Working Document to

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Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 30th of June – 6th of August 2018

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1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from June 30th to August 6th in 2018 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 ICES mackerel benchmark. A standardised pelagic swept area trawl method is used to obtain the abundance index and to study the spatial distribution of mackerel in relation to other abundant pelagic fish stocks and to environmental factors in the Nordic Seas, as has been done annually since 2010. Another aim is to construct new time series for blue whiting (*Micromesistius poutassou*) abundance index and for Norwegian spring-spawning herring (NSSH) (*Clupea harengus*) abundance index. This is obtained by utilizing standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations.

The 2018 index decreased 40% for biomass and decreased 30 % for abundance (numbers of individuals) compared to the 2017 index. In 2018, the most abundant year classes were 2010, 2011, 2014, 2016 and 2017 with 11 %, 14 %, 14 %, 15 % and 13 % (in numbers). The incoming 2017-year class has the largest age-1 index value recorded in IESSNS and is 150 % larger than the incoming age-1 cohort in 2017. Mackerel cohort internal consistency remained relatively high. Internal consistency is strong for ages 1 to 5 years ($r > 0.8$) and a fair/good internal consistency for ages 5 to 11 years ($r > 0.5$), except for 7-8 year old mackerel. The survey coverage area was 2.8 million square kilometres in 2018 which is the same as in 2017. Furthermore, 0.25 million km^2 was surveyed in the North Sea. Mackerel was observed in most of the survey area. Distribution zero boundaries were found in majority of survey area with a few exceptions of low mackerel abundance at the survey boundaries south of Faroe Island, and north and south of the strata adjacent to Greenland.

The mackerel appeared more evenly distributed within the survey area and more easterly distributed than in 2017. This difference in distribution primarily consists of a marked biomass decline in the west (76 % decrease in biomass west of stratum 3, see StoX results). In the eastern areas, the decline was less (21 %). Furthermore, there was also an eastward shift of distribution within the Norwegian Sea.

The acoustic abundance index of Norwegian spring-spawning herring was 13.6 billion corresponding to 4.46 million tonnes (Table 8). The abundance estimate of herring from the 2017 survey was 20.6 billion corresponding to 5.88 million tonnes, i.e. a reduction of approx. 24.2% in terms of biomass this year. This drop cannot be easily explained but migration of NSSH south of 62 ^{0}N, where it would mix with other stocks, might influence the result. Older fish dominated in the western and southwestern part and a range of year classes are present in this area. In the north-eastern part of the Norwegian Sea, at the entrance to the Barents Sea, mainly juvenile fish age 4-5 years and younger were present.

The acoustic abundance index of blue whiting was 16.3 billion corresponding to 2.0 million tonnes (Table 9). The abundance estimate of blue whiting from the 2017 survey was 22.3 billion corresponding to 2.3 million tonnes, corresponding to decrease in 2018 of approximately 11% in terms of biomass and 27% in terms of abundance of age 1+ fish. It should be noted that in 2017, there were some strong registrations of 0-group blue whiting south of the Faroe Islands which accounted for 15% of the abundance that year. However, in 2018, no 0-group was registered in the survey. The blue whiting was distributed in the entire survey area with exception of the area north of Iceland influenced by the cold East Icelandic Current and in the East Greenland area.

As in previous years, the spatio-temporal overlap between NEA mackerel and NSSH was highest in the southern and south-western parts of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea. Herring distribution was limited to the area east and north of Iceland and the southern Norwegian Sea. Mackerel, on the other hand, was distributed in most of the surveyed area.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 65% of surface trawl stations distributed across the surveyed area from Cape Farwell, Greenland, to western part of the Barents Sea. Abundance was greater north of latitude 66 °N compared to southern areas. A total of 80 North Atlantic salmon were caught, mainly in central northern and north-western part of the Norwegian Sea.

Environmental conditions were different in 2018 compared to 2017. Temperature in the surface layer was 0.5-2°C colder in most of the surveyed area. The 2018, sea surface temperature (SST) was 1-2 °C lower than the long-term average (20-year mean) south and west of Iceland, but similar to the long-term mean in central and northern part of the Norwegian Sea, and warmer on the east Greenland shelf and north of Iceland. The average zooplankton index declined 18% compared to 2017. It was slightly lower in Greenlandic waters (15.8 g m^{-2}; n=27) and in the Norwegian Sea (7.2 g m^{-2}; n=167), while it was 18% higher in Icelandic waters (9.9 g m^{-2}; n=64).

1 Introduction

During approximately five weeks of survey in 2018 (30th of June to 6th of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Tróndur í Gøtu" from Faroe Islands, the R/V "Árni Friðriksson" from Iceland, the M/V "Finnur Fridi" operating in Greenland waters and M/V "Ceton" operating in the North Sea by Danish scientists, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS).

The main aim of the coordinated IESSNS have been to collect data on abundance, distribution, migration and ecology of Northeast Atlantic mackerel (*Scomber scombrus*) during its summer feeding migration phase in the Nordic Seas, used as tuning series in stock assessment of mackerel at the annual meeting of ICES working group of widely distributed stocks (WGWIDE). Since 2016, systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) have also been conducted. This objective was initiated to provide an additional abundance index for these two stocks because the current indices used in the stock assessments by ICES have shown some unexplained fluctuations (ICES 2016). It was considered that a relatively small increase in survey effort would accommodate a full acoustic coverage of the adult fraction (spawning stock biomass (SSB)) of both species during their summer feeding distribution in the Nordic Seas (Utne et al. 2012; Trenkel et al. 2014; Pampoulie et al. 2015). The pelagic trawl survey was initiated by Norway in the Norwegian Sea in the beginning of the 1990s. Faroe Islands and Iceland have participated in the joint mackerel-ecosystem survey since 2009, Greenland since 2013 and Denmark for the first time in 2018.

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

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

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

The North Sea was included in the survey area in 2018, following the recommendations of WGWIDE. This was done by scientists from DTU Aqua, Copenhagen, Denmark. The commercial fishing vessels "Ceton S205" was used, and in total 39 stations (CTD and fishing with the pelagic Multipelt 832 trawl) were successfully conducted. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths deeper than 50 m and no plankton samples were taken.

3 Material and methods

Coordination of the IESSNS was done during WGWIDE 2017 meeting in August-September 2017 in Copenhagen, Denmark, and at the WGIPS meeting in January 2018 in Den Helden, Nederlands, and by correspondence in spring and summer 2018. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calm with good survey conditions for all six vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. There were sporadic windy periods in Greenland and Faroese waters. The weather was good and calm for the two Norwegian vessels and the Icelandic vessel operating in the central and northern part of the Norwegian Sea and in Icelandic waters.

During the IESSNS, the special designed pelagic trawl, Multpelt 832, has now been applied by all participating vessels since 2012. This trawl is a product of cooperation between participating institutes in designing and constructing a standardized sampling trawl for the IESSNS. The work was lead by trawl gear scientist John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway (Valdemarsen et al. 2014). The design of the trawl was finalized during meetings of fishing gear experts and skippers at meetings in January and May 2011. Further discussions on modifications in standardization between the rigging and operation of Multpelt 832 was done during a trawl expert meeting in Copenhagen 17-18 August 2012, in parallel with the post-cruise meeting for the joint ecosystem survey, and then at the WKNAMMM workshop and tank experiments on a prototype (1:32) of the Multpelt 832 pelagic trawl, conducted as a sequence of trials in Hirtshals, Denmark from 26 to 28 February 2013 (ICES 2013a). The swept area methodology was also presented and discussed during the WGISDAA workshop in Dublin, Ireland in May 2013 (ICES 2013b). The standardization and quantification of catchability from the Multpelt 832 pelagic trawl was further discussed during the mackerel benchmark in Copenhagen in February 2014. Recommendations and requests coming out of the mackerel benchmark in February 2014, were considered and implemented during the IESSNS survey in July-August 2014 and in the surveys thereafter. Furthermore, recommendations and requests resulting from of the mackerel benchmark in January-February 2017, were carefully considered and implemented during the IESSNS survey in July-August 2017. In 2018, the Faroese and Icelandic vessels employed new, redesigned cod-ends with the capacity to hold 50 tonnes. This was done to avoid the cod-end from bursting during hauling of large catches as occurred at three stations in the 2017 IESSNS.

Table 1. Survey effort by each of the five vessels during the IESSNS 2018. The number of predetermined ("fixed") trawl stations being part of the swept-area stations for mackerel in the IESSNS are shown after the total number of trawl stations.

Vessel	Effective survey period	Length of cruise track (nmi)	Total trawl stations/ Fixed stations	CTD stations	Plankton stations
Árni Friðriksson	2/7-2/8	6300	91/71	71	70
Tróndur í Gøtu	30/6- 21/7	3350	54/48	48	48
Finnur Fríði	18/7-6/8	2900	37/31	32	31
Ceton	2/7-13/7	1600	39/39	39	-
Vendla	4/7-5/8	5275	100/74	74	74
Kings Bay	4/7-5/8	5205	87/66	68	66
Total	30/6-6/8	24230	408/329	332	289

3.1 Hydrography and Zooplankton

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

Zooplankton was sampled with a WP2-net on 5 of 6 vessels, Ceton did not take any plankton samples. Mesh sizes were 180 μm (Kings Bay and Vendla) and 200 μm (Árni Friðriksson, Tróndur í Gøtu and Finnur Fridi). The net was hauled vertically from a depth of 200 m (or bottom depth at shallower stations) to the surface at a speed of 0.5 m/s. All samples were split in two, one half preserved for species identification and enumeration, and the other half dried and weighed. Detailed description of the zooplankton and CTD sampling is provided in the survey manual (ICES 2014a).

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

3.2 Trawl sampling

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

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

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 30th June to 6th August 2018. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Kings Bay**	**Árni Friðriksson**	**Vendla**	**Ceton**	**Tróndur í Gøtu**	**Finnur Fríði**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynex	Dynema – 32mm	Dynex-38 mm	+
Warp length during towing	350	350	350	350	350-370	350	0
Difference in warp length port/starb. (m)	2-10	16m	2-10	10	5-20	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×400	2×500	0
Setback (m)	0	14m	0	6	6	6	+
Type of trawl door	Seaflex 7.5 m² adjustable hatches	Jupiter	Seaflex 7.5 m² adjustable hatches	Thybron type 15	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	1970	2000	2000	+
Area trawl door (m²)	7.5 with 25% hatches (effective 6.5)	6	7.5 with 25% hatches (effective 6.5)	7	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots)	4.8 (4.2-5.8)	4.9 (4.5-5.8)	4.5 (3.3-5.3)	5.1 (4.6-5.4	4.7 (4.4-5.0)	4.6 (4.1-5.0)	+
Trawl height (m)	28-40	34.1 (28.5-39.3)	28-37	31 (24-35)	44.1	-	+
Door distance (m)	115-132	117 (106 - 127)	115-128	122 (116-127)	109.2	105 (85-112)	+
Trawl width (m)*	68.2	66.1	66.5	68 (66-70)	62	60.3	+
Turn radius (degrees)	5-10	5	5-10	5-10	5-10 BB turn	5-10	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m)	5-15, 7-18	4-17, 8-20	6-18, 7-19	3-12, 4-14	11.2, 13.4	-	+
Headline depth	0-1 m	0	0-1 m	-	0 m	0-1 m	+
Float arrangements on the headline	Kite with fender buoy +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite with fender buoy + 2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite + 2 buoys on wingtips	Kite + 2 buoys on wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	-	All weighed	All weighted	+

* calculated from door distance

Table 3. Protocol of biological sampling during the IESSNS 2018. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

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

*Length measurements / weighed individuals
**Stomachs sampled at every third station
*** One fish per cm-group from each station was weighed, aged and the stomach was sampled.

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and escapement from the cod end and through meshes. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. No light source was employed with cameras; hence, recordings were limited to day light hours. Some recordings were also taken during night time when there was midnight sun and good underwater visibility. Video recordings were collected at 83 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 3rd July and 4th August 2018 onboard M/V "Kings Bay" and M/V "Vendla", respectively. Opportunistic marine mammal observations were also done on R/V Árni Friðriksson by crew members without any dedicated whale observers.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson" and M/V "Finnur Fridi" were tagged with Peterson disc tags and released. When the catch was brought aboard, any lumpfish caught were transferred to a tank with flow-through sea water. After the catch of other species had been processed, all live lumpfish larger than ~15 cm were tagged. The tags consisted of a plastic disc secured with a titanium pin which was inserted through the rear of the dorsal hump. Contact details of Biopol (www.biopol.is) were printed on the tag. The fish were returned to the tank until all fish were tagged. The fish were then released, and the time of release was noted which was used to estimate the latitude and longitude of the release location.

3.5 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 2nd July 2018 for 18, 38 and 200 kHz. Árni Friðriksson was calibrated in April 2018 for the frequencies 18, 38, 120 and 200 kHz. Tróndur í Gøtu was calibrated on 27th June 2018 for 38 and 200 kHz. Calibration of the acoustic equipment onboard Finnur Fríði was done after the cruise on the 5th of August. 120 and 200 kHz were calibrated, but the calibration of 38 kHz failed. Ceton did not use acoustic recording equipment. All vessels used standard hydro-acoustic calibration procedure for each operating frequency (Foote 1987). CTD measurements were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

Acoustic recordings were scrutinized to herring and blue whiting on daily basis using the post-processing software (LSSS or Echoview, see Table 4 for details of the acoustic settings by vessel). Species were identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms.

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

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

Table 4. Acoustic instruments and settings for the primary frequency (38 kHz) during IESSNS 2018.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu	M/V Finnur Fríði	M/V Ceton *
Echo sounder	Simrad EK80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 60	
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 120, 200	18, 38, 70, 120, 200	38,120, 200	38,120, 200	
Primary transducer	ES38B	ES38B	ES38B	ES38B	ES38B	
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull	
Transducer depth (m)	9	10	9	6	8	
Upper integration limit (m)	15	15	15	7	Not used	
Absorption coeff. (dB/km)	9.6	10.6	9.1	9.7	9.7	
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	
Band width (kHz)	2.43	2.43	2.43	2.43	2.43	
Transmitter power (W)	2000	2000	2000	2000	2000	
Angle sensitivity (dB)	21.90	21.9	21.90	21.9	21.9	
2-way beam angle (dB)	-20.7	-20.81	-20.6	-20.6	-20.7	
TS Transducer gain (dB)	24.33	24.34	25.56	24.04	23.75	
s_A correction (dB)	0.01	-0.61	-0.69	-0.64	-0.59	
alongship:	7.01	7.28	7.03	7.07	7.17	
athw. ship:	7.00	7.23	7.09	7.09	7.01	
Maximum range (m)	500	500	500	500	500 (750 in part of the survey)	
Post processing software	LSSS	LSSS v.2.3.0	LSSS	Sonardata Echoview 9.x	Sonardata Echoview 8.x	

* No acoustic data collection

Multibeam sonar

M/V Kings Bay was equipped with the Simrad fisheries sonar SH90 (frequency range: 111.5-115.5 kHz), with a scientific output incorporated which allow the storing of the beam data for post-processing. M/V Vendla was equipped with the Simrad fisheries sonar SX93 (frequency range: 20-30 kHz). Acoustic multibeam sonar data was stored continuously onboard Kings Bay and Vendla for the entire survey.

