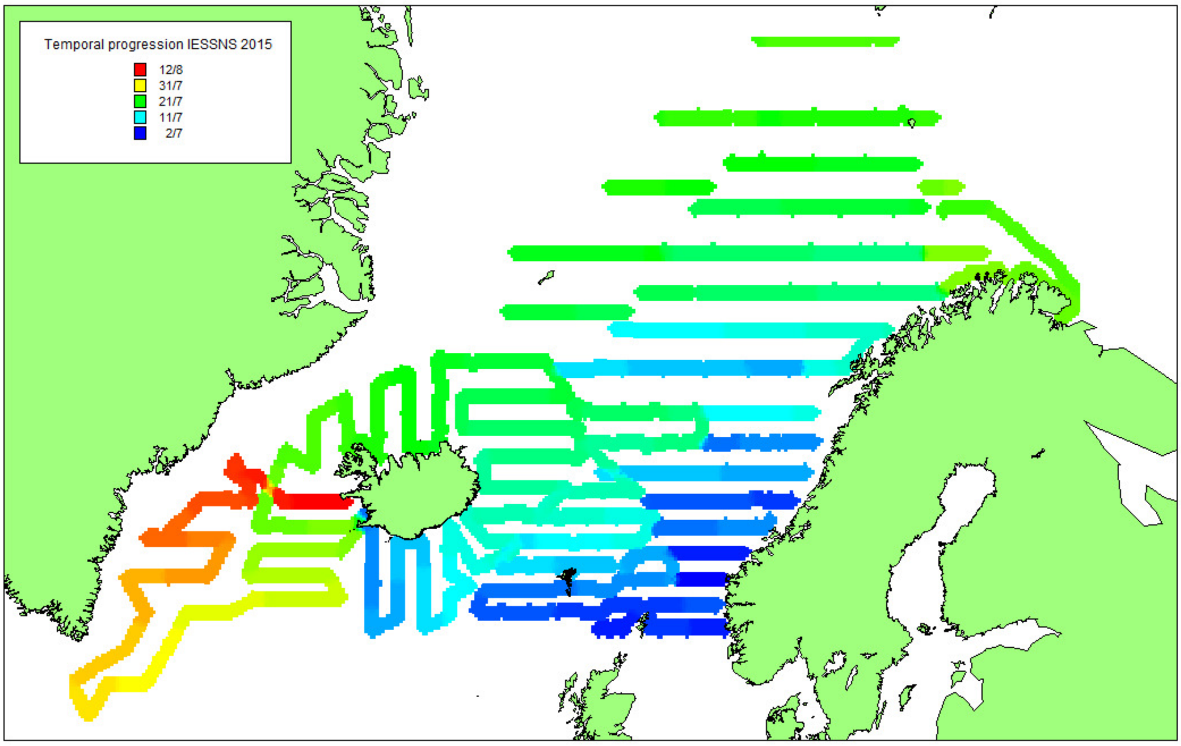


Figure 1. Cruise tracks showing the temporal progression from blue (2/7) to red (12/10) within the covered areas of the Norwegian Sea and surrounding waters from 1st of July to 10th of August 2015.

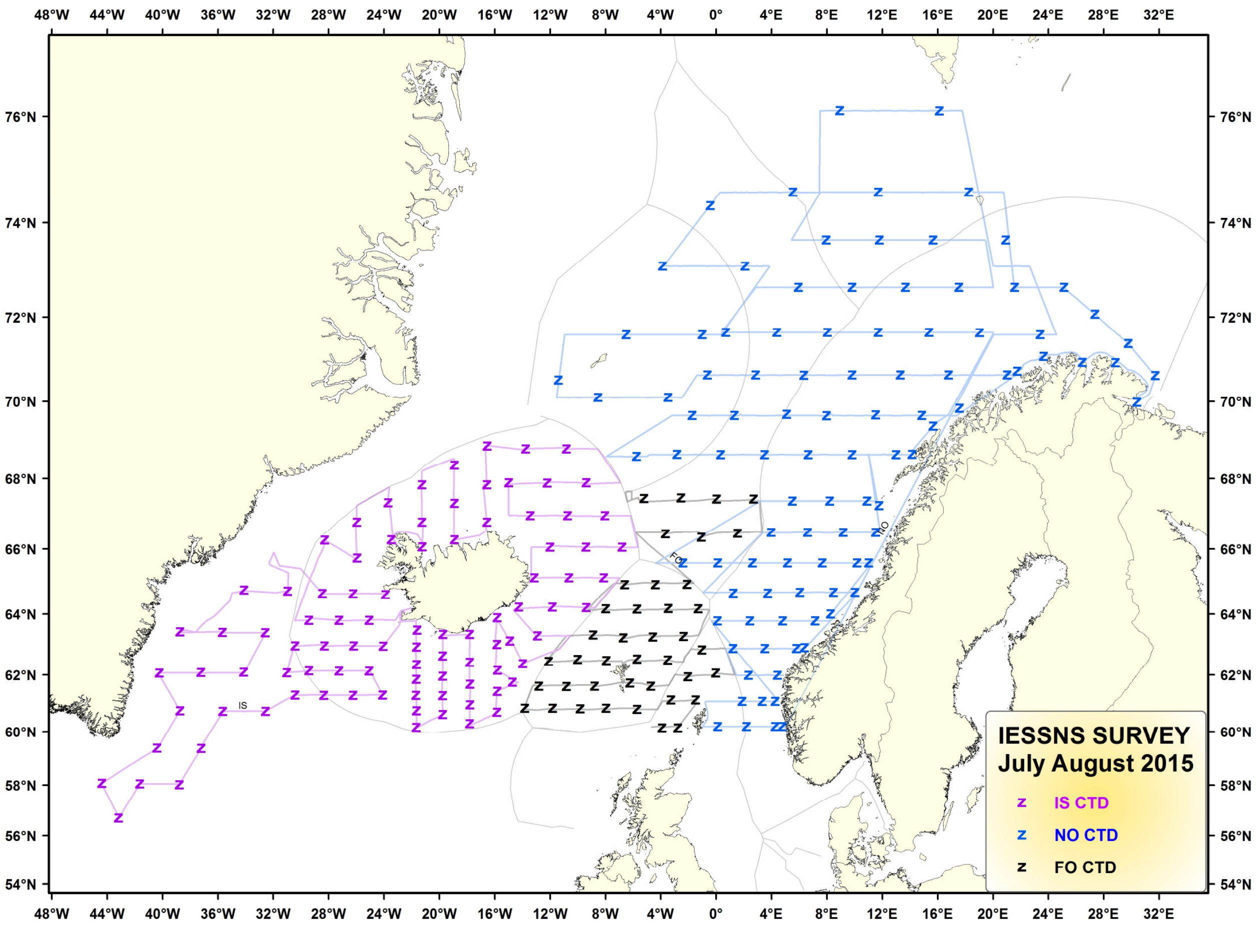


Figure 2. CTD stations (0-500 m) using SEABIRD SBE 37 (Arni Fridriksson, purple) SEABIRD SB 25+ (Christian í Grótinum, black) and SAIV SD200 (Brennholm and Eros, blue) CTD sensors and WP2 plankton net samples (0-200 m depth). These were taken systematically on every pelagic trawl station on all four 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 56°N and 76°N and 44°W and 32°E. Rectangle dimensions were 2° latitude by 4° longitude, i.e. the rectangle size was increased as compared to that used in estimates from previous years. This was done to make up for an increased distance between the trawl stations in some of the strata and thereby avoid interpolation of number of rectangles. Allocation of the biomass to exclusive economic zones (EEZs) was done in the same way as in 2010-2014 (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).

	Chr. í Grótinum	RV Árni Friðriksson		Brennholm	Eros
Trawl doors horizontal spread (m)					
Number of stations	43*	53*	90	52	48
mean	108*	111*	109	118.2	120
max	113*	116*	121	122	125
min	104*	104*	80	115	116
st. dev.	2.6*	2.5*	5	4.4	4
Vertical trawl opening (m)					
Number of stations	43*	48*	86	52	48
mean	39.7*	35*	36	31	33
max	52*	43*	55	36	38
min	36*	31*	30	28	29
st. dev.	2.9*	2.4*	3.5	4	4
Horizontal trawl opening (m) **					
mean	60.7	63		66	67
Speed (over ground, nmi)					
Number of stations	43	53*	92	52	48
mean	4.5	4.9*	4.9	5.0	4.8
max	5.3	5.4*	5.4	5.7	6.0
min	3.3	4.2*	3.4	4.1	4.2
st. dev.	0.4	0.2*	0.2	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 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 temperature in the surface layer from Iceland over Jan Mayen and to Svalbard was 1-2°C warmer in July 2015 than the average for the last 20 years (Figure 3). In the central and eastern part of the Norwegian Sea the SST was close to the 20 year average. South of the Greenland-Scotland ridge the SST was about 1 °C lower than the 20 year average. In 2014 much warmer SSTs were observed north of Iceland (Figure 4) and generally warmer in the whole Northeast Atlantic.

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) was 1-2°C colder in 2015 compared to 2014 more or less throughout the surveyed area (Figures 5 and 6). However, the temperature in the upper layer was more than 6°C, except along the north-western margin of the surveyed area where it was lower. In the deeper layers (50 m and deeper), the hydrographic features in the area were similar to 2013 and 2014. At all depths there was a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

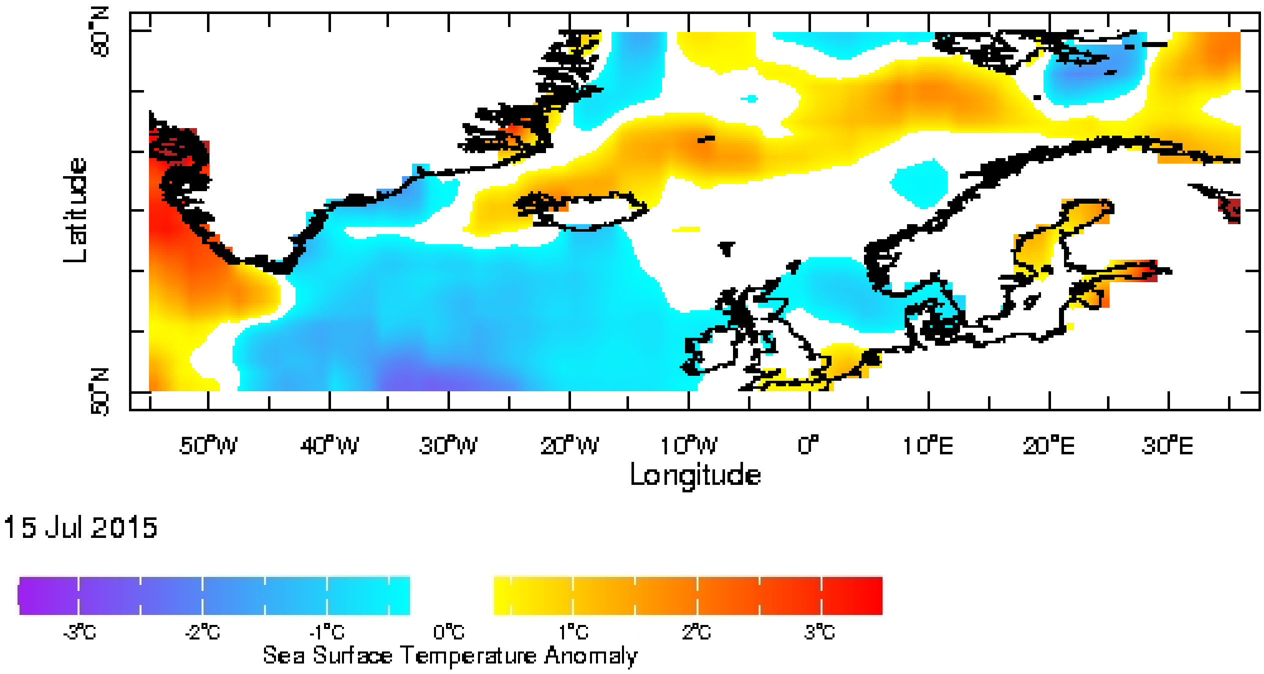


Figure 3. Sea surface temperature anomaly in July (°C; centered for mid July 2015) showing warm and cold conditions in comparison to a 20 year average.

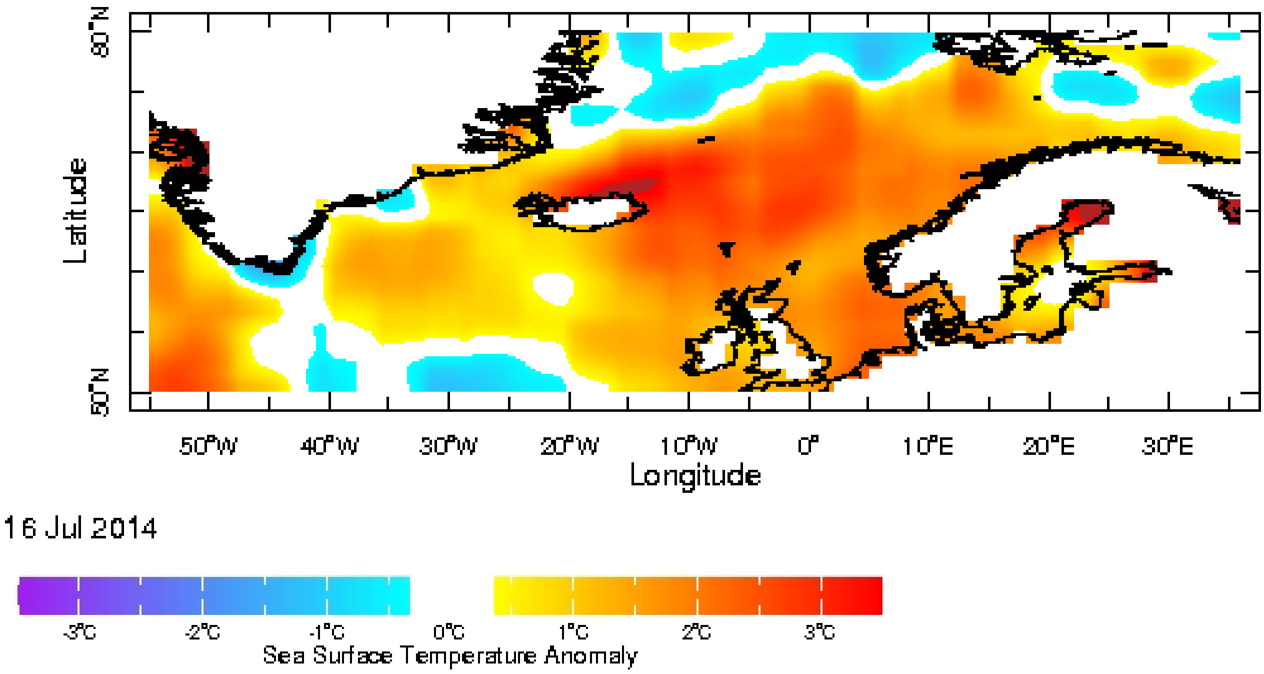


Figure 4. Sea surface temperature anomaly in July (°C; centered for mid July 2014) showing warm and cold conditions in comparison to a 20 year average.

