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**Cruise report from the coordinated ecosystem survey
(IESSNS) with R/V "G. O. Sars", M/V "Brennholm"; M/V
"Christian í Grótinum" and R/V "Arni Fridriksson" in the
Norwegian Sea and surrounding waters,
1 July-10 August 2012**



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Abstract

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 1 July to 10 August 2012 by four vessels from Norway (2), Iceland (1) and Faroese (1). A standardised pelagic trawl swept area method has been developed and used to estimate a swept area abundance estimate of NEA mackerel in the Nordic Seas in recent 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 2012 was 5.1 million tonnes based with a coverage of 1.5 million square kilometres in the Nordic Seas from about 61 degrees up to 70 degrees north and from the Norwegian coast in east and west to the fishery border between Iceland and Greenland. The 2006 year class contributed to more than 20% in number followed by equally abundant 2005, 2007 and 2008-year classes around 15% each, respectively. The 2010 year class was very well represented in the catches, or 12% of the total number. The mackerel was distributed in most of the surveyed area, and the zero boundaries were only found in the south-western area in the Faroe zone and in the southern Icelandic zone. In the northern area the zero boundary was not reached.

The geographical coverage and survey effort in 2012 was largely comparable to the survey in 2010, while the coverage in 2011 was less, as it did not cover the northern part of the Norwegian Sea properly. Therefore it is possible to compare the swept area estimates of 4.8 million tonnes in 2010 with the 5.1 million tonnes estimate in 2012. Thus, these estimates indicate that the NEA mackerel remain at a stable level. Both these biomass estimates must be considered to be underestimations and only represent part of the stock north of approximately 62°N. The overlap between mackerel and NSS herring was highest in the south-western part of the Norwegian Sea (Faroe and east Icelandic area).

Acoustic estimations of herring and blue whiting were also done during the survey from calibrated echosounder data. The biomass of Norwegian spring-spawning herring was estimated to 7.3 million tonnes in July–August 2012. The previous acoustic abundance estimates of NSS herring from the survey were 13.6 million tonnes in 2009 and 10.7 million tonnes in 2010. Thus, the trend in the July survey clearly follows the negative trend in the biomass estimates from the assessment. The herring was mainly found in the outskirts of the Norwegian Sea; i.e. from north of the Faroes, the east Icelandic area and north in the Jan Mayen area, with small concentrations in the central and eastern areas.

This survey confirmed the presence of young blue whiting (ages 1–3) in the summer feeding areas. The concentrations were highest in the eastern Norwegian Sea and in the area south and southwest of Iceland.

The temperatures in the Nordic Seas in 2012 are still well above long-term average. Especially in the area west of Iceland and in the Irminger Sea the surface temperatures were up to three degrees higher than the long-term average. However, the south-western Norwegian Sea seems a bit cooler in summer 2012 compared to the last two years.

The concentrations of zooplankton are still at a low level compared to historic values.

Whale observations were done by the two Norwegian vessels during the survey. The number of marine mammal sightings was very low as compared to previous years, with very few sightings of fin and humpback whales in the Norwegian Sea.

The swept area methodology for abundance estimation of NEA mackerel was further developed by dedicated experiments. In order to be able to use the results from the different vessels in a combined swept area estimate, it is necessary to calibrate the pelagic trawl catch efficiency and acoustic equipment among the different vessels. This inter-calibration was done during two days of the survey in a pre-agreed area. The newly designed pelagic sampling trawl (Mulpelt 832) was used by all vessels, and seven inter-calibration hauls were performed with the four vessels during this exercise. An acoustic intercalibration was also performed just after finishing the trawl experiments. The ultimate goal to use this combined swept area estimate as an abundance index in the assessment of NEA mackerel will require allocation of survey time dedicated for inter-calibration between the participating vessels in future surveys.

Introduction

In July–August 2012, four vessels; R/V “G. O. Sars” and one chartered trawler/purse seiner, M/V “Brennholm” (Norway), M/V “Christian í Grótinum” (Faroe Islands), and the research vessel R/V “Arni Friðriksson” (Iceland) participated in the joint ecosystem survey (IESSNS) in the Norwegian Sea and surrounding waters. The six weeks cruises from 2 July to 10 August are 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 and blue whiting, oceanographic conditions and prey communities. Whale observers were operating on the Norwegian vessels to collect data on distribution and aggregation of marine mammals. The survey was initiated by Norway in the Norwegian Sea in 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.

Material and methods

Coordination of the survey was done by correspondence during the spring and summer 2012. The participating vessels together with their effective survey periods are listed in Table 1.

Figure 1 shows the cruise tracks and the trawl stations and Figure 2 the cruise tracks and the CTD/WP-2 stations.

In general, the weather was mostly calm with good survey conditions for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. Some bad weather with gale force and storm in the northern and northeastern part of the survey area, did to some extent affect the survey with reduced survey speed and deleting some planned predefined stations for a few days period in total for one vessel. Overall, the weather conditions did not affect the quality of the various scientific data collection during the survey for the involved survey vessels, except for Brennholm which experienced bad weather at the shelf off northern Norway.

During this year’s survey a new pelagic trawl, Multpelt 832, was used by all four participating vessels. 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 John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway, has been in progress for two 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.

Table 1. Survey effort by each of the four vessels in the July–August survey in 2012.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton station
Arni Friðriksson	12/7–10/8	5955	104	91	91
Christian í Grótinum	3/7–18/7	1825	37	28	28
G.O. Sars	2/7–20/7	2754	57	49	48
Brennholm	6/7–27/7	3722	50	40	40
Total	2/7–10/8	14256	248	208	207

Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 2. G. O. Sars and Arni Fridriksson were equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. On G. O. Sars and Árni Friðriksson CTD profiles were taken down to 500 m depth when depth allowed. Christian í Grótinum was equipped with a mini SEABIRD SBE 25+ CTD sensor, recording temperature, salinity, fluorescence and pressure (depth) from the surface down to 500 m, or when applicable as linked to maximum bottom depth. Brennholm was equipped with a SAIV SD200 CTD sensor recording temperature, salinity, 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 (G. O. Sars and Brennholm) and 200 μm (Arni Fridriksson 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.

Zooplankton sampling was performed on each predefined station; 48 stations on G. O. Sars, 40 stations on Brennholm, 91 stations on Arni Fridriksson and 28 stations on Christian í Grótinum.

Trawl sampling

Catches from trawl hauls 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.

Table 2. Summary of biological sampling in the survey from 1st of July to 10th of August 2012 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	10	50	25
	Herring	10	50	25
	Blue whiting	10	50	25
	Other fish sp.	10*	10*	0
Otoliths/scales collected	Mackerel	10	50	25
	Herring	10	50	25
	Blue whiting	10	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*

*Depends on species

All vessels used the newly designed and constructed Mulpelt 832 pelagic trawl aimed for standardization of fishing gear used in the survey. The most important properties of the trawls during the survey and their operation were as shown Table 3.

Table 3. Trawl settings and operation details during the international mackerel survey in the Nordic Seas in July-August 2012. The column for influence indicates observed differences between vessels likely to influence performance during intercalibration. Influence is categorized as 0 (no influence), + (some influence) and ++ (high influence).

Properties	G.O. Sars	Arni Fridriksson	Brennholm	Christian í Grótinum	Influence
Trawl producer	Egersund Trawl AS	Tornet	Egersund Trawl AS	Vónin	0
Warp in front of doors	Steel wire, 24 mm	Dynex-34 mm	Dynema -36 mm	Dynex – 34mm	++
Warp length during towing	340 m (320-360 m)	350 m	340 m	350 m	0
Difference in warp length port/starboard	3-12 m	15-40 m	5-10 m	5-12 m	0
Weight at the lower wing ends	250 kg	No weights	400 kg	375 kg	++
Setback in metres	4 m	0	4 m	8 m	++
Type of trawl door	ET Speed	Polar.Jupiter t4	Seaflex w. adjustable hatches	Thyborøn V-doors	0
Weight of traw door	1200 kg	2000 kg	2000 kg	2000 kg	+
Area trawl door	7.5 m ²	6 m ²	9 m ² 65-75% hatches	8 m ²	++
Towing speed (GPS) in knots	4.7 (4.7-4.8)	5.1 (4.7-5.2)	5.1 (5-5.2)	4.7 (4.1-5.1)	+
Setting time	15 min	12 min	5-10 min	15 min	+
Trawl height	25.5 (20-38)	27-30	28-30	~ 30.7 (SE = 0.33)	+
Door distance	110 m	98-104 m	115 m	Not measured	++
Trawl width*	-	62 m	-	70 m	+
Turn radius	2-4 degrees turn	2700-2800 m	5 degrees turn	5-10 degrees turn	+
Hauling time warp	6 min	4-5 min	5 min	8 min	+
Hauling time trawl	20 min	17 min	15 min	10 min	++
Trawl door depth (port and starboard)	0-10, 5-15 m	8-13, 10-15 m	10-15 m	Not measured	+
Headline depth	0-2 m	0-1 m	0-2 m	0 m	+
Float arrangements on the headline	Kite + 2 buoys on wings	Kite	Kite + 2 buoys on wings	Dynex float rope, whole headline (382 kg buoyancy) + 2 buoys on wings and 2 in middle (2880 kg buoyancy)	+
Weighing of catch	All weighted	All weighted	Codend weighted with large scale digital weight	Semi quantitative estimate (larger hauls estimated)	+

* Trawl width was not estimated constantly during intercalibration, for Christian í Grótinum it was done during the two first hauls of the trip

Marine mammal observations

The two Norwegian vessels, G. O. Sars and Brennholm, conducted observations of marine mammals. Two dedicated marine mammal observers were present on board both G. O. Sars and Brennholm, respectively. The observations were done from the roof/outdoor or from the bridge when the weather conditions were unfavourable. Two observers were watching permanently. Among the equipment were: angle boards, binoculars 7x50 with reticles, portable two-way radio for communication with bridge, GPS device, microphones connected to personal computers with special software for the sound recording and simultaneous registration of the vessel's position. Each observer monitored a 90 degree sector, starboard and port side respectively, in the line of the course. They shifted the sides every hour and took short breaks every two hours. The main sector of observation was 45 degrees port and starboard of the course line. The priority periods of observing were during the transport stretches from one trawl station to another. When the weather conditions were nearly excellent, observing was also conducted during the trawl stations with the purpose of tracking marine mammals, which could possibly appear. Weather conditions were noted every hour of observation. Sightings were spoken into a microphone. Later, the recordings were transcribed to a special Sighting form. Fields in the sighting form included date, time, position, species, number, group size, behaviour, angle from the vessel course and swimming direction. A diary summarizing each day's activities was produced by the observers. Data were summarized and presented in tables and a distribution map. Scientific personnel and crew members on board G. O. Sars and Brennholm also recorded incidental sightings of marine mammals more or less continuously on the bridge. Digital filming and photos were taken whenever possible for each registration from scientists onboard.

Meteorology

Wind conditions as derived from the Beaufort scale, air temperature, weather, cloud coverage and sea state were monitored and noted in the cruise logger program at each station onboard the vessels.

Digital photos and filming

Digital photography with Nikon D70 and D200 in addition to digital filming with Sony TCR TRV50 was done throughout the cruise for documentation of trawl catches, various scientific activities and visual observations of marine mammals and seabirds along the cruise tracks on board G. O. Sars and Brennholm.

Acoustics

The acoustic equipment onboard G.O. Sars were calibrated July 2012 for 38, 70, 120 and 200 kHz. Brennholm was calibrated in April 2012 for 18, 38, 70 120 and 200 kHz. Arni Fridriksson was also calibrated in April 2012 for all frequencies 18, 38, 120 and 200 kHz, whereas Christian í Grótnum was calibrated 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. Salient acoustic settings are summarized in the text table below.

Sonar recordings

M/V "Brennholm" was equipped with the new Simrad fisheries sonars SH90 (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.

MS70 – Multibeam sonar

Onboard G.O. Sars the Simrad MS 70 recorded sonar data from the entire survey (1-21 July 2012). Post-processing and analyses of these data will be explored in more detail later.

ME70 – Multibeam echosounder

During the first leg of the Brennholm survey, multibeam acoustic data was collected from the Simrad ME70 echosounder, which operates in a range of frequencies between 70 to 120 kHz. These data have not been processed yet.

Acoustic doppler current profiler (ADCP)

R/V “G. O. Sars”, R/V “Arni Fridriksson” and 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 between the four surveying vessels

The procedure and results of the intercalibration of the Multpelt 832 pelagic trawl, which was used by all the four vessels in the survey, are provided in Annex 1. Shortcomings and recommendations for future use of the trawl in the survey are also given there.

Acoustic intercalibration between the four surveying vessels

Immediately after finalizing the intercalibration for the pelagic trawling with Multpelt 832 close to the surface, we decided to perform an acoustic intercalibration between G. O. Sars, Brennholm, Christian í Grótinum and Arni Fridriksson. The direction of the intercalibration was from east to west starting at the continental shelf off Iceland. The weather conditions were extremely favorable for acoustic intercalibration with calm sea and 0-1 m wave height during the entire intercalibration.



The convoy structure shown with fixed distances and angles between the vessels during the acoustic intercalibration 17th of July 2012 in Icelandic waters. The photo is taken onboard G.O. Sars and show R/V “Arni Fridriksson”, followed by M/V “Christian í Grótinum” and M/V “Brennholm” in front of the convoy. Photo: Leif Nøttestad, Institute of Marine Research, Norway.

The acoustic intercalibration started 17th of July 2012 at 07:05 UTC and ended at 13:30 UTC. The practical performance of the intercalibration were done in the following manner: G. O. Sars started in front of the “convoy” with a normal cruising speed of 10 knots in a straight east-west direction. Brennholm followed 0.8 cables (~150 m) and 100 degrees angle to G. O. Sars in front. Christian í Grótinum came third in the convoy and Arni Fridriksson was the last vessel in the convoy when the acoustic intercalibration started (see picture for illustration). When all vessels were in position in relation to each other and maintained a cruising speed of about 10 knot, the actual acoustic intercalibration could start. Contact between the vessels during the entire intercalibration was maintained continuous via the VHF system on Channel 16 and 67. One hour after G. O. Sars had leaded the way westwards, the vessels changed positions. Arni Fridriksson as the last vessel moved in front with full speed, while the other vessels slowed down to 5 knots. The same procedure was repeated six times, always with the last vessel moving up in front. Only data from the acoustic intercalibration when all vessels where aligned with a certain distance and angle to each other and the survey speed was 10 knots for all vessels will be used in the later analyses of these data. In the area of intercalibration we recorded mackerel and herring in the surface region and blue whiting deeper down in the water column. Consequently the data should be highly applicable to compare acoustic SA values and biomass estimates for at least herring and blue whiting (and possibly mackerel at a later stage) between the acoustic echosounder recordings onboard G. O. Sars, Brennholm, Christian í Grótinum and Arni Fridriksson. The data on the acoustic intercalibration will be explored and analysed in more detail in the near future. The aim is to write scientific articles on both the trawling intercalibration and acoustic intercalibration from the IEESNS survey between the four participating vessels from July 2012.

Cruise tracks

G. O. Sars, Brennholm, Christian í Grótinum and Arni Fridriksson followed predetermined survey lines with pre-selected pelagic trawl stations. On a few stations performed G. O. Sars pelagic trawl stations on registration from acoustics (herring and blue whiting) (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.

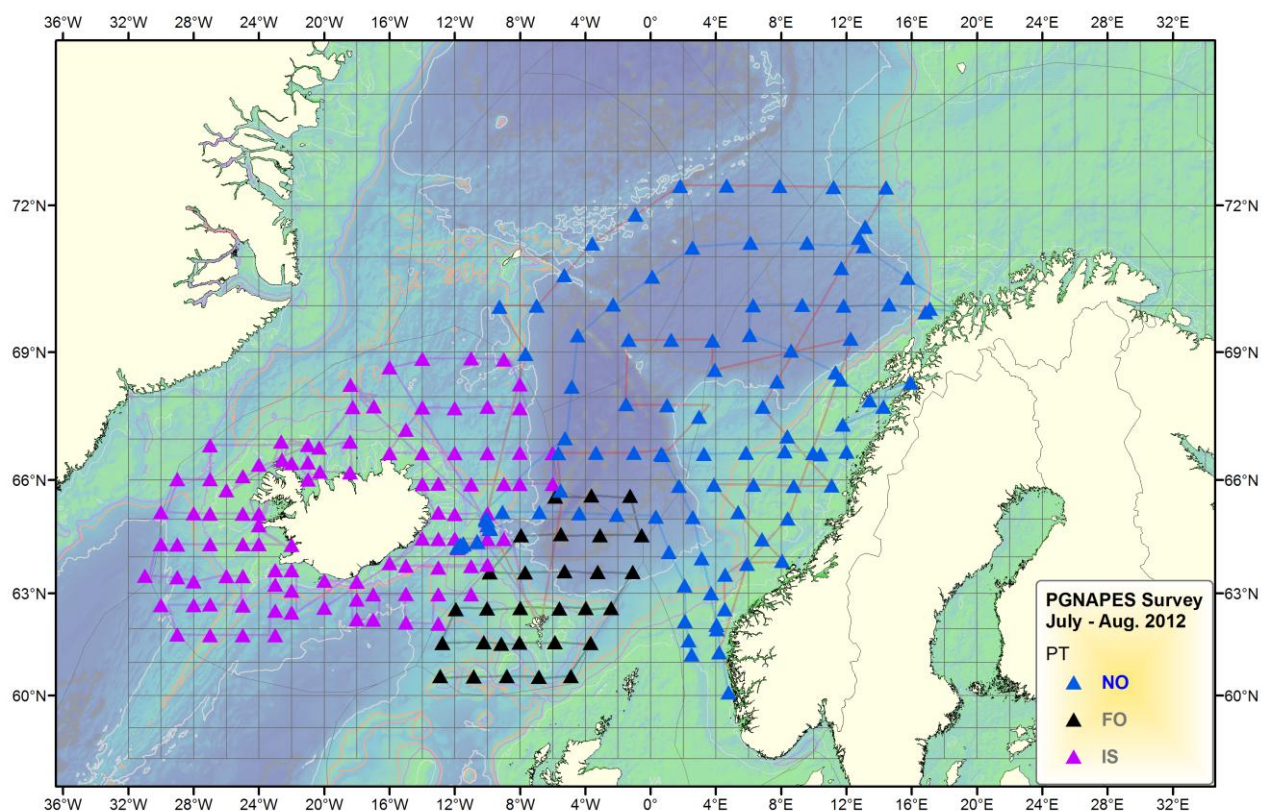


Figure 1. Cruise tracks and pelagic trawl stations shown for R/V “G. O. Sars” in green, M/V “Brennholm” (Norway) in blue, M/V “Christian í Grótinum” (Faroe Islands) in black R/V “Arni Fridriksson” (Iceland) in red within the covered areas of the Norwegian Sea and surrounding waters from 2nd of July to 10th of August 2012.