Cruise tracks

The six participating vessels followed predetermined survey lines with predetermined surface trawl stations (Figure 1). Calculations of the mackerel index are based on swept area approach with the survey area split into 13 strata, permanent and dynamic strata (Figure 2). Distance between predetermined surface trawl stations is constant within stratum but variable between stratum and ranged from 35-90 nmi. The survey design using different strata is done to allow the calculation of abundance indices with uncertainty estimates, both overall and from each stratum in the software program StoX (see Salthaug et al. 2017). In addition, the Norwegian vessel Vendla had four stations in the Barents Sea as there was some available time at the end of the survey. Temporal survey progression by vessel along the cruise tracks in July-August 2018 is shown in Figure 3. The cruising speed was between 10-13 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

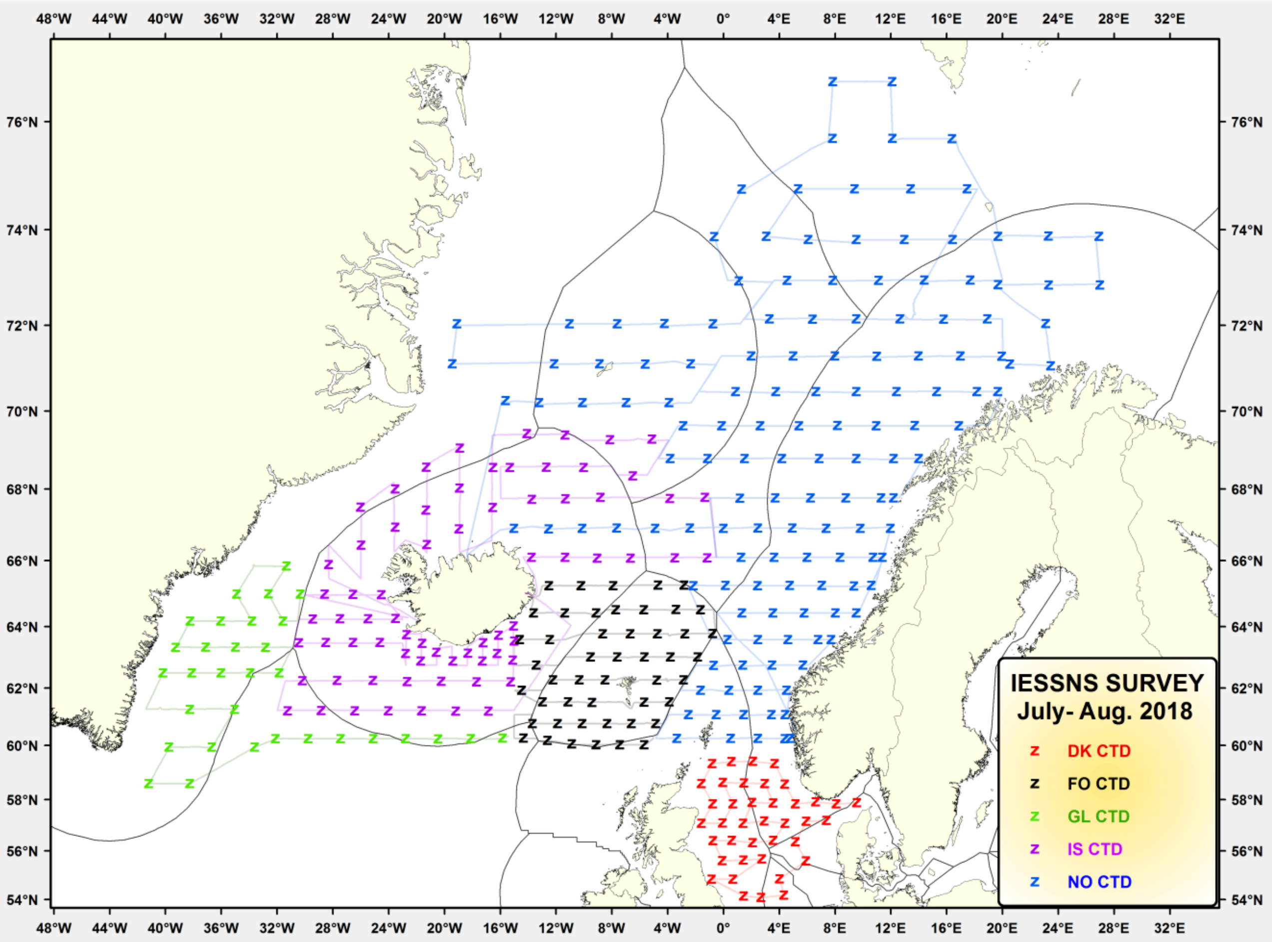


Figure 1. Fixed predetermined trawl stations included in the IESSNS 30th June – 5th August 2018. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue), Finnur Fríði (green) and Ceton (red).

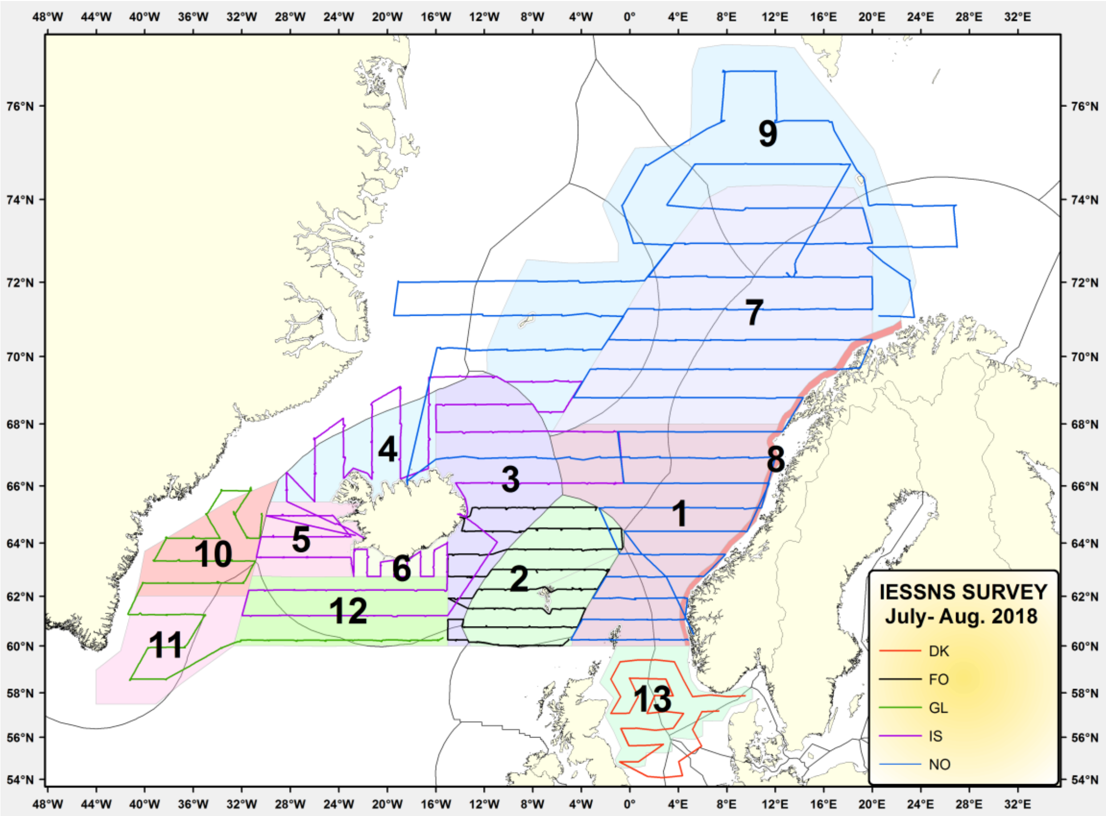


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2018. The dynamic strata are: 4, 9 and 11.

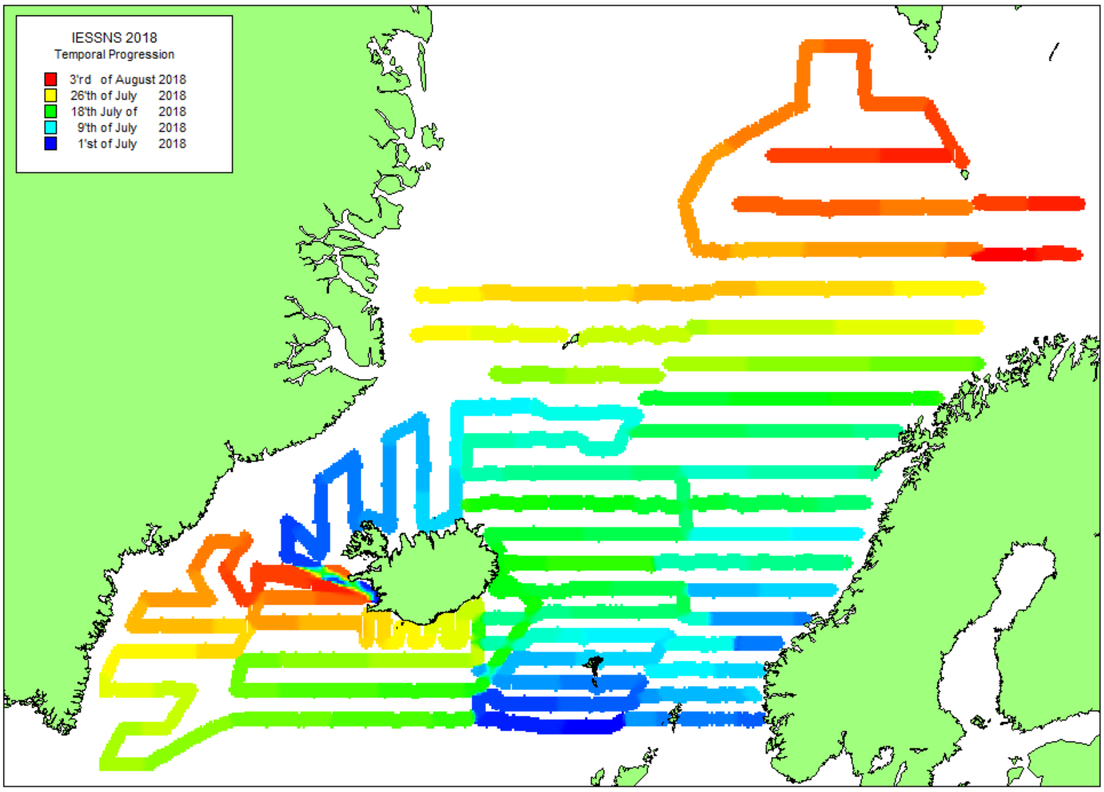


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2018: blue represents effective survey start (1st July) progressing to red representing the effective end of the survey (3rd August).

3.6 StoX

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

3.7 Swept area index and biomass estimation

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

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

$Mac\_D = h * d * c$

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

Table 5. Descriptive statistics for trawl door spread, vertical trawl opening and tow speed for each vessel. Number of trawl stations used in calculations is also reported. Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (details in Table 6).

	Tróndur í Gøtu	RV Árni Friðriksson	Kings Bay	Vendla	Finnur Fríði	Ceton
Trawl doors horizontal spread (m)						
Number of stations	48	54	66	74	31	39
Mean	109.2	117	125	121	105	122
max	116.8	127	132	128	112	127
min	98.9	106	115	115	85	116
st. dev.	6.1	3.9	3.8	1.8	4.9	2.5
Vertical trawl opening (m)						
Number of stations	48	49	66	74	-	39
Mean	44.1	34.1	31.7	31	-	31
max	51.2	39.3	40	37	-	35
min	39.9	28.5	28	28	-	24
st. dev.	7.7	2.3	3.1	1.3	-	2.5
Horizontal trawl opening (m)						
mean	62	66.1	68.2	66.1	60.3	68
Speed (over ground, nmi)						
Number of stations	48	54	66	74	31	39
mean	4.7	4.9	4.8	4.5	4.6	5.1
max	5.0	5.8	5.8	5.3	5.0	5.4
min	4.4	4.5	4.2	3.3	4.1	4.6
st. dev.	0.11	0.2	0.3	0.4	0.2	0.2

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

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

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

Table 6. Horizontal trawl opening as a function of trawl door spread and towing speed. Relationship based on simulations of horizontal opening of the Multpelt 832 trawl towed at 4.5 and 5 knots, representing the speed range in the 2014 survey, for various door spread. See text for details. In 2017, the towing speed range was extended from 5.0 to 5.2.

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

4 Results

4.1 Hydrography

Surface temperature in the Norwegian Sea was similar to the average for 1990-2009 based on Sea Surface Temperature (SST) anomaly plot (Figure 4). On the other hand, south and west of Iceland SST was 1-2°C colder than the average, but 1-2°C warmer on the east Greenland shelf and north of Iceland. Surface temperature in 2018 was similar to 2015 although this year was warmer on the east Greenland shelf and north of Iceland. SST was noticeably lower in 2018 compared to 2017 for majority of the survey area, excluding the east Greenland shelf.

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 *in situ* features of SSTs between years (Figures 5-8). However, since the anomaly is now based on the average for the whole month of July, it should give representative results of the surface temperature.