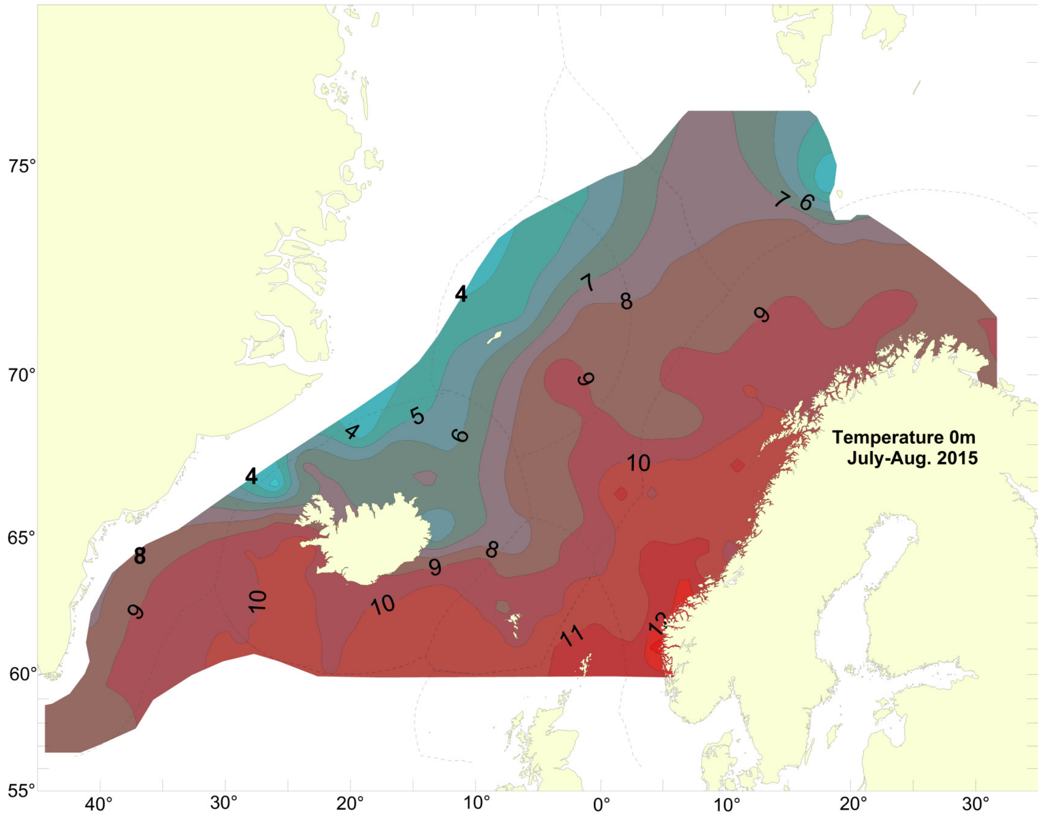


Figure 5. Temperature (°C) at 0 m depth in the Norwegian Sea and surrounding waters in July/August 2015.

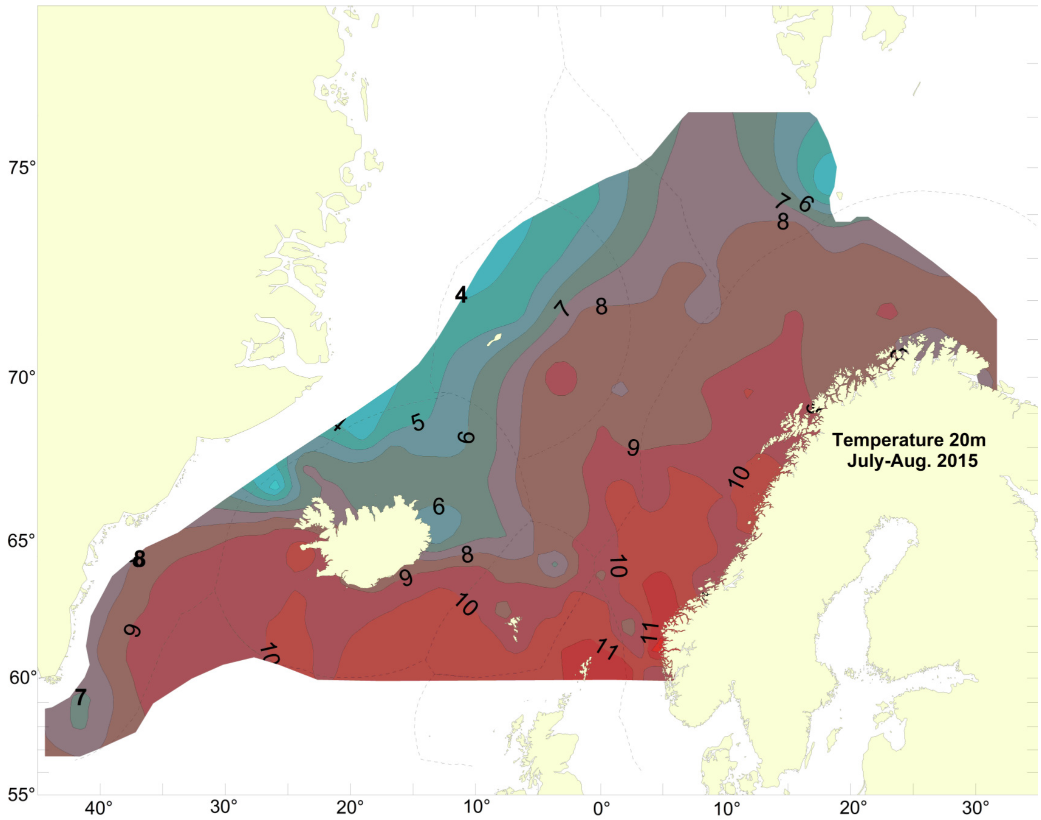


Figure 6. Temperature (°C) at 20 m depth in the Norwegian Sea and surrounding waters in July/August 2015.

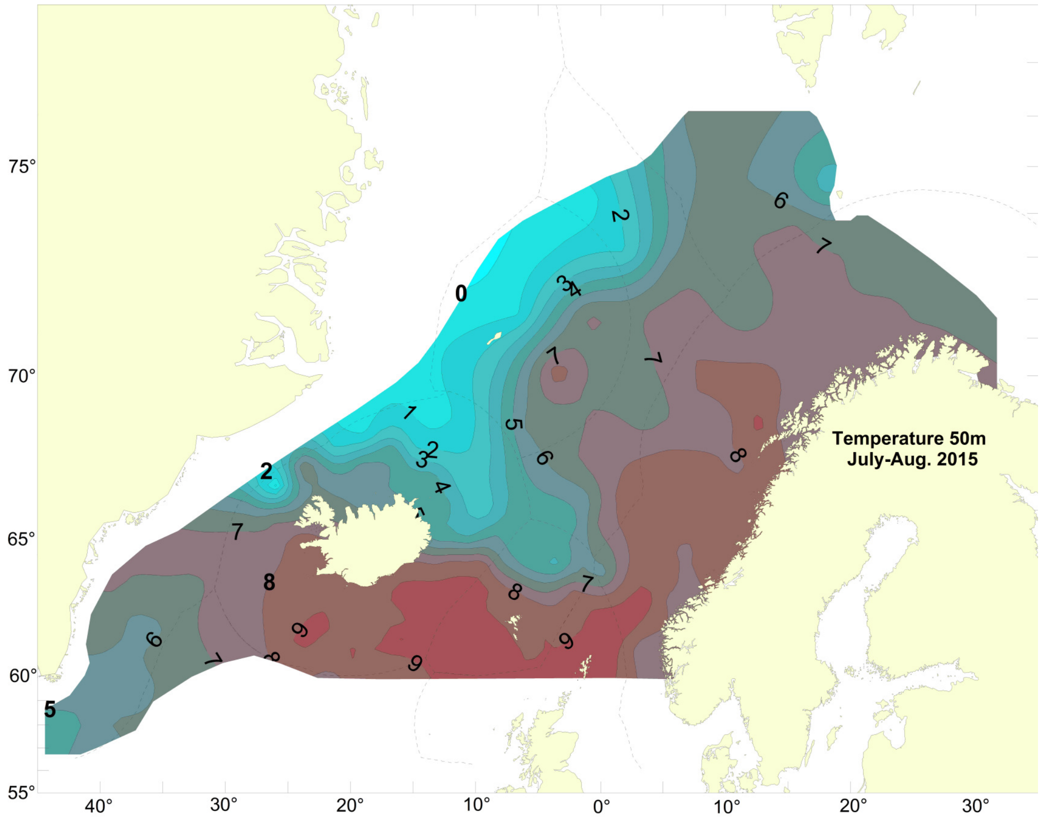


Figure 7. Temperature (°C) at 50 m depth in the Norwegian Sea and surrounding waters in July/August 2015.

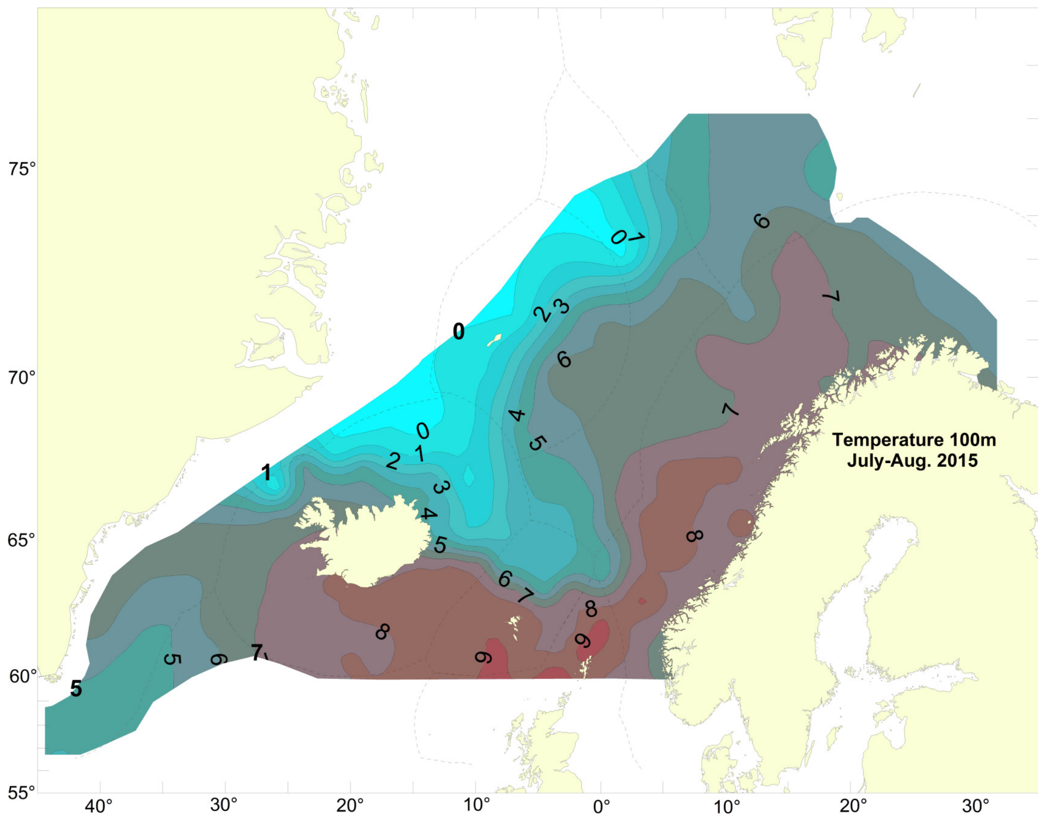


Figure 8. Temperature (°C) at 100 m depth in the Norwegian Sea and surrounding waters in July/August 2015.

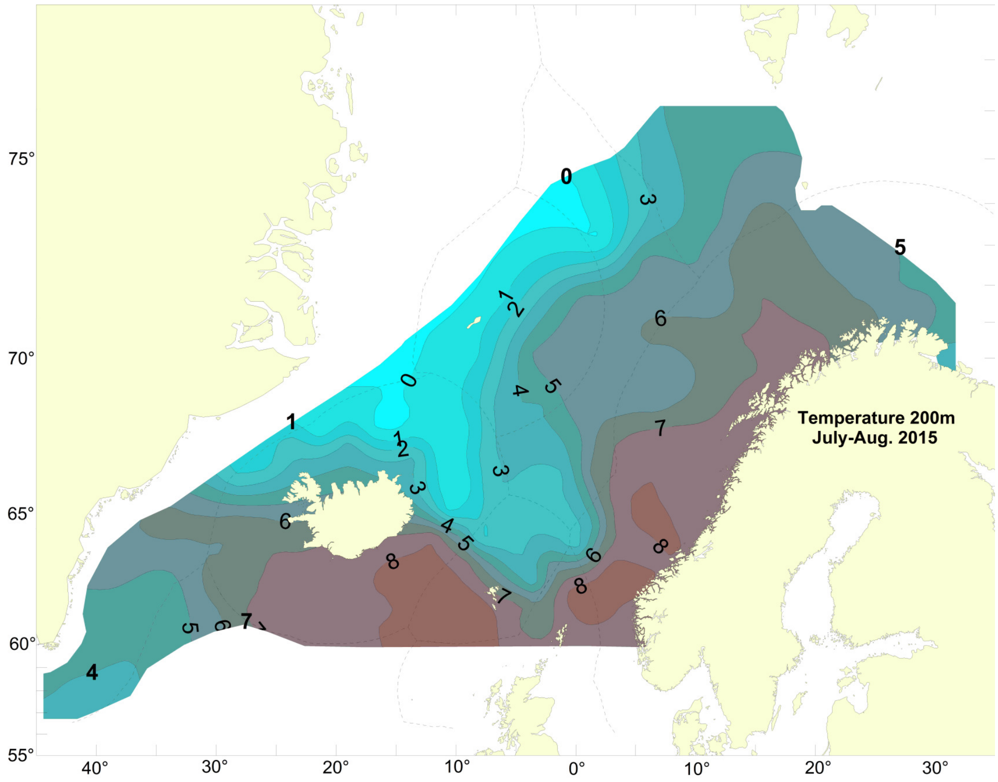


Figure 9. Temperature (°C) at 200 m depth in the Norwegian Sea and surrounding waters in July/August 2015.

