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Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 28th June – 5th August 2019

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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 28th to August 5th in 2019 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 a 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 mackerel index increased by 85% for biomass and 56 % for abundance (numbers of individuals) compared to the 2018 index. In 2019, the most abundant year classes were 2011, 2010, 2016, 2014 and 2013, respectively. Overall, the cohort internal consistency remained good and was similar to 2018.

The survey coverage area was 2.9 million km^2 which is similar as in 2017 and 2018. Furthermore, 0.3 million km^2 was surveyed in the North Sea. Distribution zero boundaries were found in majority of the survey area with a notable exception of high mackerel abundance at the survey boundary south-west of Faroe Island and in the northern Norwegian Sea. The mackerel were more north-easterly distributed in 2019, compared to the period from 2012 to 2018. This was specifically apparent in Greenland waters, where the catch was the lowest for the time series.

The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2019 was 15.2 billion and the total biomass index was 4.78 million tonnes, which is slightly higher compared to 2018. The herring stock is dominated by 6-year old herring (year class 2013) in terms of numbers and biomass. This year class is now distributed in all areas with herring in the survey compared to last year when it was mainly found in the north-eastern part. It contributes 23% and 22% to the total biomass and total abundance, respectively.

The total biomass of blue whiting registered during IESSNS 2019 was 2.0 million tons, which is the same compared to 2018. The stock estimate in number for 2019 is 16.2 billion compared to 16.3 billion of age groups 1+ in 2018. The age group five is dominating the estimate (36% and 30% of the biomass and by numbers, respectively). A good sign of recruiting year class (0-group) was also seen in the survey this year.

As in previous years, the spatio-temporal overlap between mackerel and NSSH was highest in the southern and south-western parts of the Norwegian Sea. There was practically no overlap between mackerel and NSSH in the central part of the Norwegian Sea, whereas we had some overlap between mackerel and herring in the northern part of the Norwegian Sea. Herring distribution was mostly limited to the area east and north of Iceland and the southern Norwegian Sea. However, NSSH was also found in the central northern part for the first time in many years, dominated by the 2013- and 2016- year classes.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 73% 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 58 North Atlantic salmon were caught, mainly in central and northern part of the Norwegian Sea. More salmon was caught in western regions compared to previous years.

Sea surface temperature (SST) was 1-2°C warmer in Icelandic and Greenland waters in July 2019 compared to the long-term average (20-year mean), but similar to the long-term average in eastern part of the

Norwegian Sea. This contrasts with the situation in 2018 when SST was 1-2°C colder than the average in Icelandic and Greenland waters. The SST in the entire Norwegian Sea in July 2019 was similar to July 2018.

The overall average zooplankton index in 2019 declined substantially compared to 2018. In 2019, the index decreased in both Greenland and Icelandic waters, whereas the index increased in the Norwegian Sea compared to 2018.

2 Introduction

During approximately five weeks of survey in 2019 (28th of June to 3rd of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Finnur Fridi" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland, the M/V "Eros" 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 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, predominantly from the bridge. The major objectives were 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 (ICES 2014). In the benchmark process in 2017 methodological and statistical changes were made to calculation of the index (ICES 2017).

The North Sea was included in the survey area again in 2019, following the recommendations of WGWIDE. This was done by scientists from DTU Aqua, Denmark. The commercial fishing vessels "Ceton S205" was used, and in total 38 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 (see Appendix 1 for comparison with 2018 results).

3 Material and methods

Coordination of the IESSNS 2019 was done during WGWIDE 2018 meeting in August-September 2018 in Torshavn, Faroe Islands, and at the WGIPS meeting in January 2019 in Santa Cruz, Tenerife, Canary Islands, and by correspondence in spring and summer 2019. 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 waters. The weather was good and calm for the two Norwegian vessels and the Icelandic and Faroese vessels operating in the central and northern part of the Norwegian Sea and in Icelandic and Faroese waters The chartered vessel Ceton encountered some bad weather in the North Sea, without influencing the swept area trawling.

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 (ICES 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 2019. 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	3/7-29/7	5500	69/61	61	60
Finnur Fríði	28/6- 12/7	3150	47/40	42	41
Eros	19/7-3/8	2881	27/27	27	27
Ceton	2/7-12/7	1870	38/38	38	-
Vendla	4/7-5/8	5933	91/66	71	71
Kings Bay	4/7-5/8	5639	88/77	76	76
Total	28/6-5/8	24873	360/309	315	275

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. Finnur Fríði was equipped with a mini SEABIRD SBE 25+ CTD sensor, Kings Bay and Vendla were both equipped with SAIV CTD sensors. Eros used a SEABIRD 19+V2 CTD sensor. Ceton used a Seabird SeaCat 4 CTD. 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, Finnur Fríði and Eros). 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 ground rope 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 specimens sampled per station (Table 3).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 28th June to 5th August 2019. 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**	**Finnur Fríði**	**Eros**	**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 – 30 mm	Dynex-34 mm	+
Warp length during towing	350	350	350	350	350-360	340-347	0
Difference in warp length port/starb. (m)	2-10	16	2-10	10	0-10	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)	6	14	6	6	6	6	+
Type of trawl door	Seaflex 7.5 m^2 adjustable hatches	Jupiter	Seaflex 7.5 m^2 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 (m^2)	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) mean (min-max)	4.8 (4.3-5.3)	4.9 (4.1-5.2)	4.5 (3.8-5.6)	4.8 (4.8-5.5)	4.5 (3.8-5.3)	4.9 (4.1-5.9)	+
Trawl height (m) mean (min-max)	28-40	35.3 (27.4-41.0)	28-37	32 (25-41)	42.7	-	+
Door distance (m) mean (min-max)	115-120	103 (91 - 116)	118-126	119 (114-128)	102.8	118 (113-121)	+
Trawl width (m)*	66.8	60.4	67.3	67.4	58.5	66.5	+
Turn radius (degrees)	5-10	5	5-12	5-10	5-10 BB turn	6-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	5-15, 7-18	4-21, 4-17	6-22, 8-23	4-28	3-12, 4-19	(11.4-11)	+
Headline depth (m)	0-1	0	0-1	0	0	0-1	+
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 + 1 buoy on each wingtip~~s~~	Kite + 1 buoy on each wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	All weighed	All weighted	+

* calculated from door distance

Table 3. Protocol of biological sampling during the IESSNS 2019. 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	≥ 75 (as appropriate)
	Herring	100	100/50*	200	100	
	Blue whiting	100	100/50*	100	100	
	Lumpfish	10	All	all	all	all
	Salmon	all	All	all	all	-
	Other fish sp.	100	25/25	50	25	As appropriate
Weight, sex and maturity determination	Mackerel	25	25	50	25	***
	Herring	25	25	50	25	0
	Blue whiting	50	25	50	25	0
	Lumpfish	10		1^	25	0
	Salmon	1		0	25	0
	Other fish sp.	0	0	0	0	0
Otoliths/scales collected	Mackerel	25	25	25	25	***
	Herring	25	25	50	25	0
	Blue whiting	50	25	50	25	0
	Lumpfish	0	0	1	0	0
	Salmon	1	0	0	0	0
	Other fish sp.	0	0	0	0	0
Fat content	Mackerel Herring Blue whiting	0 0 0	50 0 50	10** 10** 10	0 0 0	0 0 0
Stomach sampling	Mackerel	5	20	10**	10	***
	Herring	5	20	10**	10	0
	Blue whiting	5	20	10	10	0
	Other fish sp.	1	0	0	10	0
Tissue for genotyping	Mackerel	0	0	0	0	0
	Herring	0	0	0	0	0

*Length measurements / weighed individuals
**Sampled at every third station
*** One fish per cm-group from each station was weighed, aged, stomachs were sampled from each second station.
^All live lumpfish were tagged and released, only otoliths taken from fish which were dead when brought aboard

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 and 5 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and possible 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 nighttime when there was midnight sun and good underwater visibility. Video recordings were collected at 65 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 4th July and 6th August 2019 onboard M/V "Kings Bay" and M/V "Vendla", respectively. Opportunistic marine mammal observations were also done on R/V Árni Friðriksson from the bridge between 3rd and 29th July 2019 by crew members and by one student between 3rd July and 15th July.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson" and M/V "Eros" 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 3rd July 2019 for 18, 38 and 200 kHz. Árni Friðriksson was calibrated in May 2019 for the frequencies 18, 38, 120 and 200 kHz. Finnur Fríði was calibrated on 27th June 2019 for 38 kHz. Calibration of the acoustic equipment onboard Eros was done after the cruise on the 5th of August. All frequencies were calibrated successfully. Ceton did not conduct any acoustic data collection because no calibrated equipment was available. All the other 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). Acoustic measurements were not conducted onboard Ceton in the North Sea. 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 2019.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Finnur Fríði	M/V Ceton *	Eros
Echo sounder	Simrad EK80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad ES 80	Simrad EK80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 120, 200	18, 38, 70, 120, 200	38,120, 200	38	18, 38, 70, 120, 200
Primary transducer	ES38B	ES38B	ES38B	ES38B		ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull		Hull
Transducer depth (m)	9	8	9	8		8
Upper integration limit (m)	15	15	15	Not used		15
Absorption coeff. (dB/km)	9.6	10.0	9.1	9.8		9.3
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	-20.3		-20.7
TS Transducer gain (dB)	24.33	24.36	24.56	26.67		25.63
s_A correction (dB)	-0.58	-0.58	-0.69	-0.58		-0.6
alongship:	7.01	7.28	7.03	7.16		6.86
athw. ship:	7.00	7.23	7.09	7.22		7.05
Maximum range (m)	500	500	500	500		750 for 18 and 38 kHz 500 for 70, 120 and 200 kHz
Post processing software	LSSS v.2.5.1	LSSS v.2.3.0	LSSS v.2.5.1	Sonardata Echoview 10.x		LSSS v.2.5.1

* 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 strata 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). Temporal survey progression by vessel along the cruise tracks in July-August 2019 is shown in Figure 3. The cruising speed was between 10-12 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

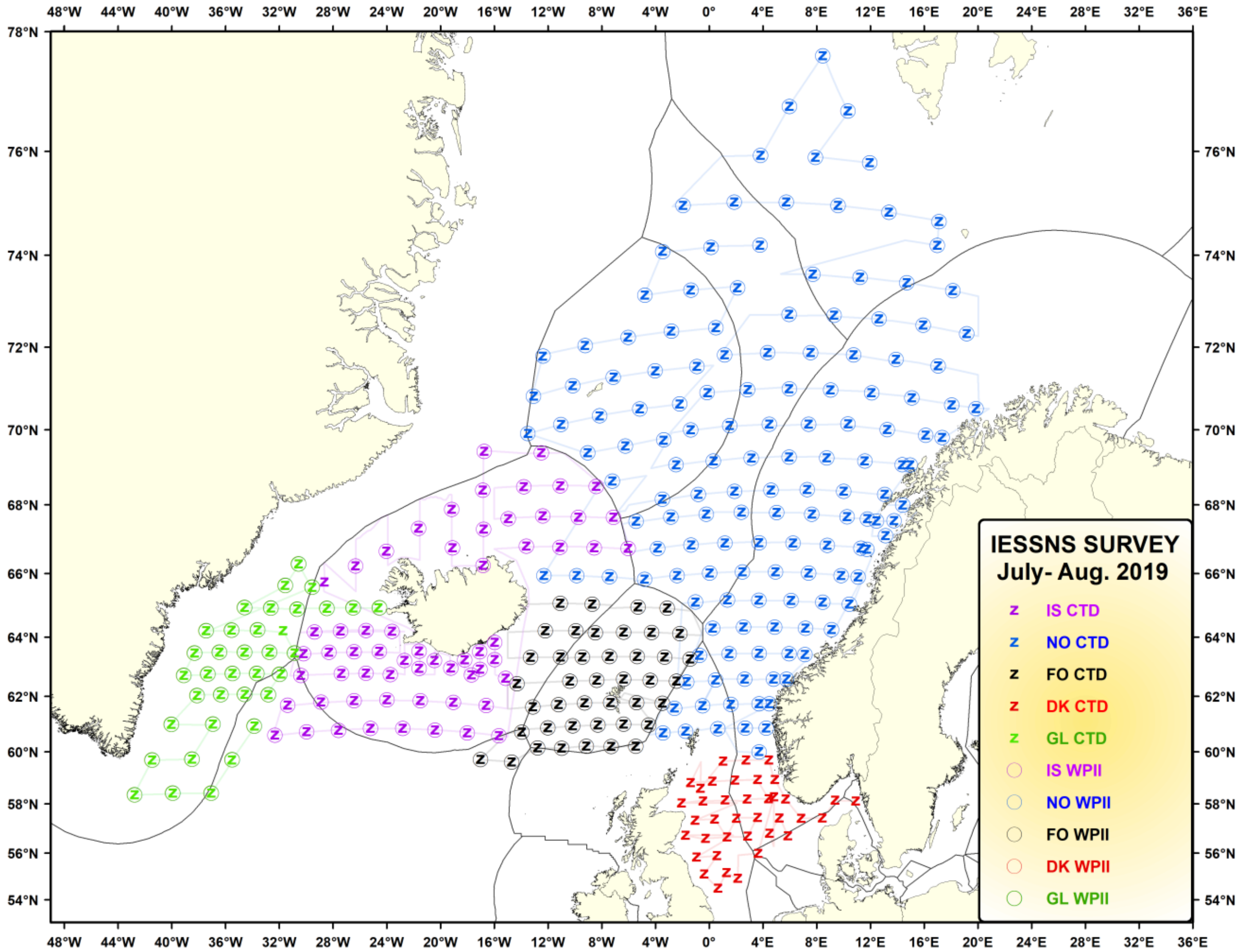


Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 28th June – 5th August 2019. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Finnur Fríði (black), Kings Bay and Vendla (blue), Eros (green) and Ceton (red).