The upper layer (< 20 m depth) was 0.5-2.0°C colder in 2018 compared to 2017 in most of the surveyed area (Figures 5). The temperature in the upper layer was higher than 7°C in most of the surveyed area, except along the north-western fringes of the surveyed areas north of Iceland, west of Jan Mayen and north of Bear Island where it was slightly lower. In the deeper layers (50 m and deeper; Figure 6-8), the hydrographical features in the area were similar to the last three years. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

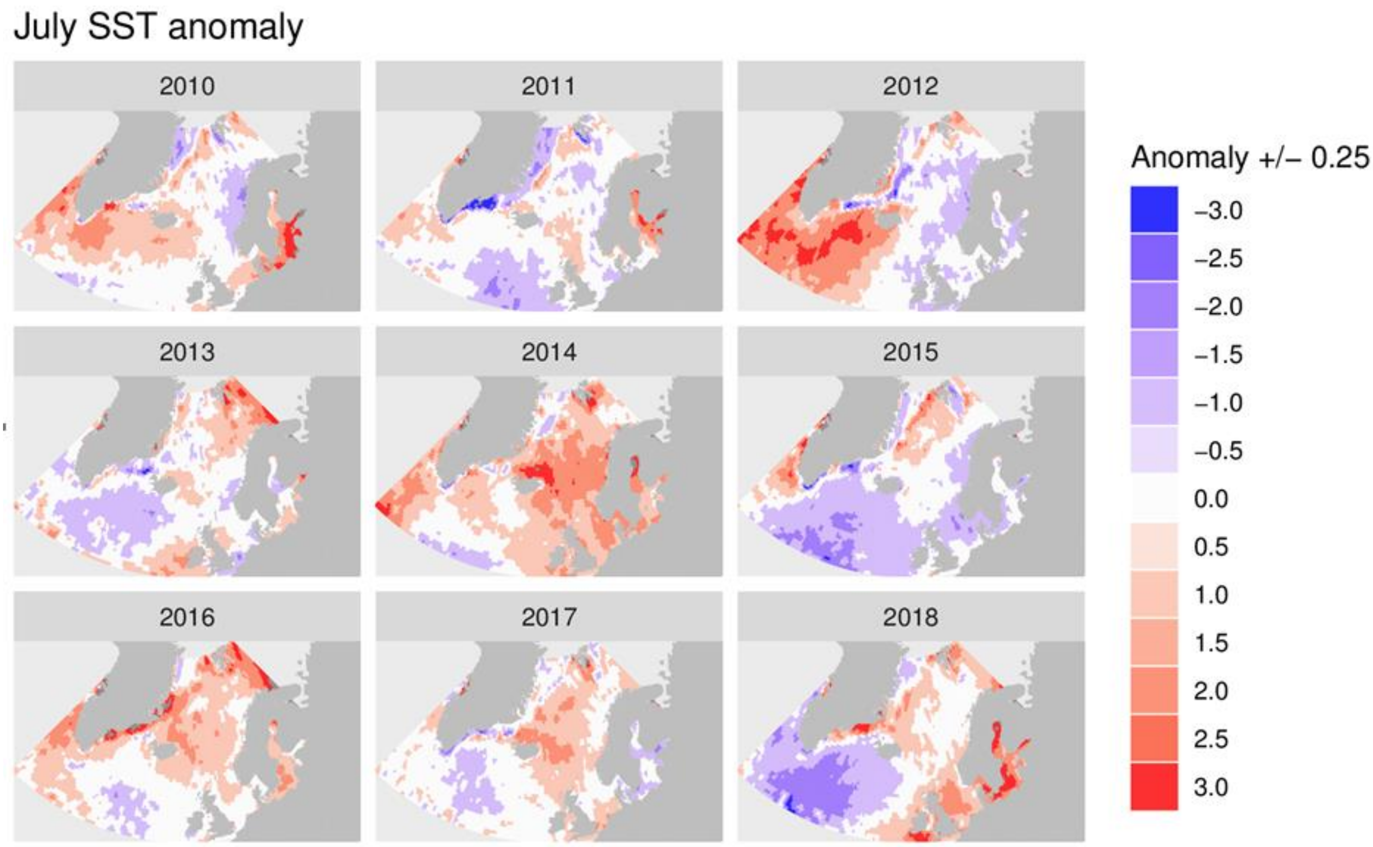


Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2018 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

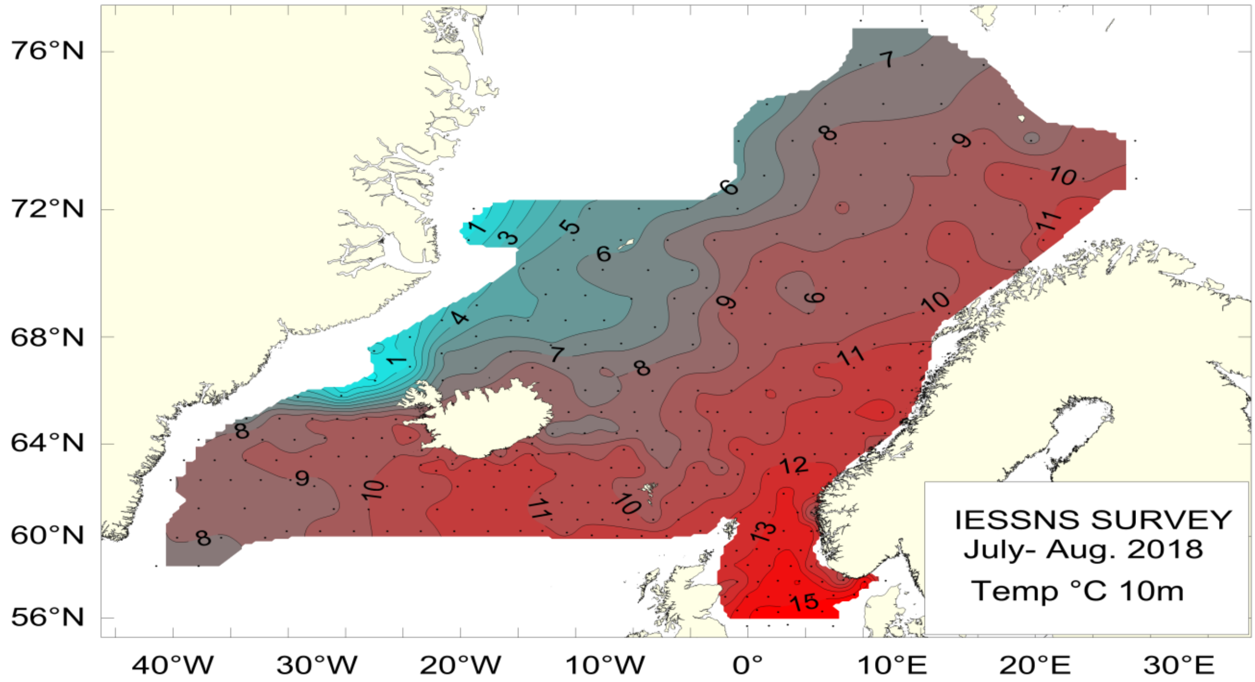


Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2018.

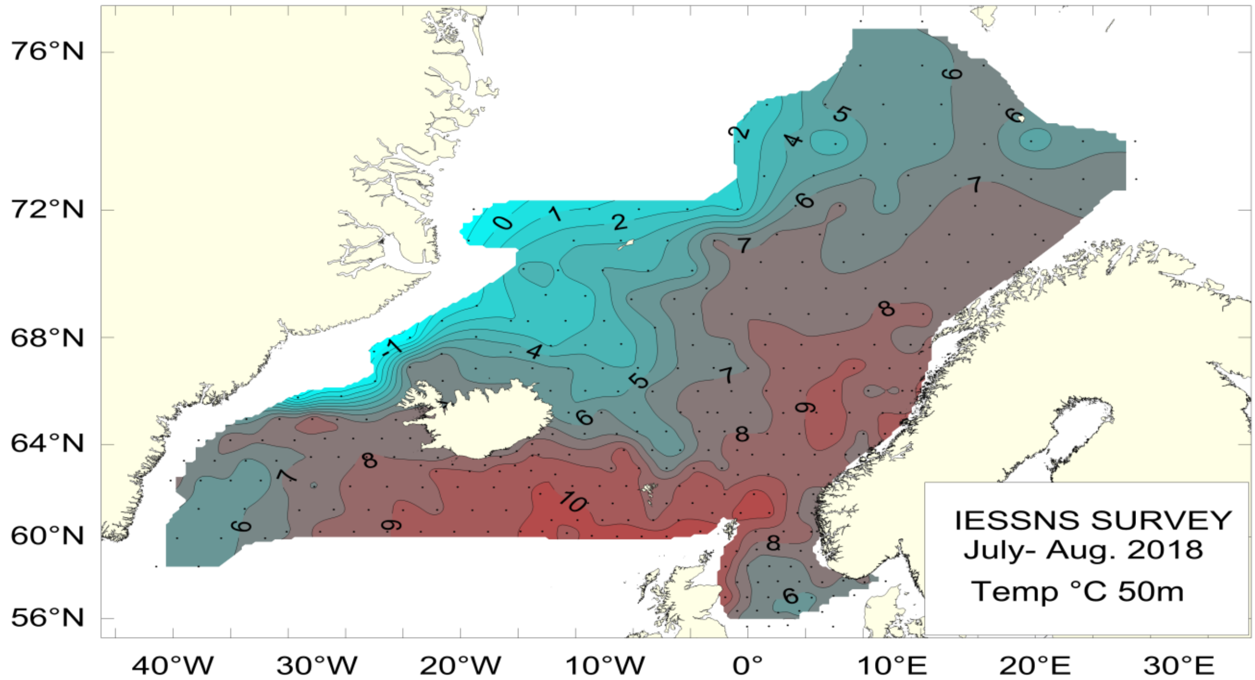


Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2018.

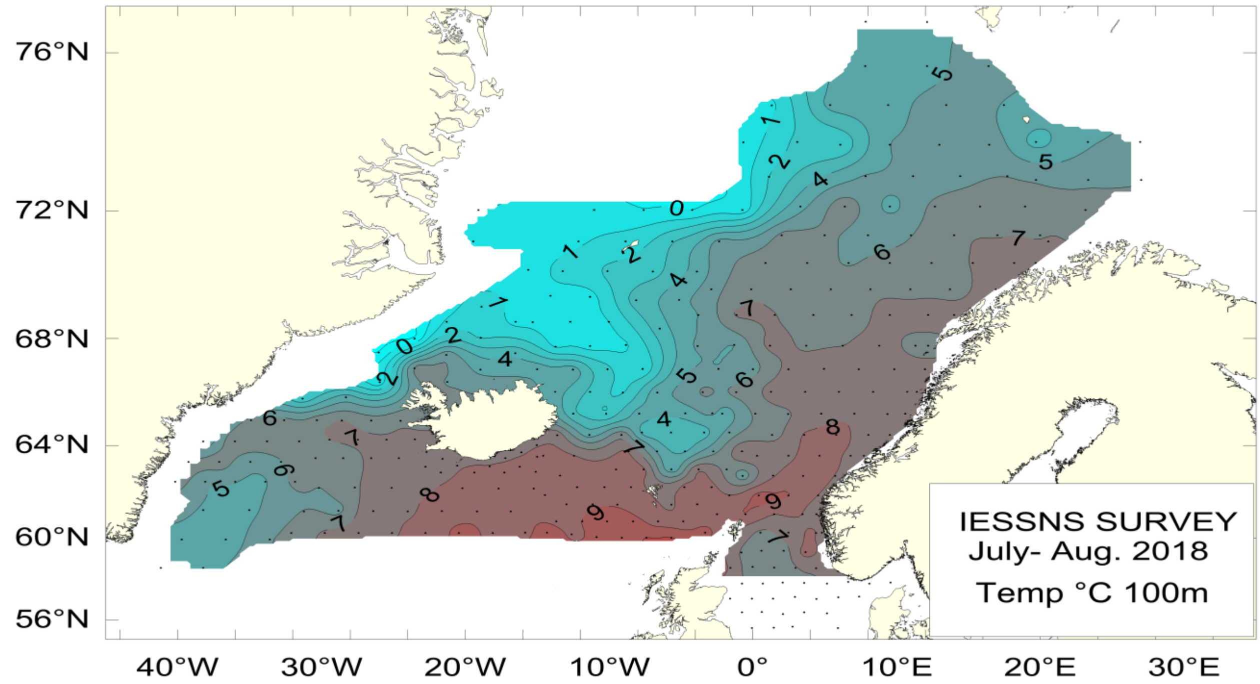


Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2018.

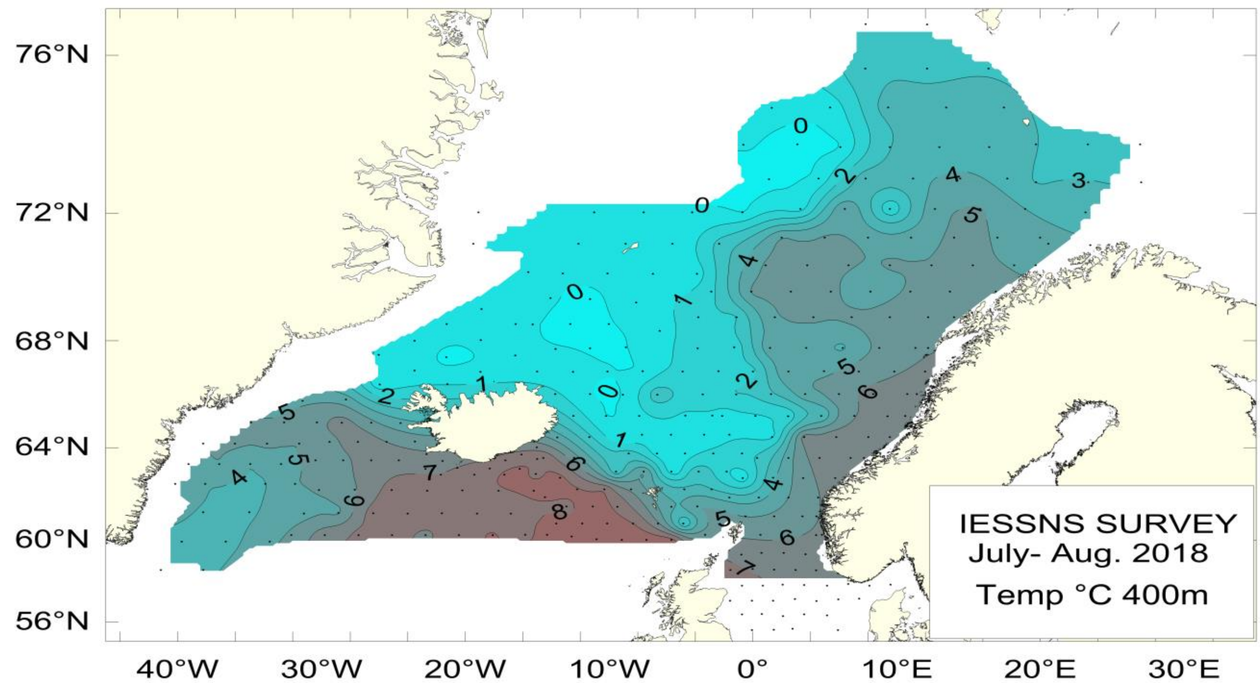
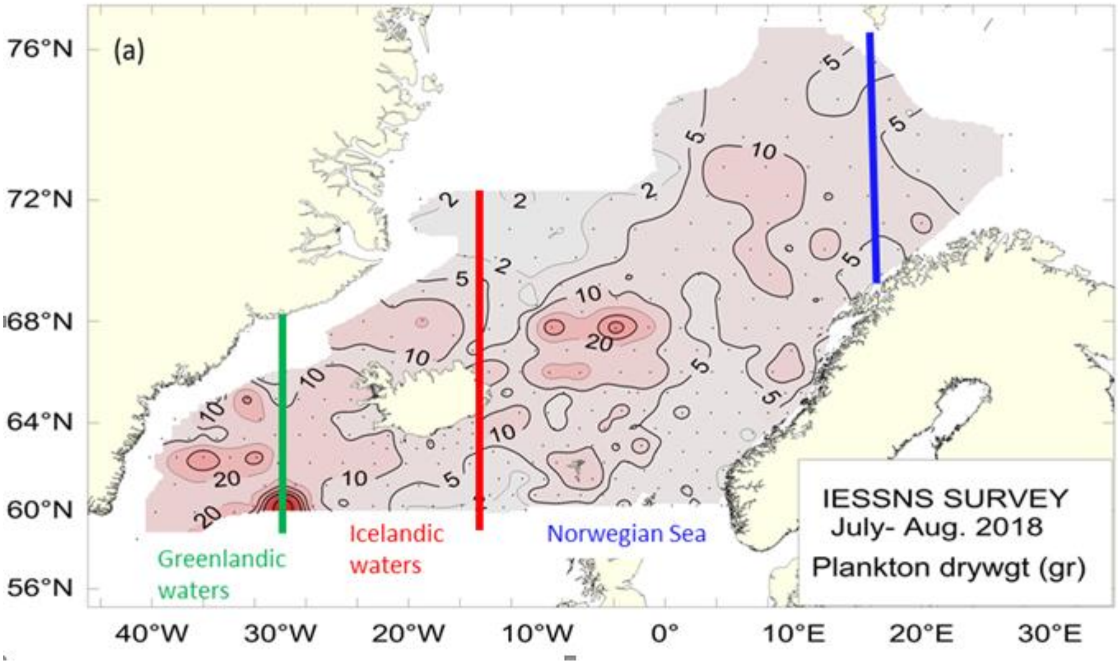


Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2018.