CTD sensors in combination with WP2 plankton net samples from the surface and down to maximum 200 m depth were taken systematically on almost every pelagic trawl station onboard all four vessels (Figure 2).

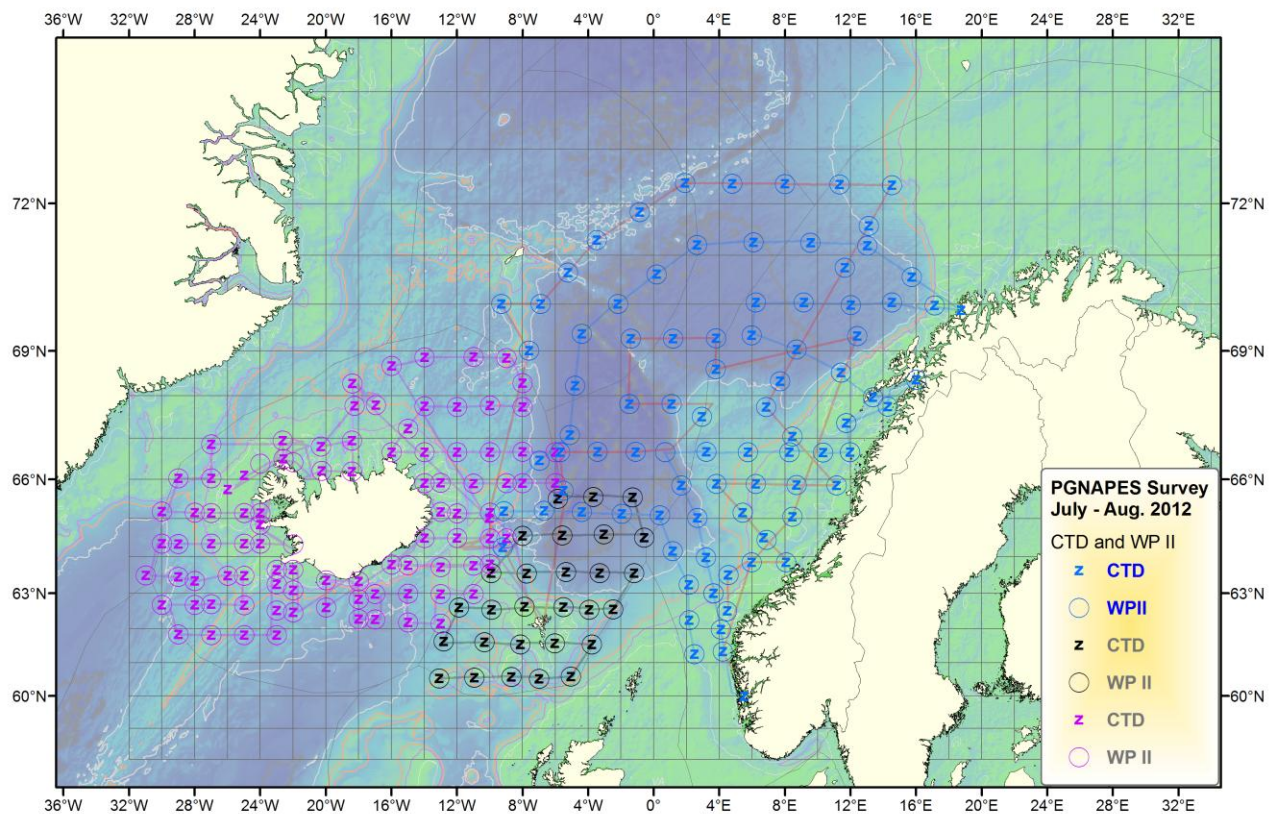


Figure 2. CTD stations (0–500 m) using SEABIRD SBE 37 (G. O. Sars and Arni Fridriksson) SEABIRD SB 25+ and SAIV SD200 (Brennholm) CTD sensors and WP2 plankton net samples (0–200 m). These were taken systematically on every pelagic trawl station on all four vessels

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

Generally, acoustic recordings were scrutinized using the LSSS onboard G.O. Sars, Brennholm and Arni Fridriksson and scrutinized using Echoview software onboard Christian í Grótnum on daily basis. 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.

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 2012). The acoustic methods were unchanged from last year (ICES 2012).

Table 4. Acoustic instruments and settings for the primary frequency in the July/August survey in 2012.

	R/V G.O. Sars	R/V Arni Friðriksson	M/V Brennholm	M/V Christian í Grótinum
Echo sounder	Simrad EK60	Simrad EK 60	Simrad EK 60	Simrad EK 60
Frequency (kHz)	18, 38, 70, 120, 200, 333	38, 18, 120, 200	18, 38, 70, 120, 200	38, 120, 200
Primary transducer	ES38B	ES38B	ES38B serial	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull
Transducer depth (m)	9	8	6	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	26.16
s_A correction (dB)	-0.60	-0.84	-0.65	-0.68
alongship:	6.89	7.31	7.01	7.05
athw. ship:	6.87	6.95	7.11	6.98
Maximum range (m)	500	750	750	500
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 5.1

Swept area index and biomass estimation

The swept area estimate is based on catches in the whole area covered in the survey, or between 60°N and 73°N and 30°W and 18°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 and 2011, i.e.: **a)** allocation of sea area to EEZs is based on a table taken from a NEAFC blue whiting report, and **b)** sea area proportion of rectangles overlapping land were calculated with polygon clipping in R using packages 'geoextras' and 'geo' (available on <http://r-forge.r-project.org>) and 'maps', 'mapdata' (available on <http://cran.r-project.org>) (Jónsson et al. 2011; Björnsson 2010; Becker and Wilks 2010, R Development Core Team 2011). Estimation of sea area proportion was improved from that used in 2010.

An experimental bootstrap approach to estimating uncertainty was used this year. The bootstrap units were the 1° lat by 2° lon rectangle biomass estimates themselves, across the whole area. The total biomass for each bootstrap replicate was summed and stored in a vector of bootstrap biomass estimates, yielding bootstrap CV and 90% CI. Number of replicates was 100 thousands. For this report we bootstrapped only occupied rectangles but not and interpolated rectangle values (Fig. 19).

Exclusive Economic Zone's (EEZ's) in the Northeast Atlantic shown as overlays on some of the figures in this report were taken from shape files on <http://www.vliz.be/vmdcdata/marbound/>.

Results

Hydrography

There have been considerable changes in the temperature regime in the Norwegian Sea and adjacent waters the last few years compared to a 20 years average. However, in July/August 2012 these changes seem to be less pronounced compared to previous periods, although with a pronounced exception in the western and northern part of Icelandic and Greenland waters, where surface temperatures were considerable higher (up to 3°C) compared with the 20 year average (Figure 3). 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 one month part (Figures 3 and 4).

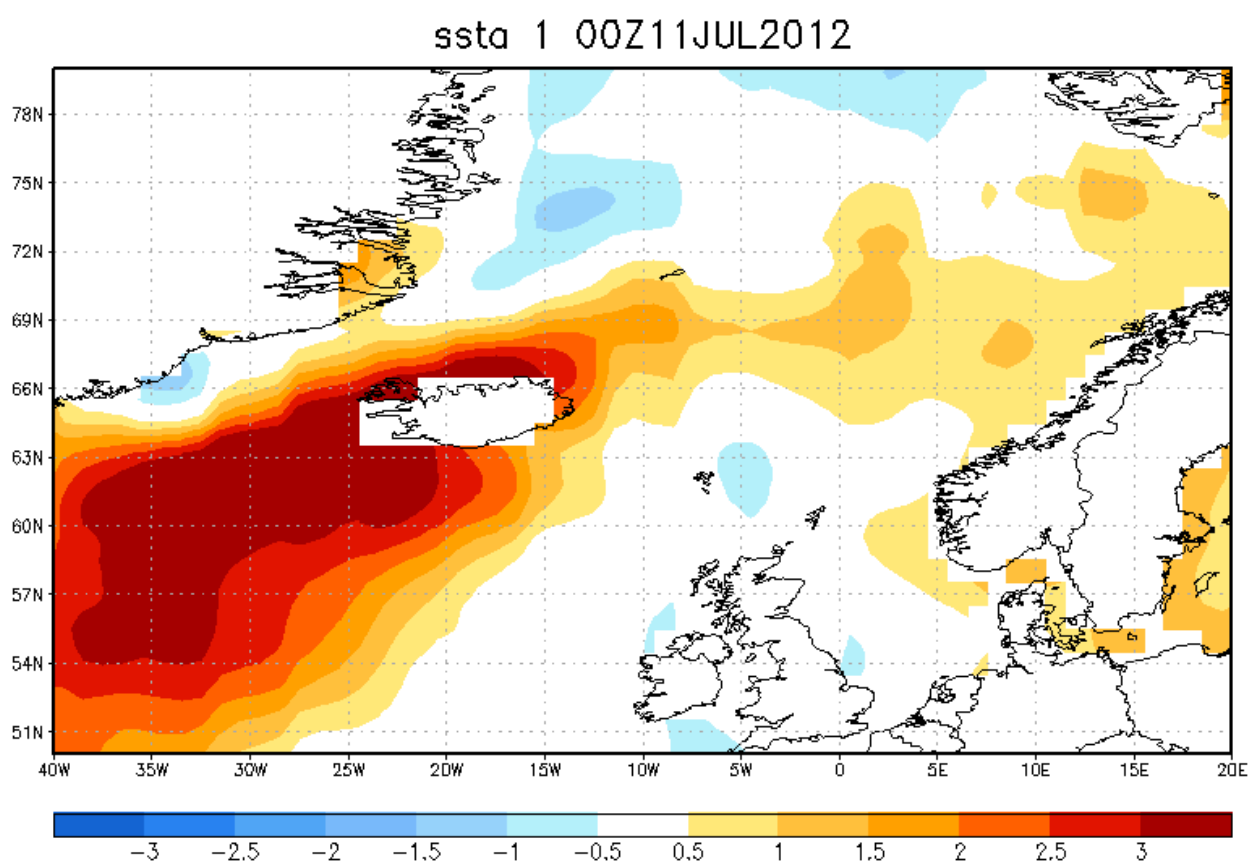


Figure 3. Sea surface temperature anomalies (°C; centered in week 28, mid July 2012) showing warm and cold conditions in comparison to a 20 year average.

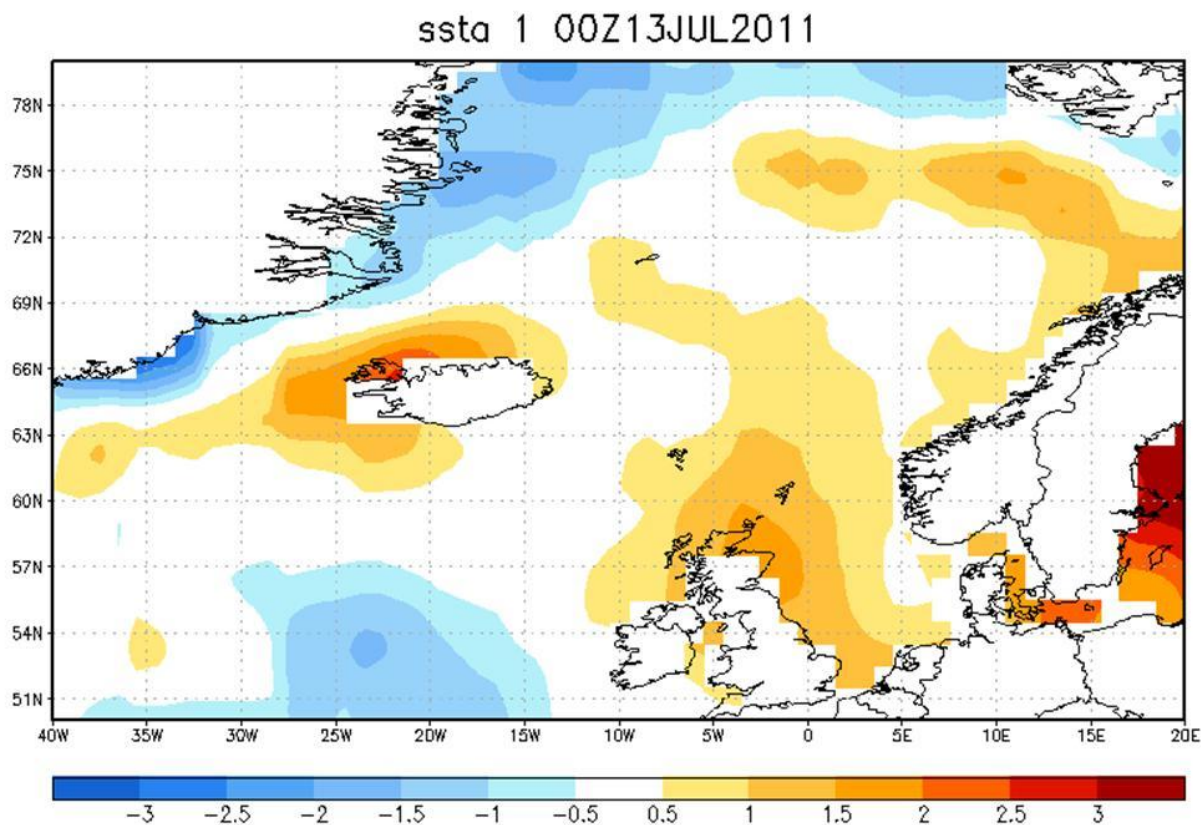


Figure 4. Sea surface temperature anomalies (°C; centered in week 28, mid July 2011) showing warm and cold conditions in comparison to a 20 year average.

The temperature at depth based on CTD measurements from the four participating vessels is shown in Figures 5 - 10. The temperature in the upper layers (10m and 20m) shows warm water of Atlantic origin covering most of the survey area. The temperature was highest southwest of Iceland where it reached 13°C, and in the southeastern Norwegian Sea where it was 12°C. The front between the cold East Iceland Current (EIC) and the warmer Atlantic water (the Iceland-Faroe Front, IFF) which usually is located in the south western Norwegian Sea, was clearly visible in these layers. The warm Atlantic water extended north beyond the 70 degrees in the eastern Norwegian Sea, as well as north of Iceland. North/northwest of Iceland the temperature was lower and reaching 4°C. The temperature distribution at 50m depth was similar as the surface layers but with cooler water, especially in the south-western Norwegian Sea, where the cold EIC and features like the IFF was clearly detected. In deeper layers below 100m the same main features were detected as described for 50m depth. South and west of Iceland, warm Atlantic water dominated the entire water column with temperature of 7-9°C at 400m depth. In the eastern Norwegian Sea warm Atlantic water was also detected down to 400m depth.

The appearance of the IFF in the upper layers indicates less stratification in the surface waters in summer 2012 compared to 2011, and also weaker thermocline between 20 and 50 m depths. It seems as the surface waters in the southern Norwegian were (more than one degree) cooler in 2012 than in 2011, most likely due to the persistent north-easterly winds during most of the spring and summer. This was also observed in the IESNS survey in May 2012 in the same area (ICES 2012). The surface waters southwest of Iceland seemed to be warmer in 2012, however, this difference disappeared at depths below 50-100m. In waters deeper than 100m the influence of the EIC is more pronounced and extends further south into Faroese and especially east into Norwegian waters. This can clearly be seen at 400m depth, where the eastern extension of the EIC reaches the Norwegian coast at 63°N (Fig. 10).

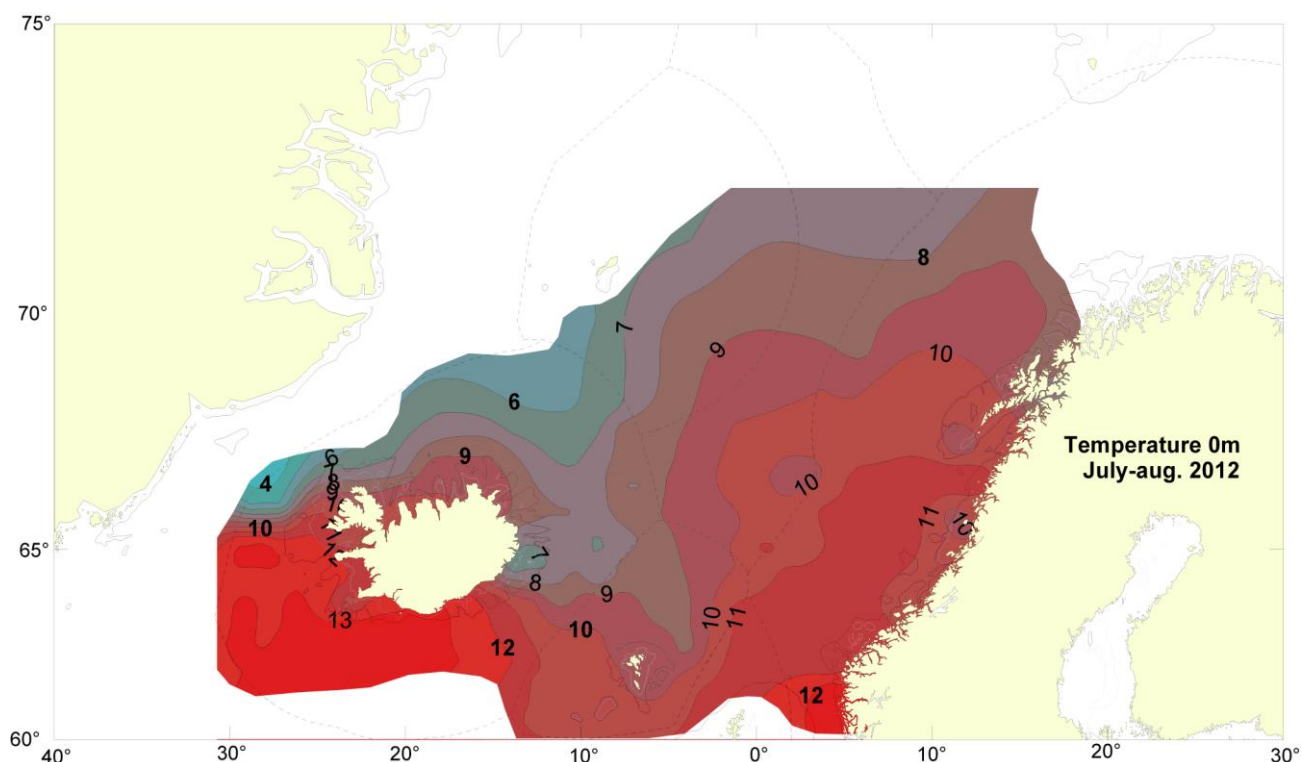


Figure 5. Temperature (°C) at 10 m depth in the Norwegian Sea and surrounding waters in July/August 2012.