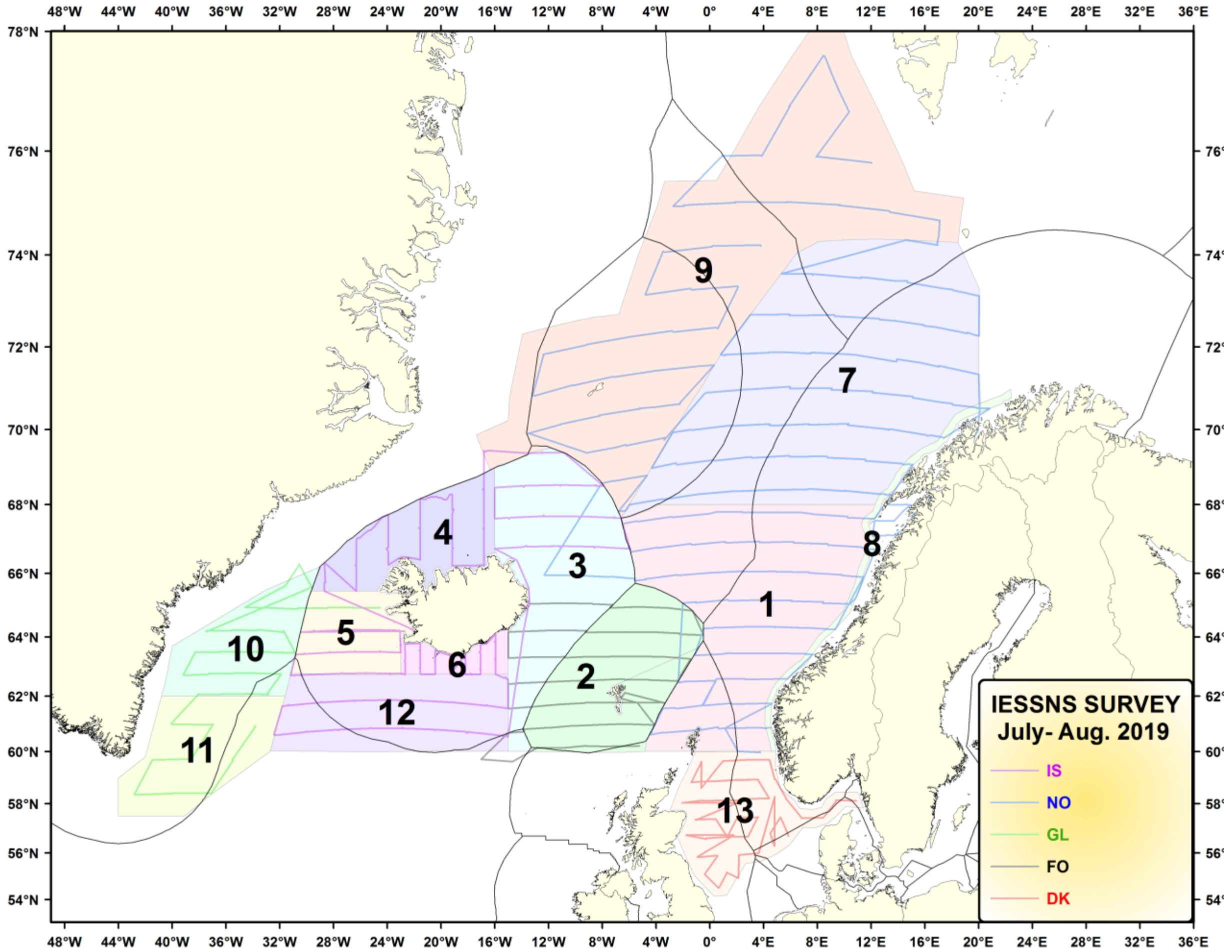


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2019. The dynamic strata are: 4, 9 and 11.

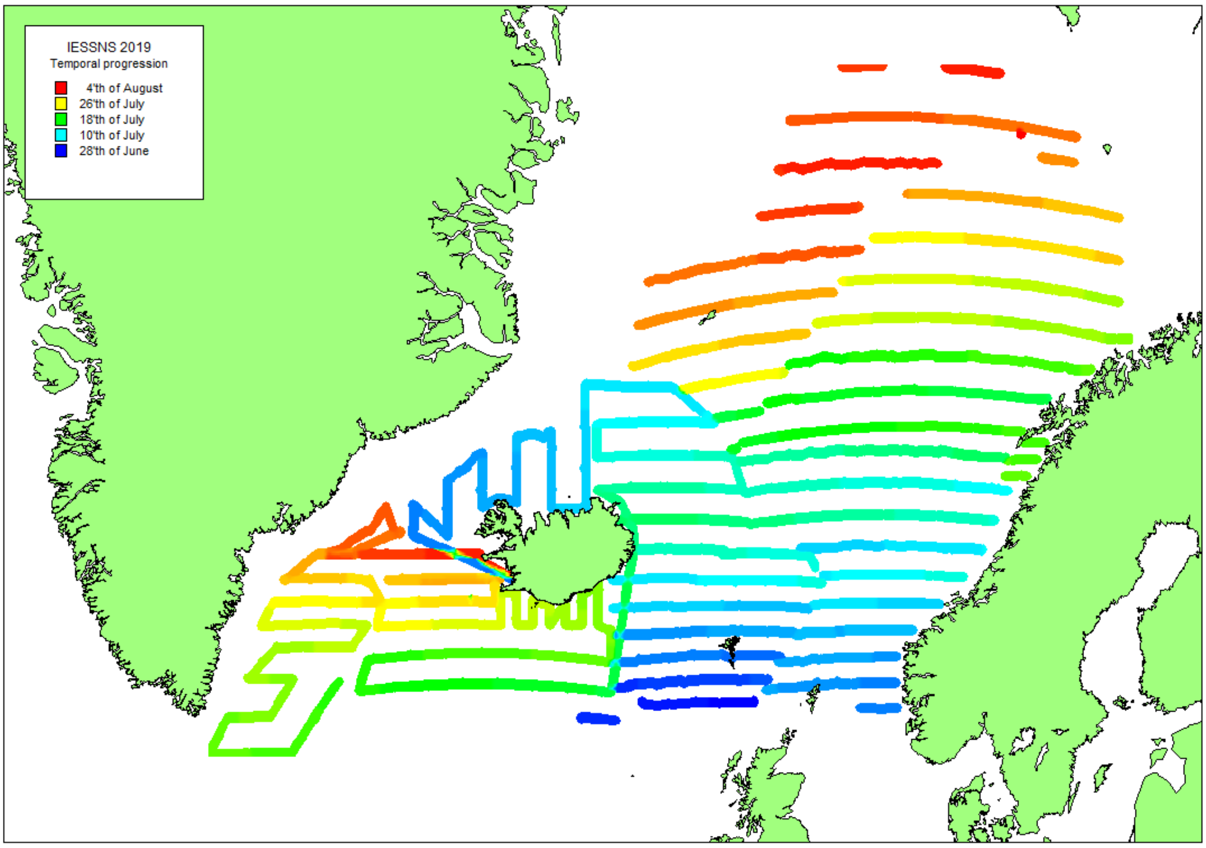


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2019: blue represents effective survey start (28th of June) progressing to red representing the effective end of the survey (4th of August). Ceton is not included in the survey progression map for the North Sea, due to no acoustic recordings.

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 (version 2.7).

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 78°N and 44°W and 20°E in 2019.

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).

	Finnur Fríði	RV Árni Friðriksson	Kings Bay	Vendla	Eros	Ceton
Trawl doors horizontal spread (m)						
Number of stations	39	60	68	57	27	38
Mean	102.8	103	119	126	119	119
max	111	116	120	130	127	128
min	97	91	115	117	113	114
st. dev.	3.3	6.7	1.5	4.2	3.1	4.9
Vertical trawl opening (m)						
Number of stations	40	61	68	57	27	38
Mean	42.7	35.3	37.8	34.2	34.7	32
max	47	41.0	40	36	39.0	41
min	35	27.4	30	28	31.5	25
st. dev.	2.5	2.5	3.6	2.6	2.0	4.5
Horizontal trawl opening (m)						
mean	58.5	60.4	66.8	67.3	66.5	67.4
Speed (over ground, nmi)						
Number of stations	42	61	68	57	27	38
mean	4.45	4.9	4.6	4.2	4.9	4.8
max	5.3	5.2	5.3	5.6	5.9	5.5
min	3.8	4.1	4.3	3.8	4.1	4.1
st. dev.	0.41	0.2	0.41	0.7	0.3	0.3

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 * Door spread (m) + 13.094

Towing speed 5.0 knots: Horizontal opening (m) = 0.3959 * Door spread (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 and discussion

4.1 Hydrography

Satellite measurements of sea surface temperature (SST) in the eastern part of the Norwegian Sea in July 2019 was similar to the average for July 1990-2009 based on SST anomaly plot (Figure 4). Surface temperature in the western part of the Norwegian Sea in July 2019 was slightly higher (1°C) compared to the average (Figure 4). The SST situation in the entire Norwegian Sea in July 2019 is very similar to July 2018. In Icelandic and Greenland waters, on the other hand, the SST was 1-2°C warmer than the average in July 2019 (Figure 4). This contrasts with the situation in 2018 when SST was 1-2°C colder than the average in Icelandic and Greenland waters. Sea Surface Temperature in July 2019 was most like the situation in July 2010 and partly in July 2012, whereas quite different than most other years for the time series from 2010 to 2019.

It must be mentioned that the NOAA 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 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 1.0-2.0°C warmer in 2019 compared to 2018 in most of Icelandic and Greenland waters (Figure 5). The temperature in the upper layer was higher than 8°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 Svalbard where it was lower. In the deeper layers (50 m and deeper; Figure 6-8), the hydrographical features in the area were similar to the last four years (2014-2018). At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

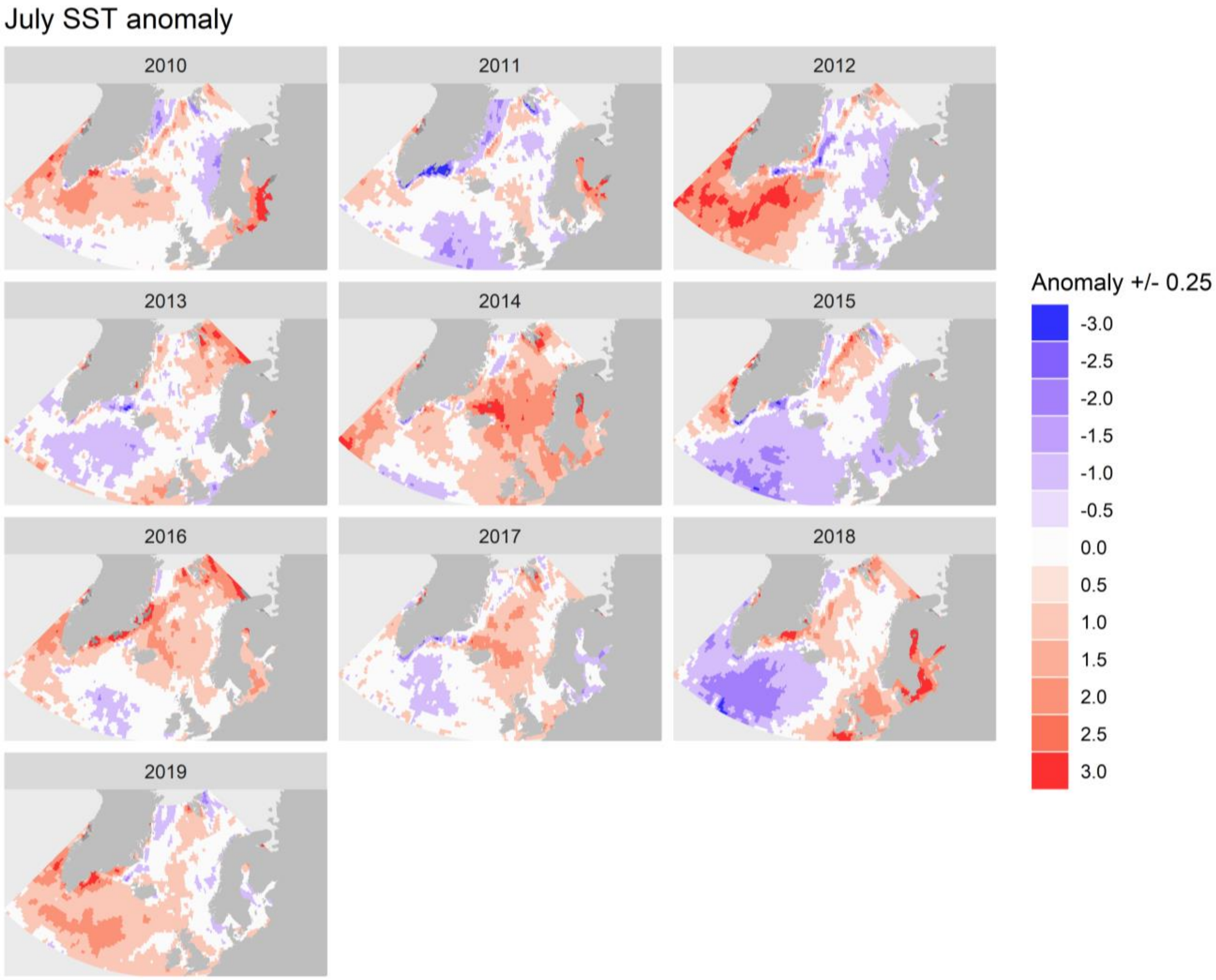


Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2019 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