4.2 Zooplankton

Zooplankton biomass varied between areas and was highest in Greenland waters where it ranged from 10-20 g m^{-2} for most of the area compared to 5-10 g m^{-2} in the Norwegian Sea and in Icelandic waters (Figure 9a). Mean zooplankton biomass for the survey area was 6.9 g m^{-2} (n=287) which is an 18 % decline compared to 2017. In 2018, the average index was slightly lower in Greenland waters (15.6 g m^{-2}; n=27) and in the Norwegian Sea (7.2 g m^{-2}; n=167) compared to 2017 while 18% higher in Icelandic waters (9.9 g m^{-2}; n=64; Figure 9b). This relatively short time-series show much more pronounced fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea. Iceland and Greenland waters fluctuate a lot, however, they fluctuate in the same way from one year to the next.



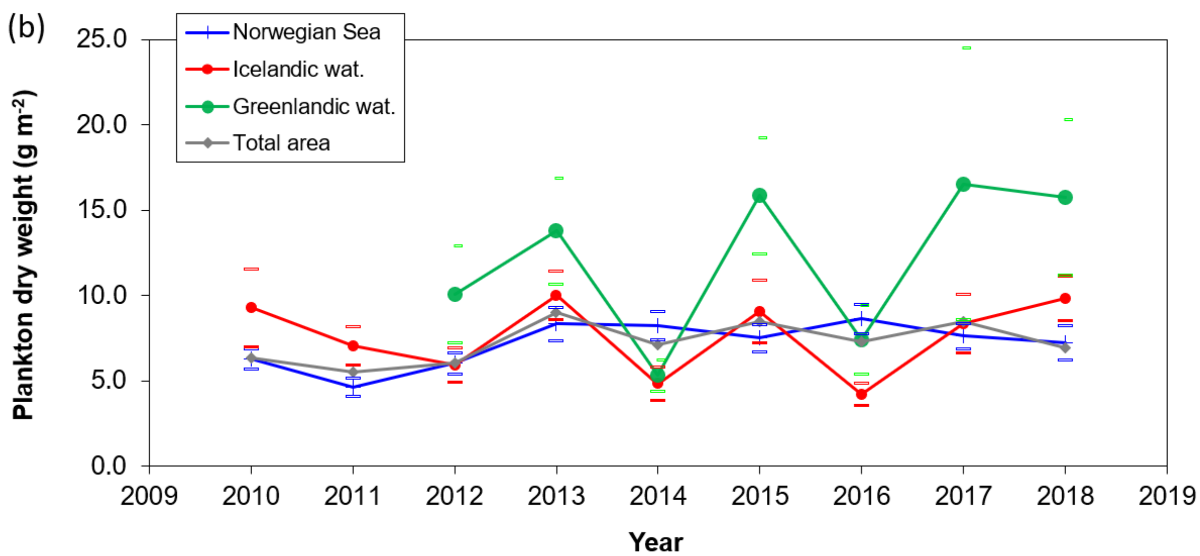


Figure 9. Zooplankton biomass indices (g dw/m², 0-200 m) (a) in Nordic Seas in July-August 2018 and (b) time-series of mean zooplankton biomass, with 95% confidence intervals, for the total survey area and three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W). Boundaries of subareas displayed in (a).

4.3 Mackerel

The mackerel biomass index i.e. catch rates by trawl station (kg/km²) measured at predetermined surface trawl stations is presented in Figure 10a together with the mean catch rates per 1*2° rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 5 tonnes, corresponding to approximately 2.3 tonnes/km² on average. High density areas were found in the Norwegian Sea as well as in south-eastward and westward of Iceland. The mackerel were spread over a greater area with a more easterly distribution than in 2017 (Figure 10a vs. 10b).

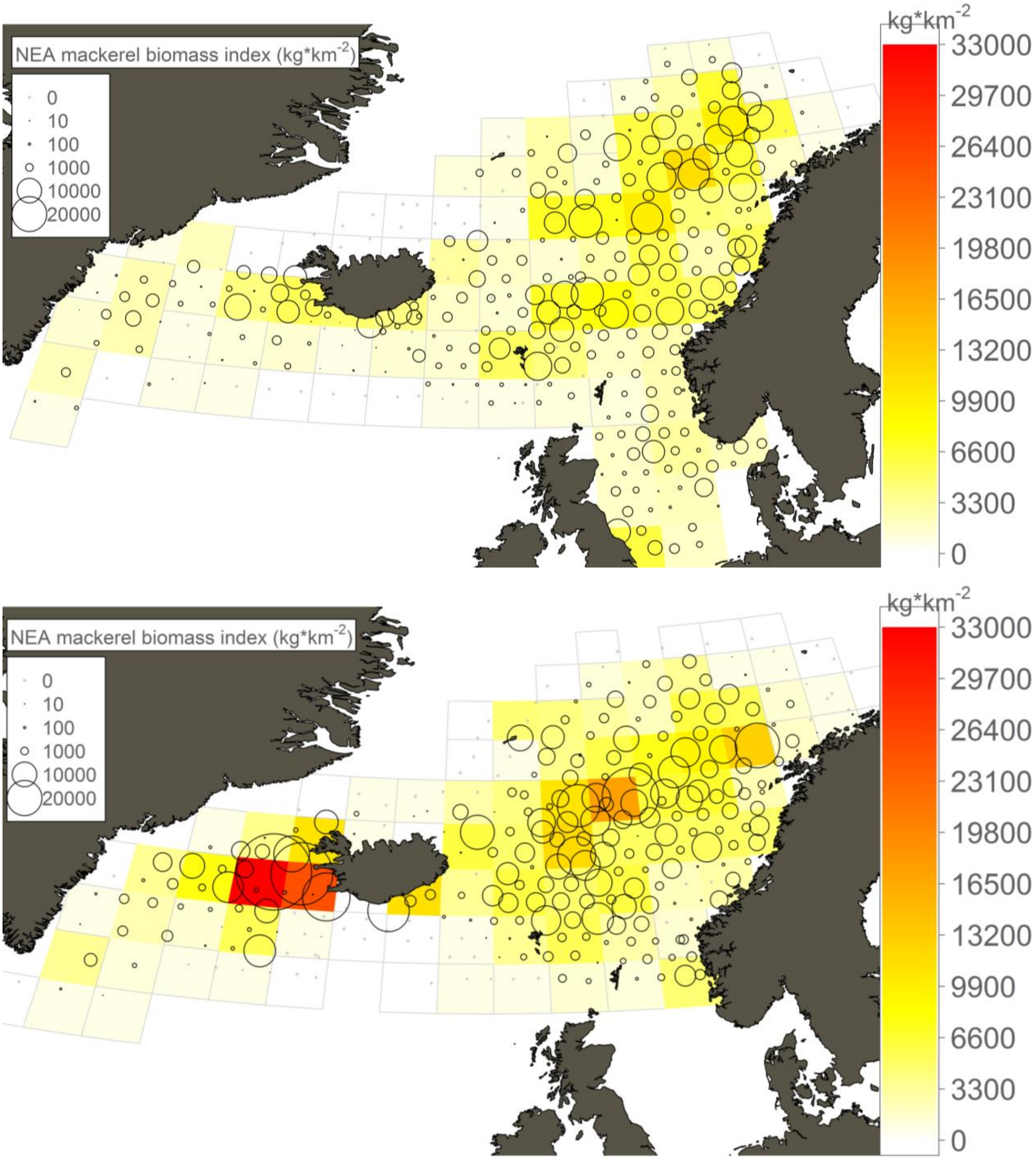


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (1° lat. x 2° lon.). Upper map: IESSNS 2018, lower map: IESSNS 2017.

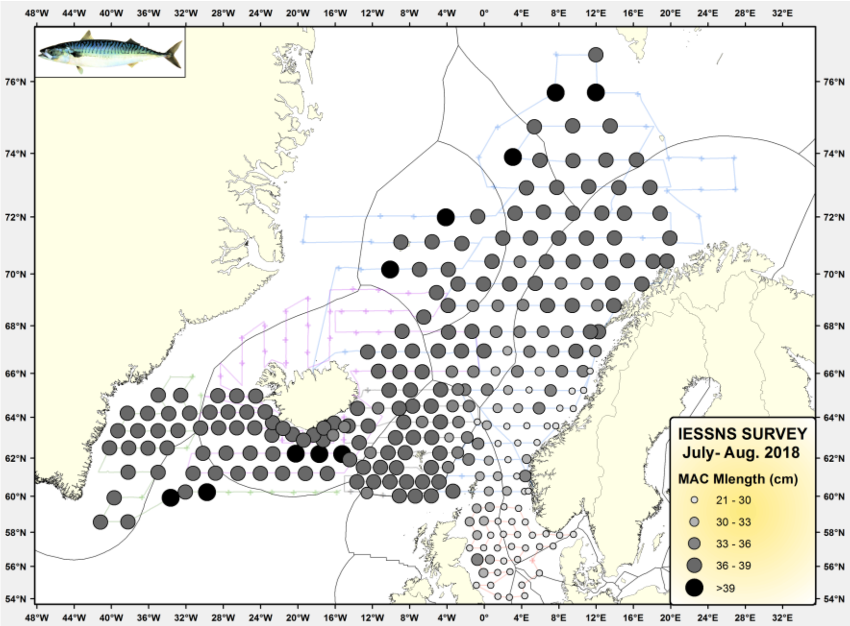


Figure 11. Average length of mackerel at predetermined surface trawl stations during IESSNS 2018.

Mackerel caught in the pelagic trawl hauls onboard the six vessels varied from 16.5 to 48.5 cm in length, with an average of 35.7 cm. Individuals in length range 35–38 cm dominated in numbers and biomass. The mackerel weight (g) varied between 32 to 952 g with an average of 424 g. As in previous years, age-1 dominated the catches along the Norwegian coast from Bergen in the south to Lofoten area in the north, and mackerel length distribution showed a trend of length-dependent distribution pattern both with regards to latitude and longitude. On average, larger mackerel were found further northward and eastward in the survey area (Figure 11). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon (*Salmo salar*), lumpfish) in 2018 according to the catches is shown in Figure 12.

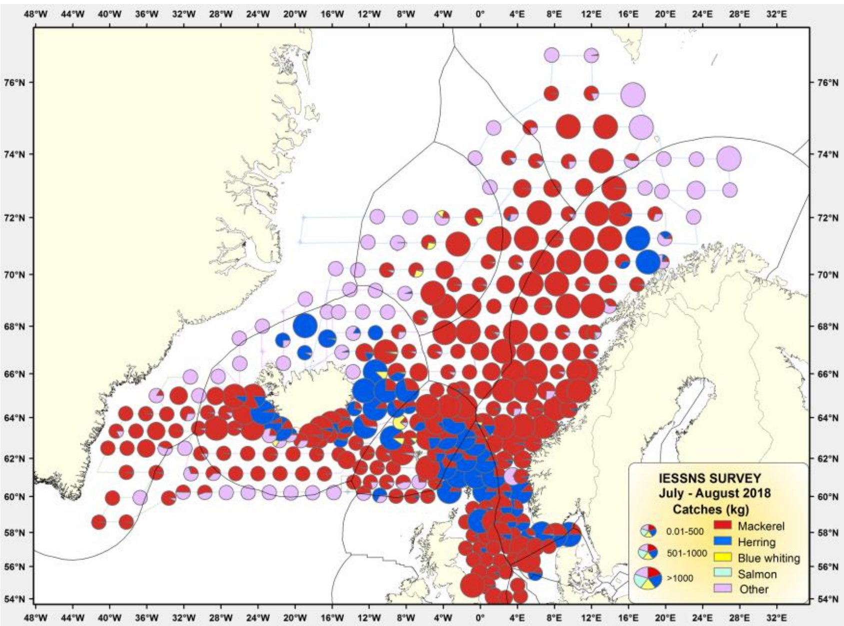


Figure 12. Distribution and spatial overlap between pelagic fish in 2018 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2018 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX (version 2.6). Mackerel were distributed over more or less the entire survey area excluding the area north of Iceland. Mackerel biomass index and abundance index was average in 2018 compared to the whole timeseries from 2007 to 2017 (Table 7). Comparing the 2018 mackerel estimate to the 2017 results shows a 30 % decline in abundance and 40 % decline in biomass. The 2018 biomass index is lower than measured in the IESSNS for the last five years (Figure 13) The survey coverage area was 2.8 million km² in 2018 which is the same as in 2017. The most abundant year classes were 2010, 2011, 2014, 2016 and 2017 with 11, 14, 14, 15, and 13 % (in numbers). The incoming 2017-year class appears promising and is the largest age-1 cohort recorded in the IESSNS timeseries. The total survey index for number-at-age is 17 billion individuals. The dominating age groups are 1, 2, 4, 7 and 8 years old (Figure 14) and they contributed to 66 % of the total abundance estimate. Variance in age index estimation is provided in Figure 15.

Mackerel index calculations from the catch in the North Sea (stratum 13 in Figure 2) were excluded from the index calculations presented in the current chapter to facilitate comparison to previous years and because the 2017 mackerel benchmark stipulated that trawl stations south of latitude 60 °N be excluded from index calculations (ICES 2017). Results from the mackerel index calculations for the North Sea are presented in Appendix 1.