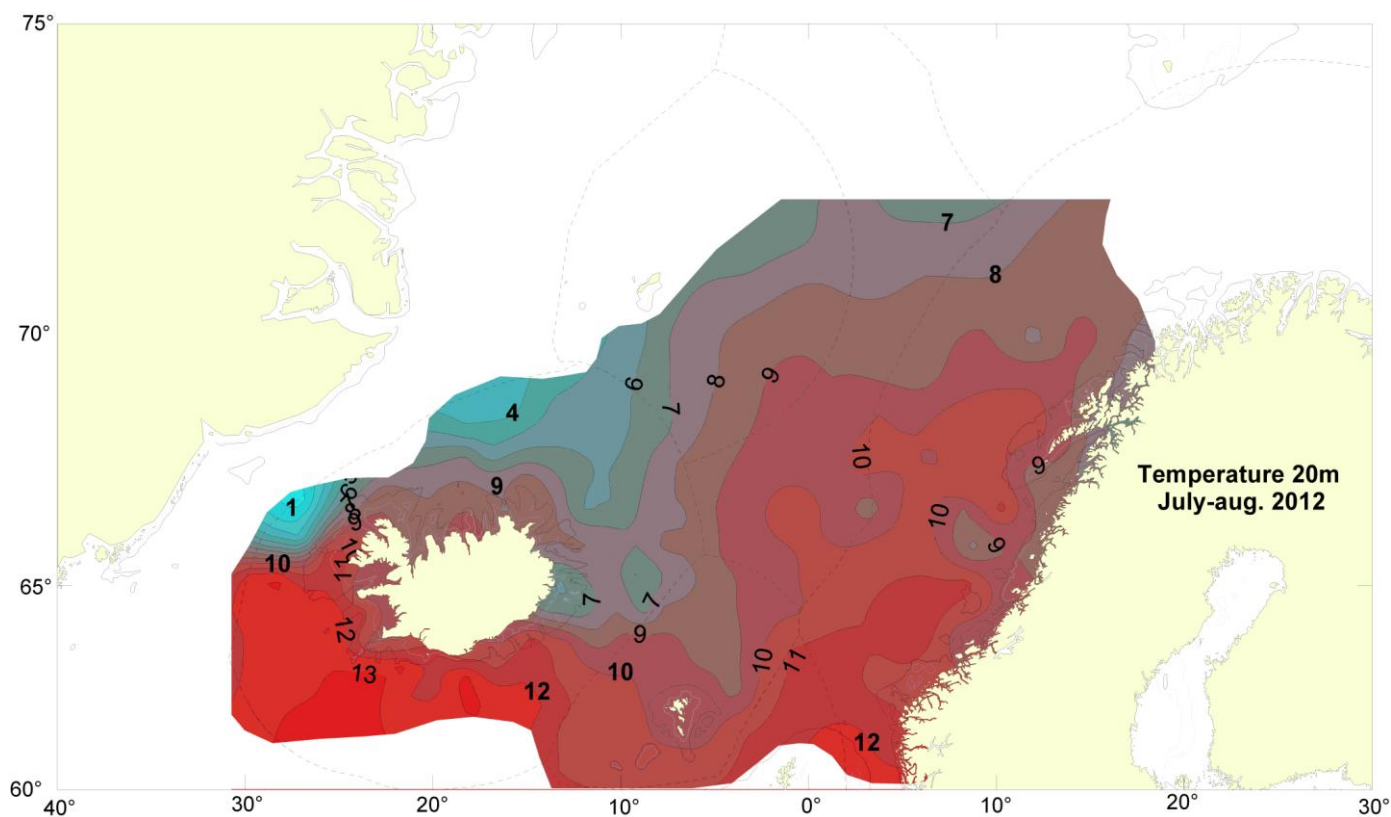


Figure 6. Temperature (°C) at 20 m depth in the Norwegian Sea and surrounding waters in July/August 2012.

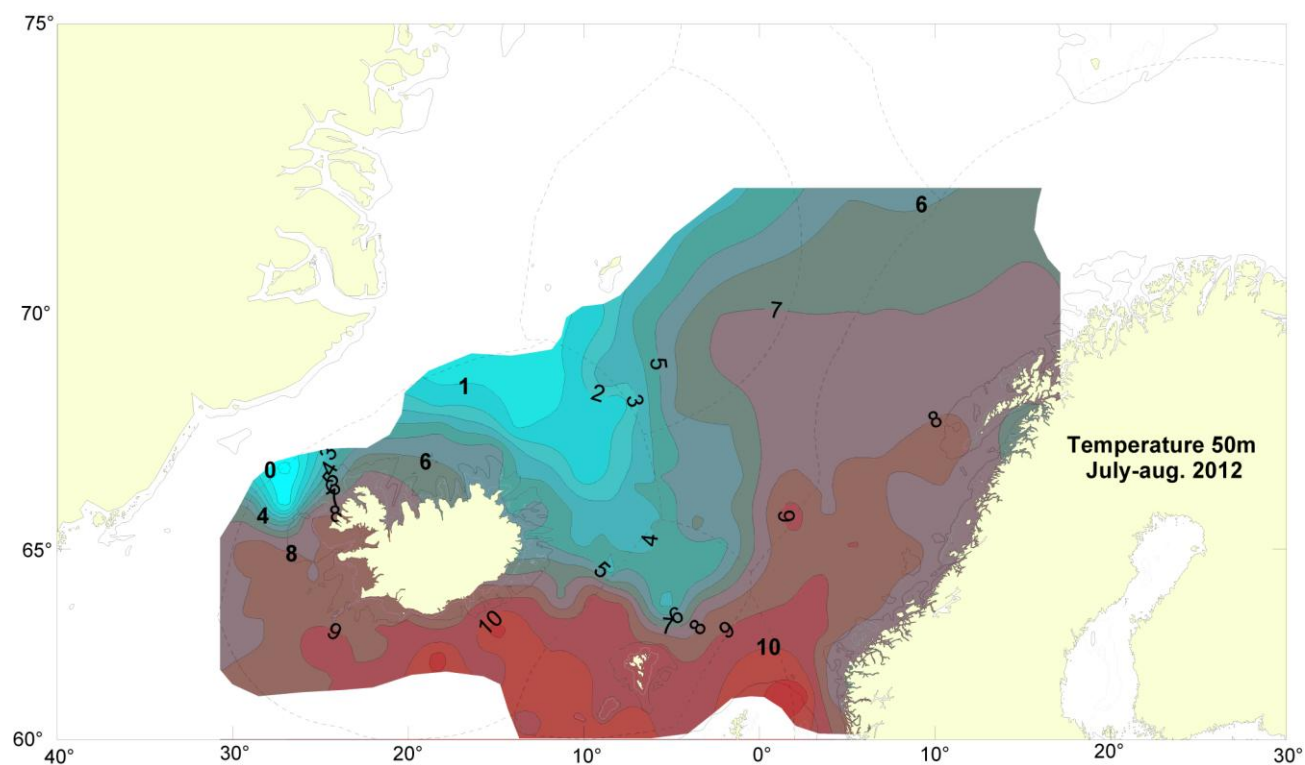


Figure 7. Temperature (°C) at 50 m depth in the Norwegian Sea and surrounding waters in July/August 2012.

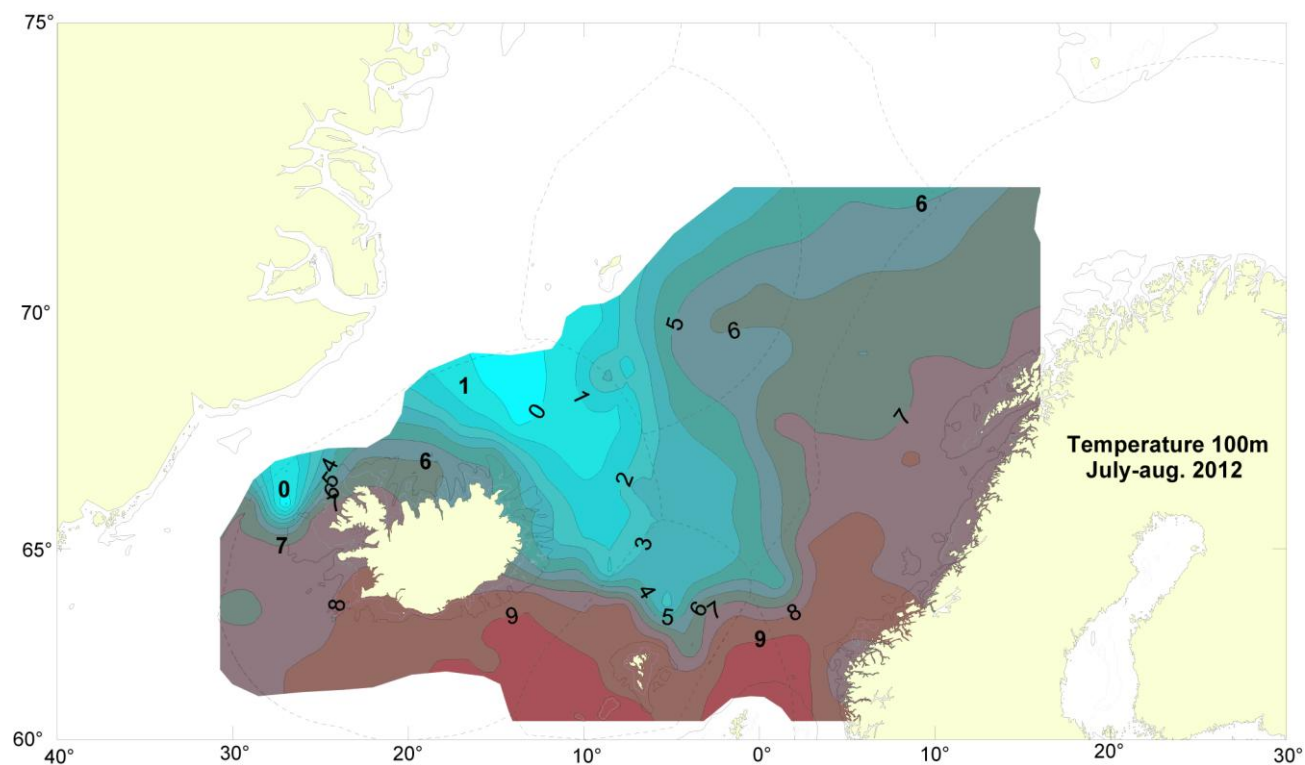


Figure 8. Temperature (°C) at 100 m depth in the Norwegian Sea and surrounding waters in July/August 2012.

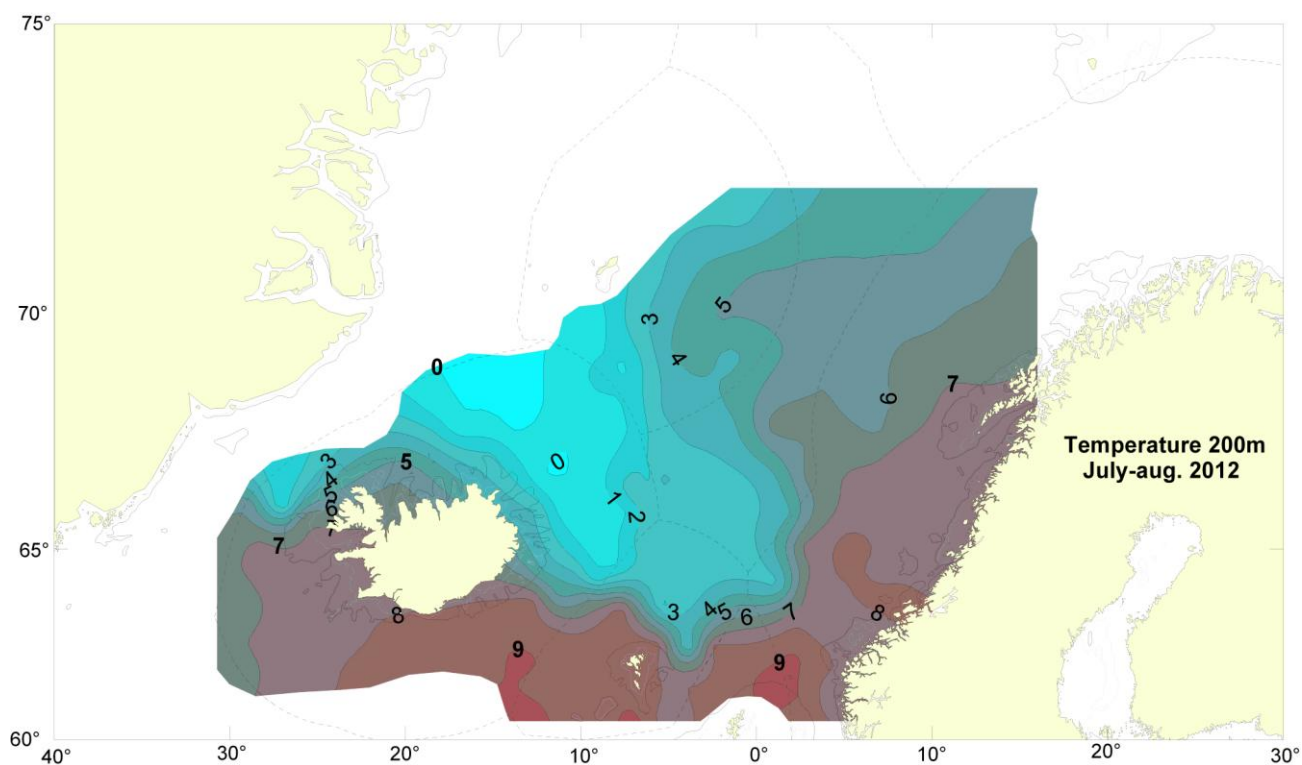


Figure 9. Temperature (°C) at 200 m depth in the Norwegian Sea and surrounding waters in July/August 2012.

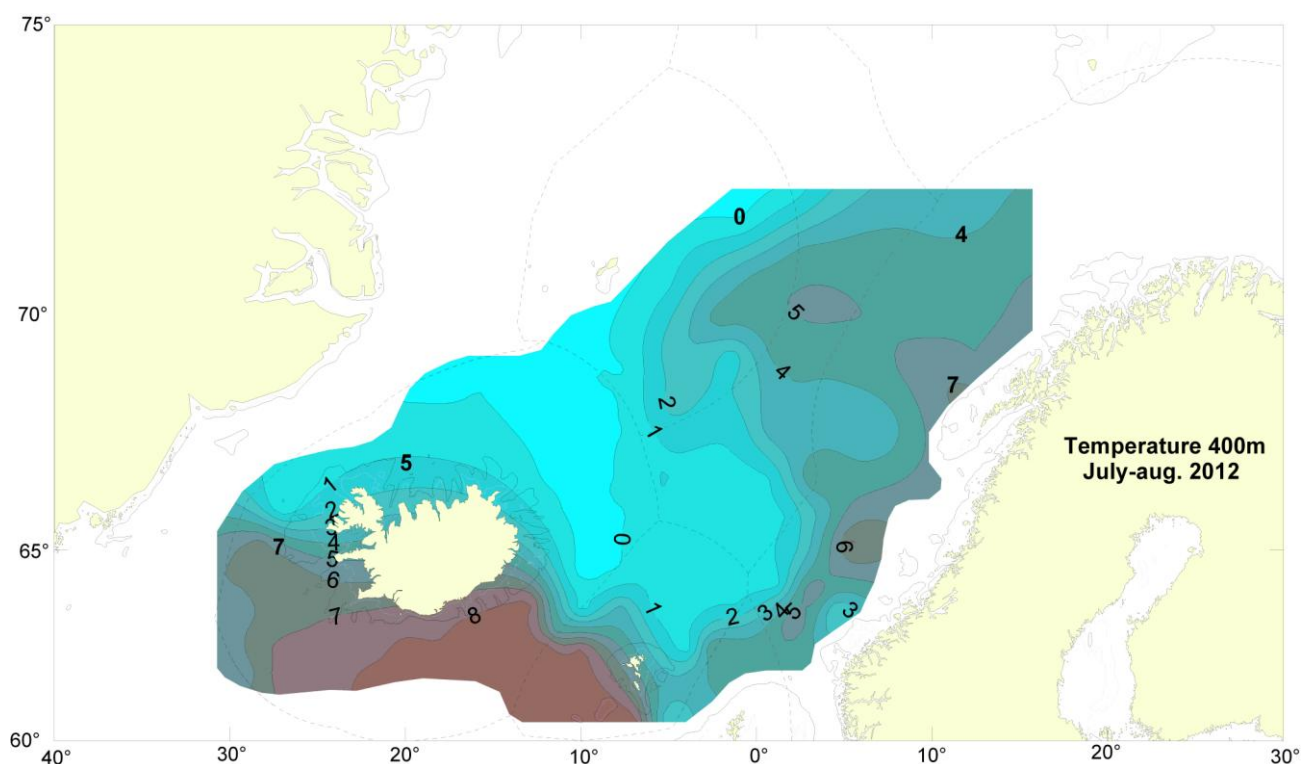


Figure 10. Temperature (°C) at 400 m depth in the Norwegian Sea and surrounding waters in July/August 2012.