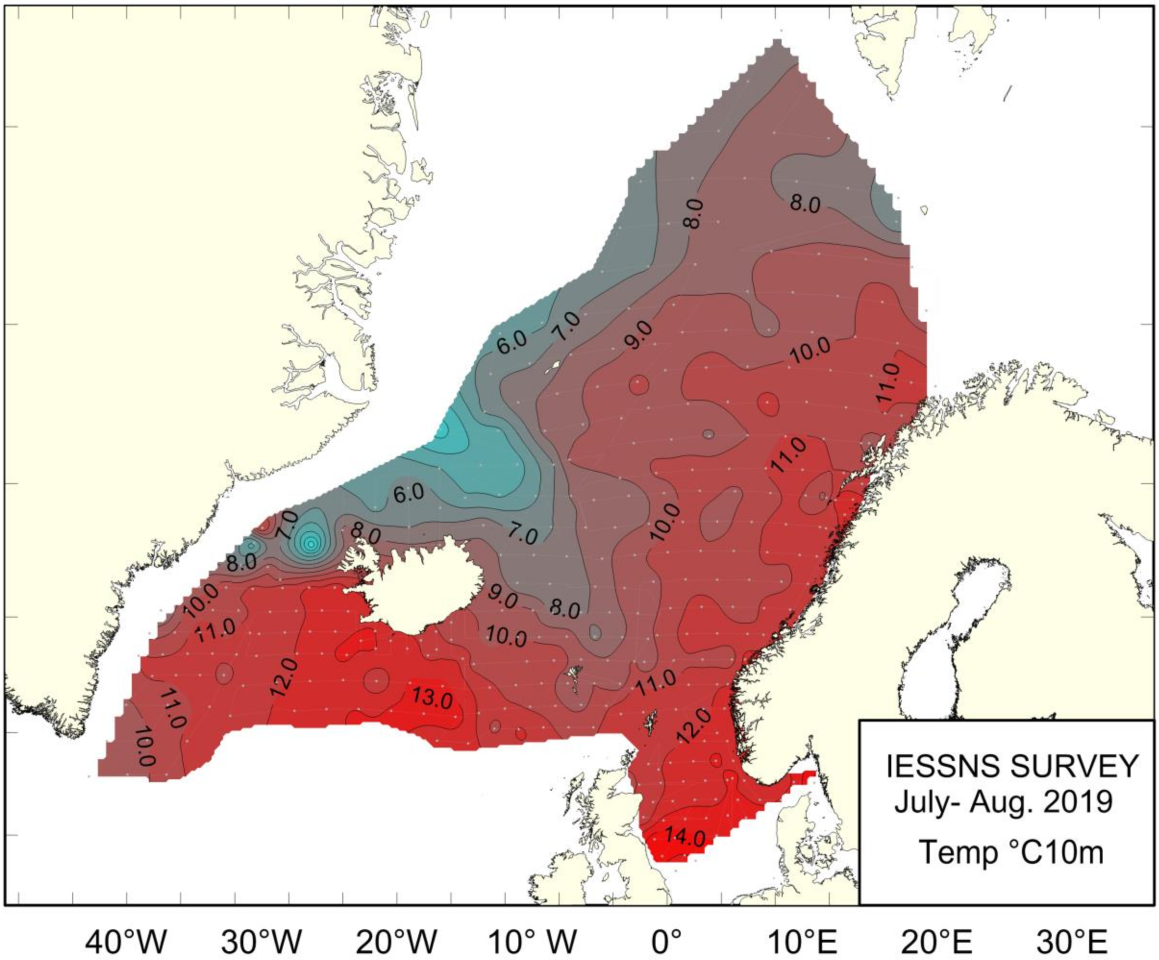


Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2019.

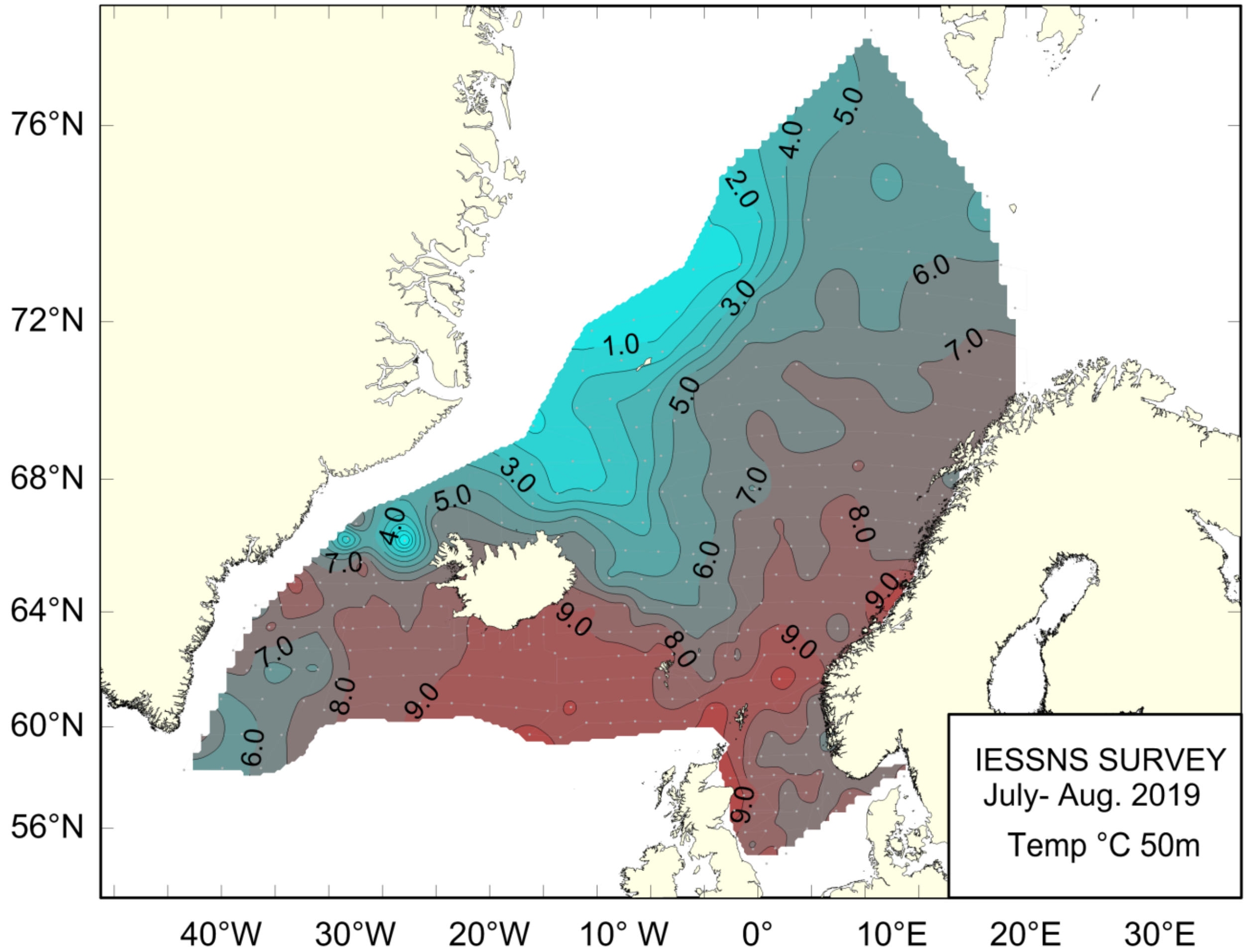


Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2019.

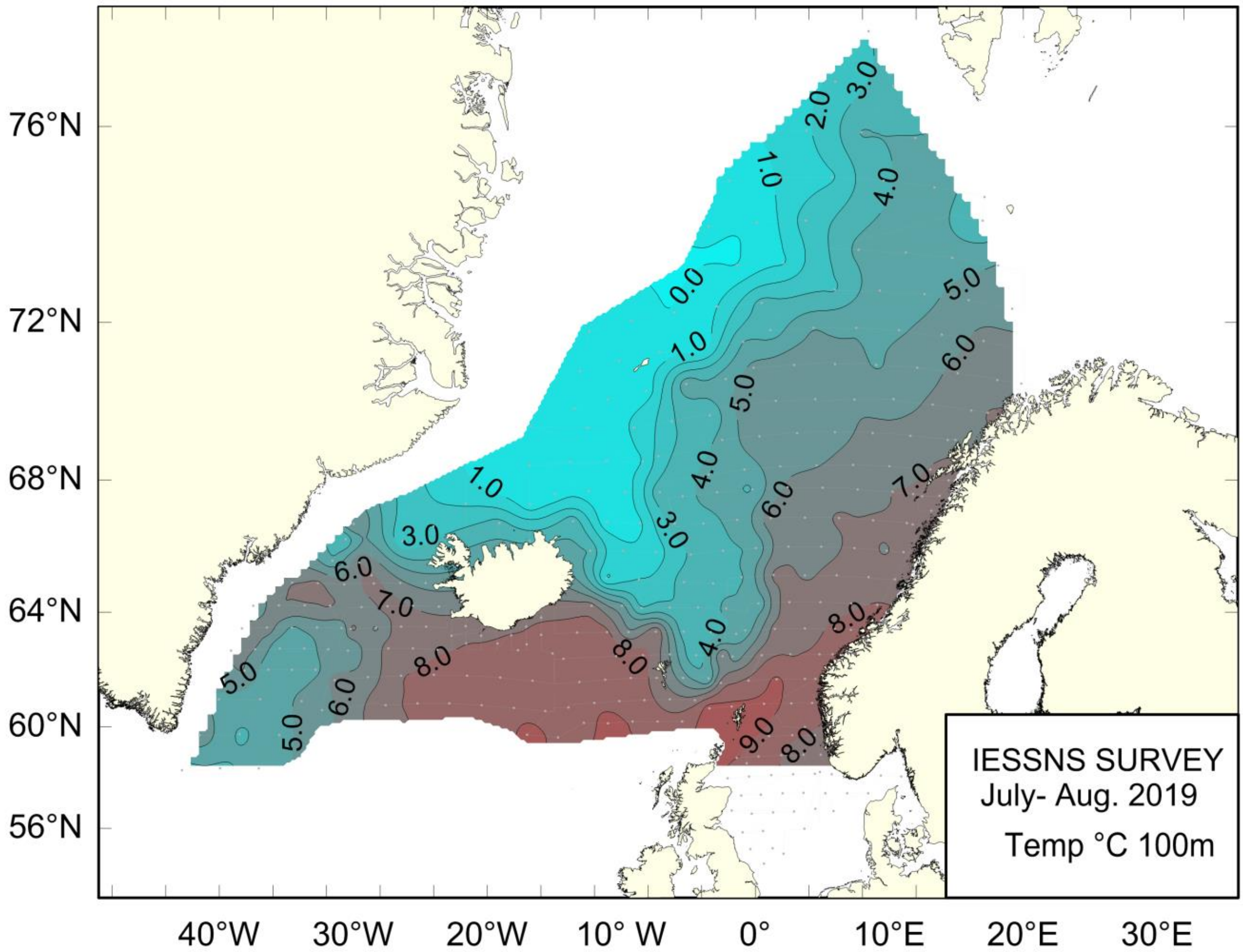


Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2019.