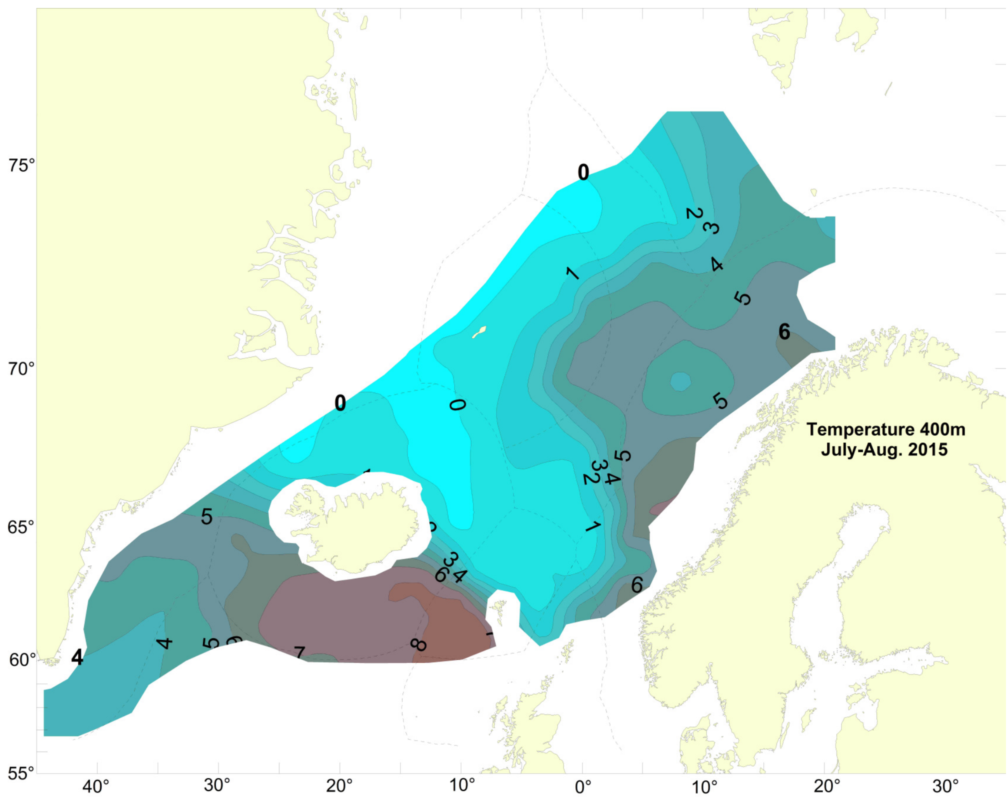


Figure 10. Temperature (°C) at 400 m depth in the Norwegian Sea and surrounding waters in July/August 2015.

Zooplankton

The average plankton biomass in the Norwegian Sea (north of 61°N and between 14°W and 17°E) in July-August was 7.4 g/m2, slightly lower than in 2014 and 2013 (8.1 g/m^2 and 8.4 g/m^2 respectively) (Table 7). However, the plankton concentrations were high in the northeastern part of the Icelandic area and the northern part of the Faroese area (Figure 11), as they also were in 2014 and 2013. The plankton density south and west of Iceland, as well as in the Greenlandic waters, was in the higher and highest range in the relatively short time series (Table 7). The concentrations in the central part of the Norwegian Sea were lower than in 2014, as were the concentrations in the north-eastern part (Svalbard area).

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

The decreased biomass of zooplankton in the Norwegian Sea as compared to 2014 is in agreement with what has been observed in the IESNS survey in May (ICES, 2015), where the zooplankton estimate in 2015 also decreased, compared to 2014. These data, however, need 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 as available food for pelagic planktivorous fish.

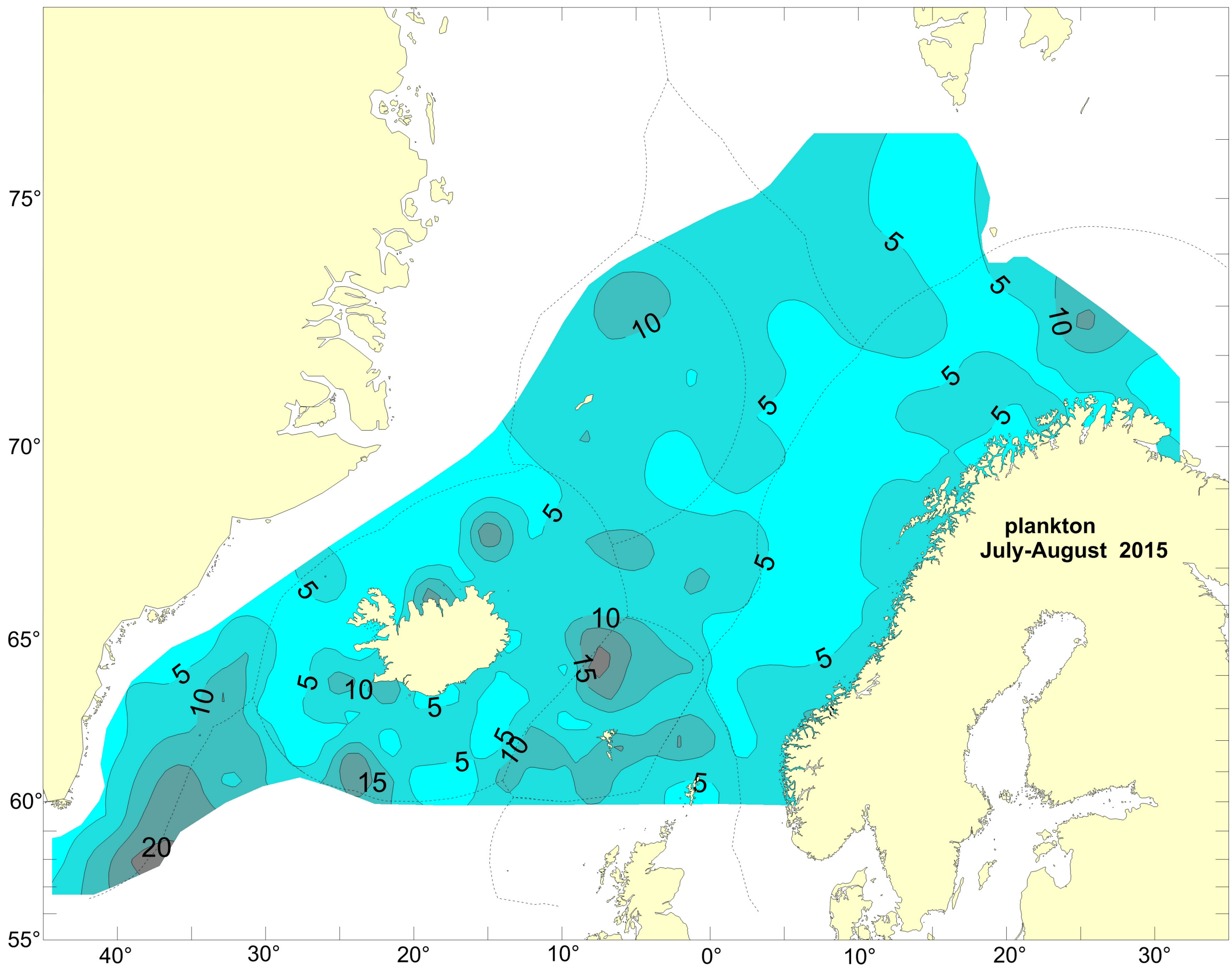


Figure 11. Zooplankton biomass (g dw/m^2, 0-200 m) in the Norwegian Sea and surrounding waters, 1st of July - 10th of August 2015.

Table 7. The time-series of zooplankton dry weight in IESSNS during 2010 to 2015 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/m^2)			
Year	Norwegian Sea	Icelandic waters	Greenlandic waters	Total survey area
2010	6250 (168)	9276 (8)*		6387 (176)
2011	4622 (110)	7058 (61)		5491 (171)
2012	6014 (139)	5926 (55)	10086 (2)	6031 (196)
2013	8581 (188)	9990 (49)	13787 (14)	9147 (251)
2014	8155 (175)	4834 (47)	5308 (33)	7174 (255)
2015	7339 (138)	9064 (49)	15865 (20)	8705 (207)

*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 2*4° rectangles in Figure 12. The map is showing different concentrations of mackerel from zero catch to more than 5000 kg.

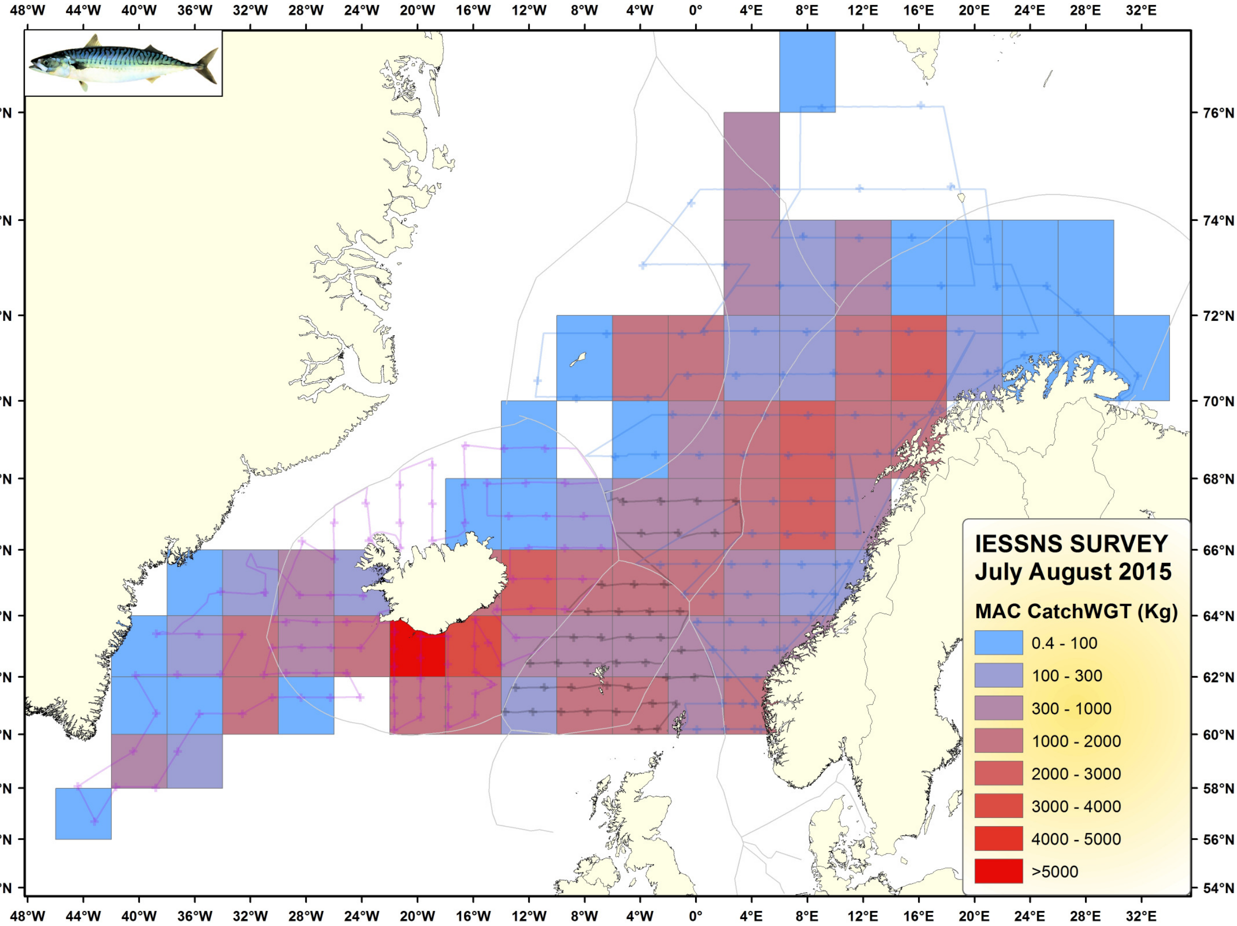


Figure 12. Catches of mackerel in kg represented in standardized rectangles (2° lat. x 4° lon.). Light blue represents small catches (0.3-100 kg), while dark red represents catches of more than 5000 kg mackerel after 30 min standardized towing with the Multpelt 832 pelagic trawl. Vessel tracks are shown 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 (including northeast in the Barents Sea) and westernmost part of the covered area in July-August 2015 (Figure 13).