Zooplankton

The zooplankton biomass was generally low with an average plankton biomass of 6.0 g/m² over all stations throughout the survey area (see Figure 11). The plankton concentrations were lowest in the central Norwegian Sea (Fig. 11). This is a comparable pattern that was observed during the 2011 surveys. The biomass was slightly higher in the south western Norwegian Sea and west of Iceland in the frontal area between the warm Atlantic water and the colder Arctic water. The zooplankton samples for species identification have not been examined in detail, but the general impression was that Chaetognatha partly dominated the samples in the central Norwegian Sea with some concentrations of Gastropoda along the shelf and shelf break. *Calanus finmarchicus* was generally found in small concentrations in the western survey area, while *Calanus hyperboreus* was sampled in the northern and northwestern part of the Norwegian Sea. Krill and amphipods were found in small quantities in most areas except in the westernmost areas. In the central and eastern part of the Norwegian Sea we detected more phaeocystis (phytoplankton flagellates) in the WP 2 net samples compared to previous years.

The low biomass of zooplankton is in agreement with the decreasing trend that has been observed in the zooplankton biomass in the Norwegian Sea in the May survey for more than a decade (ICES 2011). In May 2012 the plankton concentrations were 4.7 g/m² west of 2°W and 6.7 g/m² east of 2°W (ICES 2012)

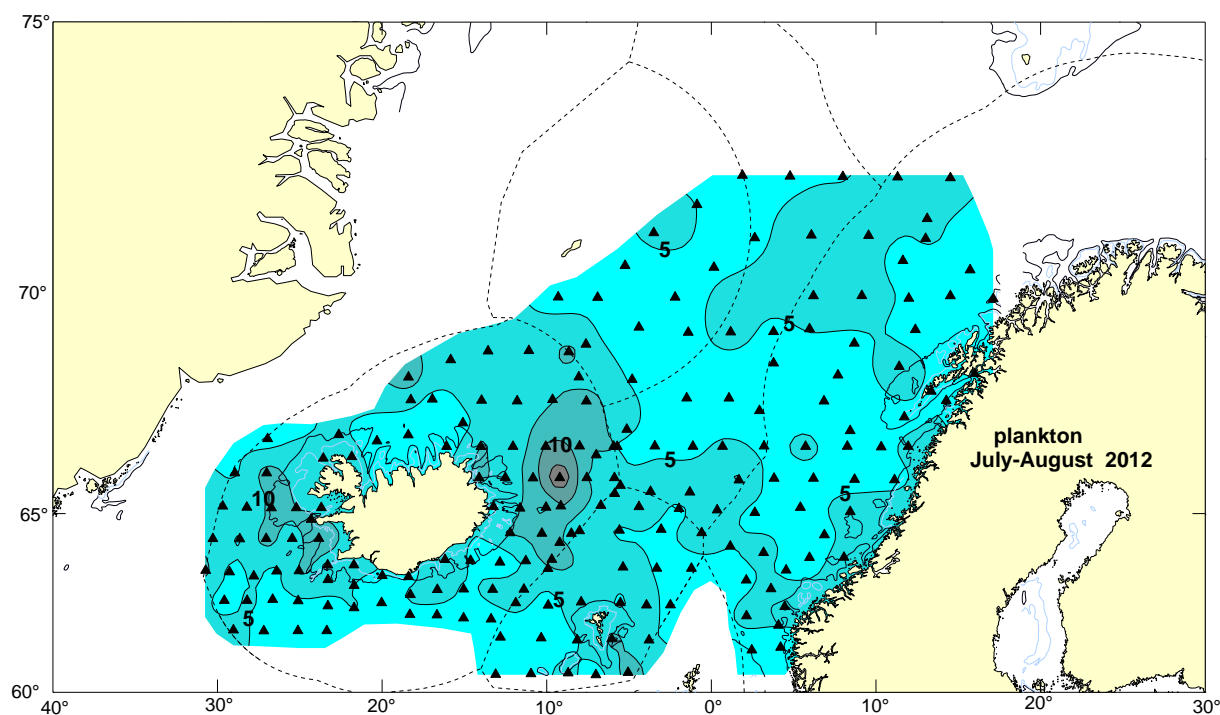


Figure 11. Zooplankton biomass (g dw/m², 0-200 m) in the Norwegian Sea and surrounding waters, 2 July - 10 August 2012. (The Icelandic plankton data in the southern and western area will very soon be available!)

Pelagic fish species

Mackerel

The total mackerel catches (kg) taken during the joint ecosystem survey is presented in standardized rectangles in Figure 12. The map is showing different concentrations of mackerel from zero catch to more than 500 kg.

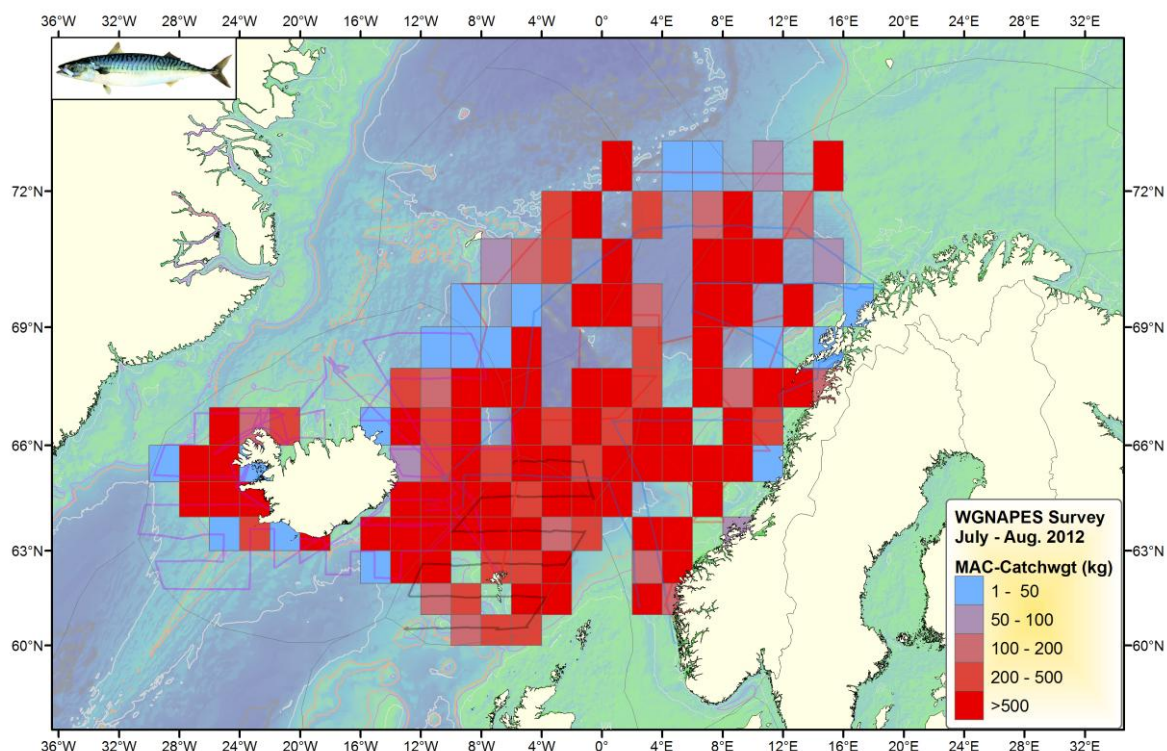


Figure 12. Catches of mackerel in kg represented in standardized rectangles. Light blue represents small catches (1–50 kg), while dark red represents catches of more than 500 kg mackerel. Vessel tracks are shown as continuous lines.

The mackerel catch rates (kg/nmi) from pelagic trawling onboard Brennholm, G.O. Sars, Christian í Grótinum and Arni Fridriksson from 2 July to 10 August 2012 are shown in Figure 13.

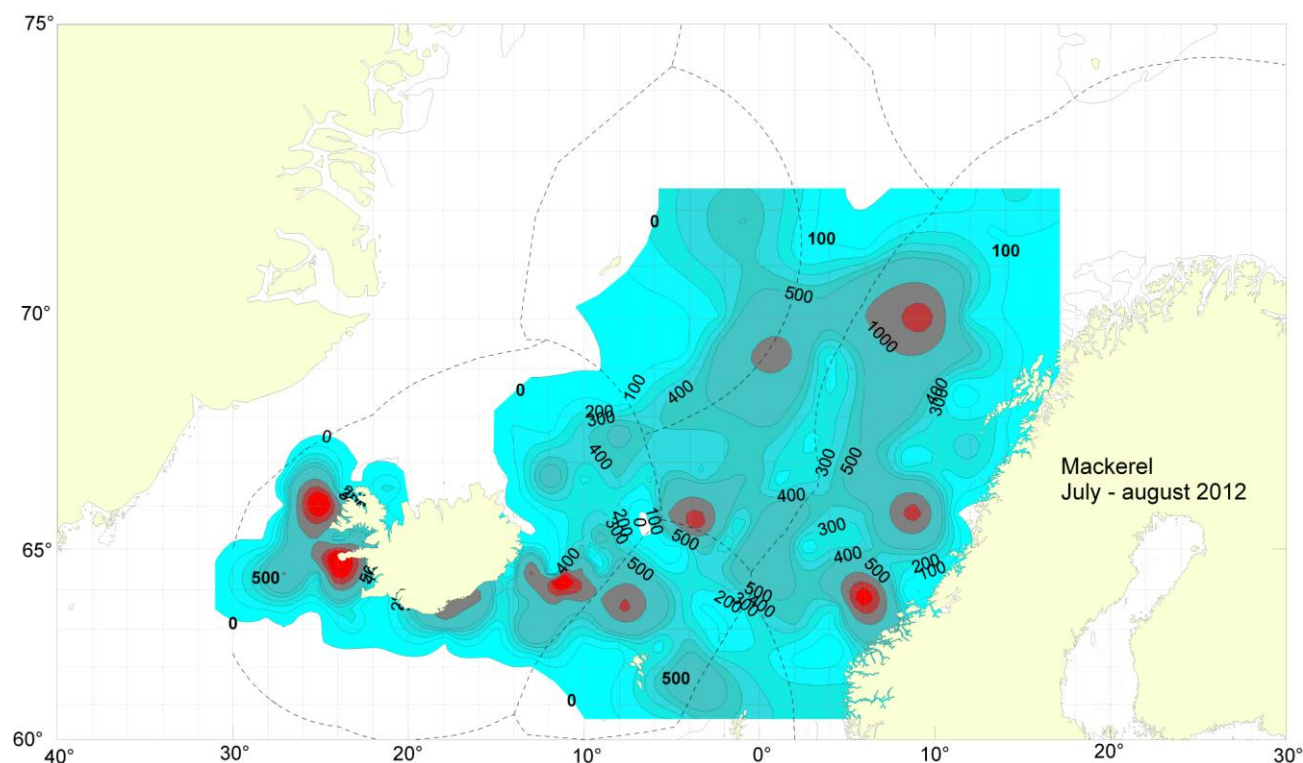


Figure 13. A contour plot of mackerel catch rates (kg/nmi) in July/August 2012.

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 2012 (Figure 14).

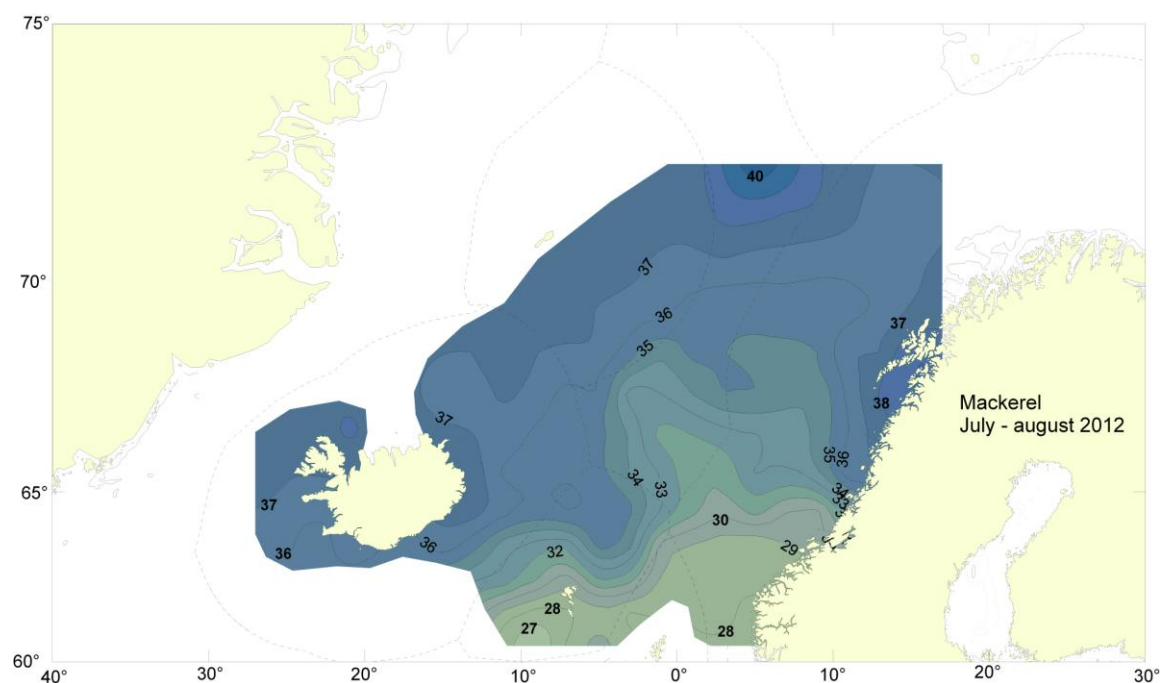


Figure 14. Average length distribution of NEA mackerel from the joint ecosystem survey with R/V “G. O. Sars”, M/V “Brennholm”, M/V “Christian í Grótinum” and R/V “Arni Fridriksson” in the Norwegian Sea and surrounding waters between 1st of July and 10th of August 2012.

Mackerel caught in the pelagic trawl hauls on the four vessels varied from 5 cm to 43 cm in length with the individuals between 33–37 cm dominating in the abundance. The mackerel weight (g) varied between 10 to 760 g (Figure 15).

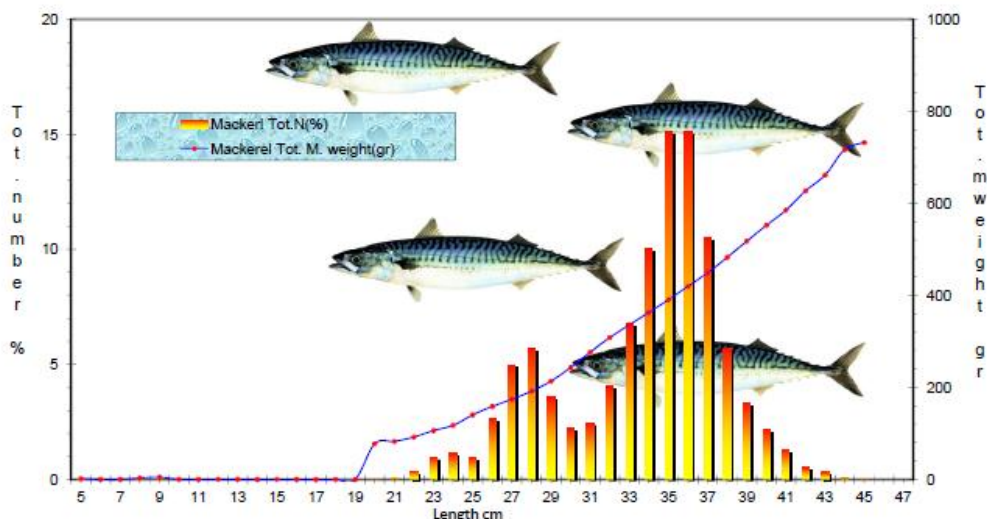


Figure 15. Total length (cm) and weight (g) distribution in percent (%) for mackerel in all catches.

The 2006-year class of mackerel dominated the catches with >20% of the mackerel in numbers, followed by equally strong 2005, 2007 and 2008-year classes around 15% each, respectively (Figure 16). The 2010 year class seems to be very strong, since it was represented with around 12% of the individual mackerel in numbers from the scientific trawl hauls from the Norwegian Sea and surrounding waters.

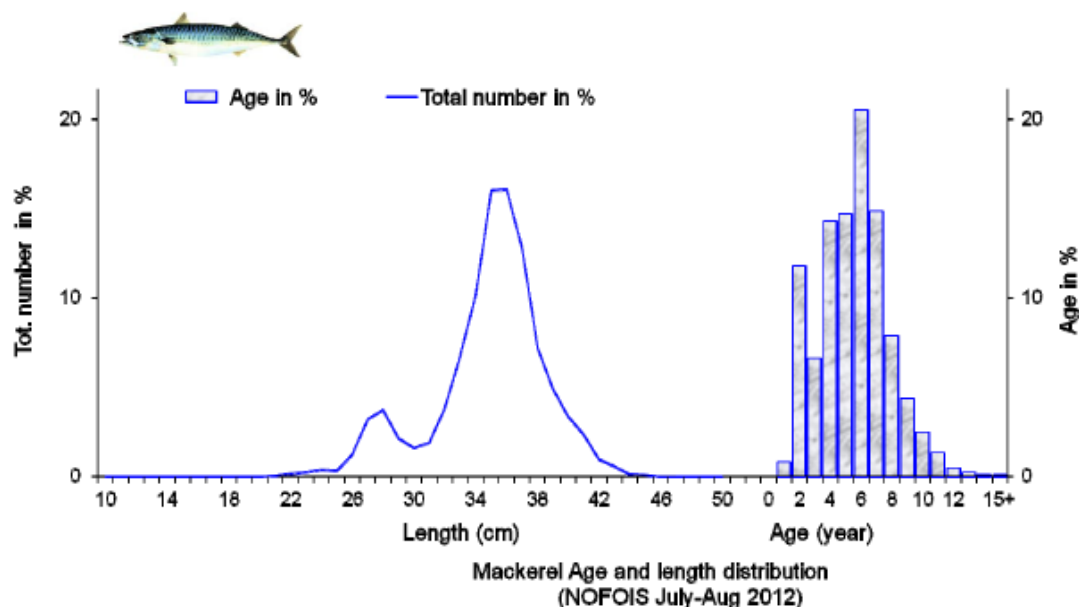


Figure 16. Age and length distribution in percent (%) of Atlantic mackerel in the Norwegian Sea and surrounding waters from 1st of July to 10th of August 2012.