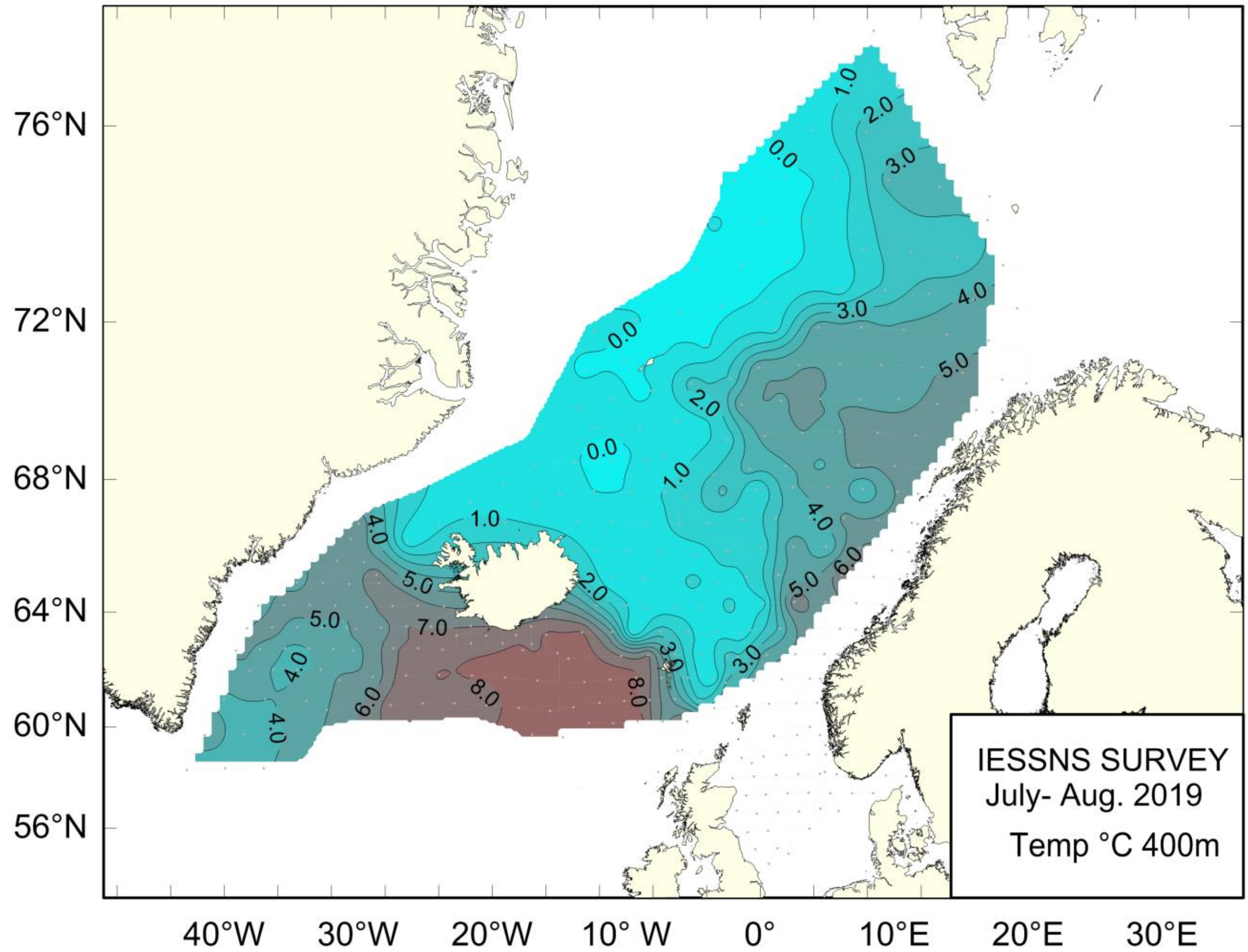
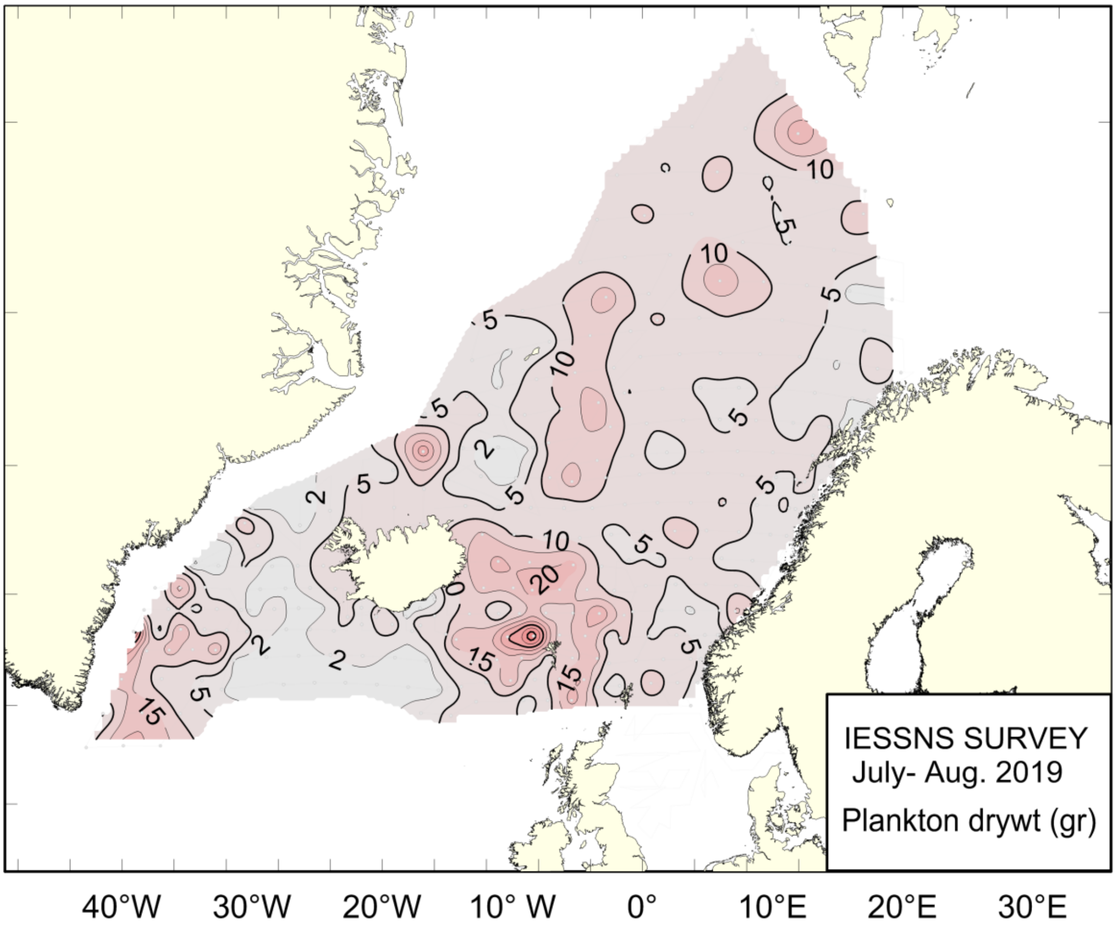


Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2019.

4.2 Zooplankton

Average zooplankton index for the survey area declined quite substantially from 2019 compared to both 2017 and 2018. Zooplankton biomass varied between areas and was highest in Greenland waters (Figure 9a). In 2019, the average had decreased in Greenland (10.1 g m^{-2}; n=27) and Icelandic waters (7.0 g m^{-2}; n=60), while it had increased in the Norwegian Sea (8.7 g m^{-2}; n=173) compared to 2018. There was a sharp decline by more than 30% of zooplankton in Greenland waters (eastward of longitude 30 °W) compared to both 2017 and 2018. There was also a decline in Icelandic waters from 2018 to 2019. 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. Zooplankton in Iceland and Greenland waters are highly variable from year to year and statistically correlated (r=0.83). 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.


76°N
72°N
68°N
64°N
60°N
56°N
40°W
30°W
20°W
10° W
0°
10°E
20°E
30°E
IESSNS SURVEY
July- Aug. 2019
Plankton drywt (gr)

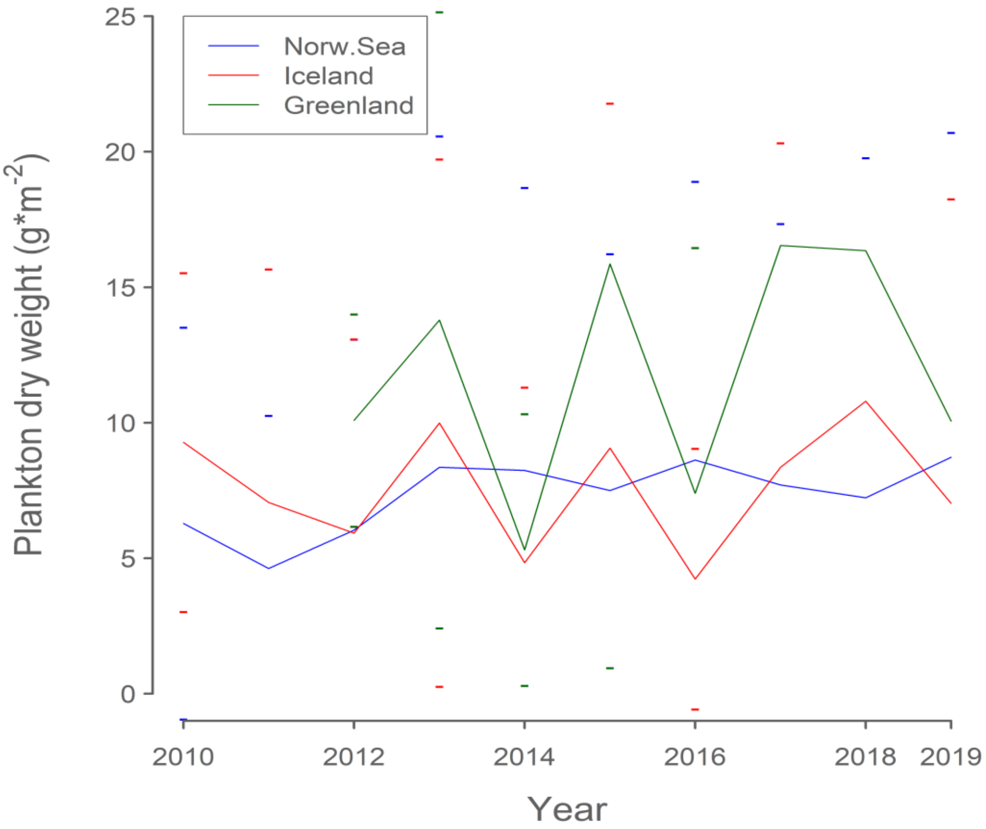


Figure 9. Zooplankton biomass indices (g dw/m², 0-200 m) (a) in Nordic Seas in July-August 2019 and (b) time-series of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W).

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 10 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 52 tonnes/km² (mean = 3.9). High density areas were found in the northern Norwegian Sea, south-east of Iceland, between Iceland and the Faroe Island, as well as south west of the Faroe Islands. The mackerel were more north-easterly distributed in 2019, compared to the years between 2012 and 2018 (Figure 11 & 12). This was apparent in Greenland waters, where the catch was the lowest in the time series.

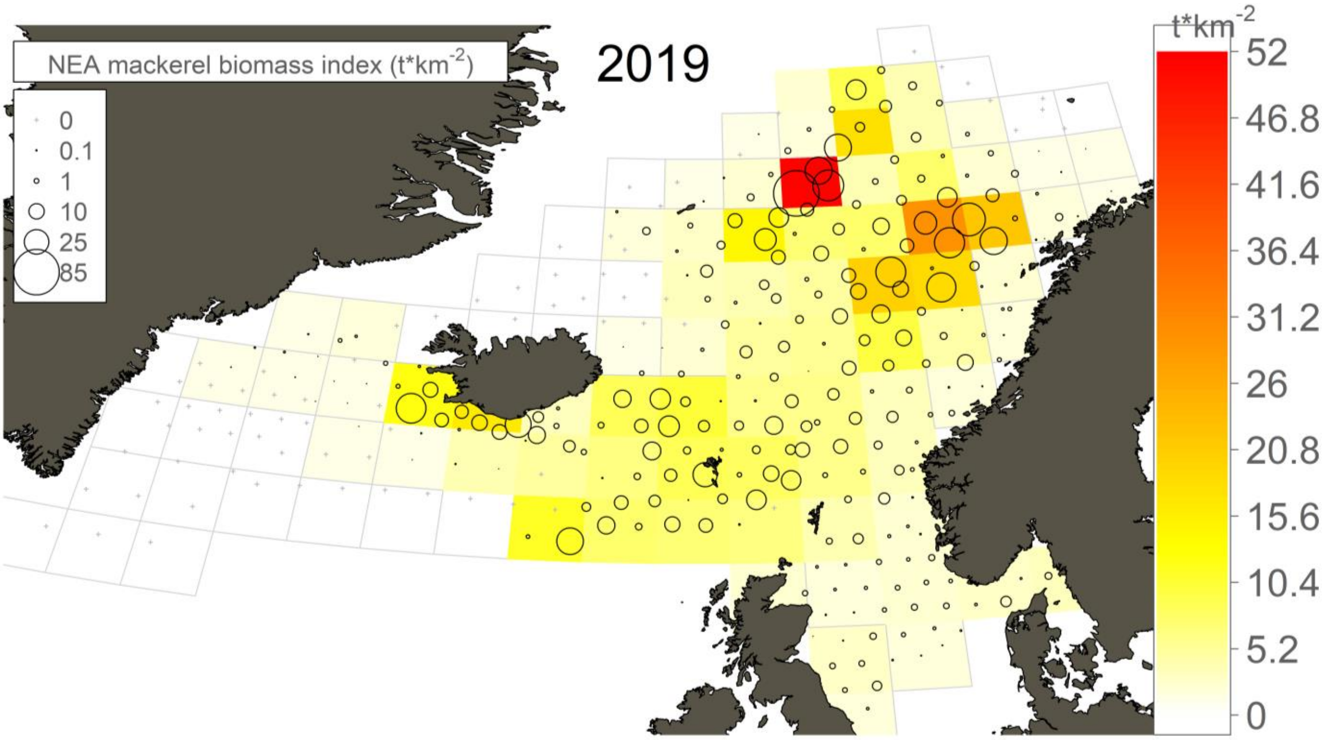


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

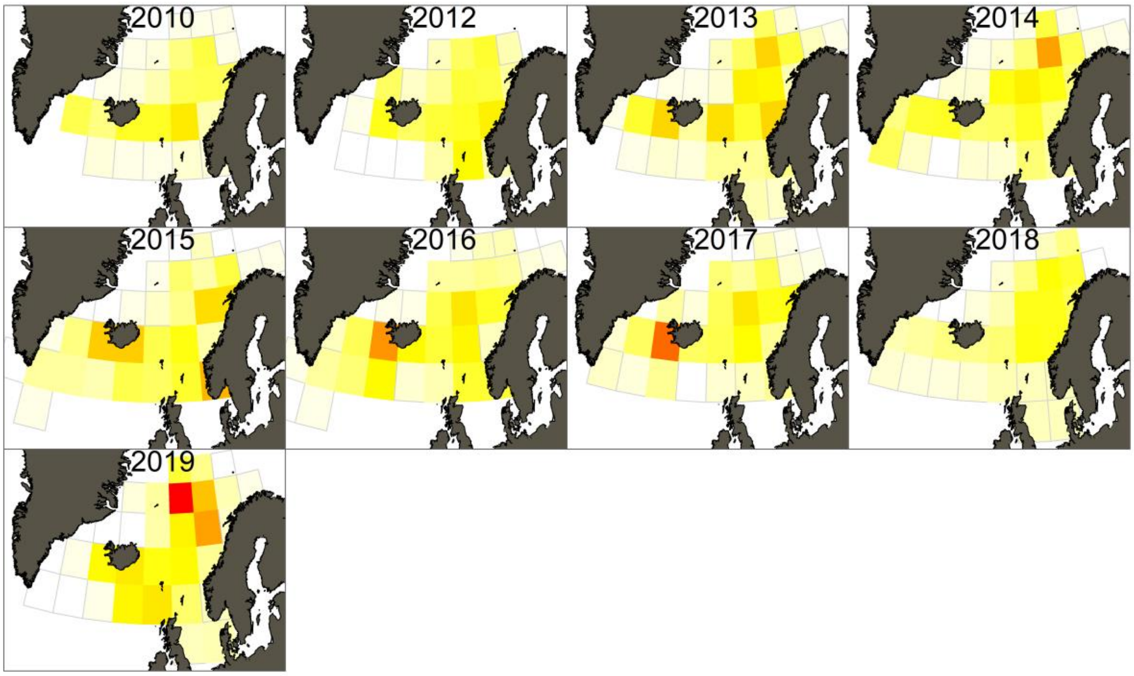


Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (4° lat. x 8° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Color scale goes from white (= 0) to red (= maximum value for the highest year).