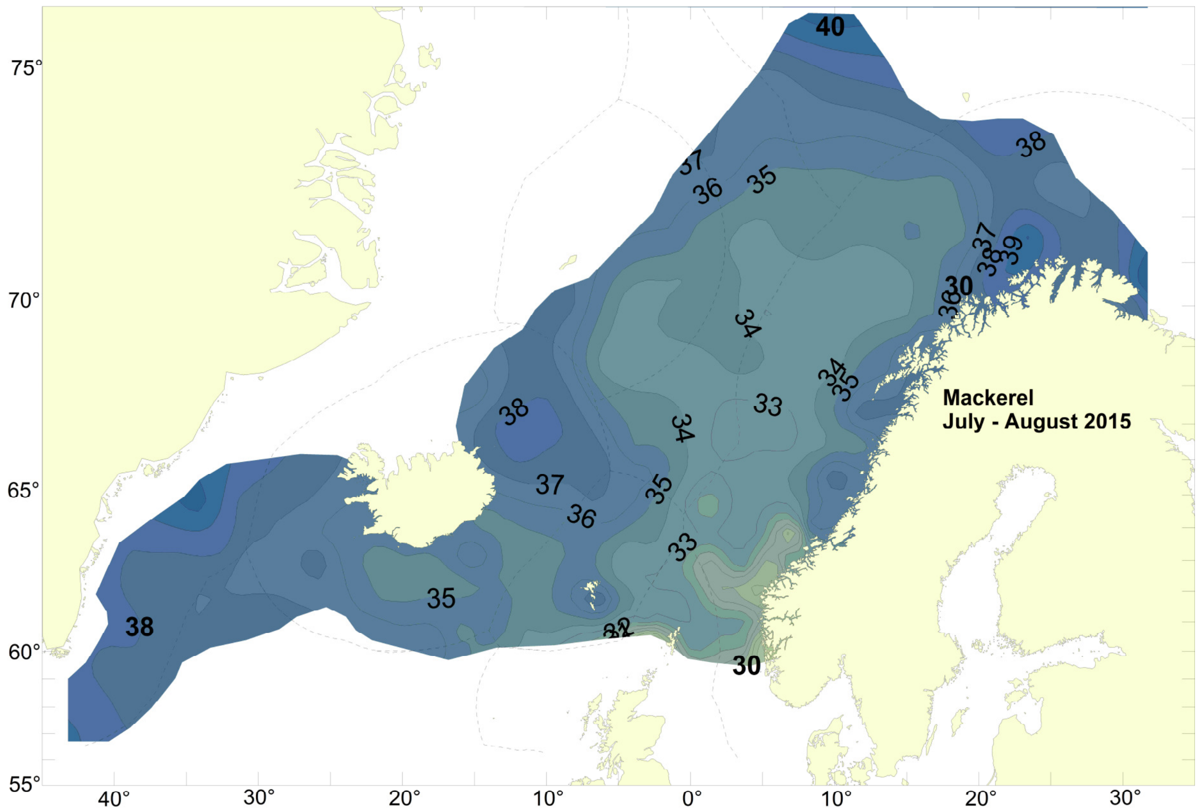


Figure 13. Average length distribution of NEA mackerel from the joint ecosystem survey with M/V "Brennholm", M/V "Eros", M/V "Christian í Grótinum" and R/V "Árni Friðriksson" in the Nordic Seas between 1st of July and 10th of August 2015.

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). Some juvenile mackerel were caught in July-August 2015. The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon, lumpsucker) from the joint ecosystem survey in the Nordic Seas according to the catches are shown in Figure 15.

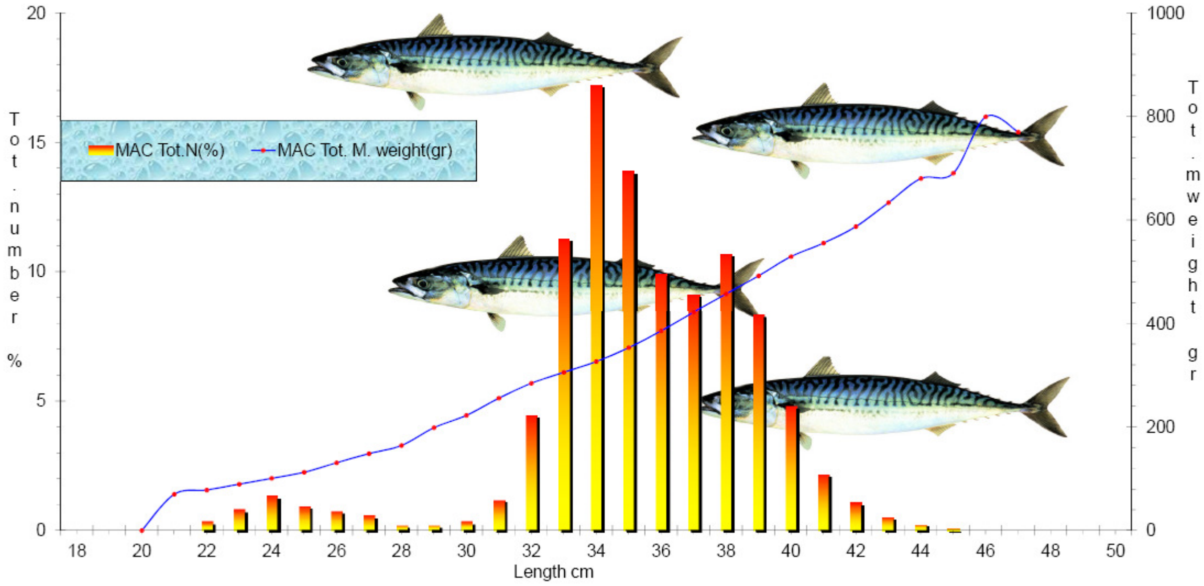


Figure 14. Length (cm) and weight (g) distribution in percent (%) for mackerel sampled in the trawl catches. Note that these values are not weighed with catch or area size and can therefore divide from the estimation of length distribution in the stock (not provided).

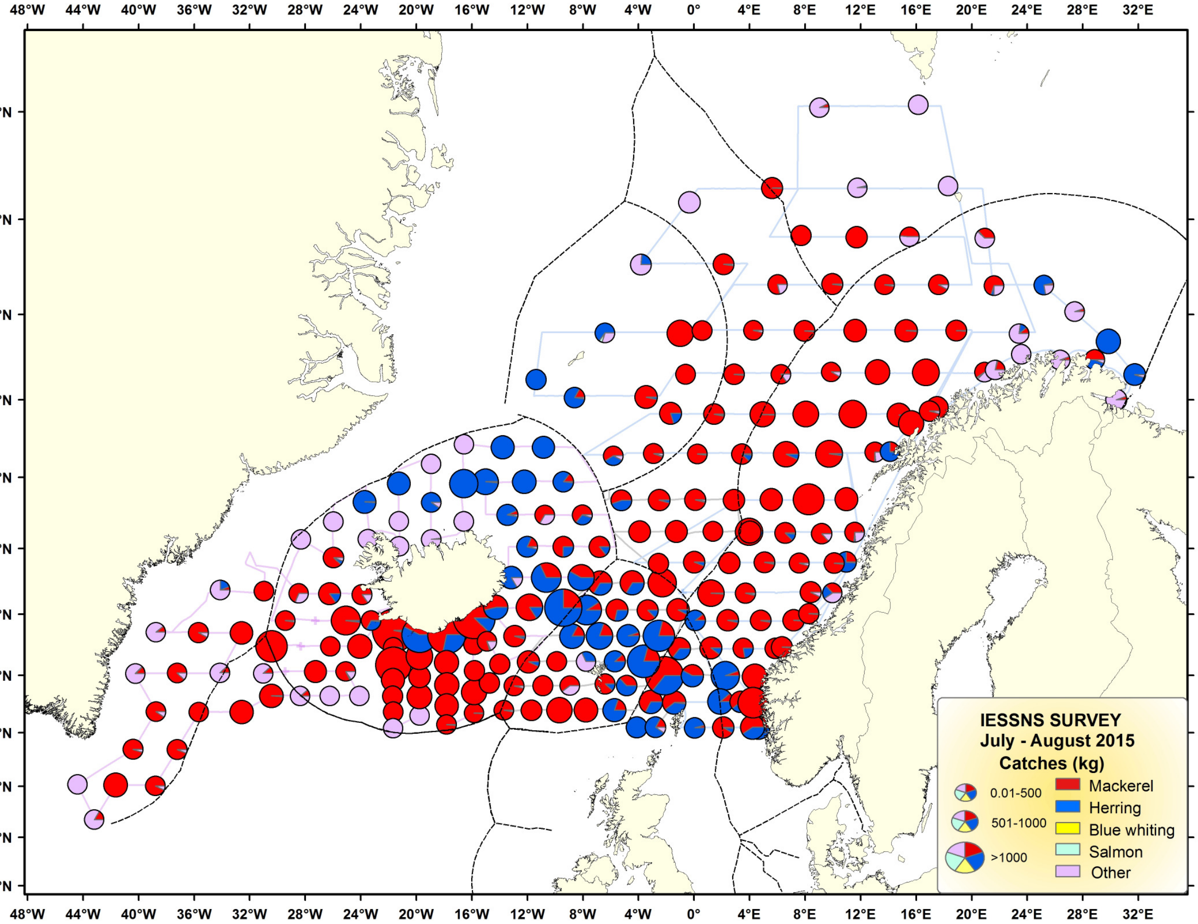


Figure 15. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (turquoise) from joint ecosystem surveys conducted onboard M/V "Brennholm" and M/V "Eros" (Norway), M/V "Christian í Grótinum" (Faroe Islands) and R/V "Árni Friðriksson" (Iceland) in the Norwegian Sea and surrounding waters between 1st of July to 10th of August 2015. 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 2015 were based on average catches of mackerel within rectangles of 2° latitude and 4° longitude and scaled by the width of horizontal opening of the trawls (Table 5), which gave catch indices (kg/km^2; Figure 16). With the increase in rectangle size (from 1° by 2° rectangles used previously) there was no need for interpolating values to rectangles not covered but assumed to hold mackerel. The swept area estimates for the different rectangles are shown in Figure 17 and in a different graphical way in Figure 18. The total biomass estimate came to 7.7 million tonnes, 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.

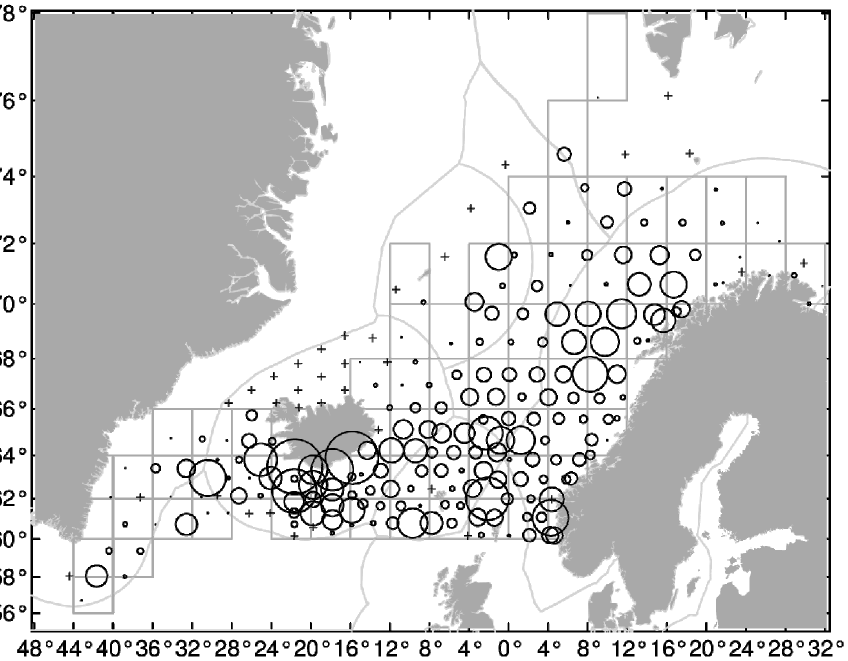


Figure 16. Stations and catches of mackerel in July/August 2015 where the circles size is proportional to square root of catch (kg/km²) and stations with zero catches are denoted with +. Rectangle grid (2° by 4°) used for averaging overlayed.

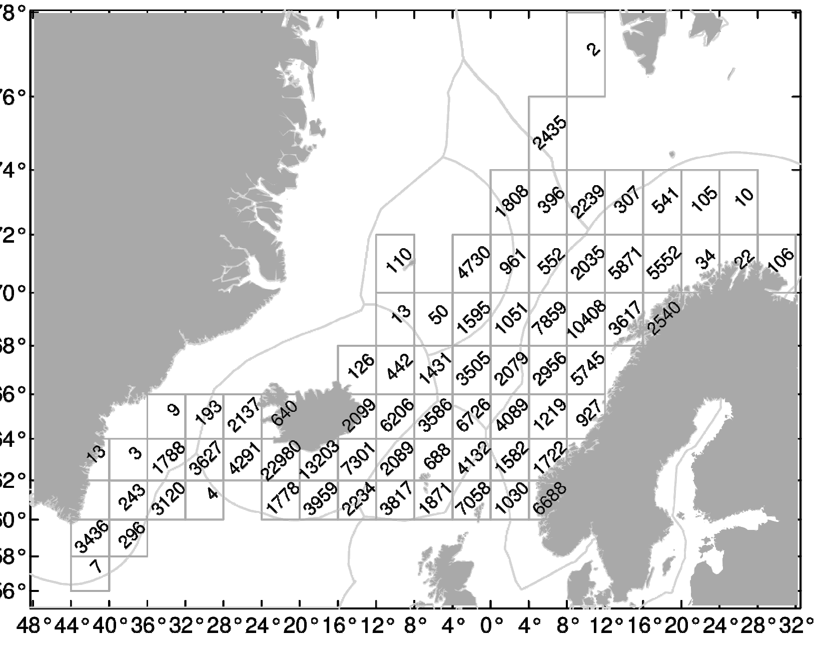


Figure 17. Standardized mackerel catch rates (kg/km²) in 2° lat. by 4° lon. rectangles from swept area estimates in July/August 2015. Rectangles with no catch are not indicated on the map – refer to Figure 18.