The spatial distribution and overlap between the major pelagic fish species from the joint ecosystem survey in the Nordic Seas are shown in Figure 17.

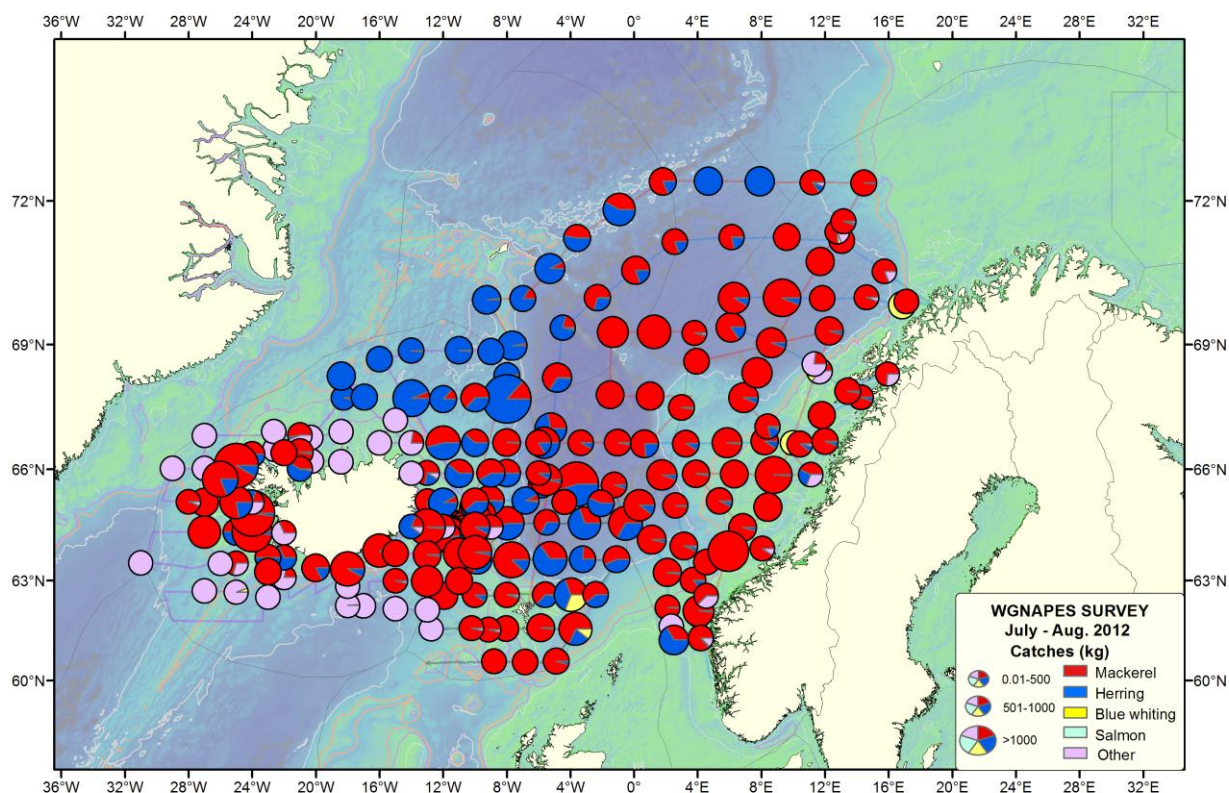


Figure 17. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) from joint ecosystem surveys conducted onboard R/V “G. O. Sars” and M/V “Brennholm” (Norway), M/V “Christian í Gróttinum” (Faroe Islands) and R/V “Arni Fridriksson” (Iceland) in the Norwegian Sea and surrounding waters between 1st of July and 10th of August 2012. Vessel tracks are shown as continuous lines.

Sonar recordings

Along the analyzed transects in the central Norwegian Sea, the schools detected were of medium to small size with generally few detections of each school along the sonar 600 m range. Medium size schools were detected better at longer ranges (between 450 and 200 m) and smaller schools at shorter ranges (10 to 150 m). This detection pattern observed in the sonar together with the detection probability from Lybin and the echo sounder data, allow elaborating the following; medium sized schools is most likely herring located at depths between 20 to 80 m, and are detected with the sonar at larger ranges, being below the sonar beam at shorter ranges. In contrary, the small schools could be mackerel schools located shallower from the surface to 30 m, and are better detected at short ranges because of their low acoustic strength.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass were based on average catches of mackerel within rectangles of 1° latitude and 2° longitude and measurements of horizontal opening of the trawls (Table above), which gave catch indices (kg/km^2 ; Fig. 18). 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 35 (Fig. 19). 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. 19 and in more graphical manners in Fig. 20. Biomass estimates were also done for the different EEZs and the total estimate came to 5.1 million tons (Table 5). The bootstrap of the biomass estimate was only done on rectangles with measured values where the total estimate was 4.354 million tons with $\text{CV}=1.0$, and 95% CI of 3.670 and 5.080.

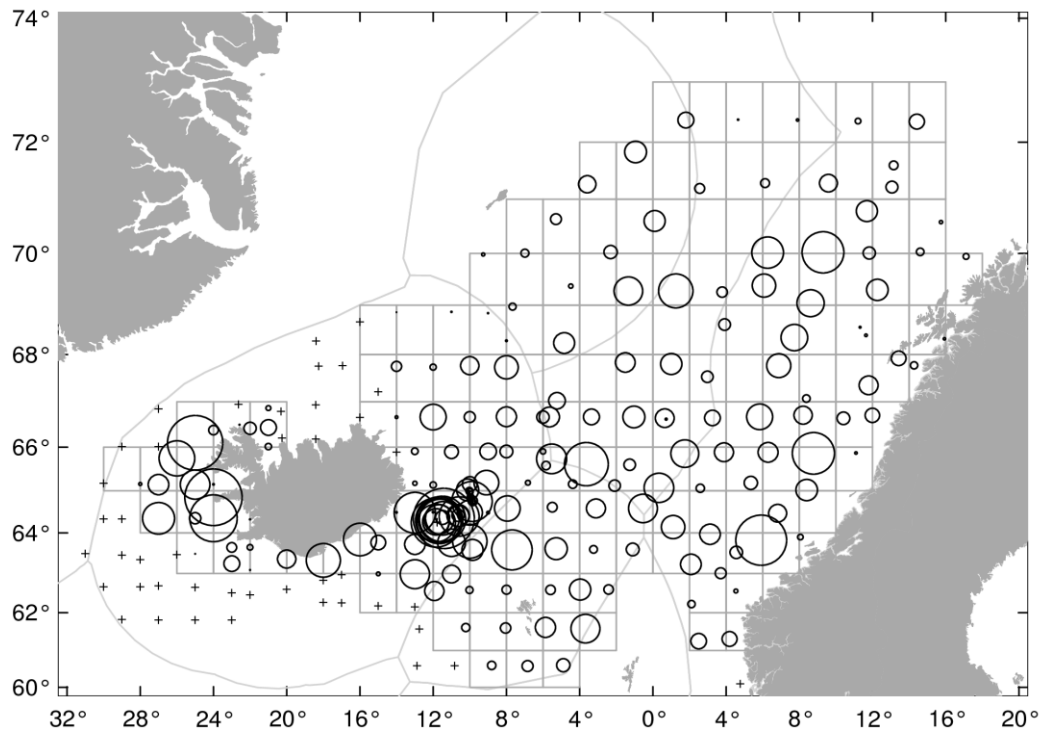


Figure 18. Stations and catches of mackerel in July/August 2012 where the circles size is proportional to square root of catch (kg/km^2) and stations with zero catches are denoted with +.

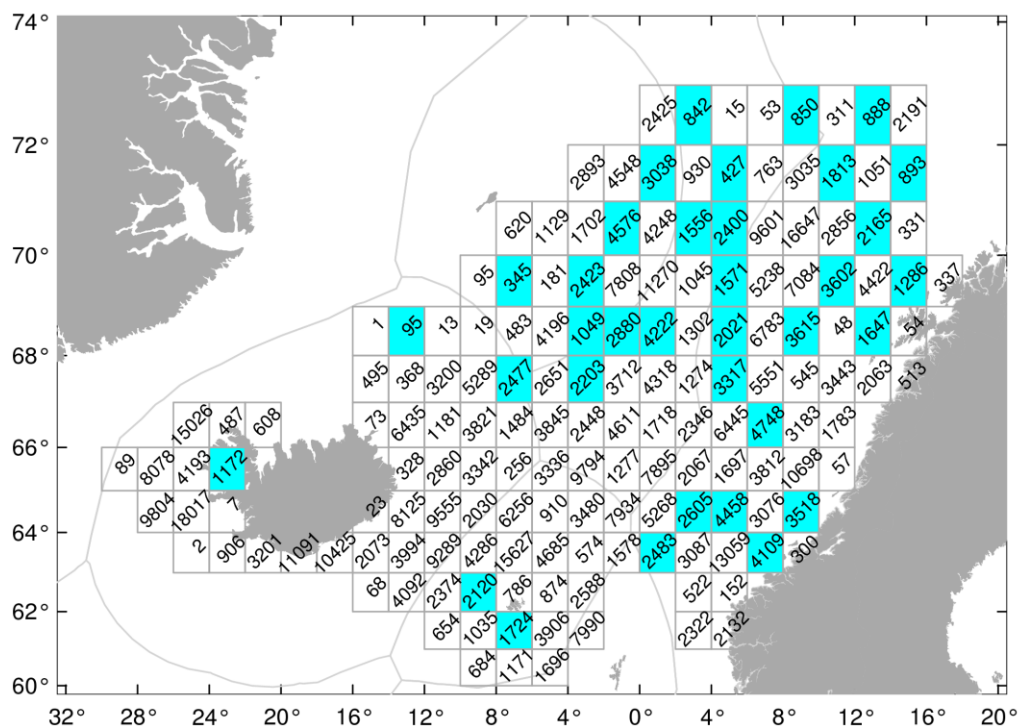


Figure 19. Mean mackerel catch index (kg/km) in 1° lat. by 2° lon. rectangles from swept area estimates in July/August 2012, where interpolated rectangles are denoted with blue shading.

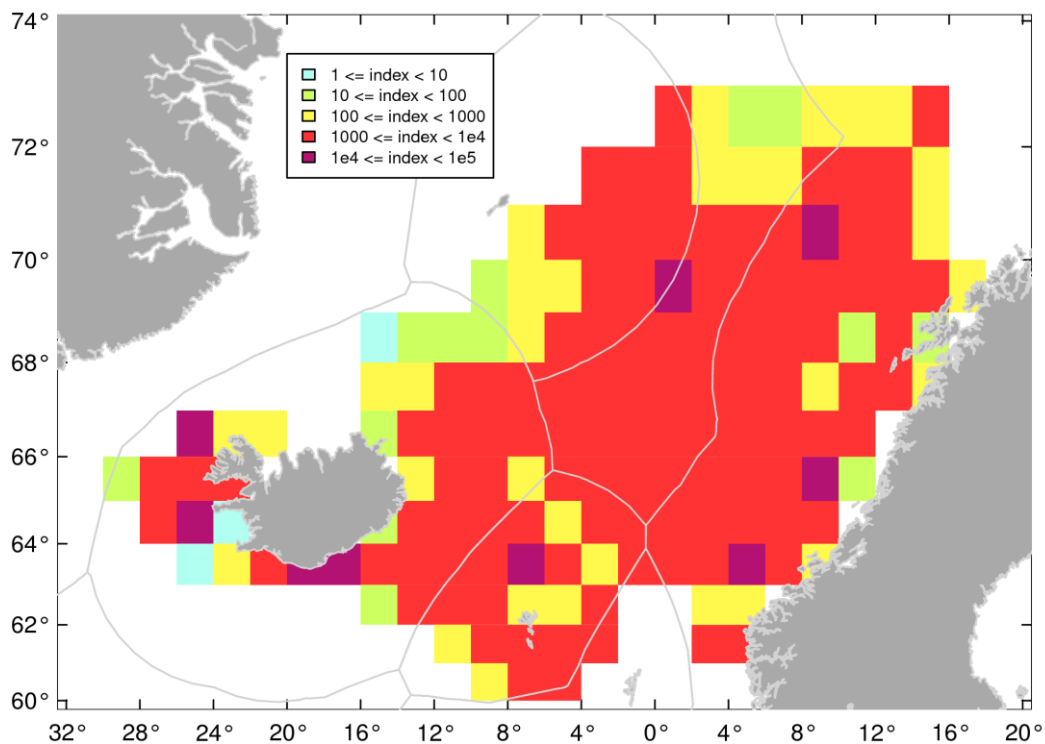


Figure 20. Mean mackerel catch index (kg/km²) for mackerel the July/August 2012 survey represented graphically. Colouring of index levels is the same as in the last IESSNS survey report (ICES 2011).

Table 5. Swept area estimates of NEA mackerel biomass in the different EEZs according to the coordinated ecosystem survey in July–August 2012.

	Area (1000 km ²)	Biomass (1000 tonnes)	Biomass (%)
Total	1528	5079	100
Faroese EEZ	234	746	14.7
Icelandic EEZ	395	1496	29.5
Norwegian EEZ	495	1680	33.1
Jan Mayen EEZ	149	395	7.8
EU EEZ	23	101	2.0
International waters	230	663	13.0

Norwegian Spring-spawning herring

The Norwegian spring-spawning (NSS) herring (*Clupea harengus*) was acoustically recorded and biological samples were taken at all pelagic trawl stations where herring was present in the upper water masses. A biomass estimate was performed on NSS herring based on the acoustic recordings using the primary frequency of 38 kHz. The biomass estimate on NSS herring was 7.3 million tons in July–August 2012.

Norwegian summer spawning herring were also sampled and acoustically monitored along the northeastern part of the Norwegian Sea and in the Vestfjord and Lofoten area in northern Norway, while Icelandic summer spawning herring were sampled in the west, south and southeast of Iceland.

The SA values shows that herring was distributed across the whole survey area except for the middle part of the Norwegian Sea (Figure 21). The concentrations were low in the northern and eastern areas. The highest concentrations were in the southern areas north of the Faroes and in the western part where NSS herring extended all the way to 20°W north of Iceland and around 14°W south of Iceland. West of these locations there were Icelandic summer spawners according to trawl samples. The periphery of the distribution of NSS herring towards north were probably not reached between 20°W and 8°E.

Herring was in the surface waters in most area feeding and possibly above the transducer (acoustic dead zone) and therefore poorly represented in the acoustic measurements. This could be the case for other areas as well where the herring is staying high in the water column actively.

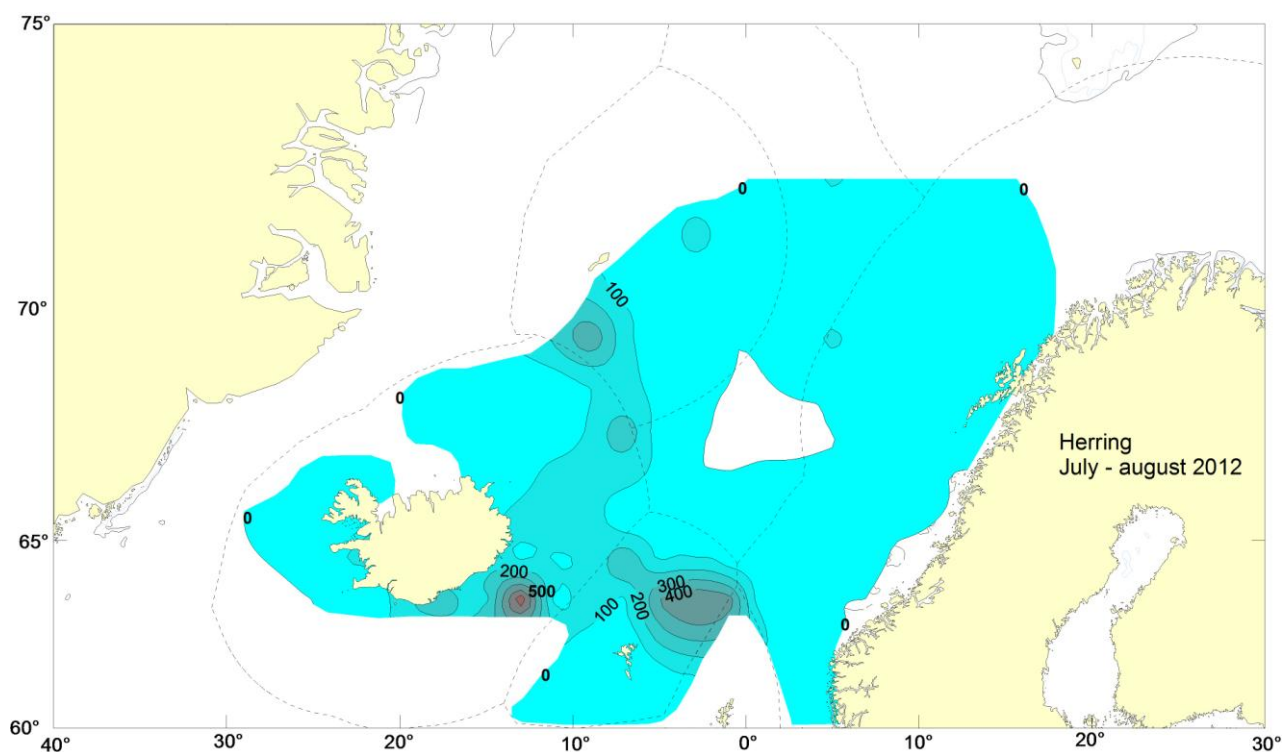


Figure 21. Contours of S_A /Nautical Area Scattering Coefficient (NASC) values of herring along the cruise track, 1 July -10 August 2012. The high density southeast of Iceland was a mixture of NSS and Icelandic summer spawning herring and herring southwest and south of 62°N of the Faroes are local Faroese autumn-spawning herring.