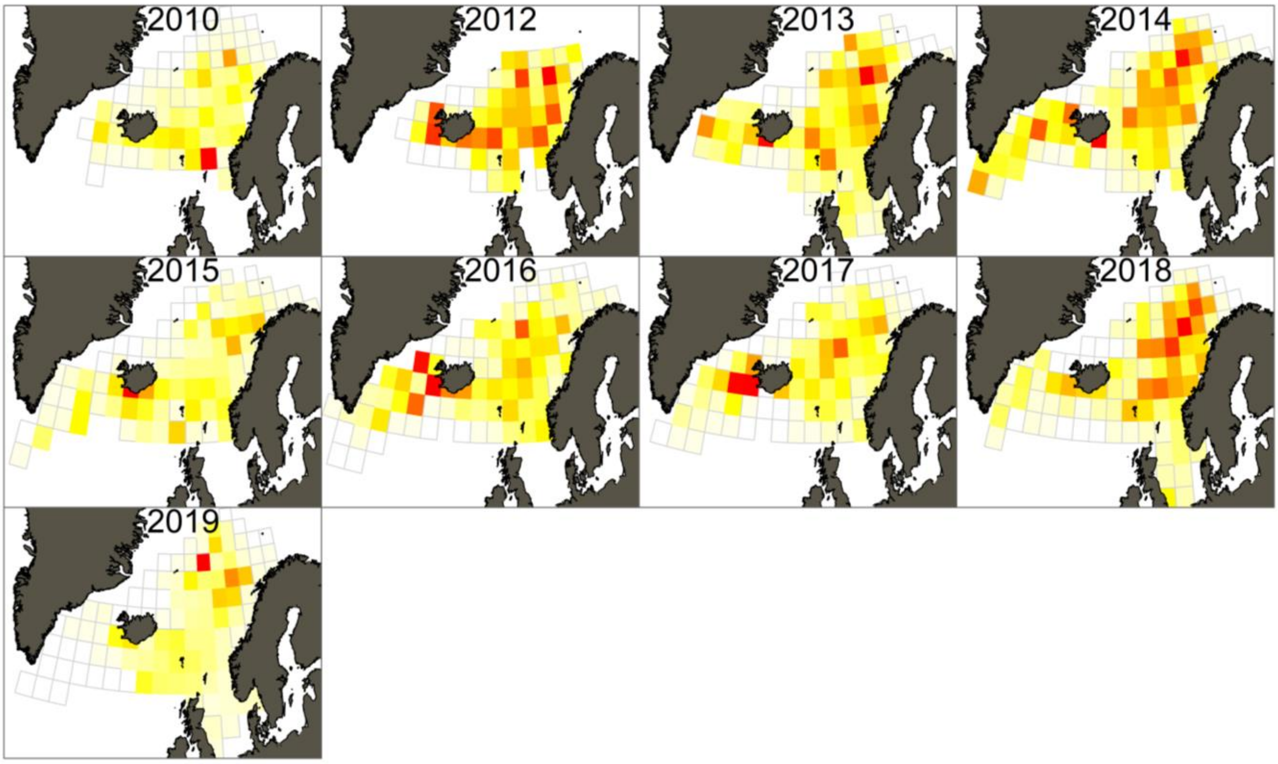


Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Color scale goes from white (= 0) to red (= maximum value for the given year).

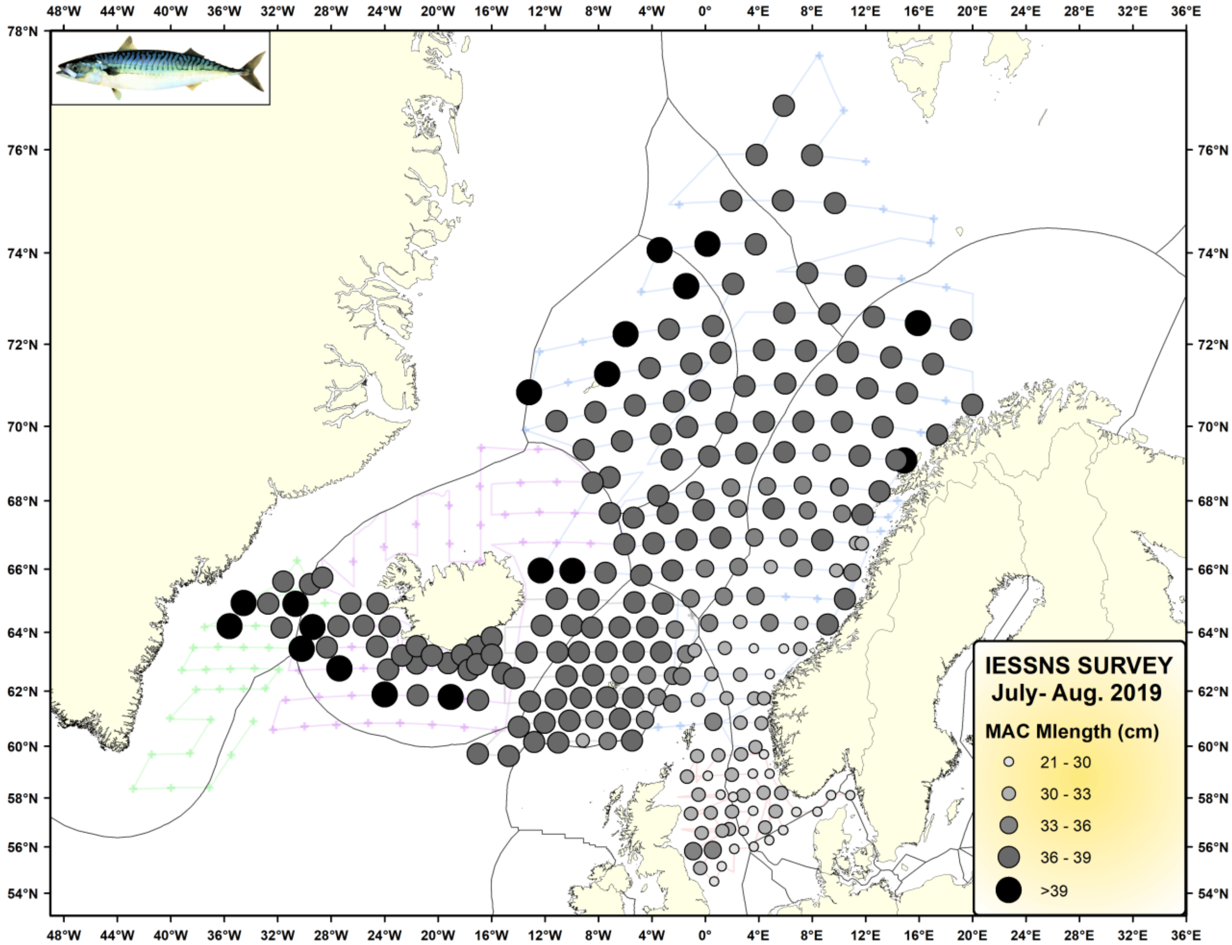


Figure 13. Average length of mackerel at predetermined surface trawl stations during IESSNS 2019.

Mackerel caught in the pelagic trawl hauls onboard the six vessels varied from 25.2 to 41.0 cm in length, with an average of 35.0 cm. Individuals in length range 30–37 cm dominated in numbers and biomass. The mackerel weight (g) varied between 192 to 641 g with an average of 422 g. Mackerel length distribution followed the same pattern as previous years in the Norwegian Sea, with increasing size towards the distribution boundaries in the north and the north-west. In the west (Iceland-Greenland waters), the largest mackerel were again found towards south and west, however, with the restricted western distribution this does appear slightly different (Figure 13). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon (*Salmo salar*), lumpfish) in 2019 according to the catches are shown in Figure 14.

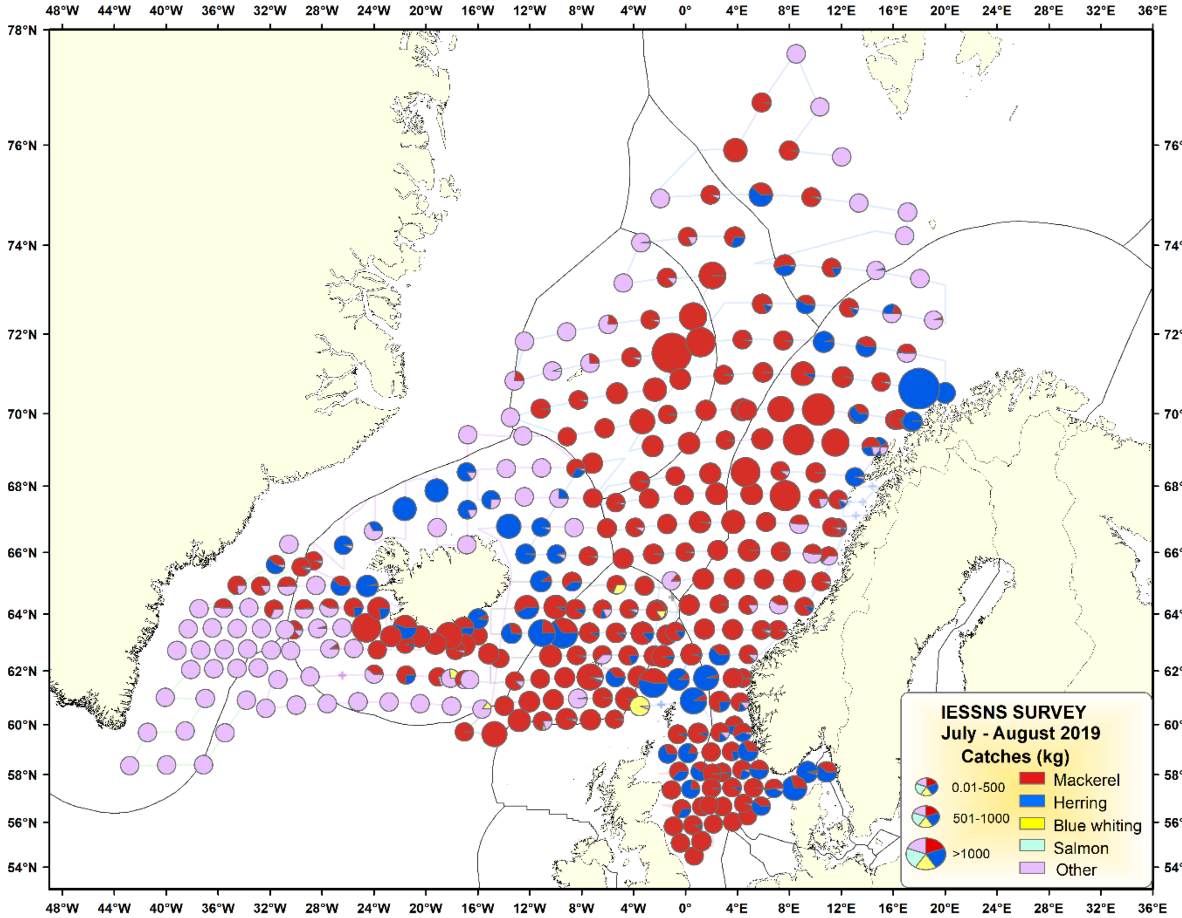


Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, lumpfish (other)) in 2019 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2019 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX. Mackerel biomass index and abundance index was the highest in the time series that started in 2010 (Table 7, Figure 15). Comparing the 2019 estimate to the 2018 estimate shows a 56 % increase in abundance and 85 % increase in biomass. The survey coverage area (excl. the North Sea, 0.3 million km^2) was 2.9 million km^2 in 2019, which is similar to 2018 and 2017. The most abundant year classes were 2011, 2010, 2016, 2014 and 2013 (Figure 16). Mackerel of age 2 and to some extent also age 3 are not completely recruited to the survey (Figure 18, bottom). Therefore, the results suggest that the incoming 2016- and 2017- year classes are large. Variance in age index estimation is provided in Figure 17.

The internal consistency plot for age-disaggregated year classes is similar to last year (Figure 18, top). There is a strong internal consistency for ages 1 to 5 years ($0.83 < r < 0.93$), it is poor ($0.13 < r < 0.31$) between age 5 and 6 as well as 7 and 8, and it is a fair/good internal consistency for ages 5 to 11 years ($0.58 < r < 0.81$).