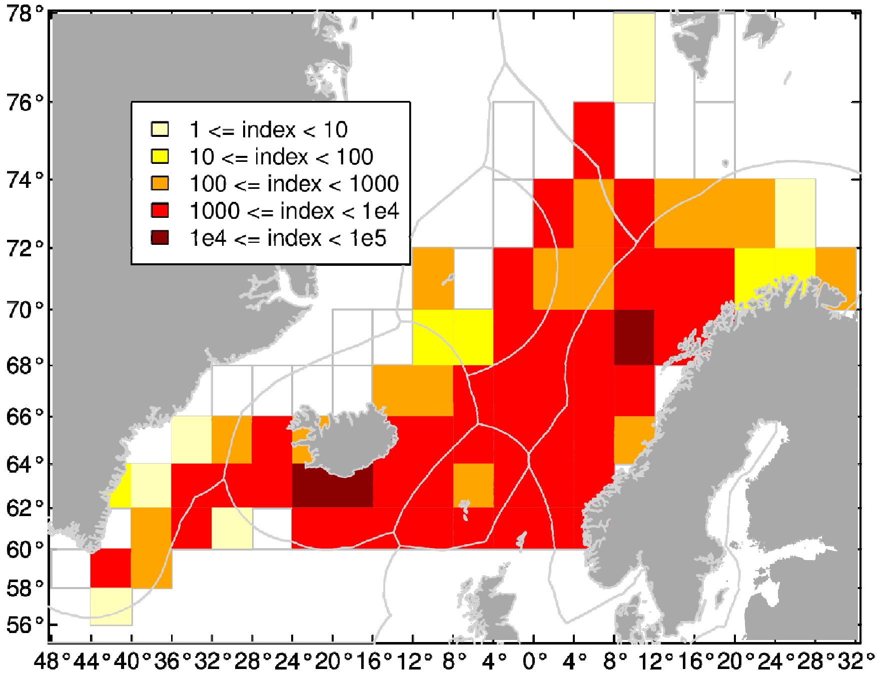


Figure 18. Standardized mackerel catch rates (kg/km²) for mackerel in the July/August 2015 survey represented graphically.

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 were updated with the 2014 and 2015 data to be used as input data into the analytical assessment of the stock (Table 8). The 2015 results show that 2011-year class contributed with 28% in number followed by the 2010-year class with 22% (Fig. 19). The 2012 year class contribute to with 12% in numbers followed by the 6 and 7 years old represented with less than 10% each in numbers. Altogether 71% of the estimated number of mackerel was less than 6 years old in the IESSNS 2015. The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2014 by the inclusion of two more survey years (2014 and 2015). This is especially apparent for younger ages (1-5 years). There is now good internal consistency for 1-10 years old mackerel, except between ages 5 and 6.

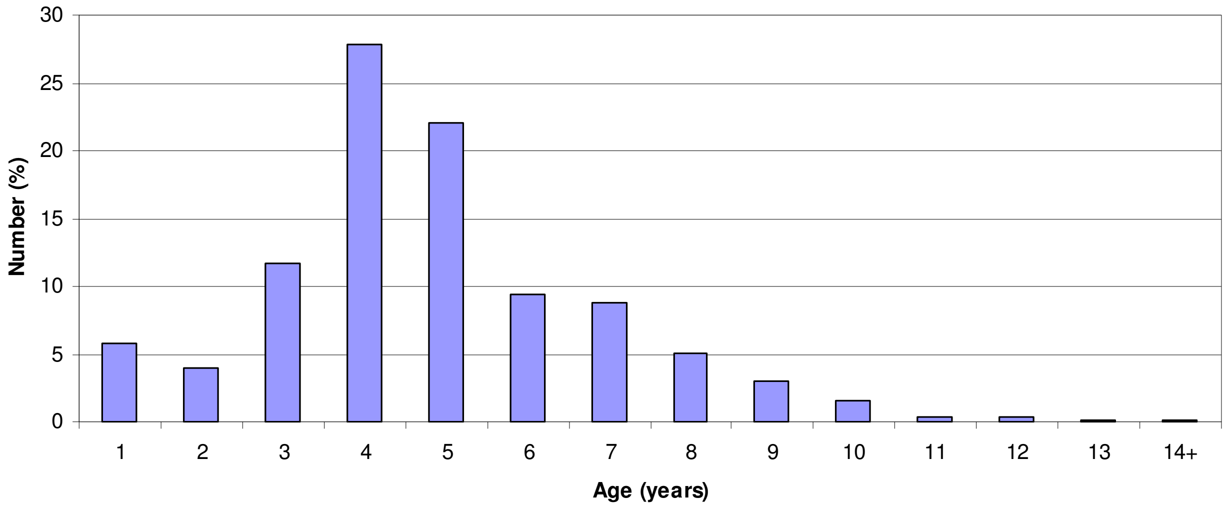


Figure 19. Age distribution in percent (%) of Atlantic mackerel, in the Nordic Seas from1st of July to 10th of August 2015.

In 2015, and swept area estimation of mackerel abundance was also done in a stratified manner with the software StoX (Annex 3). This was done for three main reasons, (1) for a comparison to the traditionally applied method where calculations are done on rectangles basis (in contrast to strata), (2) to get an uncertainty estimation of the indices, and (3) this is the method is a likely candidate to be used in the future for estimation of swept are abundance indices of NEA mackerel from the IESSNS survey. StoX is an open source software developed at the Institute of Marine Research (IMR) in Norway to calculate survey estimates from acoustic and swept area surveys.

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	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	1.2
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	1.5
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	0.36	0.086	0.054	0.02	0.004	2.45
2015	1.199	0.830	2.411	5.765	4.558	1.944	1.833	1.039	0.617	0.320	0.075	0.071	0.037	0.022	2.69

(b) Area covered where an age class is observed (km^2)

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	0.291	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	0.150	0.500	3.800	2.350	1.160	1.140	1.160	0.790	0.430	0.280	0.110	0.110	0.060	0.011
2015	2.769	0.525	1.116	2.372	1.809	0.762	0.692	0.433	0.269	0.166	0.062	0.063	0.048	0.057

(c) Density index (thousands 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	0.150	0.500	3.800	2.350	1.160	1.140	1.160	0.790	0.430	0.280	0.110	0.110	0.060	0.011
2015	2.769	0.525	1.116	2.372	1.809	0.762	0.692	0.433	0.269	0.166	0.062	0.063	0.048	0.057

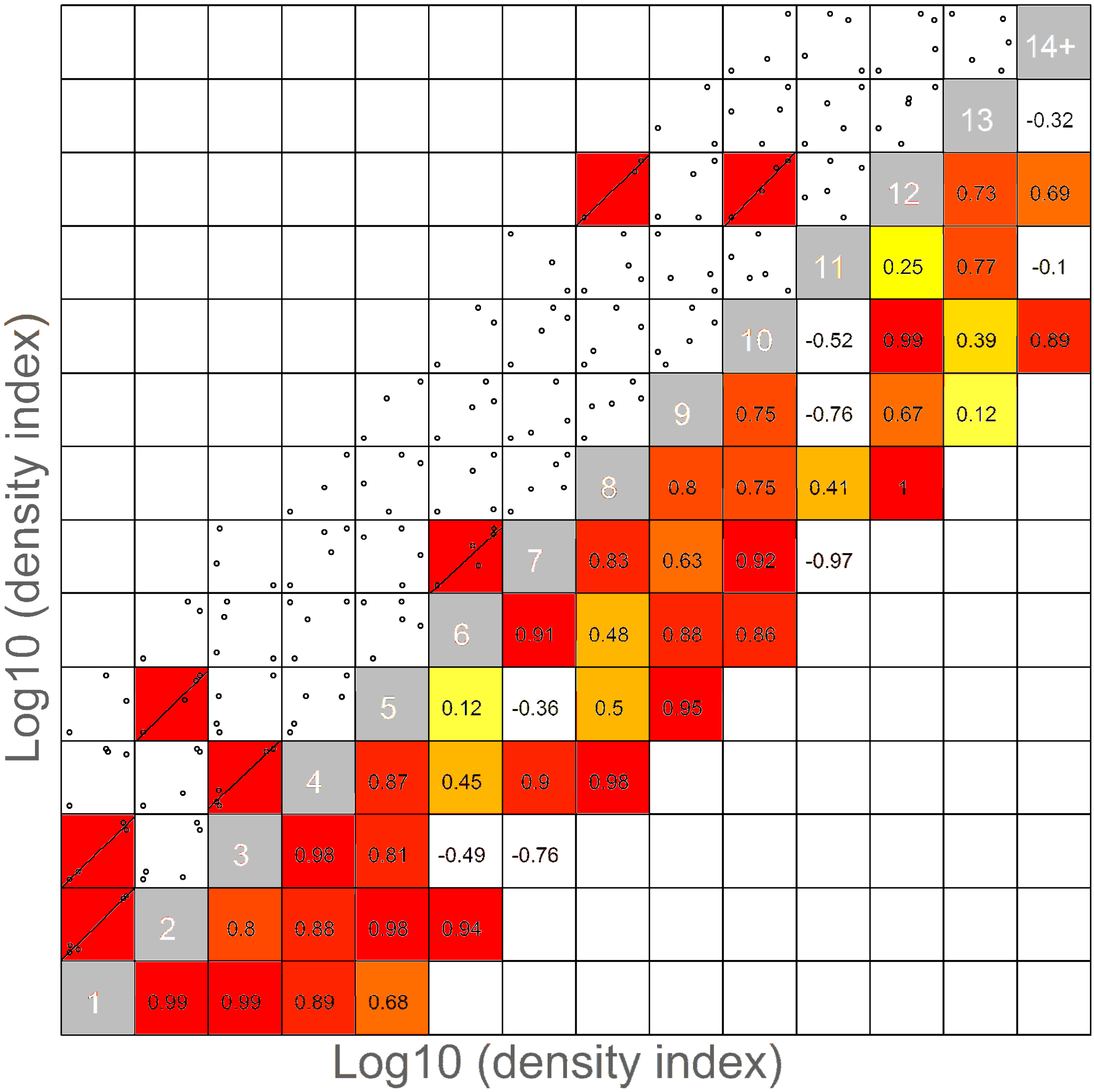


Figure 20. Internal consistency of mackerel density index. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

Multibeam sonar recordings

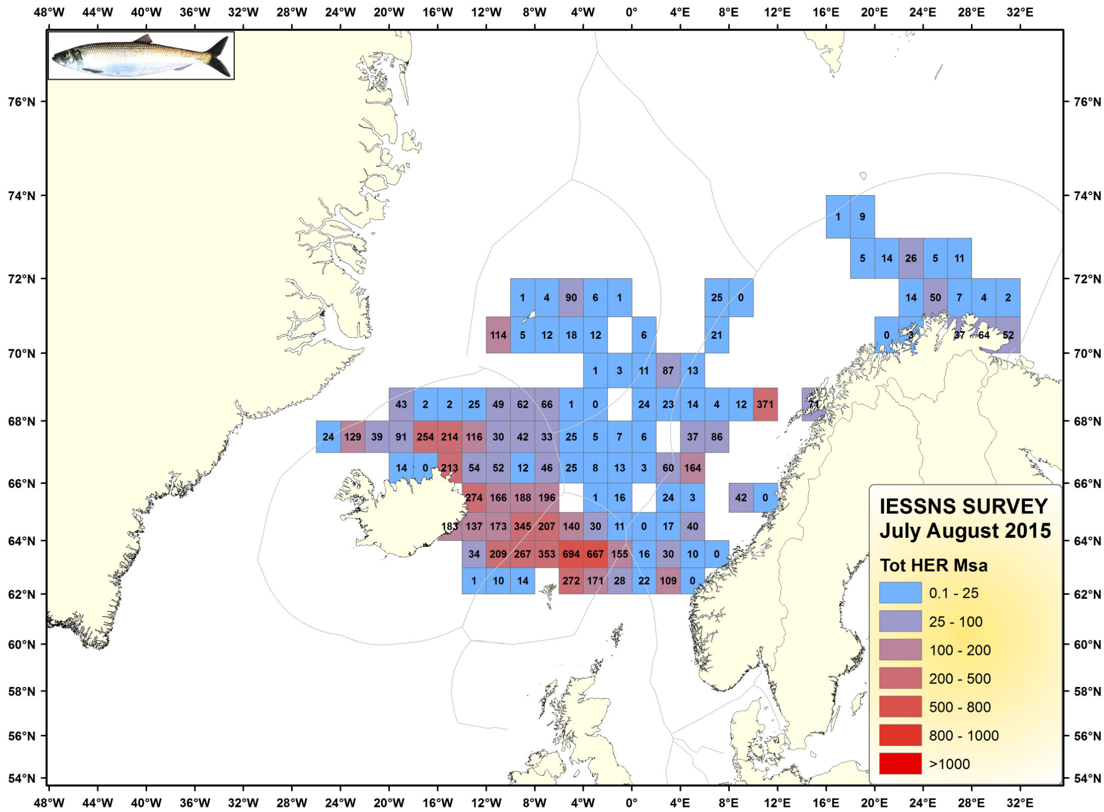
Multibeam sonar recordings were conducted and recorded onboard the two Norwegian vessels Brennholm and Eros. The mackerel schools detected were of small size predominantly with low density and appearing more as individual fish or loose aggregations. They were detected swimming in the upper 5-30 m of 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 SH80 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.

Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSS) was recorded in the eastern part of the area surveyed (Figure 21). The western boundary of its distribution was at 14°W south of Iceland and further west than probably observed for decades north of Iceland or at 23°35W and few individuals in catches at the northern most transect in Greenlandic waters at 34°08W. The herring observed west of these boundaries belonged to the Icelandic summer-spawning herring according to trawl samples (not shown on Figures 21a, b). 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 21a, b). The abundance was low in the northern and eastern areas, and herring was relatively absent from the mid Norwegian Sea. The periphery of the distribution of adult part of NSS herring was considered to be reached in all directions, which means a better spatial coverage than in recent years. It was only towards north between 14-20°W where some herring might be missing (Figure 21b and 15).

The biomass estimate of NSS herring age 4+ came to 7.7 million tons and the total number was 22.7 billions based on the acoustic recordings in July-August 2015 using the primary frequency of 38 kHz and the biological measurements of herring caught in the trawl tows. The length of the NSS herring ranged from 19-40 cm with a peak at 35 cm and a smaller peak at 30 cm (Figure 22). The weighed mean length was 34.3 cm from the whole estimations and the weighed mean weight was 335.9 g compared to 33.4 cm and 329.6 g, respectively, in the 2014 IESSNS.