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

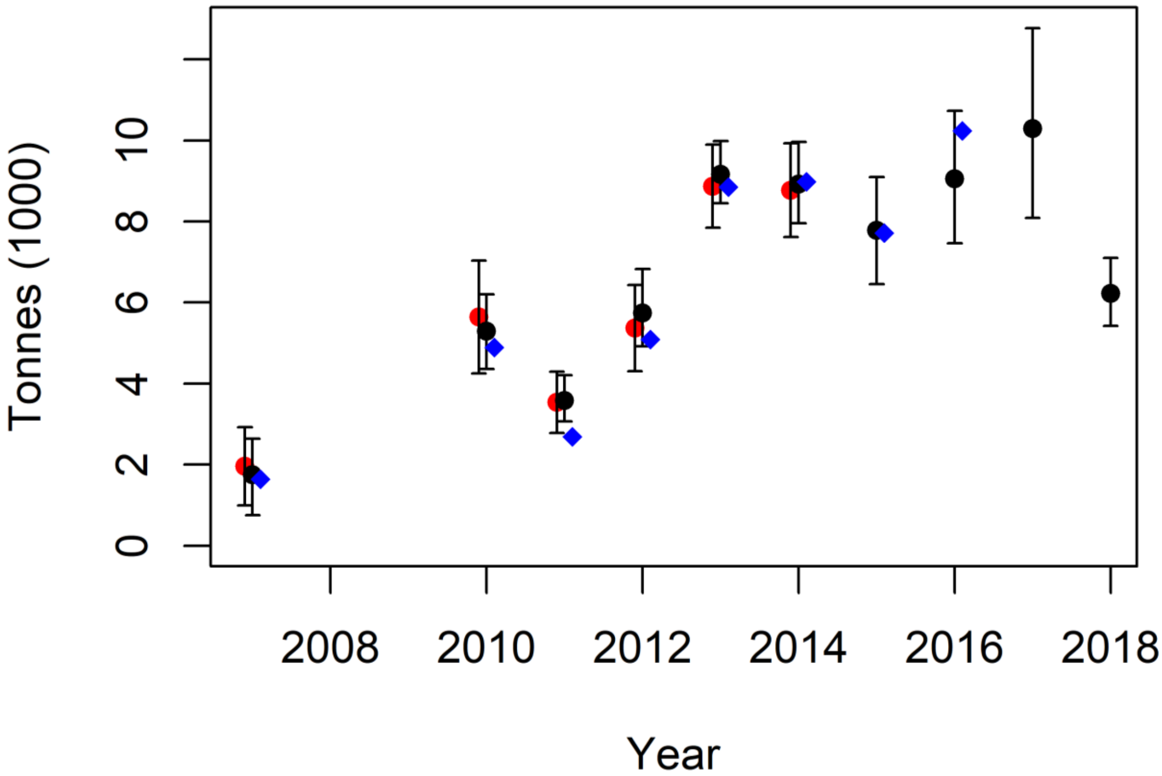


Figure 13. Estimated total stock biomass (TSB) of mackerel from StoX (black dots), Nøttestad et al. (2016) (red dots) and IESSNS cruise reports (blue diamonds). The error bars represent approximate 90 % confidence intervals.

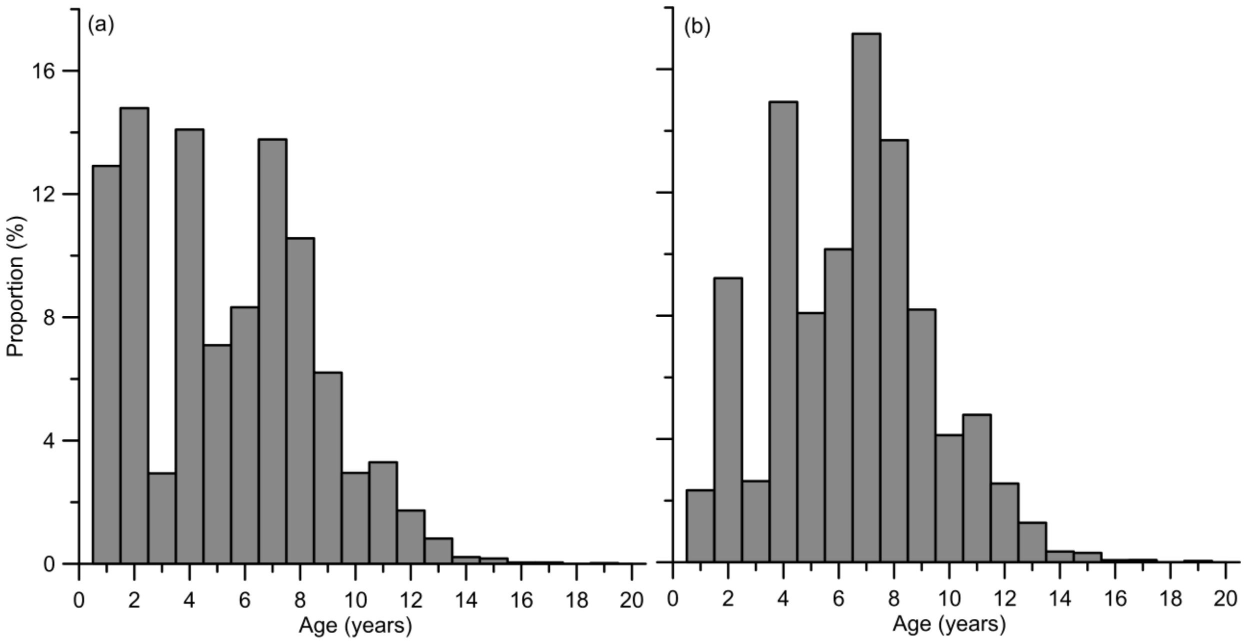


Figure 14. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2018.

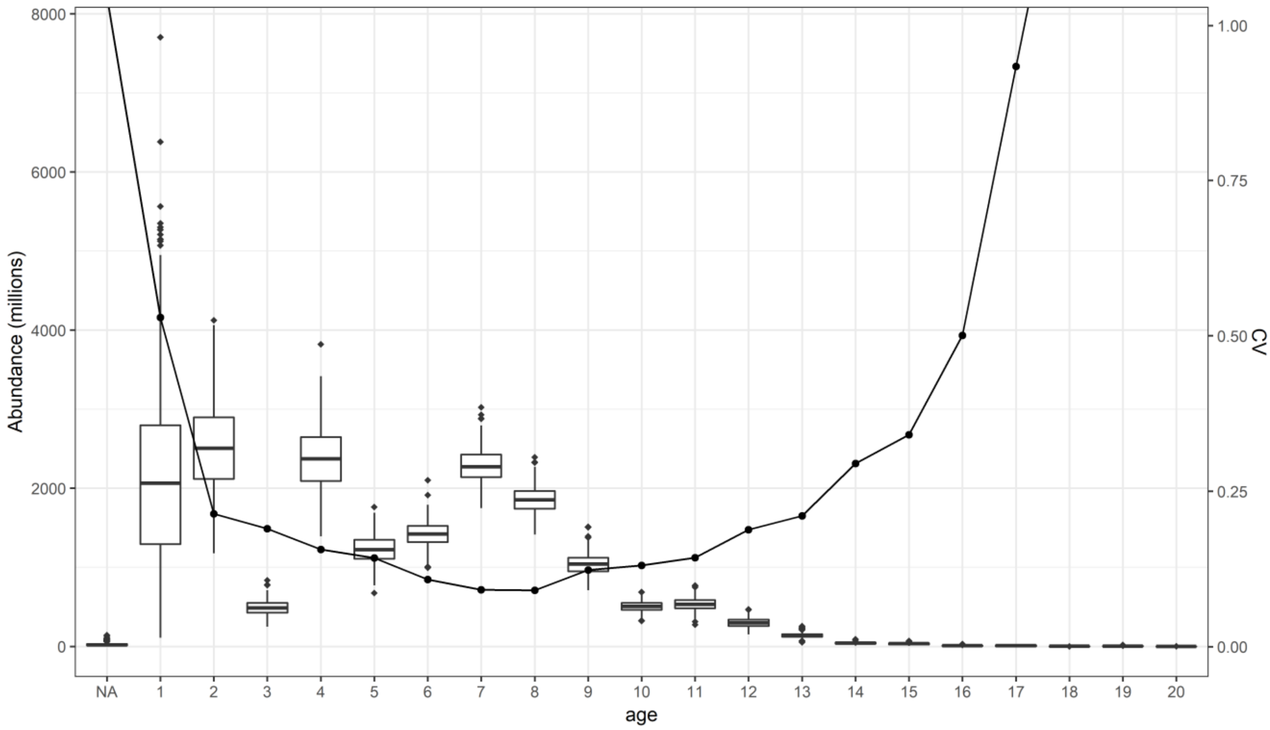


Figure 15. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. Time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (g) per age and (c) estimated biomass at age (million tonnes) from 2007 to 2018.

a)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot N
2007	1.33	1.86	0.90	0.24	1.00	0.16	0.06	0.04	0.03	0.01	0.01	0.00	0.01	0.00	5.65
2010	0.03	2.80	1.52	4.02	3.06	1.35	0.53	0.39	0.20	0.05	0.03	0.02	0.01	0.01	13.99
2011	0.21	0.26	0.87	1.11	1.64	1.22	0.57	0.28	0.12	0.07	0.06	0.02	0.01	0.00	6.42
2012	0.50	4.99	1.22	2.11	1.82	2.42	1.64	0.65	0.34	0.12	0.07	0.02	0.01	0.01	15.91
2013	0.06	7.78	8.99	2.14	2.91	2.87	2.68	1.27	0.45	0.19	0.16	0.04	0.01	0.02	29.57
2014	0.01	0.58	7.80	5.14	2.61	2.62	2.67	1.69	0.74	0.36	0.09	0.05	0.02	0.00	24.37
2015	1.20	0.83	2.41	5.77	4.56	1.94	1.83	1.04	0.62	0.32	0.08	0.07	0.04	0.02	20.72
2016	<0.01	4.98	1.37	2.64	5.24	4.37	1.89	1.66	1.11	0.75	0.45	0.20	0.07	0.07	24.81
2017	0.86	0.12	3.56	1.95	3.32	4.68	4.65	1.75	1.94	0.63	0.51	0.12	0.08	0.04	24.22
2018	2.18	2.50	0.50	2.38	1.20	1.41	2.33	1.79	1.05	0.50	0.56	0.29	0.14	0.09	16.92

b)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	W
2007	133	233	323	390	472	532	536	585	591	640	727	656	685	671	512
2010	133	212	290	353	388	438	512	527	548	580	645	683	665	596	469
2011	133	278	318	371	412	440	502	537	564	541	570	632	622	612	467
2012	112	188	286	347	397	414	437	458	488	523	514	615	509	677	426
2013	96	184	259	326	374	399	428	445	486	523	499	547	677	607	418
2014	228	275	288	335	402	433	459	477	488	533	603	544	537	569	441
2015	128	290	333	342	386	449	463	479	488	505	559	568	583	466	431
2016	95	231	324	360	371	394	440	458	479	488	494	523	511	664	367
2017	86	292	330	373	431	437	462	487	536	534	542	574	589	626	425
2018	67	229	330	390	420	449	458	477	486	515	534	543	575	643	368

c)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot B
2007	0.18	0.43	0.29	0.09	0.47	0.09	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.00	1.64
2010	0.00	0.59	0.44	1.42	1.19	0.59	0.27	0.20	0.11	0.03	0.02	0.01	0.01	0.00	4.89
2011	0.03	0.07	0.28	0.41	0.67	0.54	0.29	0.15	0.07	0.04	0.03	0.01	0.01	0.00	2.69
2012	0.06	0.94	0.35	0.73	0.72	1.00	0.72	0.30	0.17	0.06	0.03	0.01	0.00	0.00	5.09
2013	0.01	1.43	2.32	0.70	1.09	1.15	1.15	0.56	0.22	0.10	0.08	0.02	0.01	0.01	8.85
2014	0.00	0.16	2.24	1.72	1.05	1.14	1.23	0.80	0.36	0.19	0.05	0.03	0.01	0.00	8.98
2015	0.15	0.24	0.80	1.97	1.76	0.87	0.85	0.50	0.30	0.16	0.04	0.04	0.02	0.01	7.72
2016	<0.01	1.15	0.45	0.95	1.95	1.72	0.83	0.76	0.53	0.37	0.22	0.10	0.04	0.04	9.11
2017	0.07	0.03	1.18	0.73	1.43	2.04	2.15	0.86	1.04	0.33	0.28	0.07	0.05	0.03	10.29
2018	0.15	0.57	0.16	0.93	0.50	0.63	1.07	0.85	0.51	0.26	0.30	0.16	0.08	0.05	6.22

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2017 by the inclusion of two more survey years (Figure 16). This is especially apparent for 5–11 year old mackerel. There is now a strong internal consistency for ages 1 to 5 years, and a fair/good internal consistency for ages 5 to 11 years.

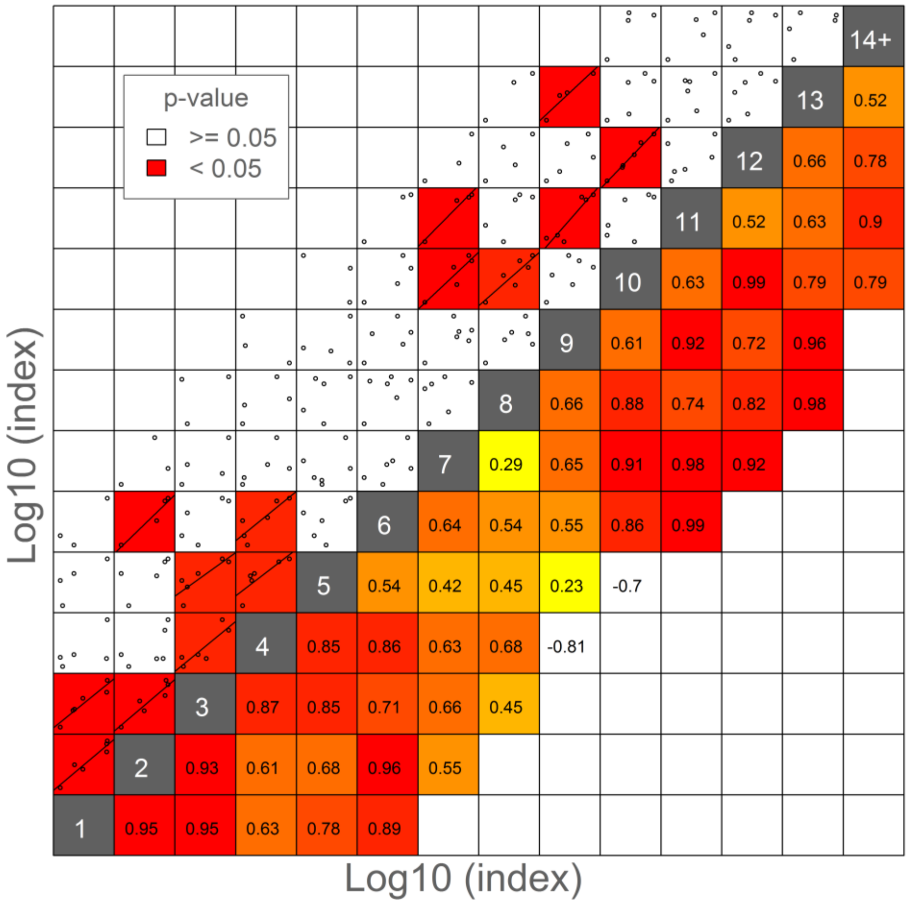


Figure 16. Internal consistency of mackerel density index from 2012 to 2018. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded mainly in the southern and western part of the Norwegian Sea basin, north of the Faroes and east and north of Iceland (Figure 17). NSSH was also recorded in the northeastern part of the Norwegian Sea close to the Norwegian coast. The fish in the northeast consisted of young adults (4-5 years old) while the fish further southwest are a range of age groups, mainly from 5 to 13 years old. Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring while the herring closer to the Faroes south of 62°N were Faroese autumn spawners. Also herring to the west in Icelandic waters (west of 14°W south of Iceland and west of 24°W north of Iceland, not shown on the map) were allocated to a different stock, Icelandic summer-spawners. The abundance of NSSH in the eastern and north-eastern part of the area surveyed were lower and consisted mainly of younger and smaller fish than in the western part. The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions.