Norwegian spring-spawning herring had a length distribution from 20-38 cm with a peak at 33 cm individual length (Figure 22), and mean weight at age ranging from 60-480 gram (Figure 23). The age distribution in NSS herring shows dominance of the 2004 year class with about 18% in numbers of the acoustic estimate, followed by the 2003 year class (15%) and 2009 year class (13%) (Figure 22).

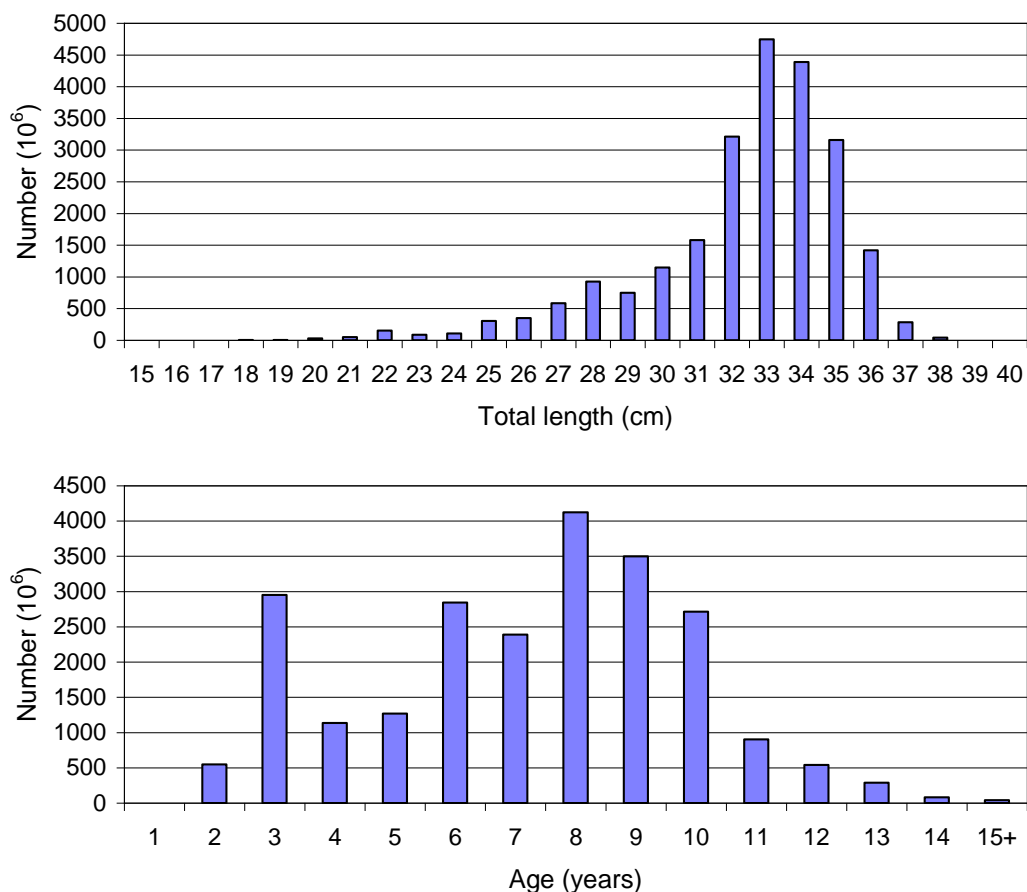


Figure 22. Number at length (upper pannel) and age (lower pannel) of NSS herring according to the acoustic estimate of the stock in July/august 2012.

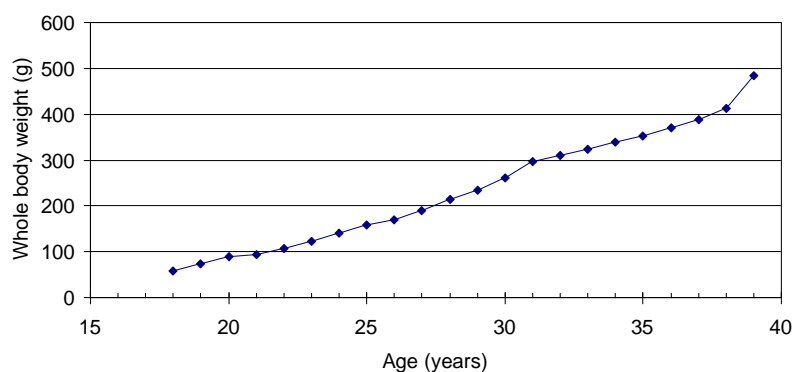


Figure 23. The mean whole body weight (g) of NSS herring in the July/August 2012 survey.

The length distribution measured on herring showed overall a pronounced length dependent migration pattern, with the largest individuals (34 cm) swam furthest west and northwest (Fig. 24). Large herring were also found in the eastern Norwegian Sea, which has been observed the last few years.

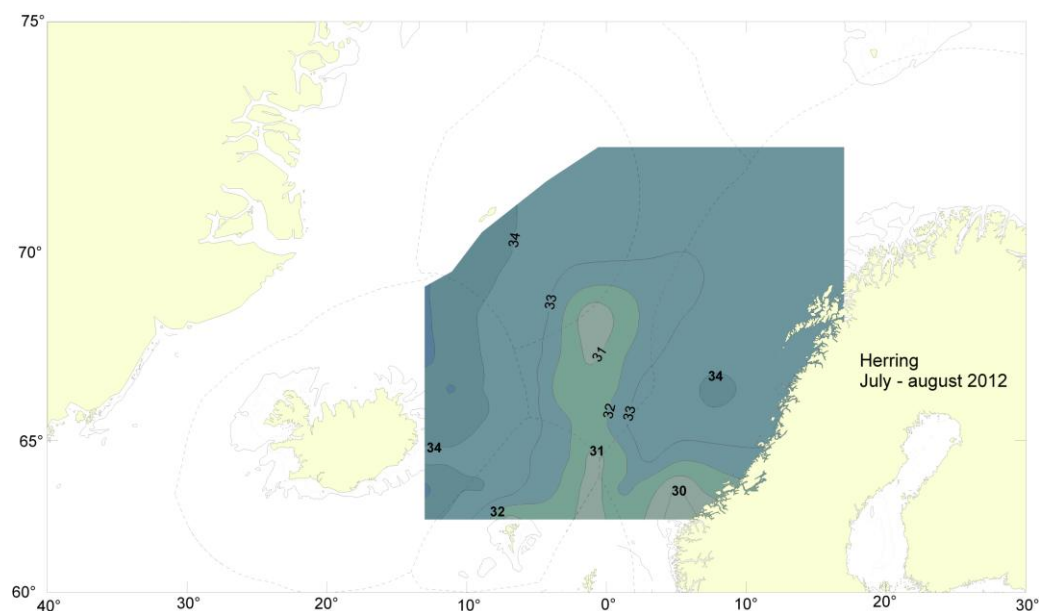


Figure 24. Length distribution of Norwegian spring-spawning herring during the coordinated ecosystem survey 1 July to 12 August 2012.

Blue whiting

Acoustic estimates of blue whiting were used to construct a geographical distribution of the stock (Figure 25). It must be considered that blue whiting was not the main target species in the survey so dedicated trawl samples from schools of blue whiting at greater depths than surface were very few. The total biomass estimate of blue whiting from the acoustic survey was 766 thousand tons, whereas 43% of it was fish at age 1. Of the total number (10.7 billions), 65% were of age 1, 15% age 2 and 11% age 3. These figures of the composition of the stock should though be taken with great cautious due to how sampling effort of blue whiting in the survey.

This survey confirm the presence of immature blue whiting in the feeding areas during summer.

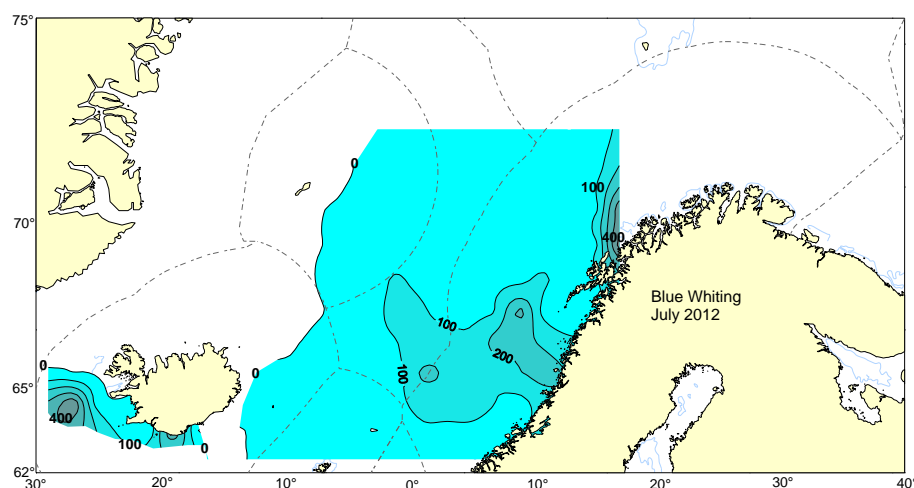


Figure 25. Contours of S_A (Nautical Area Scattering Coefficient) values of blue whiting along the cruise track, 1st of July -10th of August 2012.

Lumpfish

Lumpfish (*Cyclopterus lumpus*) is among the most widely distributed species caught in the IESSNS survey. Swept area estimates indicate highest concentrations of lumpfish near the coastal spawning grounds of Norway and Iceland, yet a widely pelagic distribution of fish is noted (Figure 26). No lumpfish was caught

in the southern most parts of the survey, i.e. south of Iceland and Faroe Island, and the lowest concentrations were in the central part of the Norwegian Sea. Variations in the distance from shore of various length classes could be an indicator of year class distribution or favourable feeding grounds for different life-history stages. A wide range of lumpfish sizes were caught in the surveys (6–54cm) and adults (>25cm) were found throughout the survey area, from coastal to pelagic waters. The widely distribution of the species raises some important management questions which will be addressed with further analyses of the IESSNS lumpfish data and with genetic analysis in the future.

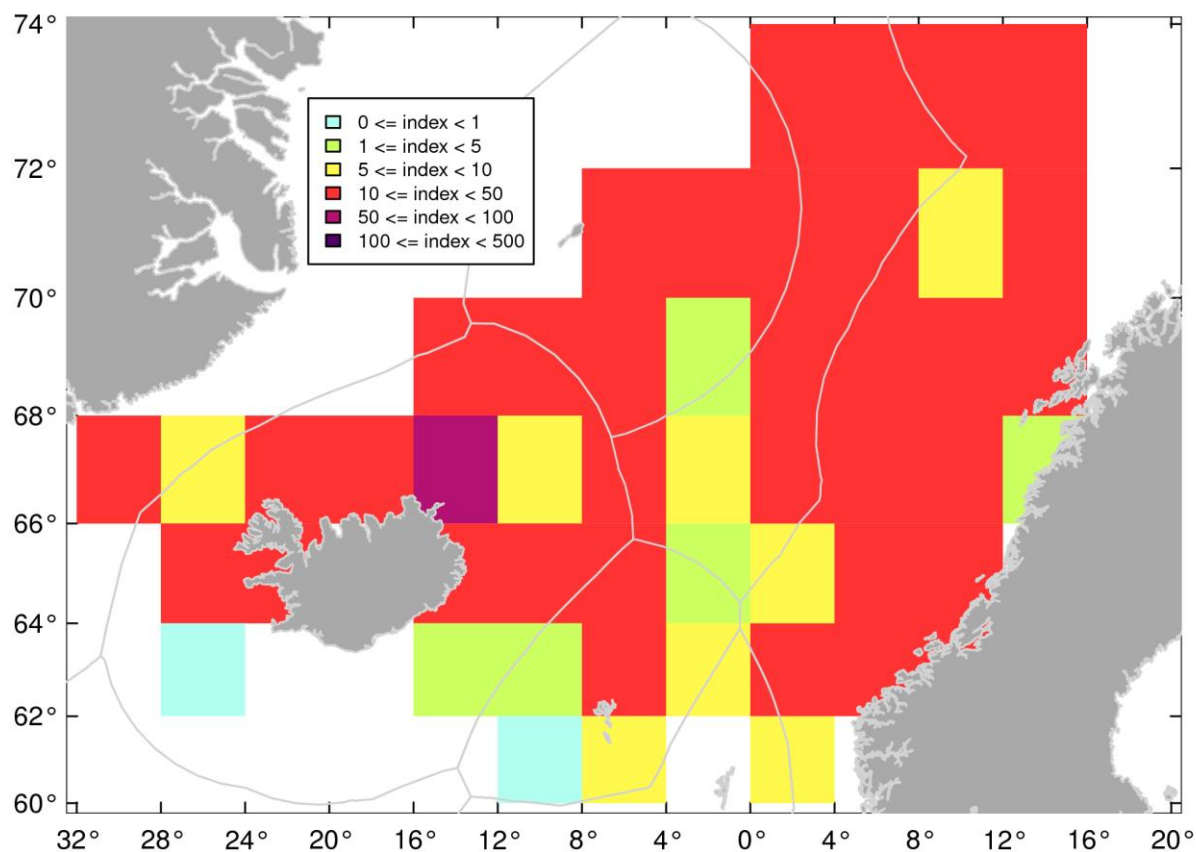


Figure 26. Rectangle average swept area index (kg/km²) for lumpfish in the July/August 2012 survey in 2°latitude and 4° longitude rectangles.

Marine Mammal Observations

The overall impression was that very few marine mammals were sighted onboard R/V “G. O. Sars” and M/V “Brennholm” in the Norwegian Sea and surrounding waters from 2 to 27 July 2012 (Fig. 27). Totally 385 marine mammals and 10 different species were observed. A total number of 119 pilot whales in seven groups were seen in coastal waters, whereas 20 bottlenose whales in six groups were found in the northwestern and western part of the survey area.

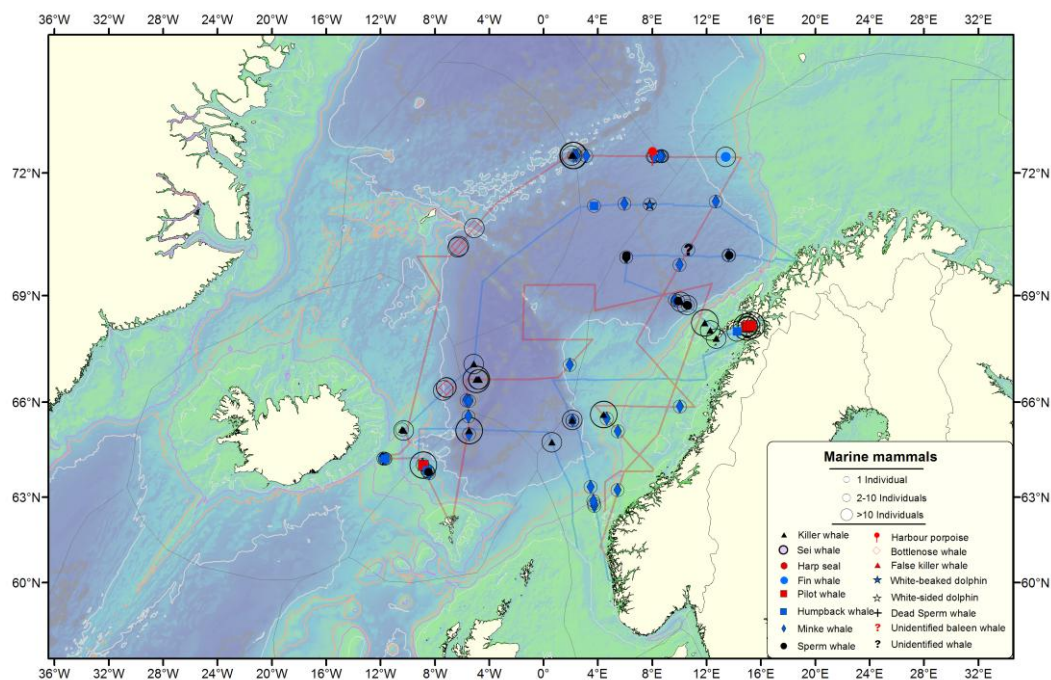


Fig. 27. Overview of all marine mammals sighted onboard R/V “G. O. Sars” and M/V “Brennholm” in the Norwegian Sea and surrounding waters from 2 to 27 July 2012. No marine mammal sightings were done onboard the Icelandic and Faroese vessels.

Extremely few sightings of large baleen whales with on 2 fin whales and 8 humpback whales were sighted during the survey with the two Norwegian vessels (Fig. 28).