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).

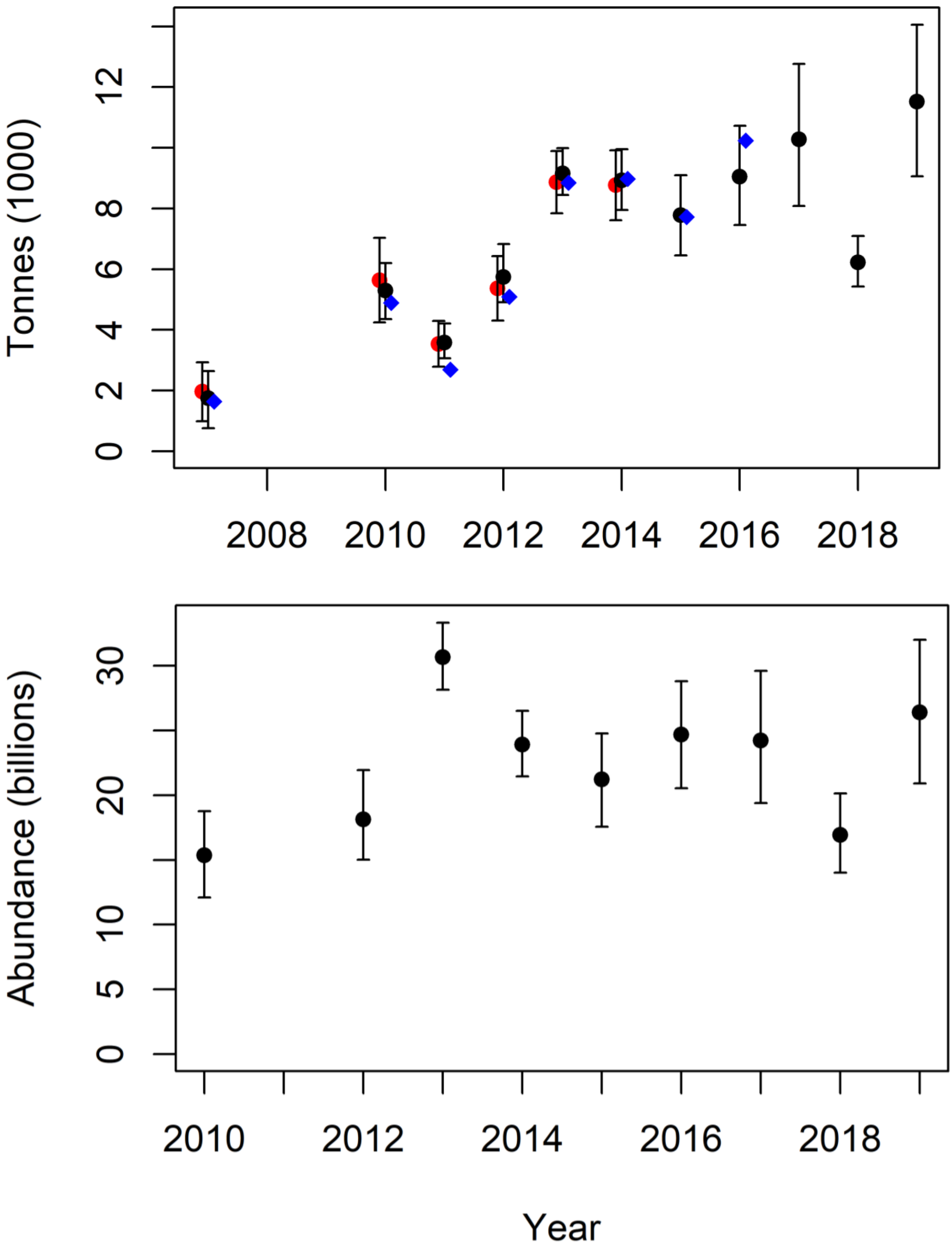


Figure 15. Estimated total stock biomass (TSB) of mackerel from StoX (black dots), Nøttestad et al. (2016) (red dots) and IESSNS cruise reports (blue diamonds) (top) and estimated total stock numbers (TSN) of mackerel from StoX (black dots) (bottom), The error bars represent approximate 90 % confidence intervals.

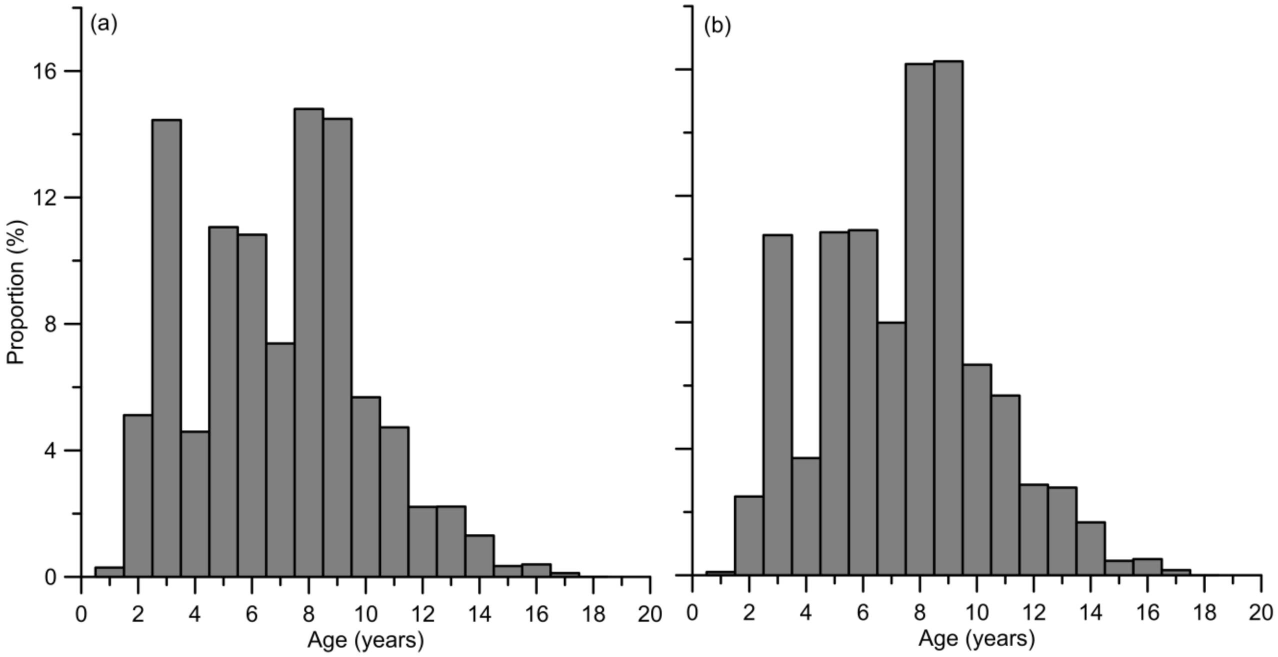


Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2019.

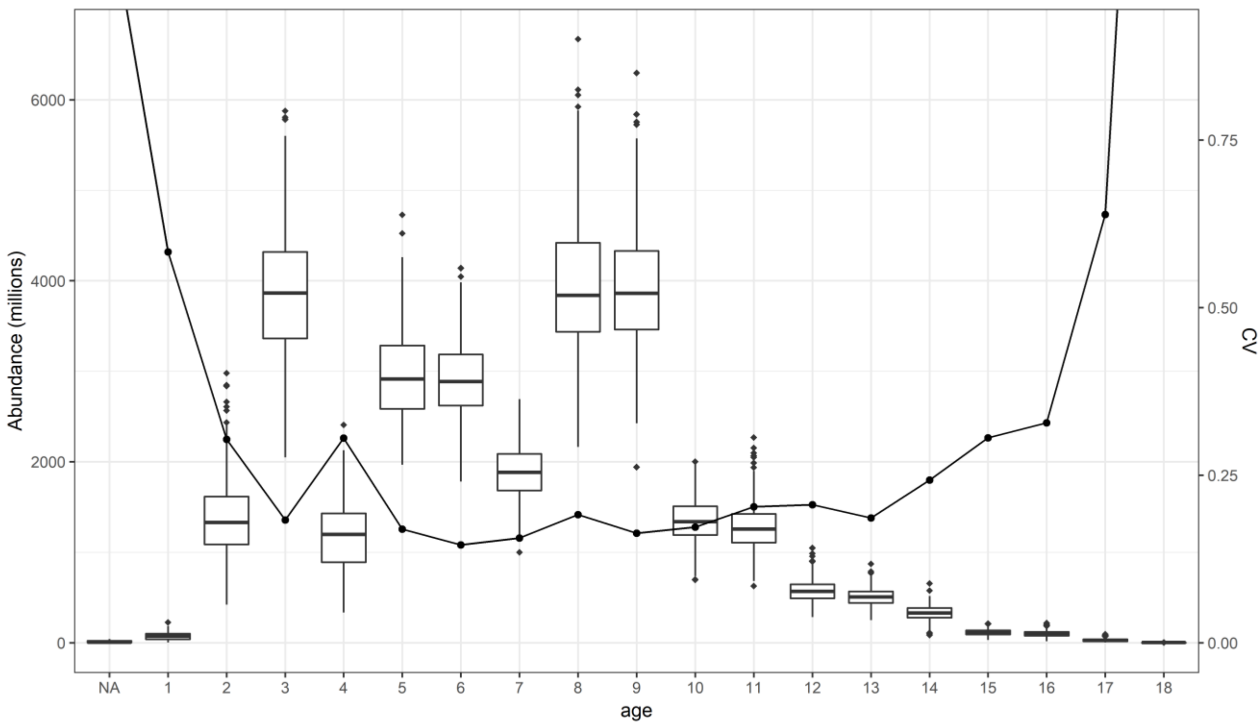


Figure 17. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-c) 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 2019. d) Output from StoX

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
2019	0.08	1.35	3.81	1.21	2.92	2.86	1.95	3.91	3.82	1.50	1.25	0.58	0.59	0.57	26.4

b)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)
2007	133	233	323	390	472	532	536	585	591	640	727	656	685	671
2010	133	212	290	353	388	438	512	527	548	580	645	683	665	596
2011	133	278	318	371	412	440	502	537	564	541	570	632	622	612
2012	112	188	286	347	397	414	437	458	488	523	514	615	509	677
2013	96	184	259	326	374	399	428	445	486	523	499	547	677	607
2014	228	275	288	335	402	433	459	477	488	533	603	544	537	569
2015	128	290	333	342	386	449	463	479	488	505	559	568	583	466
2016	95	231	324	360	371	394	440	458	479	488	494	523	511	664
2017	86	292	330	373	431	437	462	487	536	534	542	574	589	626
2018	67	229	330	390	420	449	458	477	486	515	534	543	575	643
2019	153	212	325	352	428	440	472	477	490	511	524	564	545	579

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
2019	0.01	0.29	1.24	0.43	1.25	1.26	0.92	1.86	1.87	0.77	0.65	0.33	0.32	0.32	11.52

Table 7d) Estimates of abundance, mean weight and mean length of mackerel based on calculation in StoX for IESSNS 2019.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	45.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1335	60.6	45.42
19-20	55.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2296	126.9	55.27
20-21	60.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3428	206.7	60.31
21-22	-	69.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	575	39.9	69.27
22-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	91.0	74	6.8	91.00
23-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.6	555	55.9	100.58
24-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	114.9	1142	131.2	114.88
25-26	145.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22012	3208.5	145.76
26-27	156.9	161.6	155.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65967	10477.9	158.84
27-28	159.0	175.1	189.7	175.1	165.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290352	50983.2	175.59
28-29	201.5	194.7	195.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	374768	73101.1	195.06
29-30	-	217.2	214.2	226.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	393319	85397.0	217.12
30-31	-	241.4	247.9	249.7	251.3	266.0	-	-	255.9	-	-	-	-	-	-	-	-	-	-	609333	149809.7	245.86
31-32	-	266.6	274.8	291.6	292.5	-	-	285.3	278.6	-	-	-	-	-	-	-	-	-	-	967693	269885.1	278.90
32-33	-	313.0	306.2	325.5	290.7	290.4	314.5	-	-	-	-	-	-	-	-	-	-	-	-	1237341	382196.0	308.89
33-34	-	312.3	339.2	338.0	327.4	327.7	-	-	-	-	-	-	-	-	-	-	-	-	-	1066369	359974.7	337.57
34-35	-	320.0	375.4	379.4	366.9	359.1	-	424.3	390.9	-	-	-	-	-	-	-	-	-	-	1291109	483425.5	374.43
35-36	-	412.0	418.3	411.0	409.7	406.6	400.6	423.9	423.5	387.3	359.7	-	379.6	-	-	-	-	-	-	2777412	1143483.2	411.71
36-37	-	-	362.2	443.3	444.7	437.7	443.2	445.5	452.2	455.2	456.9	429.4	428.0	-	-	-	-	-	-	4638338	2061271.9	444.40
37-38	-	-	487.1	475.7	474.0	480.4	468.7	477.2	475.9	474.9	480.0	468.6	455.4	460.0	492.1	442.5	-	-	-	5599575	2664028.8	475.76
38-39	-	-	508.8	504.0	516.9	506.6	520.3	499.1	512.1	516.5	509.4	528.2	511.3	527.3	494.4	487.8	-	-	-	3751183	1915605.3	510.67
39-40	-	-	528.0	588.5	551.4	589.5	547.5	545.4	554.4	543.9	534.8	552.5	520.8	540.0	561.8	535.5	546.0	-	-	2050873	1115916.2	544.12
40-41	-	-	-	584.0	533.7	641.9	567.3	607.9	576.9	576.4	586.5	599.8	554.4	586.3	579.3	572.7	591.7	-	-	847185	490784.8	579.31
41-42	-	-	650.0	-	-	745.9	686.6	542.0	605.4	630.8	619.6	612.1	639.3	625.1	604.9	682.9	-	-	-	335134	209209.4	624.26
42-43	-	-	-	-	756.1	-	655.1	-	659.7	665.2	697.5	710.4	657.9	699.5	685.8	663.3	-	-	-	67784	45665.2	673.69
43-44	-	-	-	-	-	802.0	772.0	-	-	-	725.6	663.1	699.5	713.3	708.0	-	-	606.4	-	6667	4717.5	707.59
44-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	707.7	471	333.4	707.66
45-46	-	-	-	-	-	-	-	-	-	-	-	-	688.0	-	833.3	-	-	-	-	860	648.1	753.97
TSN(1000)	77213	1350193	3814661	1211770	2920591	2856932	1948653	3906891	3824410	1499778	1248160	584066	586585	344601	90489	104106	31589	219	2243	26403151	-	-
TSB(1000 kg)	11778.9	286752.2	1239274.6	426846.0	1249678.7	1257274.0	920393.4	1862667.6	1872447.6	767051.0	654542.4	329619.0	319405.9	192633.1	52432.8	58693.2	18600.1	132.9	527.3	-	11520750.7	-
Mean length (cm)	25.83	28.89	32.69	33.35	35.76	36.17	37.02	37.18	37.45	38.11	38.56	39.34	39.43	39.31	40.06	39.66	39.94	43.08	28.22	-	-	-
Mean weight (g)	152.55	212.38	324.87	352.25	427.89	440.08	472.32	476.76	489.60	511.44	524.41	564.35	544.52	559.00	579.44	563.79	588.81	606.42	235.06	-	-	436.34