The NSSH stock is dominated by 5-year old herring (year classes 2013) in terms of numbers and biomass (Table 8). This year class is mainly distributed in the north-eastern part of the Norwegian Sea and it contributes 20% to the total biomass. The total number of herring recorded in the Norwegian Sea was 13.7 billion in 2018 and the total biomass index was 4.47 million tonnes. Number by age, with uncertainty estimates, for NSSH is shown in Figure 18.

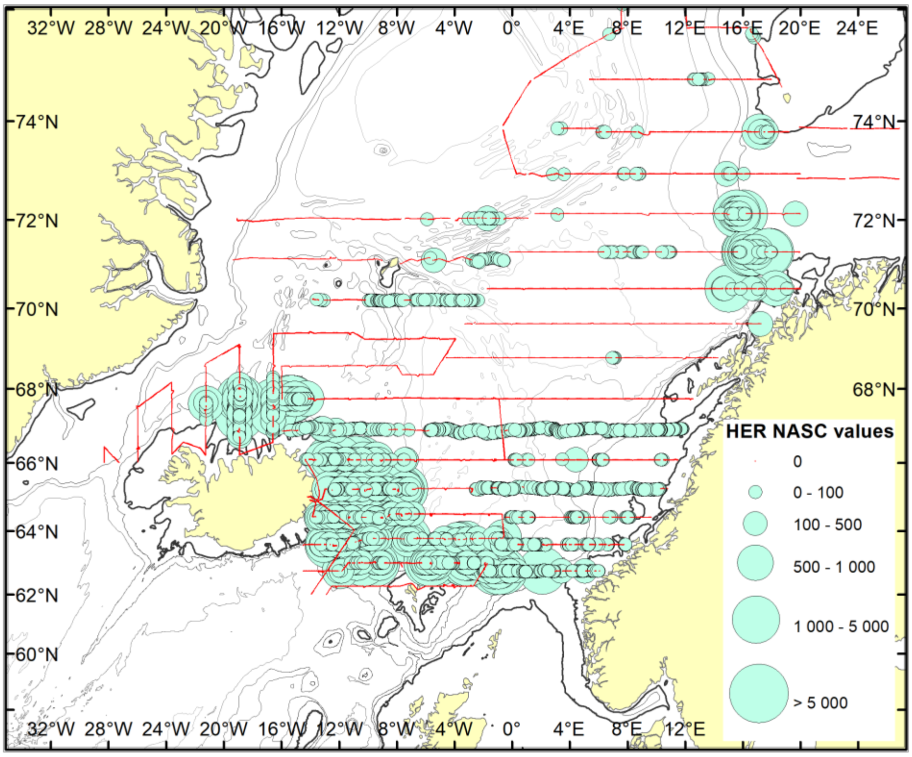


Figure 17. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring north of 62ºN and east of 14ºW, along the cruise tracks in 2018. South and west of this area the herring observed are other stocks, i.e. Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

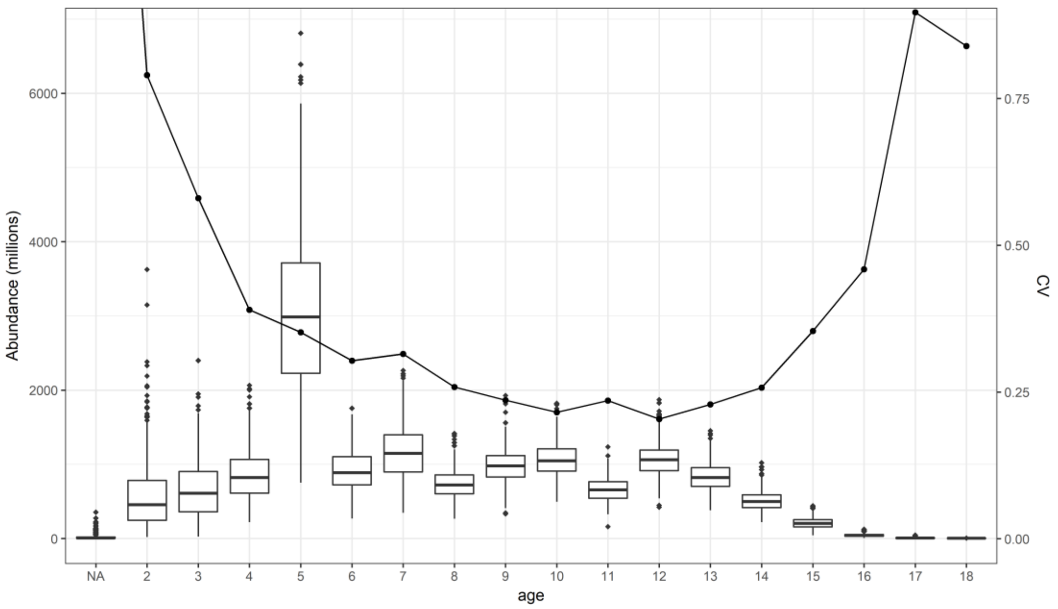


Figure 18. Number by age for Norwegian spring-spawning herring during IESSNS 2018. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 8. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2018.

	age																				
LenGrp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number	Biomass	Mean W
																			-1,00E+03	(1E3kg)	(g)
17-18 |	10292	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10292	447.7	43.50
18-19 |	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20 |	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2264	2264	153.9	68.00
20-21 |	14497	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14497	996.8	68.76
21-22 |	52468	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52468	4339.5	82.71
22-23 |	113478	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113478	10901.2	96.06
23-24 |	167087	47818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	214904	23541.5	109.54
24-25 |	147783	64018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	211801	24829.2	117.23
25-26 |	59109	17956	-	11410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	88475	12231.2	138.24
26-27 |	12361	61406	12723	-	18072	-	-	-	-	-	-	-	-	-	-	-	-	-	104562	16727.0	159.97
27-28 |	-	61024	-	42497	44904	-	-	6292	-	-	-	-	-	-	-	-	-	-	154716	28422.9	183.71
28-29 |	-	20311	28618	54703	9525	21411	-	-	-	-	-	-	-	-	-	-	-	-	134567	28349.1	210.67
29-30 |	-	58529	220195	47539	2578	-	25546	34506	-	-	36375	-	-	-	-	-	-	-	425269	100985.5	237.46
30-31 |	-	106259	220788	357674	68370	52219	58863	2637	62457	15614	11711	23421	5274	-	-	-	-	-	985287	255184.0	258.99
31-32 |	-	185583	167613	1091137	51260	29905	23137	27022	30884	7724	65595	-	-	-	-	-	-	-	1679860	474143.0	282.25
32-33 |	-	75252	80109	880209	229417	308324	-	12427	-	-	-	7429	-	-	-	-	-	-	1593168	485662.3	304.84
33-34 |	-	24234	127243	402250	327822	312089	24807	36581	21058	-	16596	-	-	-	-	3749	-	-	1296429	422052.1	325.55
34-35 |	-	-	21698	180555	108932	255273	206523	89302	118700	11797	55667	5103	14781	-	-	-	-	-	1068332	372617.4	348.78
35-36 |	-	-	-	9951	40468	224891	259078	405889	323944	201474	168535	69631	87407	81236	1260	-	-	-	1873763	701909.9	374.60
36-37 |	-	-	-	-	29812	59985	79844	128284	390552	300565	396800	301342	201506	11992	6032	-	-	-	1906715	759064.9	398.10
37-38 |	-	-	-	-	-	-	39769	176405	104649	137772	249625	404644	100843	49368	3781	1444	-	-	1268301	528268.4	416.52
38-39 |	-	-	-	-	-	-	16314	28384	18222	18657	35014	121698	80256	79185	22314	1860	1860	-	423763	183836.2	433.82
39-40 |	-	-	-	-	-	-	-	-	-	-	-	33193	18640	2360	14554	-	-	-	68747	30721.5	446.88
40-41 |	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1171	1171	-	-
TSN(1 |	577075	722390	878987	3077925	931162	1264097	733881	947728	1070466	693602	1035918	966461	508707	224140	47942	7053	1860	3435	13692829	-	-
TSB(1(|	62491.9	156106.0	228916.1	892608.0	290869.3	426574.7	258383.5	355348.4	406226.6	273767.6	402455.0	388876.2	206764.7	92574.2	19897.3	2574.9	796.8	153.9	-	4465385.1	-
Mean |	23.21	28.86	30.75	31.70	32.46	33.44	34.41	35.17	35.26	35.86	35.50	36.57	36.48	36.69	37.96	35.14	38.00	26.49	-	-	-
Mean |	108.29	216.10	260.43	290.00	312.37	337.45	352.08	374.95	379.49	394.70	388.50	402.37	406.45	413.02	415.03	365.10	428.50	68.00	-	-	326.14

4.5 Blue whiting

Blue whiting was distributed throughout the entire survey area with exception of the area north of Iceland influenced by the cold East Icelandic Current and in the East Greenland area. The highest sA-values were observed in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands as well as south of Iceland –the distribution in 2018 is quite similar to the 2017 distribution with perhaps a little less concentration west off Iceland. The main concentrations of older fish were observed in connections with the continental slopes both in the eastern and the southern part of the Norwegian Sea (Figure 19). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during IESSNS 2018 was 2.0 million tons (Table 9), which is an 11% decrease compared to 2017 when the estimated index of age groups 1+ was 2.3 million tonnes. The stock estimate in number for 2018 is 16.3 billion compared to 22.3 billion of age groups 1+ in 2017, which is a 27% decrease. The age group four is dominating the estimate (39% of the biomass and by number).

Number by age, with uncertainty estimates, for blue whiting during IESSNS 2018 is shown in Figure 20.

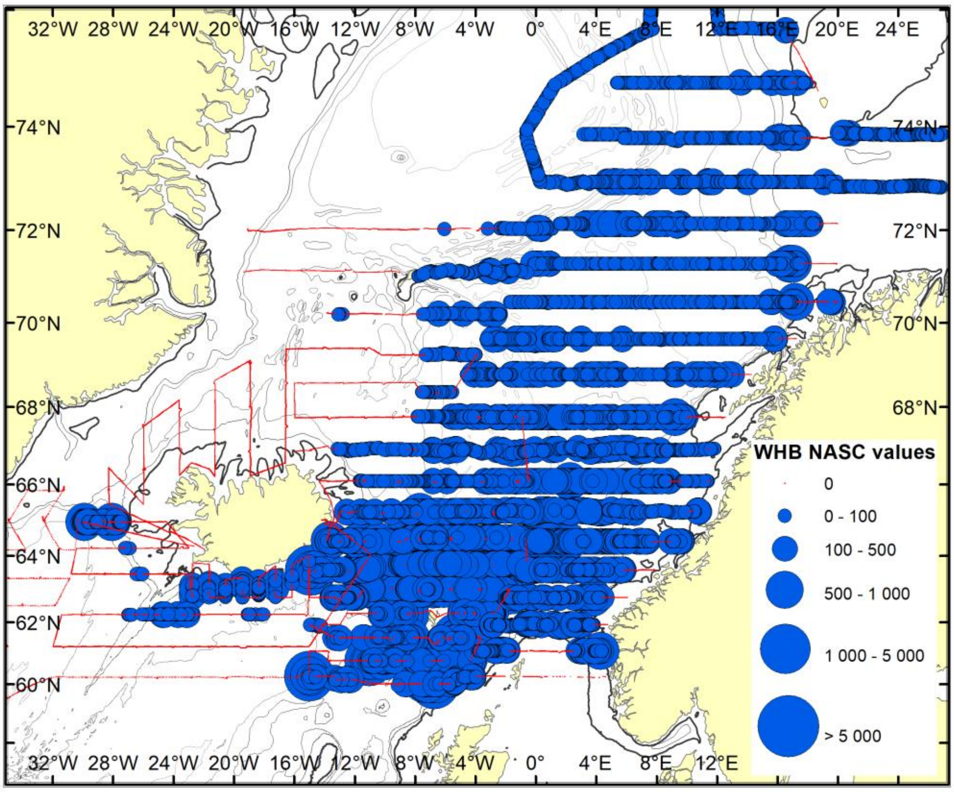


Figure 19. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2018.

Table 9. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2018.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: kolmule

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11016	11016	495.4	44.97
21-22	35568	26067	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61635	3440.5	55.82
22-23	194497	62947	-	-	12138	-	-	-	-	-	-	-	-	-	-	-	269581	17753.8	65.86
23-24	246952	129453	11762	1060	-	-	-	-	-	-	-	-	-	-	-	-	389228	29380.1	75.48
24-25	343423	166977	93173	48828	17691	-	-	-	-	-	-	-	-	-	-	-	670092	56534.4	84.37
25-26	69234	387671	618132	570315	168980	10606	-	-	-	-	-	-	-	-	-	-	1824938	174933.4	95.86
26-27	21783	175860	921339	1528898	562484	58381	-	-	-	-	-	-	-	-	-	-	3268747	345041.9	105.56
27-28	3206	178698	872232	1531573	568516	24235	14597	-	-	-	-	-	-	-	-	-	3193057	380715.2	119.23
28-29	-	24592	429051	1351247	624348	119744	14222	25278	-	-	-	-	-	-	-	-	2588482	344020.6	132.90
29-30	-	4523	211757	781889	434152	106990	50613	903	-	-	-	-	-	-	-	-	1590826	233385.8	146.71
30-31	-	4045	36533	297721	428459	125672	61608	16893	-	-	-	-	-	-	-	-	970930	156092.2	160.77
31-32	-	4467	46996	173893	148891	165373	77032	3070	11422	-	-	-	-	-	-	-	631143	110657.7	175.33
32-33	-	-	9610	36084	101201	130985	47067	276	-	10101	-	-	531	-	-	-	335856	64249.1	191.30
33-34	-	-	-	2307	73371	98836	69831	18483	-	-	2026	-	-	-	-	-	264854	54436.4	205.53
34-35	-	-	-	5709	6798	8220	37960	9050	-	-	-	-	-	5164	-	-	72901	16611.6	227.87
35-36	-	-	1237	13619	-	13893	-	12682	3405	-	-	1856	-	-	-	-	46692	11944.8	255.82
36-37	-	-	-	6533	-	33136	11911	6037	-	-	-	-	-	-	3383	-	61001	15752.0	258.23
37-38	-	-	-	-	-	-	-	-	27235	-	-	1767	-	-	-	-	29002	8652.5	298.34
38-39	-	-	-	-	3627	3830	-	-	-	-	-	-	7660	-	-	-	15117	5187.7	343.18
39-40	-	-	-	-	-	353	-	-	6815	-	-	7766	-	-	-	-	14935	5574.7	373.27
40-41	-	-	-	-	-	-	-	-	2878	-	-	353	-	-	-	-	3232	1070.7	331.31
41-42	-	-	-	-	-	-	-	7660	-	-	-	-	-	-	-	-	7660	2734.5	357.00
TSN(1000)	914663	1165301	3251822	6349676	3150656	900253	384842	100330	51755	10101	2026	11743	8190	5164	3383	11016	16320922	-	-
TSB(1000 kg)	72758.2	110519.6	375377.4	788226.6	424900.3	152361.1	68014.1	20457.0	14396.2	2129.7	402.5	3878.7	2572.7	1248.5	927.0	495.4	-	2038664.9	-
Mean length (cm)	23.61	25.20	26.84	27.54	28.29	30.58	31.48	32.49	36.11	32.00	33.17	38.22	38.08	34.45	36.33	20.32	-	-	-
Mean weight (g)	79.55	94.84	115.44	124.14	134.86	169.24	176.73	203.90	278.16	210.83	198.67	330.31	314.12	241.78	274.00	44.97	-	-	124.91