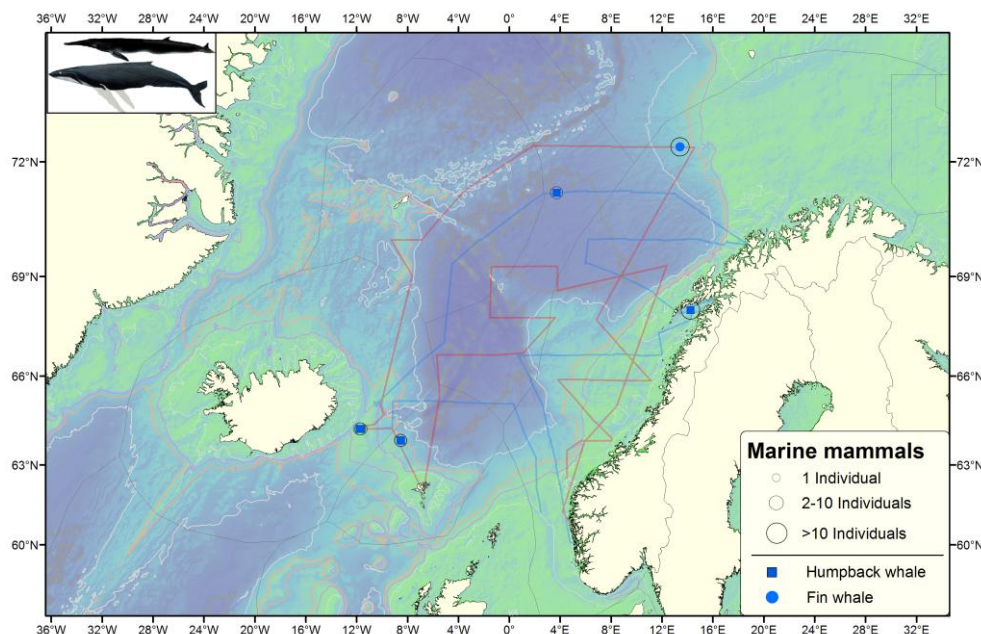


Fig. 28. Sightings of humpback whales and fin whales onboard R/V “G. O. Sars” and M/V “Brennholm” in the Norwegian Sea and surrounding waters from 2 to 27 July 2012.

A total number of 193 killer whales in 21 groups (average pod size = 9.2 ind (± 6.1 SD)) were observed in different areas including the eastern central, western and northern part of the Norwegian Sea (Fig. 29). They were spread out geographically and overlapped spatially predominantly with NEA mackerel present close to the surface.

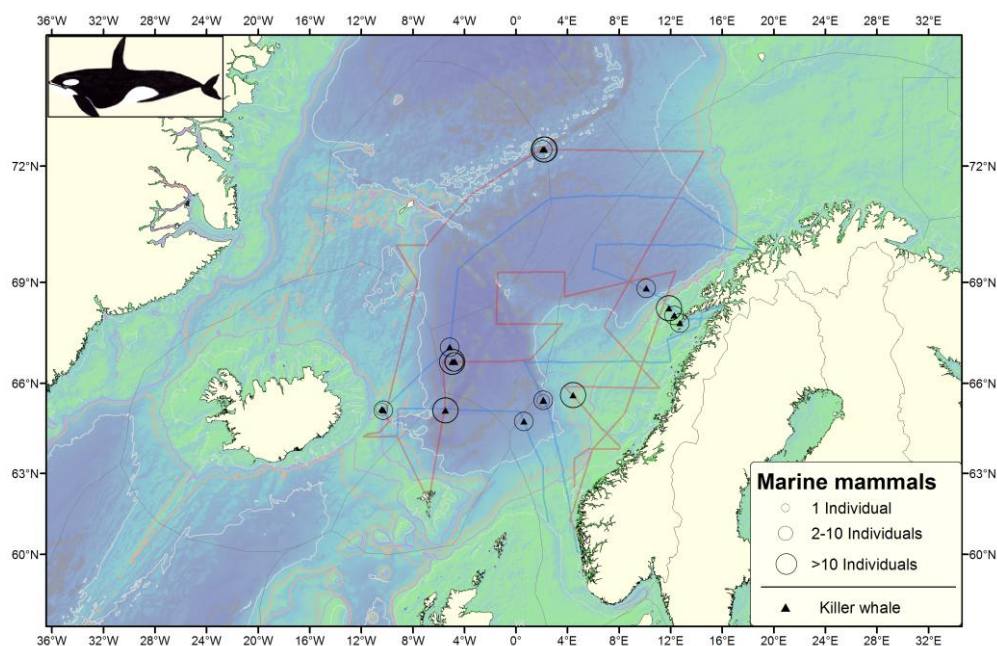


Fig. 29. Sightings of killer whales onboard R/V “G. O. Sars” and M/V “Brennholm” in the Norwegian Sea and surrounding waters from 2nd to 27th of July 2012.

Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 1 July to 12 August 2012 by four vessels from Norway (2), Iceland (1) and Faroese (1). A standardised pelagic trawl swept area method has been developed and used to estimate a swept area abundance estimate of NEA mackerel in the Nordic Seas in recent 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 2012 was 5.1 million tonnes based on a coverage of 1.5 million square kilometres in the Nordic Seas from about 61 degrees up to 70 degrees north and from the Norwegian coast in east and west to the fishery border between Iceland and Greenland. The 2006 year class contributed to more than 20% in number followed by equally strong 2005, 2007 and 2008-year classes around 15% each, respectively. The 2010 year class was very well represented in the catches, or 12% of the total number. The mackerel was distributed in most of the surveyed area, and the zero boundaries were only found in the south-western area in the Faroe zone and in the southern Icelandic zone. In the northern area the zero boundary was not reached.

The geographical coverage and survey effort in 2012 was largely comparable to the survey in 2010, while the coverage in 2011 was less (only three vessels), as it did not cover the northern part of the Norwegian Sea properly. Therefore it is possible to compare the swept area estimates of 4.8 million tonnes in 2010 with the 5.1 million tonnes estimate in 2012. Thus, these estimates indicate that the NEA mackerel remain at a stable level. Both these biomass estimates must be considered to be underestimations and only represent part of the stock north of approximately 62°N.

The overlap between mackerel and NSS herring was highest in the south-western part of the Norwegian Sea (Faroe and east Icelandic area). A high overlap between the species might increase the inter-specific competition between the species for food in the area, especially in a period with low abundance of zooplankton, as observed in recent years. 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.

Acoustic estimation of herring and blue whiting was also done during the survey. The biomass of Norwegian spring-spawning herring was estimated to 7.3 million tonnes. The previous acoustic abundance estimates of NSS herring from the survey were 13.6 million tonnes in 2009 and 10.7 million tonnes in 2010. Thus the trend in the July survey clearly follows the negative trend in the biomass estimates from the assessment. The herring was mainly found in the southern and western parts of the covered area, i.e. from north of the Faroes, the east Icelandic area and north into Jan Mayen area, with less concentration in the central and eastern areas.

This survey confirmed the presence of young blue whiting (ages 1-3) in the summer feeding areas. The concentrations were highest in the eastern Norwegian Sea and in the area south and southwest of Iceland.

The temperatures in the Nordic Seas in 2012 are still well above long-term average. Especially in the area west of Iceland and in the Irminger Sea the surface temperatures were up to three degrees higher than the long-term average. However, the south-western Norwegian Sea seems a bit cooler in 2012 compared to the last two years.

The concentrations of zooplankton are still at a low level compared to historic values.

Whale observations were done by the two Norwegian vessels during the survey. The number of sightings was very low as compared previous years, especially for large baleen whales such as fin and humpback whales. Systematic observations of marine mammals onboard all the vessels is encouraged as they can provide important ecological information.

One of the main aims of this joint survey is to map the distribution and estimate abundance of NEA mackerel, NSS herring and blue whiting in the Norwegian Sea and surrounding waters. This goal was partly achieved as there are areas outside of the covered area where mackerel can be expected to feed during this period, e.g. in the eastern part of the Greenlandic EEZ where a mackerel fishery was ongoing. Ideally we should strive to reach beyond the distribution of all target species in all directions. In order to reach this goal and to obtain a more holistic and comprehensive understanding of mackerel abundance and distribution, participation by EU and Greenland is encouraged.

The shallow distribution and absence of dense schooling behaviour in both mackerel and herring within most of the study area in July–August, makes the quantitative estimation of especially mackerel and herring challenging. Based on multibeam sonar and visual observations, concentrations of these species occurred above and close to the transducer depth and would therefore not be detected by the downward oriented echosounders. Furthermore, vessel avoidance during summer feeding may complicate these studies even further. Nevertheless, we are steadily progressing in this area of science, and recommend the further use of acoustics (echosounders and sonars) for the coordinated ecosystem survey in the years to come (see Nøttestad and Jacobsen 2009 and Nøttestad et al. 2010; Nøttestad et al. 2011).

Information on stomach content of the three main pelagic species (mackerel, herring and blue whiting), combined with concurrent information on zooplankton and the hydrographical conditions are of paramount importance for a more thorough and detailed understanding of the feeding ecology, potential inter-specific feeding competition, spatiotemporal overlap and migration patterns of mackerel, herring and blue whiting in the Norwegian Sea and surrounding waters. Although only parts of these data are currently available at the different institutes, they might prove very valuable in the future. We therefore recommend continuing systematic sampling and diet analyses on the coordinated ecosystem surveys.

The survey period extended for about six weeks from 1st July to 10th August in 2012. Due to the fact that the mackerel is a highly migratory species, the different countries should strive to minimize the total period spent at the joint ecosystem survey to maximum five weeks, in order to obtain as good and robust data on mackerel abundance and distribution as possible. The group agreed that the period from 7th of July to 15th of August was suitable as the maximum time window in the future. The distance between each trawl station should be around 50–60 nm by all countries in order to obtain comparable and representative samples, be able to cover extensive areas and reach the zero lines for selected target species. It would also be beneficial to standardize the survey design in the direction of performing predominantly east-west courses, in order to enable comparison between vessels and optimise coverage in relation to vessel effort.

In order to be able to use the results from the different vessels in a combined swept area estimate, it is necessary to calibrate the acoustic equipment and the pelagic trawl catch efficiency among the different vessels. This inter-calibration was done during two days of the survey in a pre-agreed area. The newly designed pelagic sampling trawl (Mulpelt 832) was used by all vessels, and seven inter-calibration hauls were performed with the four vessels during this exercise (Appendix 1). The ultimate goal to use this combined swept area estimate as an abundance index in the assessment of NEA mackerel, will require allocation of survey time dedicated for inter-calibration between the participating vessels in future surveys.

Recommendations

General recommendations

- Participation by EU in the survey is recommended and encouraged by the group in order to be able to expand the survey coverage to cover the entire distribution of the stock and thereby obtain a more holistic and comprehensive understanding of mackerel abundance and distribution.

To the participants in the survey

- Inter-calibration of the pelagic trawl catch efficiency and acoustic equipment should be performed each year and sufficient time should be allocated for each vessel on this vital task in order to be able to use the results in a combined swept area estimate.
- Specific recommendations to the trawling operation are given in Appendix 1.
- The transects should in general be spaced with a distance of around 50-60 nmi between them in east-west direction. When working in coastal waters some compromise needs to be done in some areas with perpendicular north-south transects to the coast.
- Next year's survey should preferably take place within a five weeks period from 7th of July to 15th of August.
- In order to have as good information as possible about the summer distribution of the NEA mackerel survey transects should be extended to reach beyond the distribution; in western, northern, eastern and southern areas.
- When the time frame and duration of the various national surveys has been decided a meeting, e.g. video-conference meeting, should be organised at which a general survey and inter-calibration plan for all participating vessels should be drawn up.
- Standardization of software used for scrutinizing would be an improvement and LSSS is recommended for this purpose.
- It is recommended that the number of fish taken to biological measurements and determination should be standardized in the survey, or as follows for mackerel, herring, blue whiting and capelin: Length and weight measurements 100; Ageing 25; Stomach sampling 10.
- Work on scientific manuscript intended for publication in high standard journal and based on data from the inter-calibration during the IESSNS 2012 survey should be initiated as soon as possible in order to strengthen and improve the scientific background and recognition of the survey.
- Systematic observations of marine mammals should be done onboard the vessels during the survey as they can provide important information in ecological context.

Survey participants

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Appendix 1

Intercalibration of the Multpelt 832 pelagic trawl between four vessels

During the ecosystem survey in July 2012, seven pairwise pelagic trawl comparison hauls at the surface were conducted between the four vessels: the research vessels G. O. Sars and Arni Fridriksson, and the commercial vessels Christian í Grótinum and Brennholm (Appendix 2). Catch differences were in favour of the commercial vessels (Table 1) and there were statistically significant differences in mackerel (t-test, $p < 0.05$) and herring (t-test, $p < 0.05$) catches between the two groups (commercial vessels versus. research vessels). For the t-test for herring, a square root transformation of the catches was performed to conform with the assumption of normality in the data. The vessels used the same type of trawl (Multpelt 832), made by different producers (Vónin, Egersund Trawl and Tornet).

Table 1. Total and average catches (kg) of Herring and Mackerel for the four vessels for all seven hauls.

Vessel	Herring (kg)		Mackerel (kg)	
	Total	Mean	Total	Mean
G. O. Sars	5151	736	3529	504
Arni Fridriksson	3509	502	6907	986
Brennholm	8372	1196	13840	1977
Christian í Grótinum	9070	1295	15097	2156

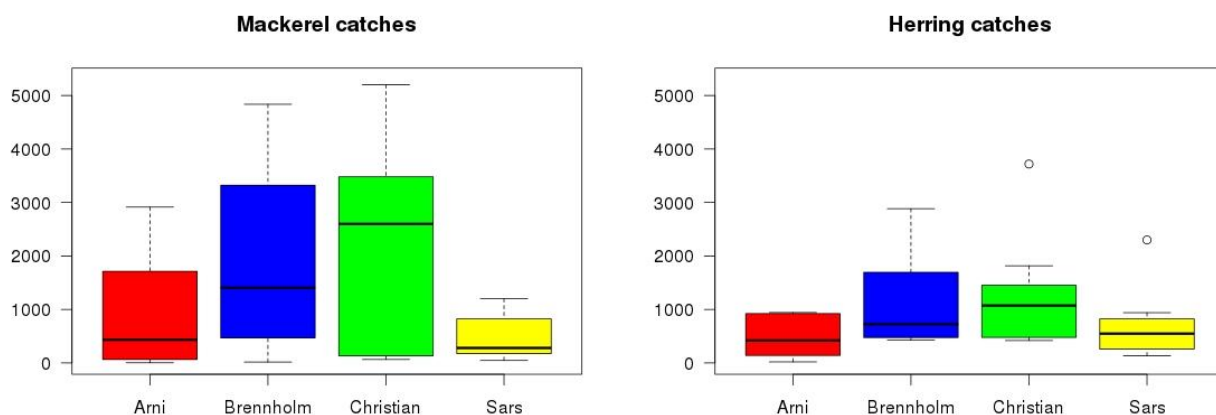


Figure 1. Boxplot of herring and mackerel catches (kg) for Arni Fridriksson, Brennholm, Christian í Grótinum and G. O. Sars.

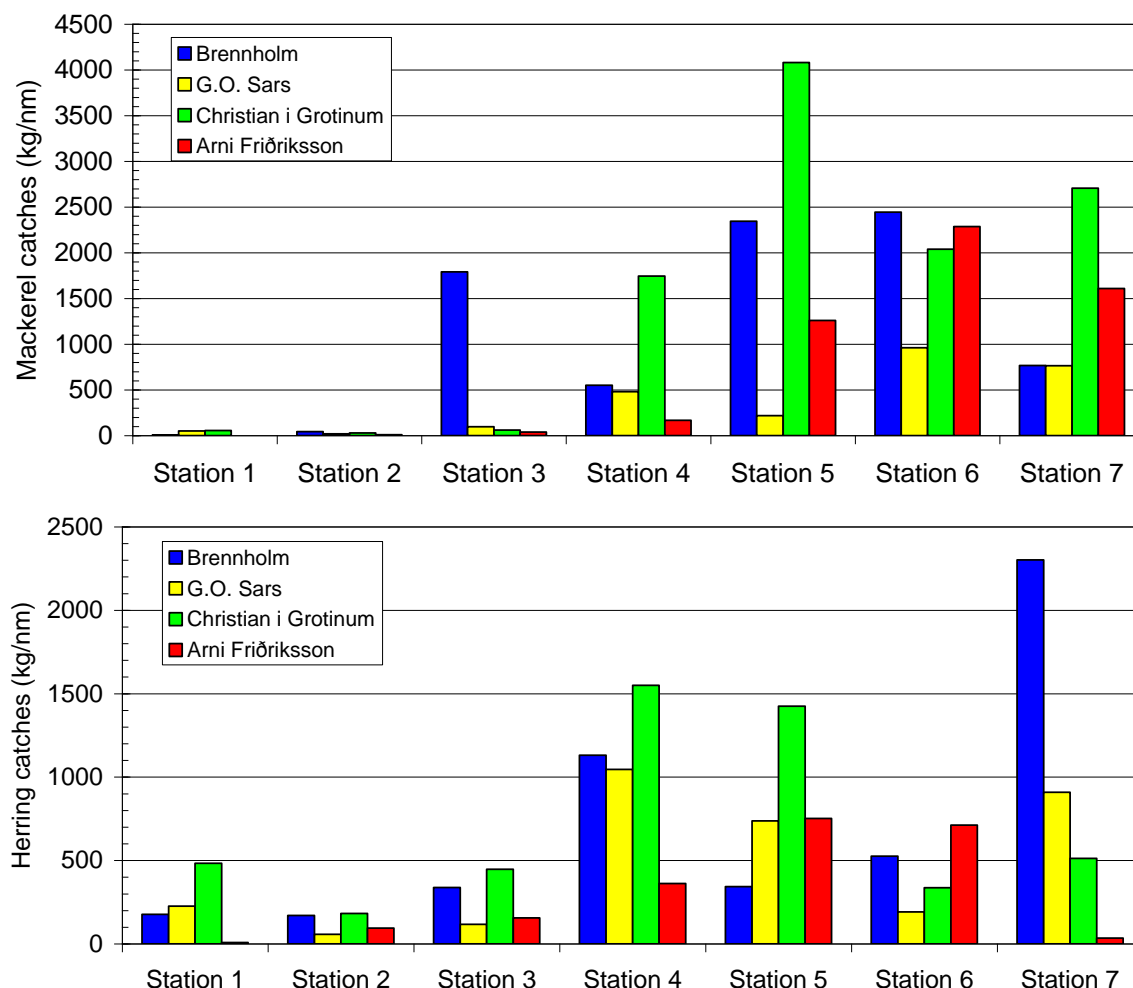


Figure 2. Individual catches of mackerel (upper graph) and herring (lower graph) from all vessels. The towing duration was 30 min for stations 1-4 and 15 min for stations 5-7.