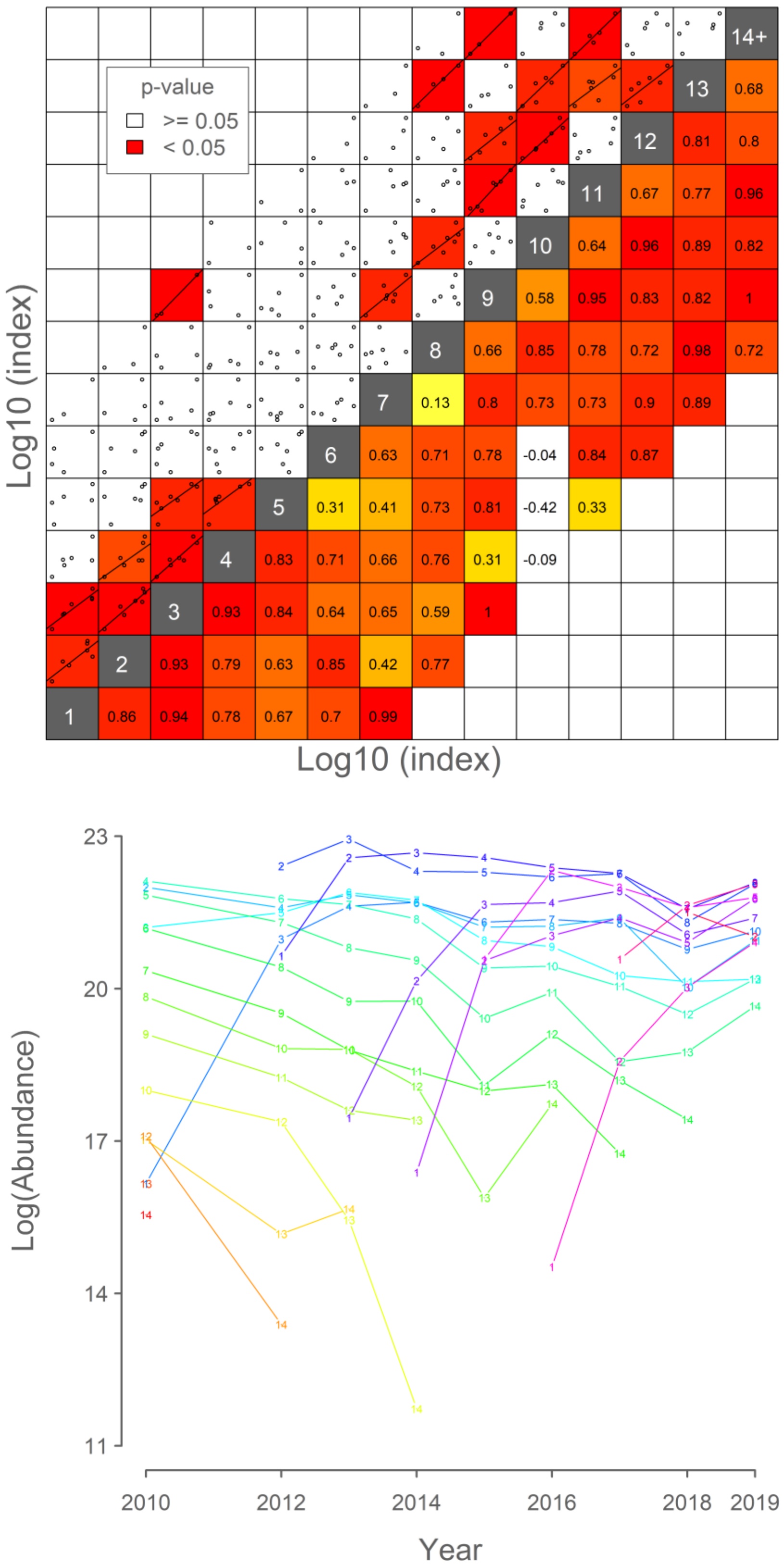


Figure 18. Diagnostics of the of mackerel density index from 2012 to 2019. Internal consistency (top), Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half. Catch curves (bottom). Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

Distribution zero boundaries were found in majority of survey area with a notable exception of high mackerel abundance at the survey boundary south-west of Faroe Island. Low densities were found in a single location at the north-western boundary west of Jan-Mayen, and high densities towards the Fram Strait west of Svalbard.

The mackerel appeared more patchily distributed within the survey area and more northerly and north-westerly distributed in 2019 compared to in 2017 and 2018. This difference in distribution primarily consists of a marked biomass decline in the west and a marked increase in the north and northwest. Furthermore, there was also a westward 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 few exceptionally large catches. 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. 2019). In 2019 there were practically no mackerel in Greenland waters during the survey. The marked increase of mackerel in the Norwegian Sea, could partly be explained by improved feeding conditions from average estimates in the Norwegian Sea in 2019 compared to previous years and more mackerel migrating into the surveyed area compared to in 2018. Furthermore, there are indications that there has been strong recruitment during the last two years from 2016-2017, based on results from the mackerel recruitment index used in the assessment. Both vertical and horizontal distribution and patchiness and avoidance behaviour of mackerel may have affected the catch rates and catchability from the swept area trawling in surface waters differently in 2018 compared to 2019 and 2017. There are indications from results at Rockall bank and other areas at the IBTS surveys, that a larger fraction of the mackerel stock may have been distributed south of our survey coverage at 60°N in July-August 2018 compared to in July-August 2019. This also indicate that it would be beneficial to have an additional future survey participation by other countries covering the southwestern waters south of 60°N. We see a strong year effect for all age groups in the results from 2019 compared to 2018. However, the biomass and abundance indices of mackerel in 2019 were much more in line with the results from 2017.

As in previous years, the spatio-temporal overlap between 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 part of the Norwegian Sea, whereas we had some overlap between mackerel and herring in the northern part of the Norwegian Sea. Herring distribution was mostly limited to the area east and north of Iceland and the southern Norwegian Sea. However, NSSH was also found in the central northern part for the first time in many years, dominated by the 2013- and 2016- year classes.

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 58.5-67.4m; 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). We have now available IESSNS survey data from 2018 and 2019 for the North Sea.

This year's survey was well synchronized in time and was conducted over a relatively short period (5 weeks) given the large spatial coverage of around 3 million km^2 (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.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southern (north of the Faroes and east and north of Iceland) and north-eastern part of the Norwegian Sea basin (Figure 19). The fish in the northeast consisted of young adults (mainly 3- and 6- year olds) while the fish further southwest are a range of age groups, mainly from 6 to 14 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. However, the second most abundant year class in the survey estimate, the 2016- year class (3- year olds) are not fully covered in this survey. Most of this young year class is still located in the Barents Sea based on results from the ecosystem surveys in the Barents Sea.

The NSSH stock is dominated by 6-year old herring (year class 2013) in terms of numbers and biomass (Table 8). This year class is now distributed in all areas with herring in the survey compared to last year when it was mainly found in the north-eastern part. It contributes 23% and 22% to the total biomass and total abundance, respectively. The total number of herring recorded in the Norwegian Sea was 15.2 billion and the total biomass index was 4.78 million tonnes in 2019, in comparison to 13.6 billion and a total biomass index of 4.46 million tonnes in 2018. This means that the biomass index was slightly higher in 2019 than in 2018. Number by age, with uncertainty estimates, for NSSH is shown in Figure 20. The group considered the acoustic biomass estimate of herring to be of good quality in the 2019 IESSNS as in the previous survey years.

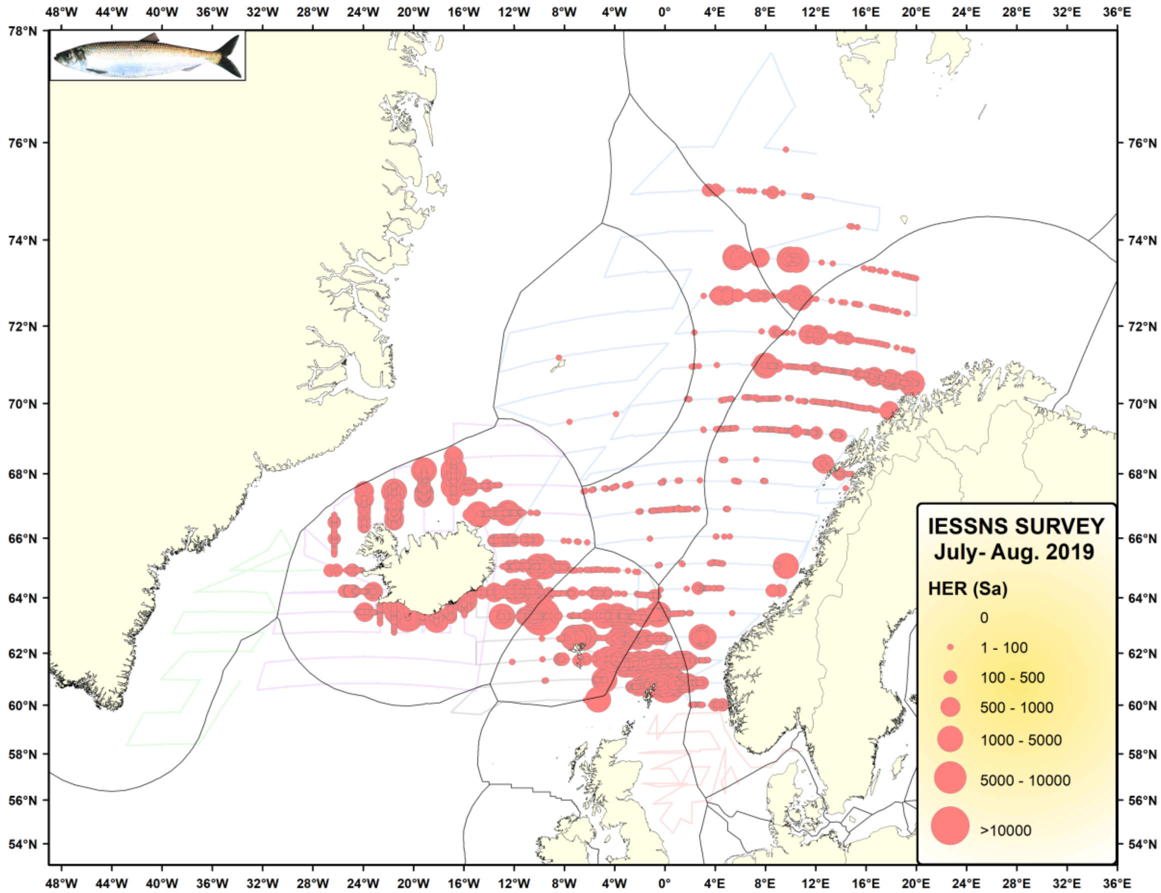


Figure 19. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2019. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