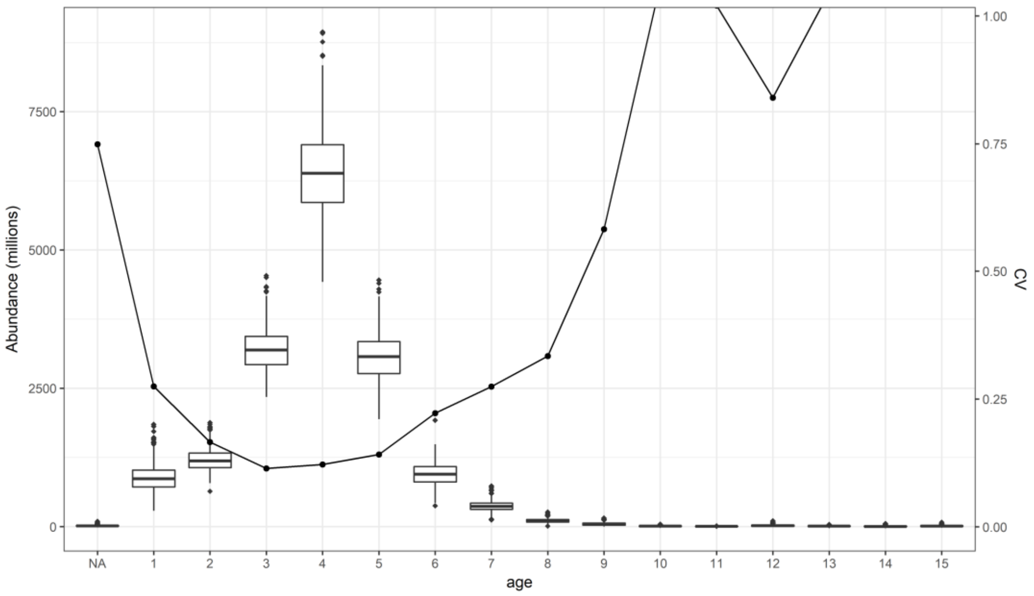


Figure 20. Number by age with uncertainty for blue whiting during IESSNS 2018. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 65% of trawl stations across the six vessels (Figure 21) and where lumpfish was caught, 79% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Of note, total trawl catch at each trawl station were processed on board R/V ”Árni Friðriksson”, M/V “Kings Bay”, M/V “Vendla” and M/V “Finnur Fríði”, whereas a subsample of 100 kg to 200 kg was processed onboard M/V “Trøndur i Gøtu” in Faroese waters. Therefore, small catches (<10 kg) of lumpfish might be missing from the survey track of M/V “Trøndur i Gøtu” (black crosses in Figure 21). However, it is unlikely that larger catches of lumpfish would have gone unnoticed by crew during sub-sampling of catch.

Abundance was greatest north of 66°N, and lower south of 65°N south of Iceland, in Faroese waters and northern UK waters. The zero line was not hit to the north, northwest and southwest of the survey so it is likely that the distribution of lumpfish extends beyond the survey coverage. The length of lumpfish caught varied from 3 to 51 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups (Figure 22). For fish ≥20 cm in which sex was determined, the males exhibited a unimodal distribution with a peak around 25-27 cm. The females also exhibited a unimodal distribution but with a peak around 27-30 cm which was positively skewed. Aboard the Norwegian vessels, the ratio of males to females was approximately 1:1. Generally, the mean length and mean weight of the lumpfish was highest in the coastal waters and along the shelf edges in southwest, west, and northwest, and lowest in the central Norwegian Sea.

A total of 289 fish (253 by R/V “Árni Friðriksson” and 36 by M/V “Finnur Fridi”) between 10 and 44 cm were tagged during the survey (Figure 23).

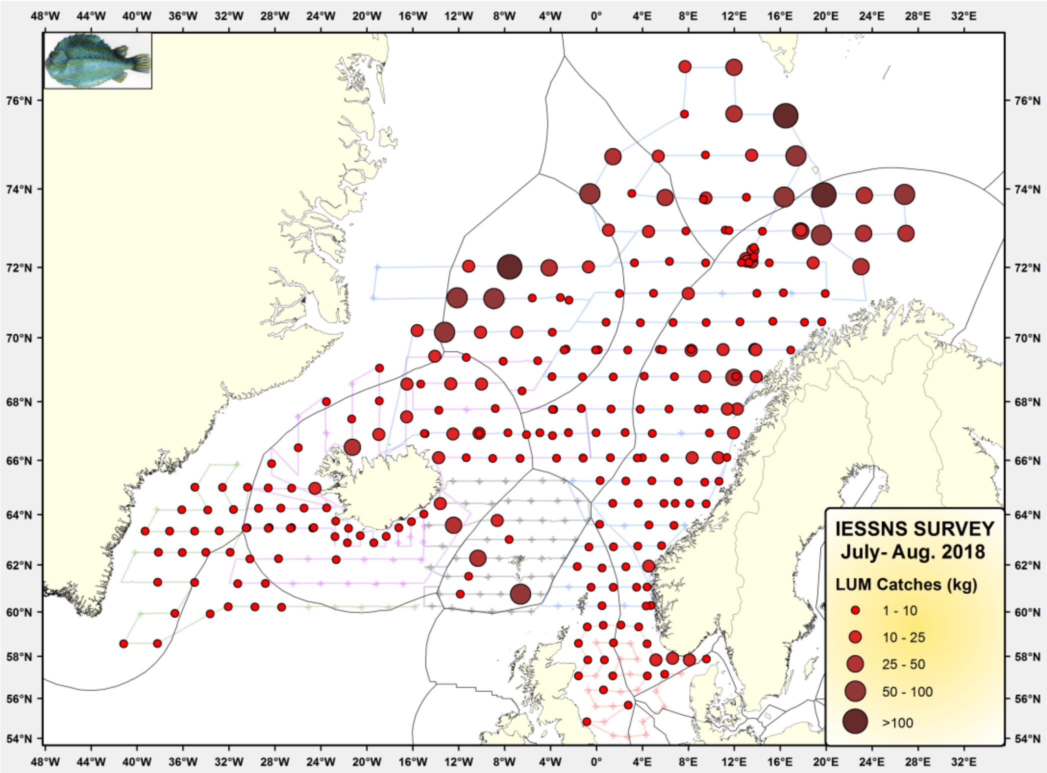


Figure 21. Lumpfish catches at surface trawl stations during IESSNS 2018.

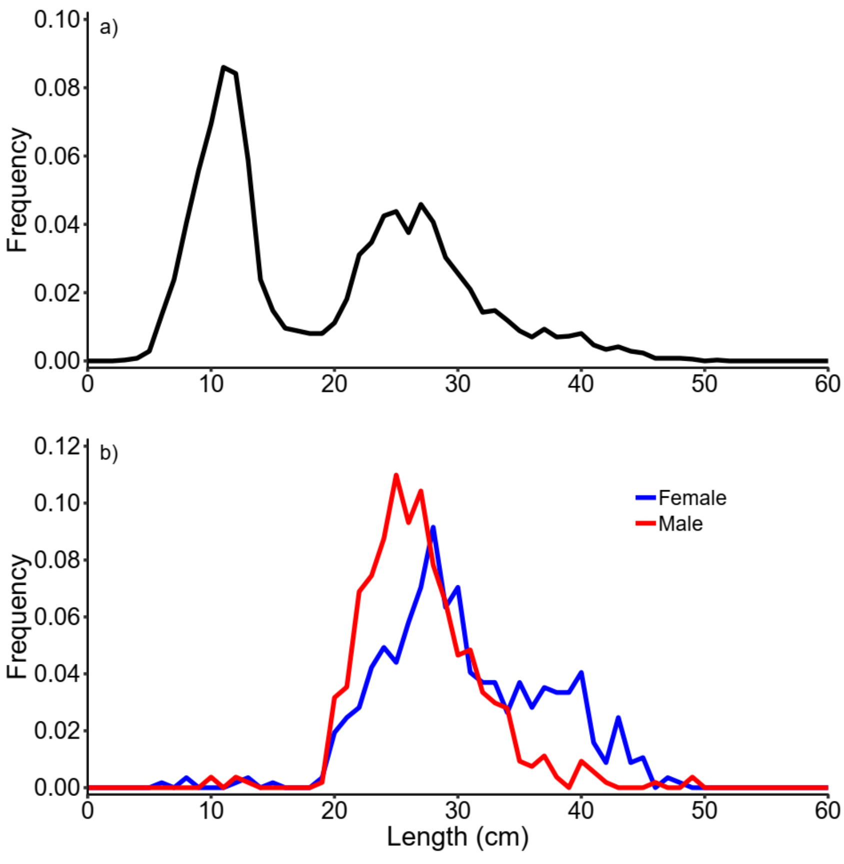


Figure 22. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

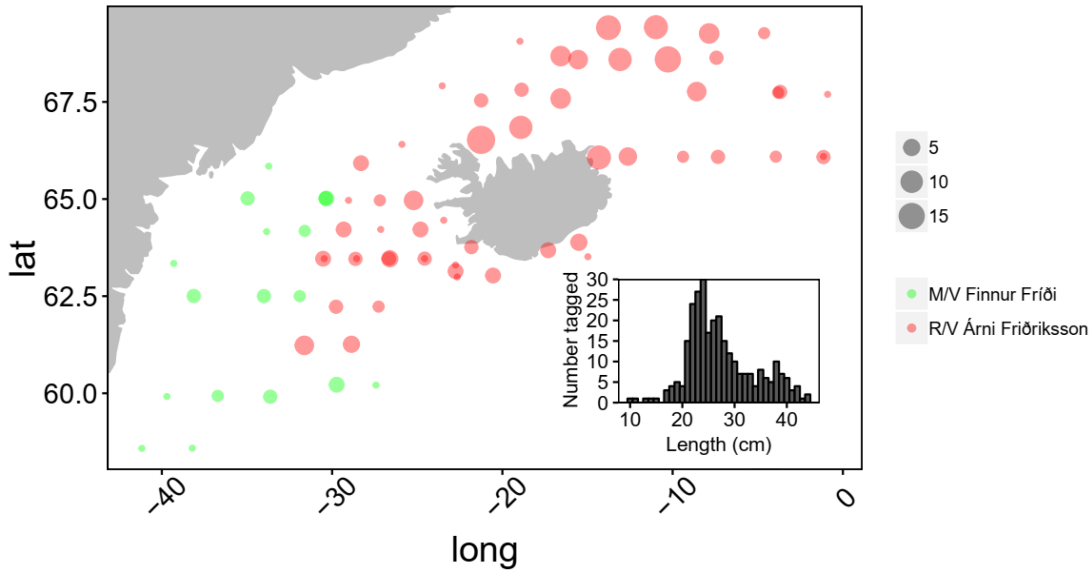


Figure 23. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 80 North Atlantic salmon were caught in 44 stations both in coastal and offshore areas in the upper 30 m of the water column during IESSNS 2018 (Figure 24). The salmon ranged from 0.06 kg to 4.82 kg in weight, dominated by postsmolt weighing 80-200 grams. The length of the salmon ranged from 20 cm to 80 cm, with a large majority of the salmon <30 cm in length. The general impression was that postsmolt was distributed further to the east in 2018 than in 2017.

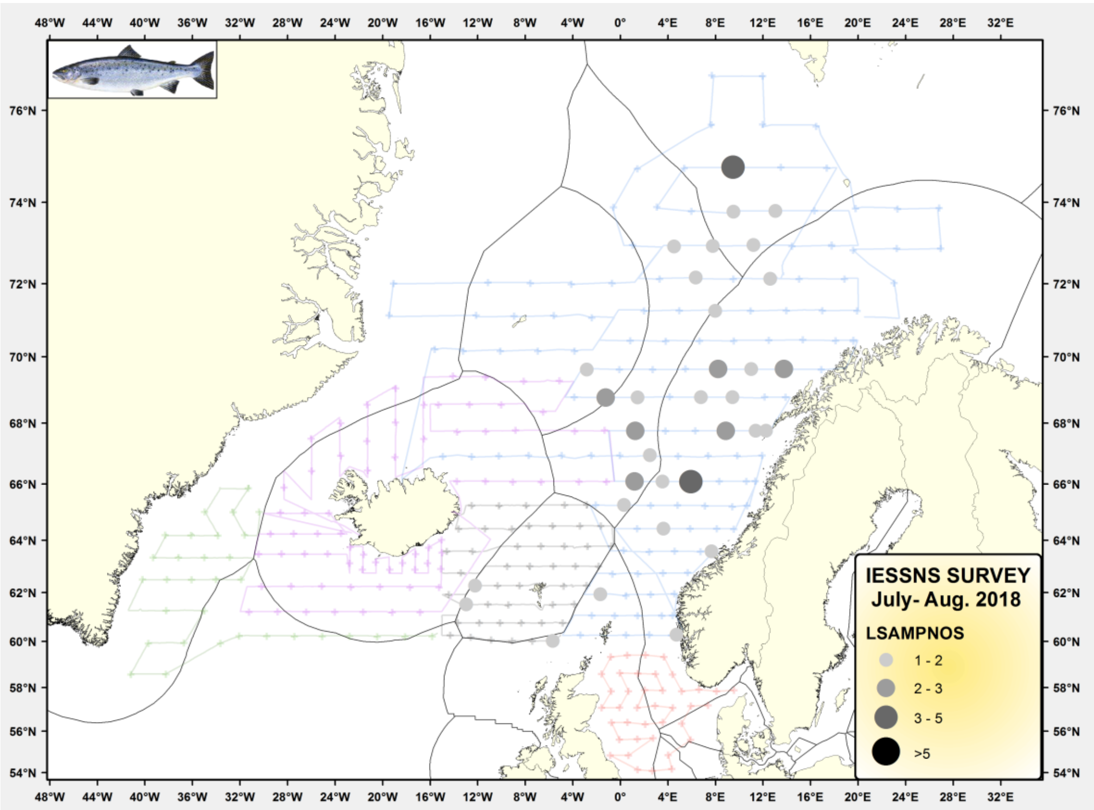


Figure 24. Catches of salmon at surface trawl stations during IESSNS 2018.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 12 stations along the cold front in SE Greenland, North of Iceland, North of Jan Mayen and at the entrance to the Barents Sea around Bear Island (Figure 25).