(a)



(b)

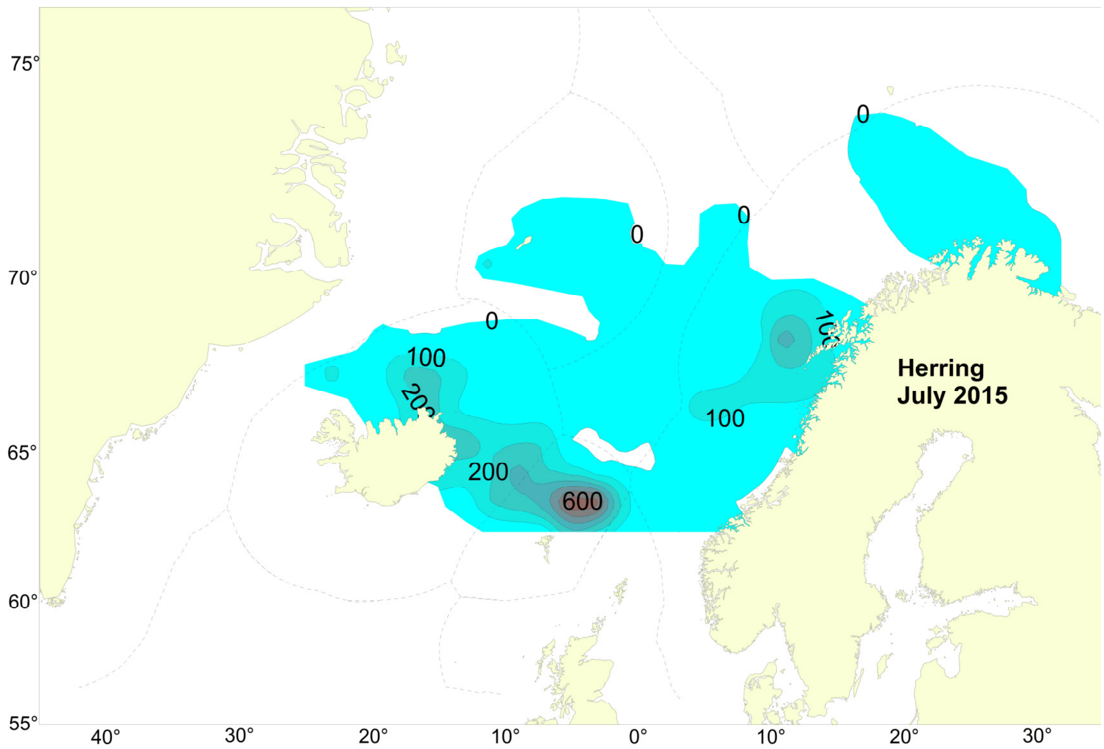


Figure 21. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring along the cruise track, 1st of July to 10th of August 2015 (a) within a rectangles and (b) shown on a contour plot.

The age distribution in NSS herring shows dominance of the 2004 year class with about 19% in numbers of the acoustic estimate, followed by the 2005 and 2009 year classes (14% each) (Figure 22). The length distribution measured on herring showed overall a pronounced length dependent migration pattern, with the largest individuals (>34 cm) furthest west and northwest (Figure 23).

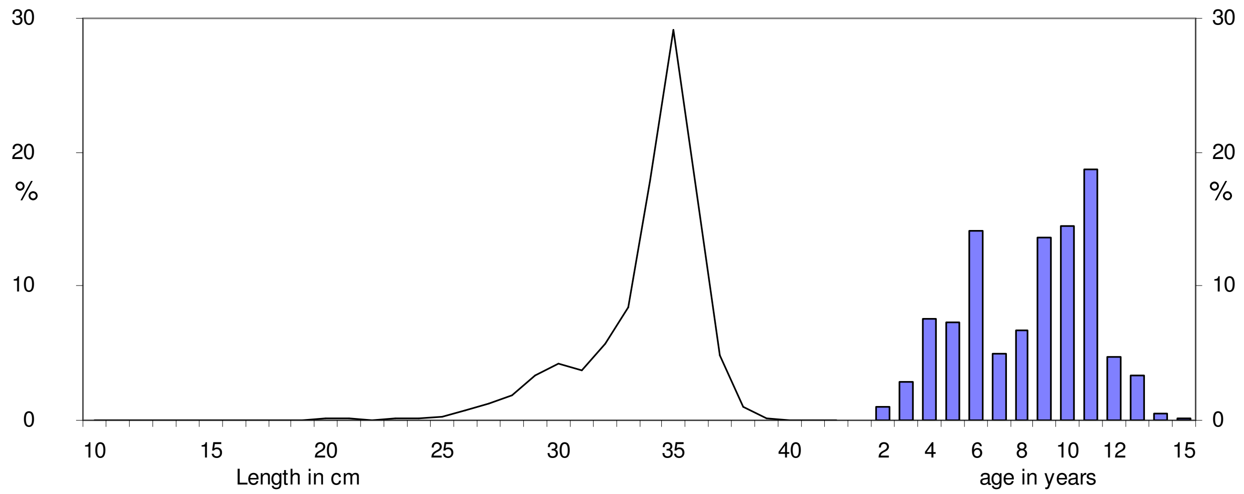


Figure 22. Age and length distribution of Norwegian spring-spawning herring from 1st of July to 10th of August 2015.

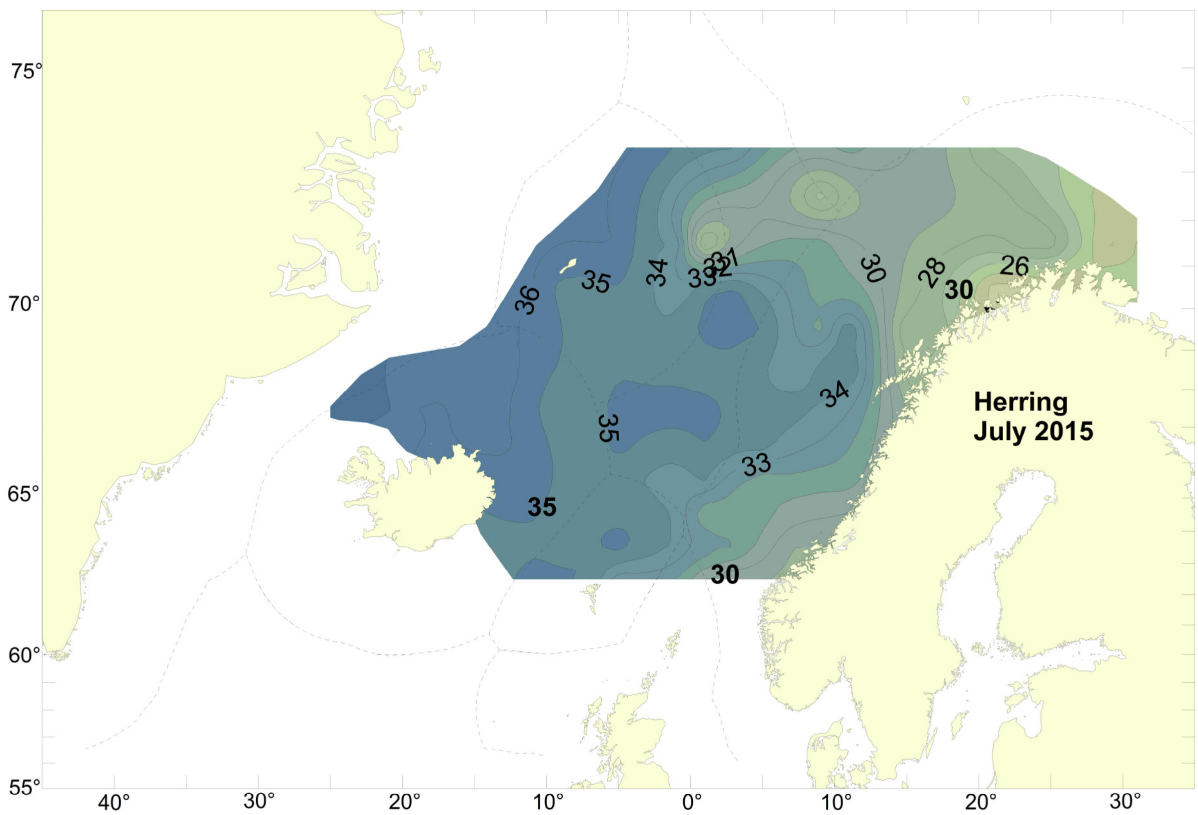


Figure 23. Length distribution of Norwegian spring-spawning herring during the coordinated ecosystem survey 1st of July to 10th of August 2015.

Blue whiting

No results are presented for blue whiting in 2015 because only two 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 78% of trawl stations (Fig. 24). Of stations with mackerel present, the mean weight of the lumpfish catches was 48 kg (114 stations) while 71 kg (23 stations) where mackerel was absent. 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 Eros whereas a subsample of 100 kg to 200 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. Generally, the mean length and mean weight of the lumpfish was highest in the coastal waters and lowest in the open sea.

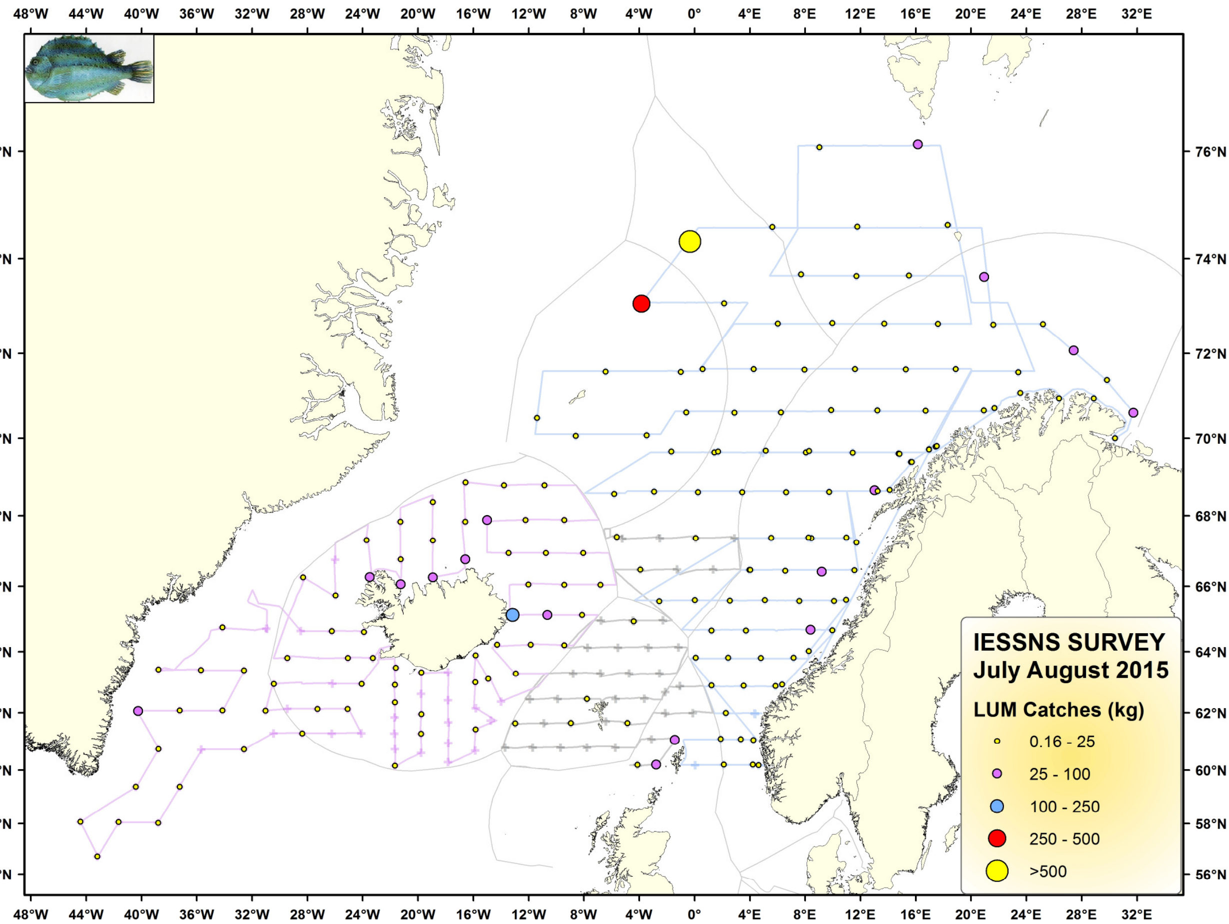


Figure 24. Lumpfish catches at surface trawl stations during the IESSNS survey in July and August 2015.

Salmon (*Salmo salar*)

North Atlantic salmon (*Salmo salar*) were caught both in coastal and offshore areas in the upper 30 m of the water column with the Multpelt 832 pelagic sampling trawl, during the IESSNS survey in July-August 2015.

The salmon weight ranged from 300 gram to 7.2 kg in size, dominated by salmon weighing between 1-3 kg. The length of the salmon ranged from 21 cm to 85 cm, with a large majority of the salmon >40 cm in length.

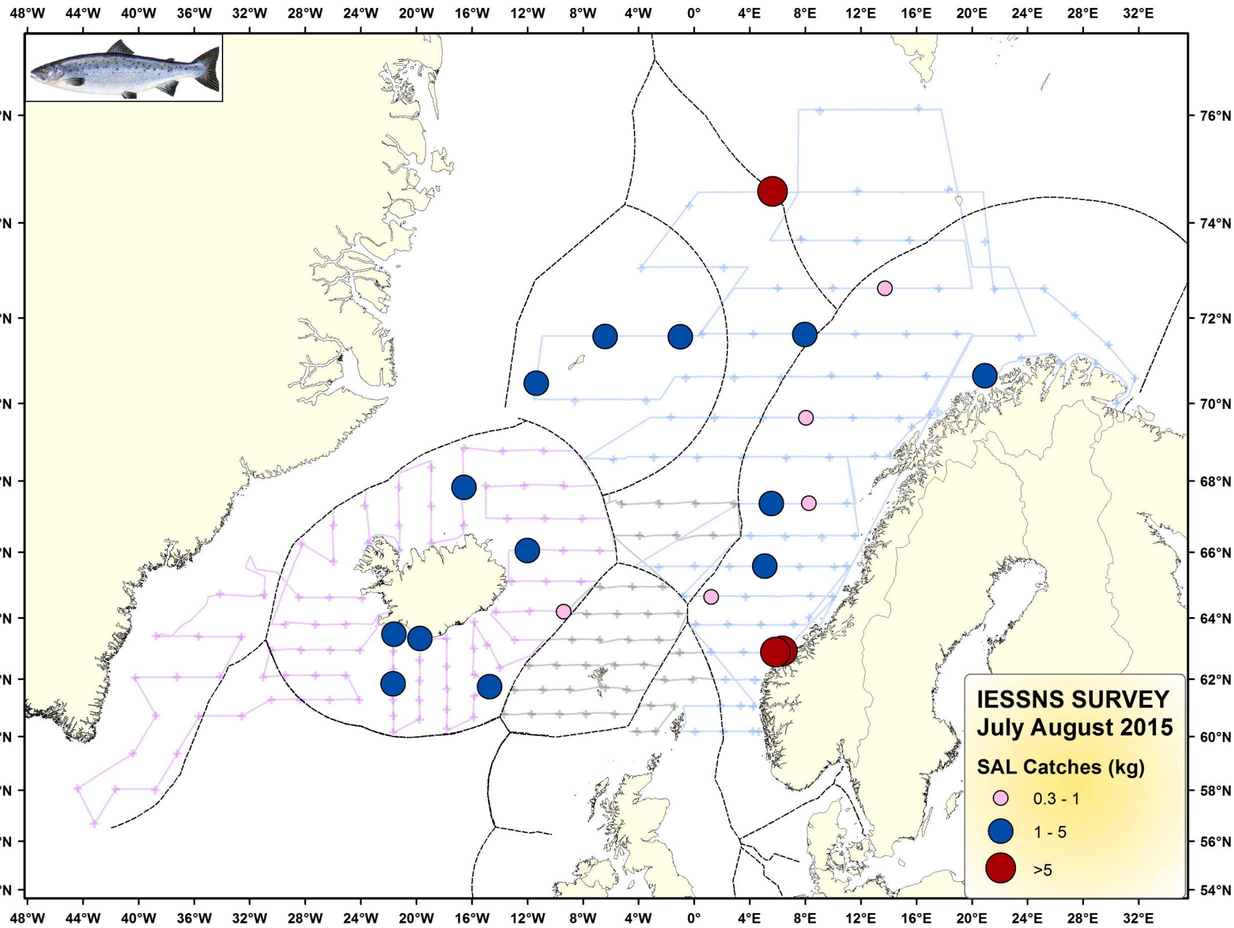


Figure 25. Salmon catches at surface trawl stations during the IESSNS survey in July and August 2015.