When catching schooling fish, catches from different vessels will vary due to logistic reasons. The catch differences, however, were consistently larger for the commercial vessels, thus it is unlikely that this is related to chance only. Sources for the differences may be related to differences between vessels, e.g. in vessel sound generation, gear parameters (rigging) and catch procedures. Our concern and focus at this stage is related to gear parameters and catch procedures.

Swept-area abundance estimates for mackerel are based on catches from pelagic trawls covering approximately the layer from surface down to 30 m times the width of the trawl. Therefore, all parameters affecting trawl geometry, speed and time are sources for variation and thus bias in catch pr. unit effort.

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas in July–August 2012. The column for influence indicates observed differences between vessels likely to influence performance during intercalibration. Influence is categorized as 0 (no influence), + (some influence) and ++ (high influence).

Properties	G.O. Sars	Arni Fridriksson	Brennholm	Christian í Grótinum	Influence
Trawl producer	Egersund Trawl AS	Tornet	Egersund Trawl AS	Vónin	0
Warp in front of doors	Steel wire, 24 mm	Dynex-34 mm	Dynema -36 mm	Dynex – 34mm	++
Warp length during towing	340 m (320-360 m)	350 m	340 m	350 m	0
Difference in warp length port/starboard	3-12 m	15-40 m	5-10 m	5-12 m	0
Weight at the lower wing ends	250 kg	No weights	400 kg	375 kg	++
Setback in metres	4 m	0	4 m	8 m	++
Type of trawl door	ET Speed	Polar.Jupiter t4	Seaflex w. adjustable hatches	Thyborøn V-doors	0
Weight of trawl door	1200 kg	2000 kg	2000 kg	2000 kg	+
Area trawl door	7.5 m ²	6 m ²	9 m ² 65-75% hatches	8 m ²	++
Towing speed (GPS) in knots	4.7 (4.7-4.8)	5.1 (4.7-5.2)	5.1 (5-5.2)	4.7 (4.1-5.1)	+
Setting time	15 min	12 min	5-10 min	15 min	+
Trawl height	25.5 (20-38)	27-30	28-30	~ 30.7 (SE = 0.33)	+
Door distance	110 m	98-104 m	115 m	Not measured	++
Trawl width*	-	62 m	-	70 m	+
Turn radius	2-4 degrees turn	2700-2800 m	5 degrees turn	5-10 degrees turn	+
Hauling time warp	6 min	4-5 min	5 min	8 min	+
Hauling time trawl	20 min	17 min	15 min	10 min	++
Trawl door depth (port and starboard)	0-10, 5-15 m	8-13, 10-15 m	10-15 m	Not measured	+
Headline depth	0-2 m	0-1 m	0-2 m	0 m	+
Float arrangements on the headline	Kite + 2 buoys on wings	Kite	Kite + 2 buoys on wings	Dynex float rope, whole headline (382 kg buoyancy) + 2 buoys on wings and 2 in middle (2880 kg buoyancy)	+
Weighing of catch	All weighted	All weighted	Codend weighted with large scale digital weight	Semi quantitative estimate (larger hauls estimated)	+

* Trawl width was not estimated constantly during intercalibration, for Christian í Grótinum it was done during the two first hauls of the trip.

Trawl design

The trawl design was identical and all trawls were produced using the same drawings. Some minor differences in the weight per length of the tread were observed in parts of the net material, although they had the same nominal descriptions.

Trawl doors

All vessels used different trawl doors. The smallest doors were used by Arni Fridriksson and the largest doors by Christian í Grótinum. This might affect the catching efficiency of the vessels.

Trawl rigging

Table 2 shows some differences in rigging of the trawl on the various vessels.

As these differences in rigging might affect the trawl catch, the important parameters are commented for each vessel below.

Flotation

G. O. Sars and Brennholm used both 4.8 m kite in the center of the headline and two bouys on each wing. Christian í Grótinum used both floatline along the whole headline and fenders on the wings and at the centre of the headline. Arni Fridriksson had kite on the centre of the headline and no bouys. The other vessels used bouys to monitor that the headline was at the surface during the trawl haul. This information was important to monitor when shooting the warps.

Sweep arrangement and weights

The two Norwegian vessels had 4 m extension of the lower bridles. The Faroese trawler had 8.3 m extension whereas the Icelandic vessel had no difference in length between upper and lower bridle. The weights used by the four vessels varied from 0 (no weights for Arni Fridriksson) to 400 kg,

Towing warp

G. O. Sars used 24 mm diameter steel warp whereas the other vessels used 340-350 m Dyneema/Dynex (floating) ropes in front of the trawl doors. The effect of this difference is unknown but the steel and Dynema/Dynex warp might herd fish differently in the path of the trawl.

Trawling procedure

The procedure for swept area tows was to shoot the net while the flotation bouys/fenders were kept at the surface. The shooting of the 350 m warp took from 10 till 20 minutes. During shooting the vessel was heading straight forward. When the 350 m warp was paid out the vessel turned to port to keep the starboard trawl door in the propeller wake. This was also the time when recording of tow started. After a tow duration of 15 or 30 minutes the haul back procedure started. This time interval was then recorded as the towing time for that haul. The four vessels towed the trawls in parallel tracks in 2-10° turn and the position of vessels were shifted between the hauls to level out possible herding effects of the different vessels (Figure 3). The haul back of the warp took 4-8 minutes. The haul-back of the trawl took between 10 and 20 minutes on the various vessels. During intake of the trawl, several stops occurred on some vessels.

Possible effects of differences in the trawl procedures;

1. During shooting of the warp, the trawl can be catching fish. Therefore, a long shooting time may contribute significantly to the total catch. This effect is more important for shorter (15 minutes) than for longer tows (30 minutes).
2. The turning procedure is meant to catch fish avoiding the passing vessel horizontally. The catch efficiency might then be effected both by the trawl path in relation to the vessel and difference in

avoidance stimulation by the various vessels.

3. During hauling, the trawl can potentially continue fishing. The hauling speed and timing should thus be standardized.
4. If trawl speed is reduced during haul-back, fish, especially mackerel has been observed to swim out of the trawl codend and could escape through the large meshes placed at the trawl belly.
5. The procedure of quantifying the total catch weight varied between vessels and must be standardized.

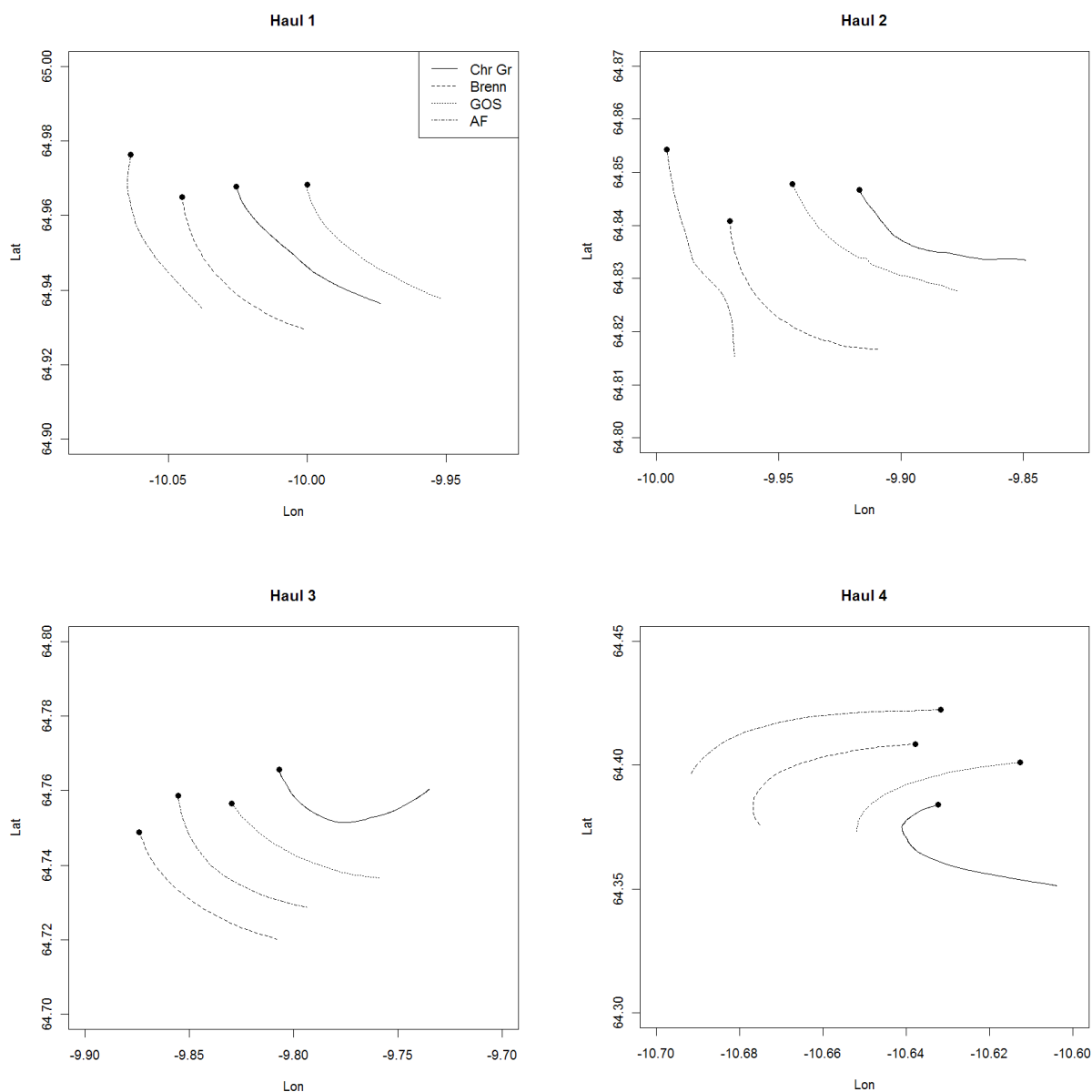


Figure 3. The tracks of the four vessels during the seven inter-calibration trawl hauls on 16-17 August 2012.

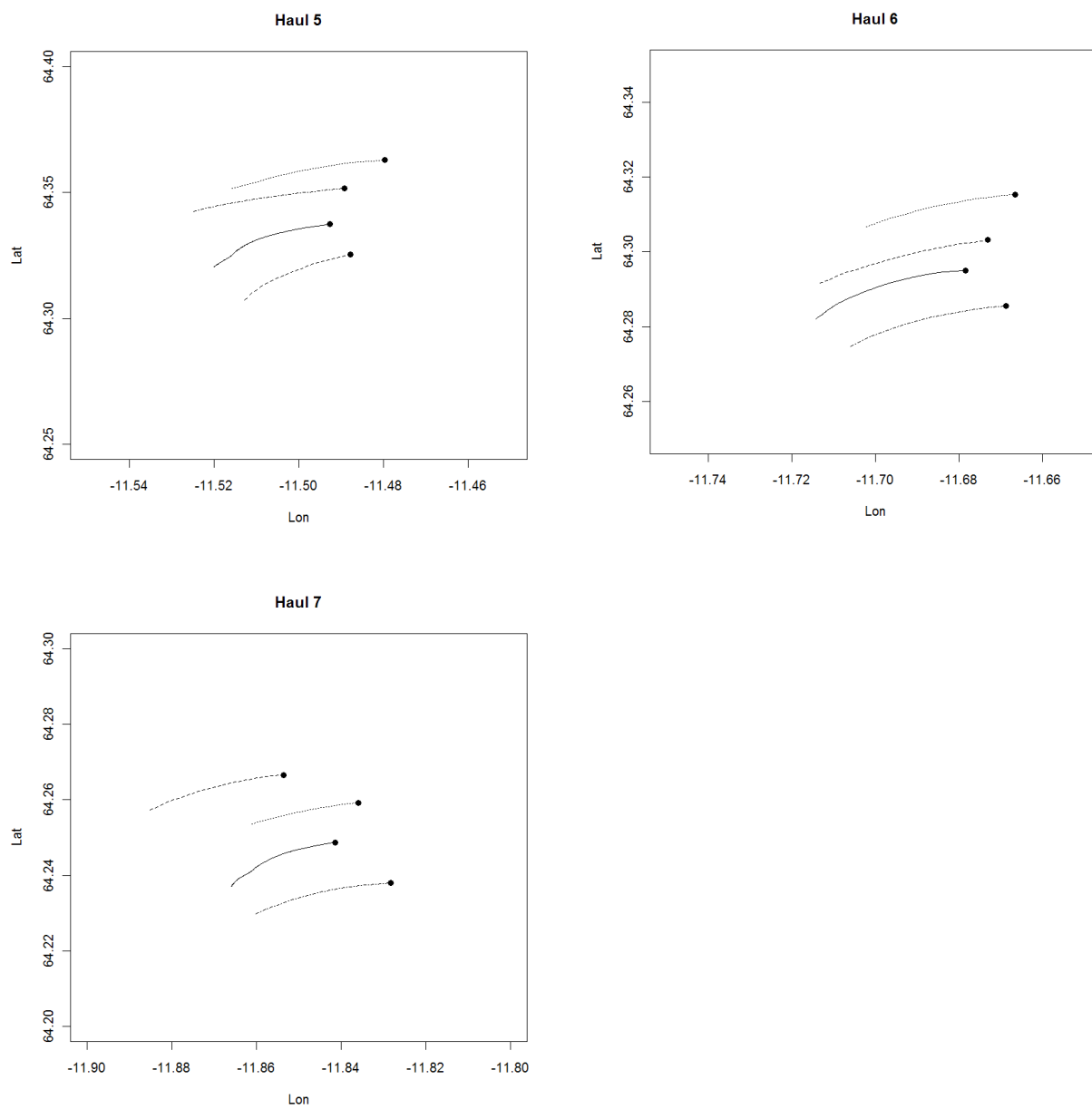


Figure 3. continues.

Recommendations

1. Towing time should be standardized to 30 minutes.
2. Towing speed should nominal be 5 knots.
3. Trawl doors should have identical performance during surface trawling (115 m spread with 80 m bridles and the depth of doors should be the same (10-15 m) for all vessels)
4. Vertical opening of the trawl mouth should be around 30 m and the horizontal opening around 70 m for optimal performance of the Mulpelt 832 trawl. These parameters should be measured and documented.
5. The differences between upper and lower bridles (setback) should be equal for all vessels (6 m)
6. The weights on the lower wings should be equal for all vessels (400 kg on each side).
7. 350 m of Dynema warp in front of doors should be used by all vessels.
8. The inner door should be in the propeller wake or at the edge of the inside of the wake while towing (i.e. if turning to the starboard, the port door should be at the starboard edge of the wake).
9. Bouys/fenders should always be used on the wings
10. Bouys/fenders should always be visual on the surface while shooting the warps and during towing
11. Arrangement to keep the whole length of the headline in surface should be used (e.g. floating rope tied to the whole headline)
12. The shooting time of the warp should be recorded and be the same for all vessels
13. Hauling time and speed should be recorded and be the same for all vessels.
14. The catch estimation should be based on weights of total catch and not by visual judgement.
15. Intercalibration of catching performance between vessels should be done in 3-4 days, preferably prior to survey.

Appendix 2

Practical procedure for the intercalibration between the sampling trawls – Multpelt 832 and echosounder Simrad EK 60 data in July 2012

- 1) All vessels meet at the agreed meeting point 65°N and 10°W on Monday 16th of July 12:00 UTC. Please adapt your ongoing survey and station work to this previously agreed plan!
- 2) We divide the area for repeated trawling between the vessels into three different agreed squared regions of similar size and name them inter-calibration trawling Area 1, 2 and 3 from east to west. We intend to trawl for approximately 7 hours constantly in Area 1, before all vessels move to Area 2 and finally after 7 more hours move to Area 3 and repeat 30 min hauls for about 7 hours.
- 3) All vessels start the standardized pelagic trawling with Multpelt 832 arbitrarily within area 1 with a towing direction from east to west. The vessels should not come closer than 300 m during the trawling exercise.
- 4) All vessels trawl for 30 minutes using the agreed and detailed trawling and rigging procedure for each trawl haul. The trawl catch are taken onboard and each vessel continue directly and continuously with new trawl hauls until 7 hours after starting time. All vessels move then to the next defined area and each vessel trawl in the same way for 7 more hours. Then all vessels move from Area 2 to Area 3 after 7 new hours. Finish the trawling exercise in area 3 after 8 hours (Tuesday 17th of July 09:00 UTC).
- 5) All vessels are kindly requested to keep all the acoustic echosounder instrumentation onboard in operation mode in the same way as during the regular survey prior to and after the inter-calibration session. **Please turn off the sonars and other instrumentation (e.g. ADCP) during the entire intercalibration period!**
- 6) Please mark each trawl haul (start and stop time for pelagic trawling) on the acoustic instrumentations, in order to be able to compare the acoustic echosounder data from different frequencies available onboard the various vessels.
- 7) The catch from each trawl haul is sorted and total weight for each species measured. Furthermore, measure weight and length of up to 100 individuals for each species per trawl haul!

Practical procedure for the intercalibration between the acoustic instrumentation – Simrad EK 60, 38 kHz and 200 kHz including other frequencies if available.

- 1) The different vessels line up with 300 m perpendicular distance at the starboard side of each other and 10° angle between each vessel. G.O. Sars followed by Arni Fridriksson, Brennholm and Christian í Grótinum.
- 2) All vessels start at the same time agreed via online communication at the location.
- 3) All vessels navigate at 10 knots speed and 90 degrees direction (east to west).
- 4) All vessels keep the same settings on the echosounder as set during the regular survey.
- 5) All vessels change positions every 1 hour of being in front and at the back of the line when cruising at 10 knots.
- 6) All vessels participate on this acoustic intercalibration for 6 hours.

Data availability for analyses and results between vessels.

All acoustic data from the available echosounder frequencies are made available for all countries after each vessel has finished their survey to be included in the WGNAPES database.

All biological data from the different trawl hauls on each participating vessel are also to be included after each vessel has finished their survey to be included in the WGNAPES database.