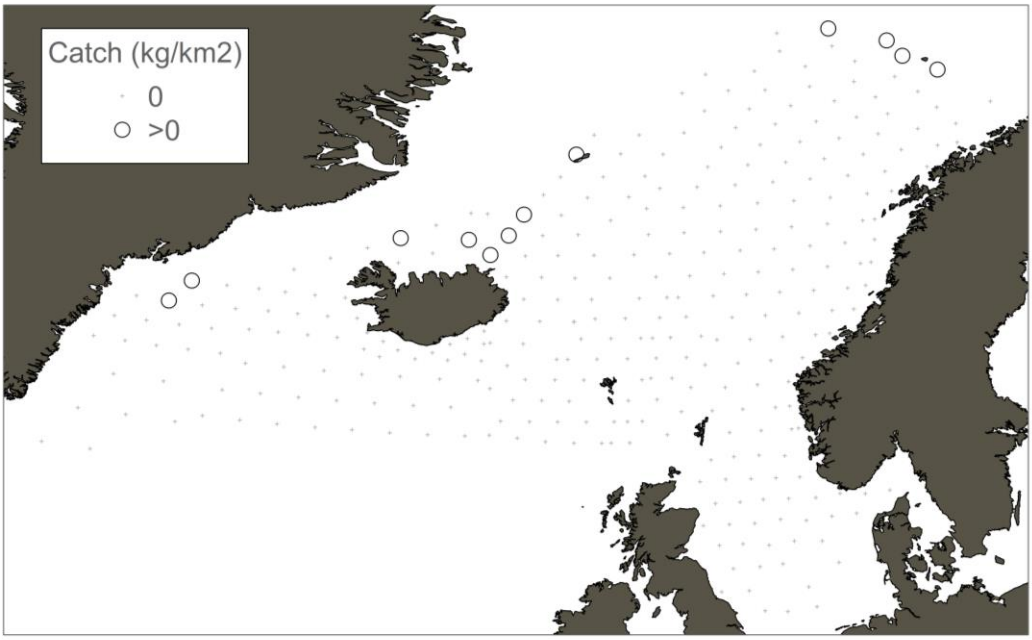


Figure 25. Presence of capelin in surface trawl stations during the IESSNS survey 2018.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Kings Bay" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland in 2018 (Figure 26). Overall, more than 600 marine mammals of nine different species were observed, which was a small reduction from last year 700+ observed individuals. This could partly be explained by reduced observation effort on R/V "Árni Friðriksson" as in 2017 dedicated whale observers were onboard which was not the case in 2018. The two Norwegian vessels with practically flat sea and excellent visibility during the entire survey period while Arni Fridriksson had occasional periods with fog north of Iceland. The species that was observed included; fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*), pilot whales (*Globicephala sp.*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), white-sided dolphins (*Lagenorhynchus acutus*) and white beaked dolphins (*Lagenorhynchus albirostris*). Marine mammal observations were north and south of Iceland, at the entrance to the Barents Sea, along the Norwegian coast and in the western outskirts of the Norwegian Sea. The observations were a mix of the species with no single species dominating. There were very few observations of marine mammals in the central Norwegian Sea and east of Iceland, and the spatial overlap between the pelagic fish and marine mammals seem to be low.

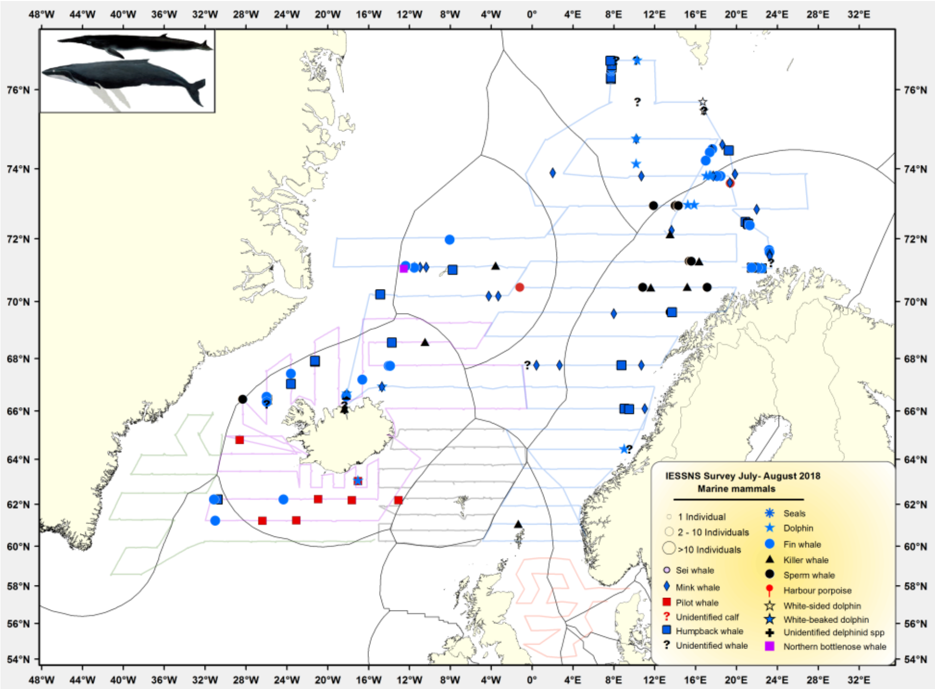


Figure 26. Overview of all marine mammals sighted during IESSNS 2018.

5 Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 30th June – 6th August 2018 by six vessels from Norway (2), Iceland (1), Faroes (1), Greenland (1), and Denmark (1). The survey coverage was slightly larger than in the previous year. Standardised surface trawling at predefined locations was used for a swept area abundance estimation of mackerel as in current years. The method is analogous to swept area bottom trawl surveys run for many demersal stocks. In addition to the surface trawling, CTD, zooplankton sampling and marine mammal sightings are also parts of the IESSNS. Deep water trawling aimed on acoustic registrations were undertaken by all vessels, except Ceton operation in the North Sea, for the third consecutive year to identify species and size distribution for acoustic estimation of blue whiting and Norwegian spring-spawning herring. The attempts are considered successful for all three years, 2016-2018, and a new time series for abundance estimation and biomass indices for blue whiting (north of 60°N) and Norwegian spring-spawning herring is being created. The IESSNS therefore provides abundance indices of three pelagic fish stocks, mackerel, blue whiting and Norwegian spring-spawning herring.

Mackerel was distributed in most of the 2.8 million km^2 survey area excluding the cold waters north and northwest of Iceland. The total swept area biomass index of mackerel in 2018 was average for the time-series from 2007 to 2018. There was a 40% decline in biomass in 2018 compared to 2017, and a 30% decline in numbers. The smaller decline in numbers is explained by record high values of age-1 mackerel and high values of age-2 mackerel in 2018. Biomass decline from 2017 to 2018 was most pronounced for age classes 3-7. The 2014 cohort (age 4) is not as large as recorded previous two summers and does not anymore appear at similar level as the big 2010 and 2011-year classes.

The mackerel appeared more evenly distributed within the survey area and more easterly distributed than in 2017. This difference in distribution primarily consists of a marked biomass decline in the west (76 % decrease in biomass west of stratum 3, see StoX results). In the eastern areas, the decline was less (21 %). Furthermore, there was also an eastward shift in distribution within the Norwegian Sea.

The marked decrease in the western areas since 2017 may have several causes, importantly; it reflects that the 2017 estimate was driven by relatively few exceptionally large catches. The strong impact of rare large catches on the index calls for an evaluation of the methods used to derive the index. Statistical methods that account for trawl catch distributions with over-dispersion has successfully been applied to mackerel trawl data before (Jansen et al. 2015; Nikolioudakis et al. 2018).

Mackerel cohort internal consistency remained relatively high. Internal consistency is strong for ages 1 to 5 years (r > 0.8) and a fair/good internal consistency for ages 5 to 11 years (r > 0.5), except for 7-8 years old mackerel.

As in previous years, the spatio-temporal overlap between mackerel and herring was highest in the southern and south-western part of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea, mainly because of very limited amounts of herring in this area (Figure 12).

The acoustic abundance index of NSSH was 13.6 billion corresponding to 4.46 million tonnes (Table 8). The abundance estimate of herring from the 2017 survey was 20.6 billion corresponding to 5.88 million tonnes, i.e. a reduction of approx. 24.2% in terms of biomass this year. This drop cannot be easily explained but migration of NSSH south of 62 ^{0}N, where it would mix with other stocks, might influence the result. Older fish dominated in the western and southwestern part and a range of year classes were present in this area. In the north-eastern part of the Norwegian Sea at the entrance to the Barents Sea is mainly juvenile fish age 5 years and younger present.

The acoustic abundance index of blue whiting was 16.3 billion corresponding to 2.0 million tonnes (Table 9). The abundance estimate of blue whiting from the 2017 survey was 22.3 billion corresponding to 2.3 million tonnes, corresponding to decrease in 2018 of approximately 11% in terms of biomass and 27% in terms of abundance of age 1+ fish. It should be noted that in 2017 some strong registrations of 0-group blue whiting south of the Faroe Islands which accounted for 15% of the abundance that year. However, in 2018 no 0-group was registered in the survey.

The group considered the two acoustic biomass estimates of herring and blue whiting to be of good quality in the 2018 IESSNS as in the two previous survey years.

Average zooplankton index for the survey area declined compared to 2017, however the decline was not uniform for the survey area. There was a slight decline in zooplankton in the Norwegian Sea and in Greenland waters (eastward of longitude 30 °W) compared to a substantial increase in Icelandic waters. These plankton indices, however, needs to be treated with some care due as it is only a snapshot of the standing stock biomass, not of the actual production in the area, which complicates spatio-temporal comparisons.

The swept-area estimate was, as in previous years, based on the standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 60-68m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

Results from the survey expansion southward into the North Sea is analysed separately from the traditional survey grounds north of latitude 60 °N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017).

This year’s survey was well synchronized in time and was conducted over a relatively short period (5 weeks) given the large spatial coverage (Figure 1). This was in line with recommendations put forward in 2016 that the survey period should be around four weeks with mid-point around 20 July. The main argument for this time period, was to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year.

6 Recommendations

Recommendation	To whom
Encourage EU to participate in the IESSNS survey again and survey the North Sea, and review the spatial coverage based on this years' results combined with the mackerel catches in IBTS Q3.	EU
The guidelines for trawl performance should be revised to reflect realistic manoeuvring of the Multpelt832 trawl.	Norway, Faroe Islands, Iceland, Greenland, EU
Criteria and guidelines should be established for discarding substandard trawl stations using live monitoring of headline, footrope and trawl door vertical depth, and horizontal distance between trawl doors. As predetermined surface trawl station, discarded hauls should be repeated until performance is satisfactory.	Norway, Faroe Islands, Iceland, Greenland, EU
Explicit guideline for incomplete trawl hauls is to repeat the station or exclude it from future analysis. It is not acceptable to visually estimate mackerel catch, it must be hauled onboard and weighted. If predetermined trawl hauls are not satisfactory according to criteria the station will be excluded from mackerel index calculations, i.e. treated as it does not exist, but not as a zero mackerel catch station.	Norway, Faroe Islands, Iceland, Greenland, EU
We recommend that observers collect sighting information of marine mammals and birds on all vessels.	Norway, Faroe Islands, Iceland, Greenland, EU

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2 Appendix 1:

StoX estimate of age segregated and length segregated mackerel index for the North Sea in 2018. Also provided is average length and weight per age class.

LenGrp	age 1	2	3	4	5	6	7	8	9	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	-	-	-	-	-	-	-	-	-	-	-	-
17-18	332	-	-	-	-	-	-	-	-	332	13.8	41.59
18-19	32024	-	-	-	-	-	-	-	-	32024	1712.7	53.48
19-20	134728	-	-	-	-	-	-	-	-	134728	7669.6	56.93
20-21	209419	-	-	-	-	-	-	-	-	209419	14330.2	68.43
21-22	155303	-	-	-	-	-	-	-	-	155303	12060.3	77.66
22-23	53594	-	-	-	-	-	-	-	-	53594	4615.5	86.12
23-24	9095	-	-	-	-	-	-	-	793	9888	985.3	99.65
24-25	9633	293	-	-	-	-	-	-	-	9926	1144.6	115.31
25-26	54163	3620	-	-	-	-	-	-	-	57783	7757.3	134.25
26-27	26501	120545	-	-	-	-	-	-	-	147046	23735.6	161.42
27-28	26069	282811	-	-	-	-	-	-	-	308879	54534.6	176.56
28-29	44374	287831	-	-	-	-	-	-	-	332205	63114.0	189.98
29-30	12520	207591	-	-	-	-	-	-	-	220111	47338.0	215.06
30-31	6963	83768	3760	1568	-	-	-	-	-	96060	22202.7	231.13
31-32	-	38363	31325	618	-	-	-	-	-	70305	18482.0	262.88
32-33	-	38580	65123	1438	-	-	-	-	-	105141	29753.3	282.98
33-34	-	20497	61592	10098	-	-	-	-	-	92186	28244.3	306.38
34-35	-	9949	33634	14386	2714	-	-	-	-	60683	19239.7	317.05
35-36	-	-	12031	10684	16019	1138	-	-	-	39872	14439.6	362.15
36-37	-	-	2177	4389	8905	5168	615	-	-	21254	8008.3	376.79
37-38	-	-	1038	157	4714	3406	256	805	-	10375	4359.1	420.15
38-39	-	-	-	-	1454	2340	295	343	-	4432	2016.2	454.96
39-40	-	-	-	-	264	941	580	89	-	1873	932.2	497.57
40-41	-	-	-	-	-	103	497	76	-	676	380.5	563.20
41-42	-	-	-	-	-	-	506	103	-	608	362.3	595.46
42-43	-	-	-	-	-	-	-	22	-	22	12.6	570.00
43-44	-	-	-	-	-	-	67	-	224	291	168.0	576.51
44-45	-	-	-	-	-	-	-	-	-	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-
46-47	-	-	-	-	-	-	-	-	-	-	-	-
TSN(1000)	774717	1093847	210679	43338	34070	13095	2816	1437	1017	2175018	-	-
TSB(1000 kg)	72289.3	218580.4	61213.7	14858.2	12933.7	5428.8	1461.2	656.9	190.3	-	387612.5	-
Mean length (cm)	21.65	28.25	32.66	33.97	35.62	36.78	38.69	37.88	27.41	-	-	-
Mean weight (g)	93.31	199.83	290.55	342.84	379.62	414.57	518.85	457.06	187.09	-	-	178.21