Marine Mammal Observations

Totally 340 marine mammals and 6 different species were observed onboard M/V "Brennholm" and M/V "Eros" from 1st to 28th of July 2015 (Figure 26). Altogether 6 groups of killer whales were found mostly in the central part of the Norwegian Sea in close association with mackerel. High densities of especially fin whales, humpback whales and white beaked dolphins were observed in the northern part of the Norwegian Sea, off the coast of Finnmark and into the southern part of the Barents 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 26).

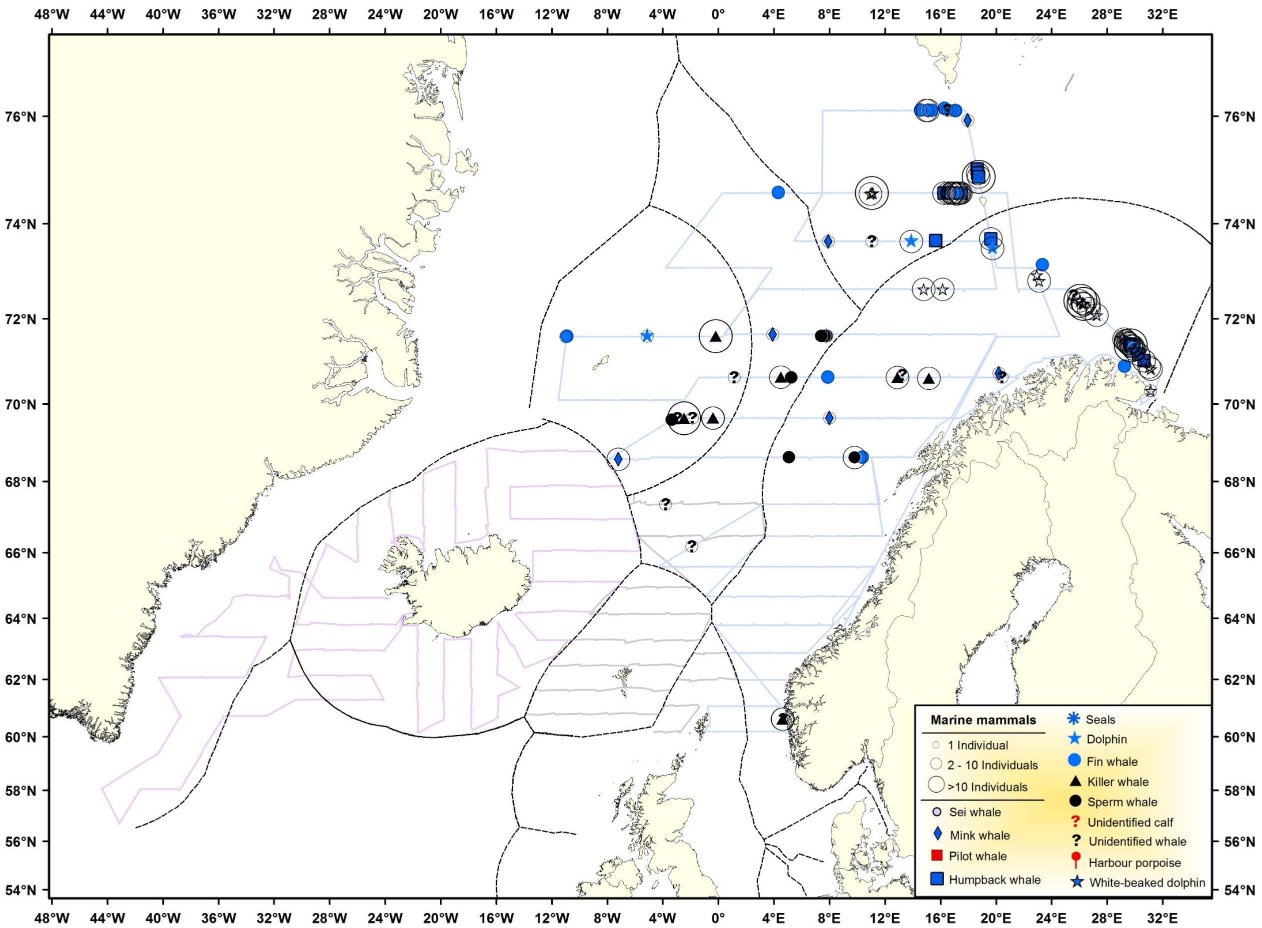


Figure 26. Overview of all marine mammals sighted onboard M/V "Brennholm" and M/V "Eros" in the Norwegian Sea and surrounding waters from 1st to 28th of July 2015.

Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 1 July to 10 August 2015 by four vessels from Norway (2), Iceland (1) and Faroese (1), beside that the Icelandic vessel was rented by Greenland to cover Greenlandic waters. 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 the various bottom trawl surveys run for many demersal stocks.

The total swept area biomass index of NEA mackerel in summer 2015 was 7.7 million tonnes distributed over an area of 2.7 million square kilometres in the Nordic Seas. This is 1.3 million tonnes lower abundance index than in 2014 when it was record high. The average density decreased also from previous two years from around 3.65 tonnes/km^2 to 2.86 tonnes/km^2. The reason for the decrease in the total biomass index of mackerel and density is not fully known, but 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), less fishable during surface trawling, due to different behaviour including possible higher patchiness compared to previous years, and/or that the abundance index from the IESSNS swept area survey in 2015 is simply reflecting the development of the stock size. None of these possible reasons can be excluded. However, the distribution of the mackerel and consequently also the feeding migration differed from previous years, with relatively less abundance in the northernmost and westernmost regions while much more in the area south of Iceland. Moreover, mackerel had relatively high density in the southeastern area covered (Figure 16), which all together could imply that higher proportion of the stock might have been missed in this year's survey because of a more pronounced southerly distribution. This emphasizes the necessity of covering 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 reasons the changes in the mackerel distribution from previous years are uncertain but are considered to be related to environmental factors. Relatively cold surface waters southeast of Iceland, around the Faroese and in the southern part of the Norwegian Sea in the spring 2015, as presented by the May survey results (ICES 2015), might for example had contributed to these changes. This needs however, further examination later including a broader scientific approach.

The 2011-year class of mackerel contributed with 28% of numbers followed by the 2010-year class with 22%. The 2012 year class had 12% in number. Altogether 71% 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 2014 by the inclusion of two more survey years. This is especially apparent for younger ages. There is now good internal consistency for 1-10 years old mackerel, except between age 5 and 6. The reason for the low consistency around age 5 is unknown, but could partly be due to similar abundance estimates of these two consecutive cohorts aged 5 and 6. 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 71% 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 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 2014. 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.

The groups recommends on the timing of the survey in the future that the survey period should be four weeks and the mid-point should be around 20 July. The main argument for this timeframe, is to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year. The mid-point of the survey is therefore earlier than the assumed maximum distribution of the mackerel stock.

The acoustic abundance index of Norwegian spring-spawning herring at age 4+ came to 22.7 billions, which is comparable to the May survey index in 2015 of 20.3 billions (~10% difference; ICES 2015). The estimated biomass was 7.7 million tonnes, which is higher than in the May survey (5.4 million tonnes). The part of the difference which is not due to increased number, can at least partly be explained by individual weight increase during the feeding season. The age composition in these two surveys was also similar with a tendency for a higher contribution of older age groups in the July/August survey compare to the May survey, where 65% vs. 53% were at age 7+ and 35% vs. 47 at age 4-6, respectively. These differences in age composition for NSS herring between the IESNS and IESSNS surveys could be due to the fact the IESSNS in July-August is only catching herring in the upper 30 m, whereas herring is also caught in deeper waters during the IESNS in May-June.

Systematic biological data on lumpfish has been collected during the entire survey and there exist a lot of interesting results on distribution, length and weight composition etc. These lumpfish data need to be further analysed in the future.

Systematic biological data on North Atlantic salmon caught during the IESSNS has also been collected. All the salmon samples have been frozen for later analyses and can be applied for a range of different scientific investigations in the future.

The temperature in the surface (SST) layer from Iceland over Jan Mayen and to Svalbard was 1-2°C warmer in July 2015 than the average for the last 20 years. In the central and eastern part of the Norwegian Sea the SST was close to the 20 year average, while around 1°C below the average south of Iceland and in Greenland Sea. The SST in July 2015 was generally colder than in July 2014 across the whole Northeast Atlantic. Despite the cooler surface waters south of Iceland, the mackerel density has never been measured as high. It should be considered in this context that the temperature there was in the range of 9-11°C, which is well above the temperature often restraining the mackerel distribution of ~6°C.

The concentrations of zooplankton in the Norwegian Sea were lower in 2015 than in 2014 (7.4 g dry weight/m^2 and 8.6 g/m^2 respectively). In the IESNS survey in May 2015 a decrease was also observed compared to 2014. There seem to be higher concentrations of zooplankton in southern areas off Iceland and Greenland than observed in previous years.

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. High numbers of white beaked dolphins appeared in the northern part of the Norwegian Sea, in southern part of the Barents Sea and along 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 (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 main effort in this year's survey to systematically quantify the catchability of the trawl and improve the standardization, was to undertake a comparison between trawling in banana and straight forward. This will require further parwise trawl hauls in the future, but the results of the tows undertaken in 2015 seems to point towards less catches in the banana tows even if not statistically significant (Annex 2).

Results on total abundance index without uncertainty estimates using the swept area method on the NEA mackerel using the new program StoX, are presented in Annex 3. These analyses are preliminary and need more careful consideration especially related to the uncertainty estimates of the total abundance index and the different age groups 1-10 years old, before these results can be used into the assessment of NEA mackerel.

Recommendations

General 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.	Norway, Faroe Islands, Iceland, Greenland
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
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 58.5N. Investigate the horizontal distribution and abundance of mackerel if standardized trawling in the surface (0-30 m) can be used to measure the abundance of mackerel in in the North West European shelf Seas south of 58.5N.	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. It is therefore recommended that WGWIDE consider using the entire time and age series of 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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We greatly appreciate and thank skippers and crew members onboard M/V "Brennholm", M/V "Eros", M/V "Christian í Grótinum" and R/V "Árni Friðriksson" for outstanding collaboration and practical assistance on the joint mackerel-ecosystem cruise in the Nordic Seas from 1st of July to 10th of August 2015.

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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).

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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. km^2)	Biomass (in thous. tonnes)	Biomass (%)
EU	101	444	5.8
Norwegian	721	2114	27.5
Icelandic	587	2866	37.3
Faroese	268	795	10.3
Jan Mayen	172	241	3.1
International north	260	579	7.5
International west	147	225	2.9
Greenland	358	321	4.2
Spitzbergen	81	103	1.3
Total	2695	7688	99.9

Annex 2

WGIPS working document 01

Comparing "banana" and "straight forward" towing for mackerel

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Abstract

Mackerel is a fast swimmer that is assumed to avoid disturbances such as the wake of a ship. This is potentially biasing density estimates of mackerel based on swept-area estimates from surface trawling. Trawling in a straight line with the trawl in the ship's wake has therefore been assumed to lead to an underestimate of the mackerel density in the sea. An alternative trawling strategy has been implemented by the International Ecosystem Summer Survey in the Nordic Seas (IESSNS), namely trawling in a curve to keep the trawl outside the wake. However, if mackerel avoids the wake of the ship in a horizontal direction, then the IESSNS solution will lead to an over-estimation of the true density. Swept area based stock estimates from surface trawling is of great value to stock assessment of epipelagic fish species, such as the economically and ecologically important North-East Atlantic mackerel. It is therefore imperative to quantify this bias.

In this study, the effect of horizontal avoidance on catch rates of mackerel was estimated from a series of trawl experiments. The catch rates were not found to differ significantly between straight trawling in the wake and curved trawling on the side of the wake. It is therefore concluded that there is no substantial horizontal avoidance of the ship and the ships wake. Vertical avoidance was not investigated in the present study.

Straight trawling in the general direction of the survey is easier and less time consuming than curved trawling. It is therefore recommended that standardized surface trawling for mackerel is done in a straight direction, if the results presented herein can be supported by additional experiments (more data). It is furthermore needed to verify if the trawl was directly in the wake in all the straight tows. Side-ways drifting due to wind could place the trawl of the side of the wake so it would in reality resemble a curved haul.

Materials and methods

Experimental surface trawling was done at 21 locations by R/V Árni Friðriksson, M/V Eros and M/V Brennholm during the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) in mid-summer 2015 (Figure 1). On each location trawling was done in straight and curved lines, respectively. The survey protocol is available in Valdemarsen et al. (2014) and (Nøttestad et al., in review). The density of mackerel d (kg nmi-2) was estimated for each trawl haul by dividing the total catch of mackerel (kg) with an estimate of swept area (= the trawl haul distance × the horizontal opening of the trawl) (Nøttestad et al., in review; Valdemarsen et al., 2014). The data are plotted in Figure 2.

The effect on the catch rates of curved trawling relative to straight trawling was estimated as a catchability factor (*CF*) for all permutations on each location:

$CF = d_{Curved} / d_{Straight}$

The box-and-whiskers-plot of *CF* estimates were made using the "boxplot()"-function in the R package "stats" v.3.0.1 (R Core Team, 2013). Boxes indicate the following quartiles: 25 %, 75 % and 50 % (median). Dots indicate outliers defined as observations that exceed 0.67 times the quartiles. The whiskers indicate the most extreme observations, excluding the outliers.

Results

CF ranged from 0.0 to 10.4 and was not found to be statistically significantly different from 1 (Figure 3).

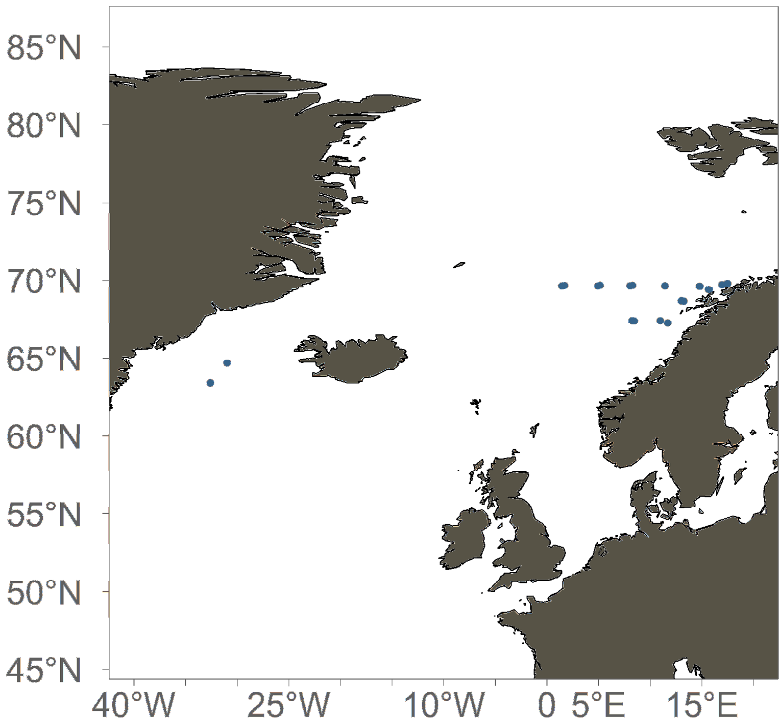

Figure 1. Map of trawl stations with direct comparison between banana shaped towing and straight forward towing for NEA mackerel with the Multpelt 832 sampling trawl.

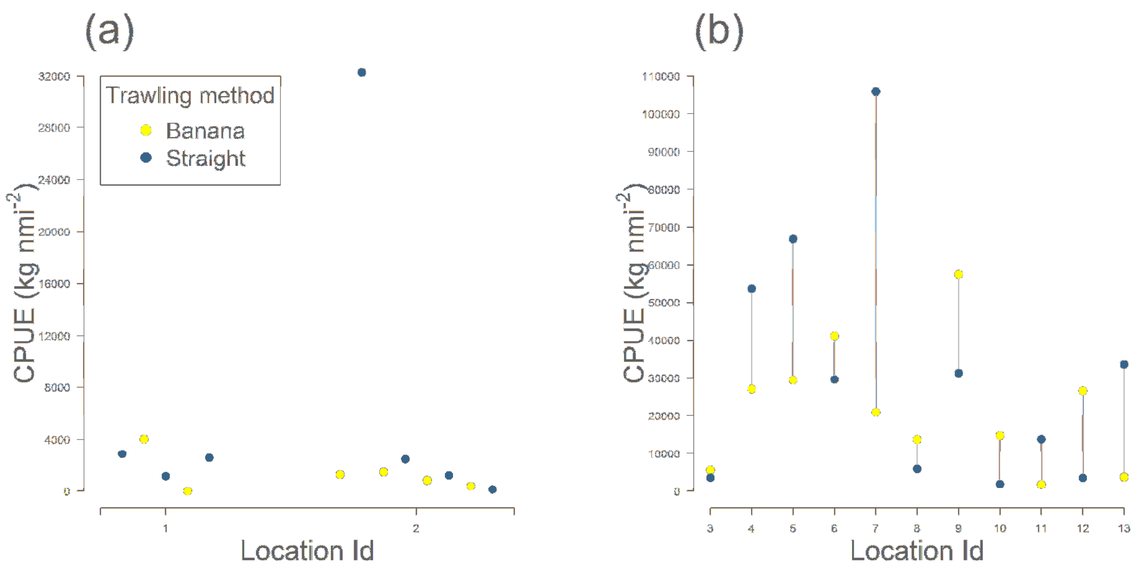

Figure 2. Catch of mackerel per swept nmi^2 by location and trawling method (straight or curved).

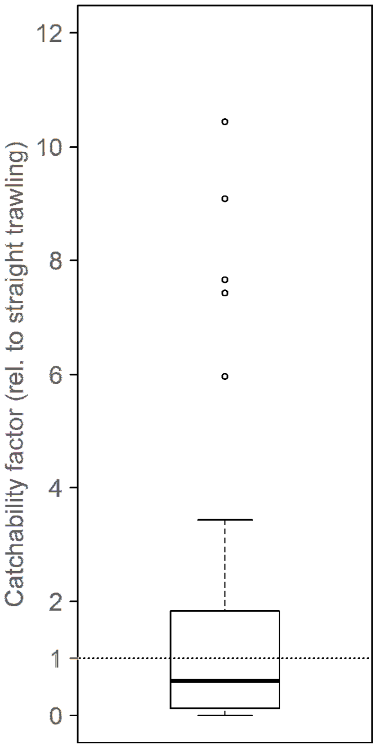

Figure 3. The effect of trawling method on the catch rate indicated by the Catchability Factor (*CF*). Boxes indicate the following quartiles: 25 %, 75 % and 50 % (median). Dots indicate outliers defined as observations that exceed 0.67 times the quartiles. The whiskers indicate the most extreme observations, excluding the outliers.

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Annex 3

Swept area biomass estimates of mackerel using StoX

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StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. 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. Accessing StoX from external software may be an efficient way to process time series or to perform boot-strapping on one dataset, where for each run, the content of the parameter dataset is altered. 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)[*] s implemented. StoX has been tested on the 2014 IESNS survey and Norwegian acoustic sandeel and cod surveys. When new statistical methods are implemented it is regarded essential that expert specification demands, documentation and statistical rigorousness is available. According to the plan, a test version of the software will be available for people outside IMR by the end of March 2014.

StoX was applied on the survey data from the IESSNS 2015 survey and the main results are presented below. This year's survey design was in a more stratified manner than in previous years to fulfil the condition made by such an approach.

[*]Jolly, G. M., and I. Hampton. "A stratified random transect design for acoustic surveys of fish stocks (1990)." *Canadian Journal of Fisheries and Aquatic Sciences* 47:7: 1282-1291.

Table A3. Swept-area biomass estimation of mackerel in July/August 2015 for the whole IESSNS survey area as based on calculation in StoX.

Length cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number	Biomass	Mean Weight (g)
21-22	2407															31209	2407	77.1
22-23	14149															159439	14149	88.7
23-24	25264															251577	25264	100.4
24-25	19922															176217	19922	113.1
25-26	16571															125063	16571	132.5
26-27	11480	877														82059	12357	150.6
27-28	2243	452														16287	2696	165.5
28-29	3255	2728														28960	5983	206.6
29-30		11159	2388													60899	13547	222.5
30-31		49508	14626	3637												262305	67771	258.4
31-32		81179	81789	119326	4441											1001928	286735	286.2
32-33		91746	130611	453376	101837	1386										2525911	778956	308.4
33-34		28672	295352	579940	275095	19750	1415		1142	1266						3650372	1202631	329.5
34-35		6490	160486	492027	350970	41708	27178	7160	293	-						3054724	1089680	356.7
35-36		16292	67670	196225	290306	123461	72019	22435	1464	3532						2037820	793404	389.3
36-37			41272	130274	228463	208552	108507	56141	28670	6354						1901538	810971	426.5
37-38			4434	68604	209499	195014	231726	128000	82889	31754	4750	939	852			2077017	958461	461.5
38-39			13676	30979	158364	131082	140878	103147	65173	20269	10511	2004	1169			1363656	677252	496.6
39-40			2823	23325	57980	85046	74017	58893	48562	22412	18431	10082	624	1407		758636	406200	535.4
40-41				512	11623	26193	38154	30791	24708	12790	3329	4812	987			271932	153898	565.9
41-42				2093	1437	7252	18931	8624	8714	9690	10309	2914	1461			120859	71423	591.0
42-43					1237	1641	14168	10601	615	1122	1502	1770	868			53323	33524	628.7
43-44					339				3582	1624	369	673	679	300	350	11468	7916	690.2
44-45								1652	-	961	1180	4324				11376	8117	713.5
45-46					1549											1836	1549	843.6
46-47							37									47	37	770.0
TSN (1000)	629866	632132	2091490	5372034	4547603	2323577	1992431	1169733	715249	305664	134957	73707	18379	4554	679	20012055		
TSB (tons)	95292	289102	815127	2100316	1693140	841085	727030	427443	265811	111772	50380	27519	6640	1707	350		7452713	
Mean length (cm)	23.3	31.2	32.7	33.1	34.6	36.0	36.6	36.9	37.3	37.7	38.6	39.6	39.5	39.3	42.6			
Mean weight (g)	103.0	278.3	320.6	333.0	380.4	428.3	446.5	458.2	473.4	470.7	505.0	511.8	500	534	733			372.4
N (%)	3.1	3.2	10.5	26.8	22.7	11.6	10.0	5.8	3.6	1.5	0.7	0.4	0.1	0.0	0.0	100		
Biomass (%)	1.3	3.9	10.9	28.2	22.7	11.3	9.8	5.7	3.6	1.5	0.7	0.4	0.1	0.0	0.0		100	

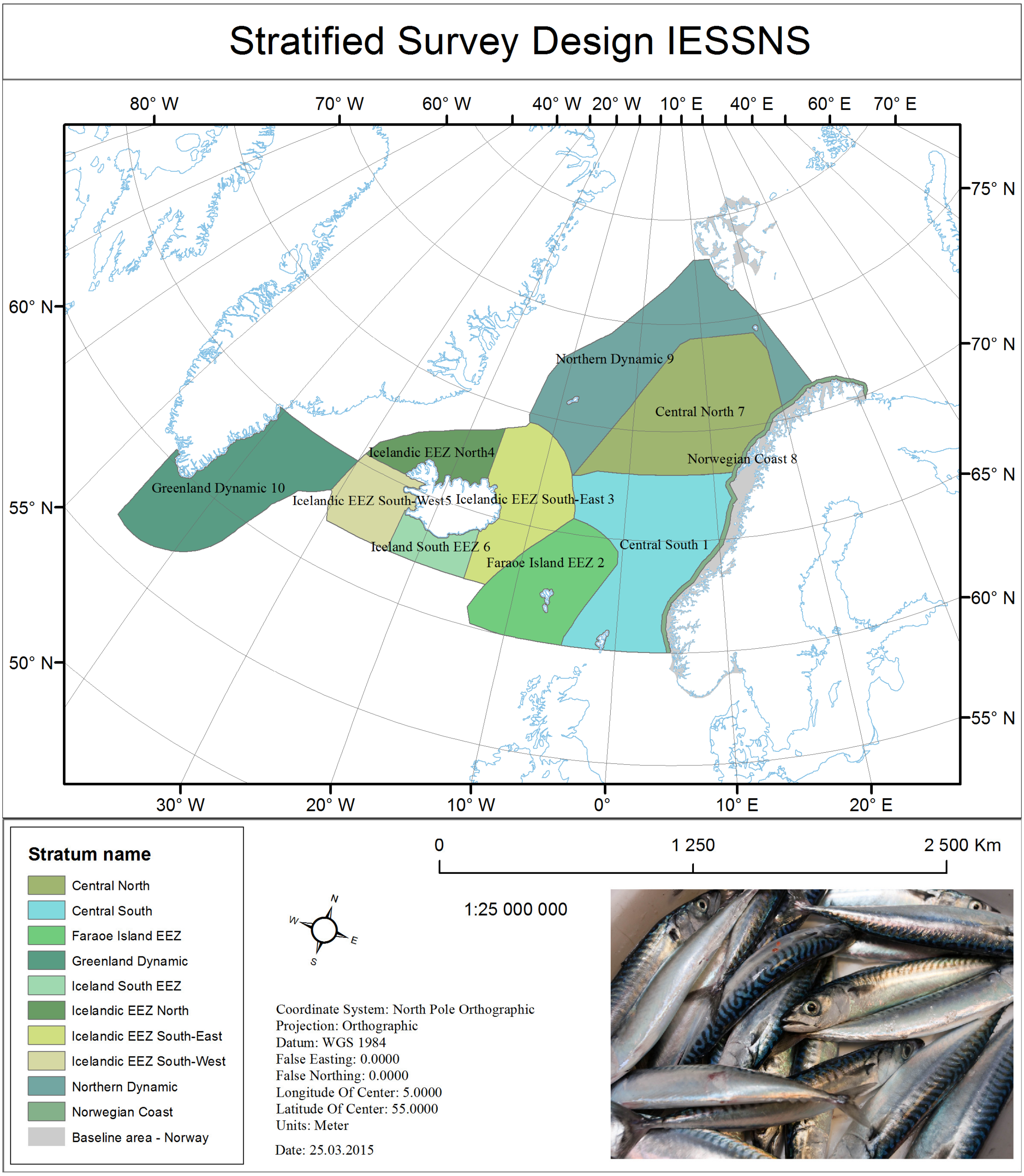

Figure A3.1. Map showing the ten stratum used in StoX for estimation of mackerel biomass indices in July-August 2015 during the IESSNS.