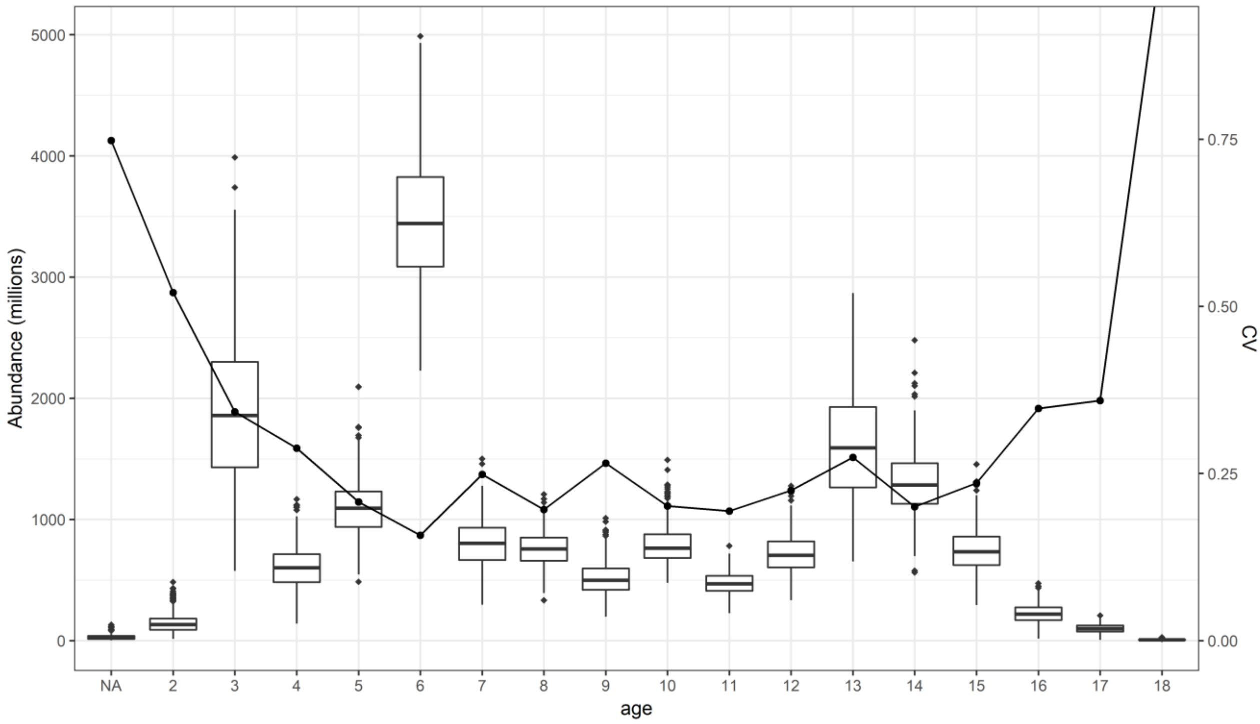


Figure 20. Number by age for Norwegian spring-spawning herring during IESSNS 2019. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 8. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2019.

	age																				
LenGrp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
14-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1893	1893	45.4	24.00
15-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1893	1893	68.1	36.00
18-19	11828	15977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27805	1119.9	40.28
19-20	6860	6860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13721	699.8	51.00
20-21	20818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20818	1311.5	63.00
21-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19762	19762	1665.9	84.30
22-23	44947	4731	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49678	4951.3	99.67
23-24	23089	-	5772	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28861	2978.4	103.20
24-25	20818	26495	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	47313	5859.2	123.84
25-26	24221	206376	9634	-	8808	-	-	-	-	-	-	-	-	-	-	-	-	-	249040	36659.0	147.20
26-27	-	420933	49037	21019	6433	-	-	-	-	-	-	-	-	-	-	-	-	-	497422	81005.6	162.85
27-28	-	518195	87141	13858	41574	3465	11319	-	-	-	-	-	-	-	-	-	-	-	675552	121158.7	179.35
28-29	-	376825	54678	59549	76814	11652	11652	2913	-	-	-	-	-	-	-	-	-	-	594082	120467.3	202.78
29-30	-	119725	71307	52850	125882	51911	-	78021	10263	16420	11146	-	-	-	-	-	-	-	537525	125525.3	233.52
30-31	-	91309	116543	254855	74004	38696	54681	12879	25538	11039	-	5520	21283	-	-	-	-	-	706348	179615.4	254.29
31-32	-	44136	131284	356156	427881	12239	10158	20316	20877	25676	49793	201390	-	10158	-	-	-	-	1310064	366915.2	280.07
32-33	-	25564	25442	229417	1297150	56852	62946	37773	62953	-	-	104911	-	-	-	-	-	-	1903010	571454.1	300.29
33-34	-	12427	33420	50212	1035752	215875	72592	30266	14503	17788	-	17788	-	-	-	-	-	-	1500623	477060.2	317.91
34-35	-	-	6145	24940	337328	352310	138168	36308	18744	-	20285	30240	-	-	-	-	-	-	964468	324725.7	336.69
35-36	-	-	-	4326	43394	74490	210462	180324	236500	66665	253222	148104	140479	48253	-	12978	-	-	1419196	511294.8	360.27
36-37	-	-	-	-	-	41430	111055	76055	119294	102076	229777	670420	348972	145974	86442	6950	-	-	1938443	729270.4	376.21
37-38	-	-	-	-	-	-	19015	40381	107311	179345	169450	419279	397974	303175	73501	52682	-	-	1762115	701554.4	398.13
38-39	-	-	-	-	-	-	-	3488	84472	43980	16075	122152	240545	233647	37842	8647	6976	-	797825	338056.4	423.72
39-40	-	-	-	-	-	-	-	1598	-	-	-	4869	83485	16253	15179	18974	-	-	140358	64743.4	461.28
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	11446	11446	-	-	-	22891	11647.0	508.80
TSN(1000)	152581	1869554	590404	1067181	3475021	858919	702048	520323	700455	462990	749748	1724672	1232738	768907	224410	100231	6976	23547	15230704	-	-
TSB(1000 kg)	15035.9	344119.4	136410.1	289293.0	1039849.0	275970.4	233783.4	173825.2	254428.6	168740.1	276301.0	635219.1	485525.1	312828.8	93800.0	39752.0	3192.1	1779.4	-	4779852.4	-
Mean length (cm)	22.42	27.33	29.53	31.00	32.30	33.40	34.03	33.86	35.28	35.75	35.59	35.55	36.77	37.05	37.14	37.20	38.00	20.20	-	-	-
Mean weight (g)	98.54	184.06	231.05	271.08	299.24	321.30	333.00	334.07	363.23	364.46	368.53	368.31	393.86	406.85	417.99	396.61	457.55	75.57	-	-	313.83

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 and the distribution in 2019 is similar to the 2018 distribution. The main concentrations of older fish were observed in connection with the continental slopes, both in the eastern and the southern part of the Norwegian Sea (Figure 21). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during IESSNS 2019 was 2.0 million tons (Table 9), which is the same compared to 2018. The stock estimate in number for 2019 is 16.2 billion compared to 16.3 billion of age groups 1+ in 2018. The age group five is dominating the estimate (36% and 30% of the biomass and by numbers, respectively). A good sign of recruiting year class (0-group) was also seen in the survey this year.

Number by age, with uncertainty estimates, for blue whiting during IESSNS 2019 is shown in Figure 22.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2019 IESSNS as in the previous survey years.

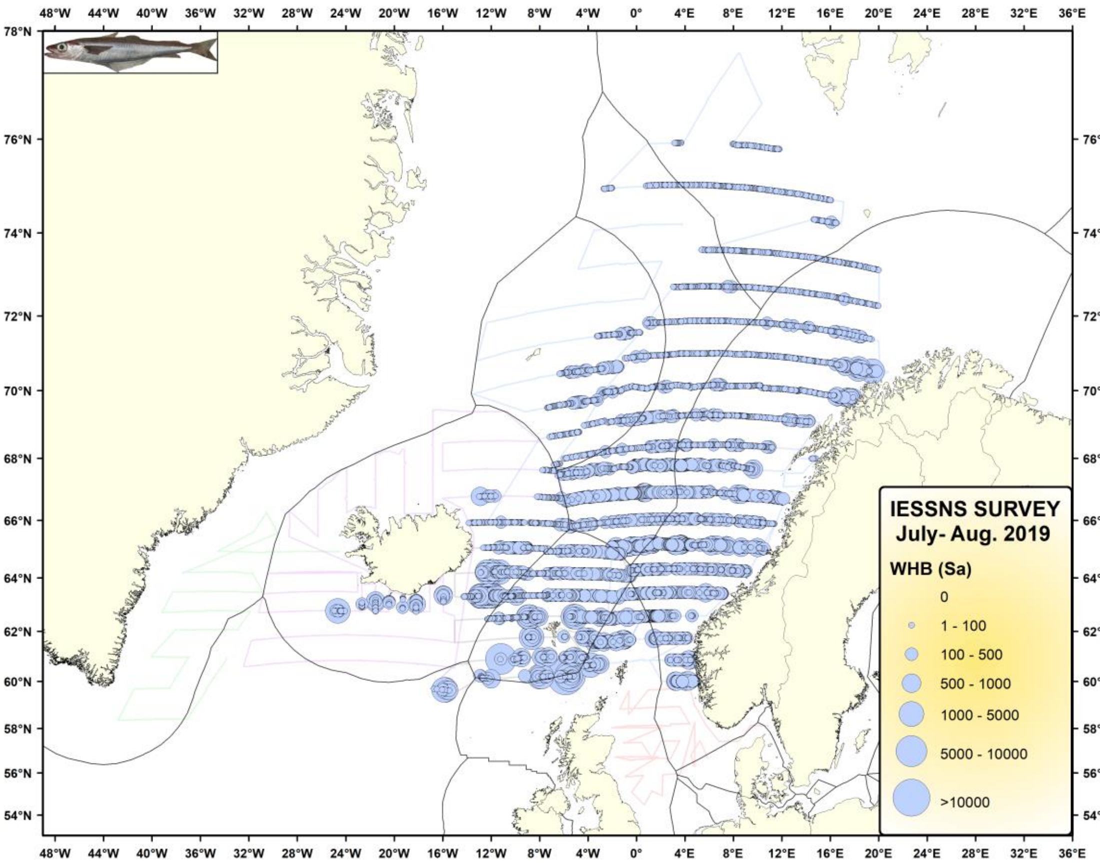


Figure 21. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2019.

Table 9. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2019.

LenGrp	age 0	1	2	3	4	5	6	7	8	9	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
9-10	-	-	-	-	-	-	-	-	-	-	-	41290	41290	-	-
10-11	179782	-	-	-	-	-	-	-	-	-	-	-	179782	1078.7	6.00
11-12	245276	-	-	-	-	-	-	-	-	-	-	-	245276	2136.9	8.71
12-13	742161	-	-	-	-	-	-	-	-	-	-	-	742161	7639.2	10.29
13-14	419538	-	-	-	-	-	-	-	-	-	-	-	419538	6041.0	14.40
14-15	431653	-	-	-	-	-	-	-	-	-	-	-	431653	7593.6	17.59
15-16	122387	-	-	-	-	-	-	-	-	-	-	-	122387	2697.5	22.04
16-17	12091	-	-	-	-	-	-	-	-	-	-	-	12091	290.2	24.00
17-18	-	-	-	-	-	-	-	-	-	-	-	3807	3807	83.8	22.00
18-19	-	13326	-	-	-	-	-	-	-	-	-	-	13326	342.7	25.71
19-20	-	58448	-	-	-	-	-	-	-	-	-	-	58448	2069.4	35.41
20-21	-	45689	81842	-	-	-	-	-	-	-	-	-	127531	6116.0	47.96
21-22	-	96286	249072	-	-	-	-	-	-	-	-	-	345358	20098.2	58.20
22-23	-	183118	363974	-	-	-	-	-	-	-	-	-	547092	36303.9	66.36
23-24	-	161561	443693	6176	-	-	-	-	-	-	-	-	611431	45728.6	74.79
24-25	-	63431	220678	-	19330	38660	-	-	-	-	-	-	342098	29877.7	87.34
25-26	-	315	238986	201293	197353	135844	6442	-	-	-	-	-	780234	77108.6	98.83
26-27	-	17527	73113	660792	687115	534868	81213	-	79485	-	-	-	2134114	231058.0	108.27
27-28	-	-	180484	567017	1286928	1341078	150141	37237	72998	-	-	-	3635883	428875.5	117.96
28-29	-	-	50015	461404	976222	1272180	305664	55484	31523	-	-	-	3152492	415762.7	131.88
29-30	-	-	22264	230403	667792	1007146	259856	33174	-	2160	-	-	2222795	324328.9	145.91
30-31	-	-	8736	49959	407292	670400	138264	9181	3768	654	-	-	1288253	211455.6	164.14
31-32	-	-	-	2295	81907	304294	92257	22691	21262	-	-	-	524705	94821.9	180.71
32-33	-	-	-	-	16676	80874	55580	8605	10445	-	6453	-	178633	35779.9	200.30
33-34	-	-	-	-	5926	47431	11451	36124	-	-	-	-	100932	21537.6	213.39
34-35	-	-	-	-	1261	1261	38534	6271	-	-	-	-	47327	10867.8	229.63
35-36	-	-	-	-	-	315	5611	-	6012	2004	2004	-	15945	4219.0	264.59
36-37	-	-	-	-	-	-	5510	-	-	-	-	-	5510	1816.8	329.71
37-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38-39	-	-	-	-	-	-	-	-	-	-	-	1904	1904	552.1	290.00
39-40	-	-	-	-	-	-	-	-	3607	-	-	-	3607	1222.7	339.00
TSN(1000)	2152887	639702	1932857	2179339	4347802	5434350	1150524	208766	229101	4817	8457	47001	18335603	-	-
TSB(1000 kg)	27477.1	41410.4	160751.9	263617.9	563266.3	734895.2	172044.0	32177.7	28457.9	938.6	1831.4	635.8	-	2027504.3	-
Mean length (cm)	12.79	22.16	23.76	27.23	27.90	28.38	29.12	29.79	28.13	31.63	32.96	11.17	-	-	-
Mean weight (g)	12.76	64.73	83.17	120.96	129.55	135.23	149.54	154.13	124.22	194.83	216.54	111.33	-	-	110.83

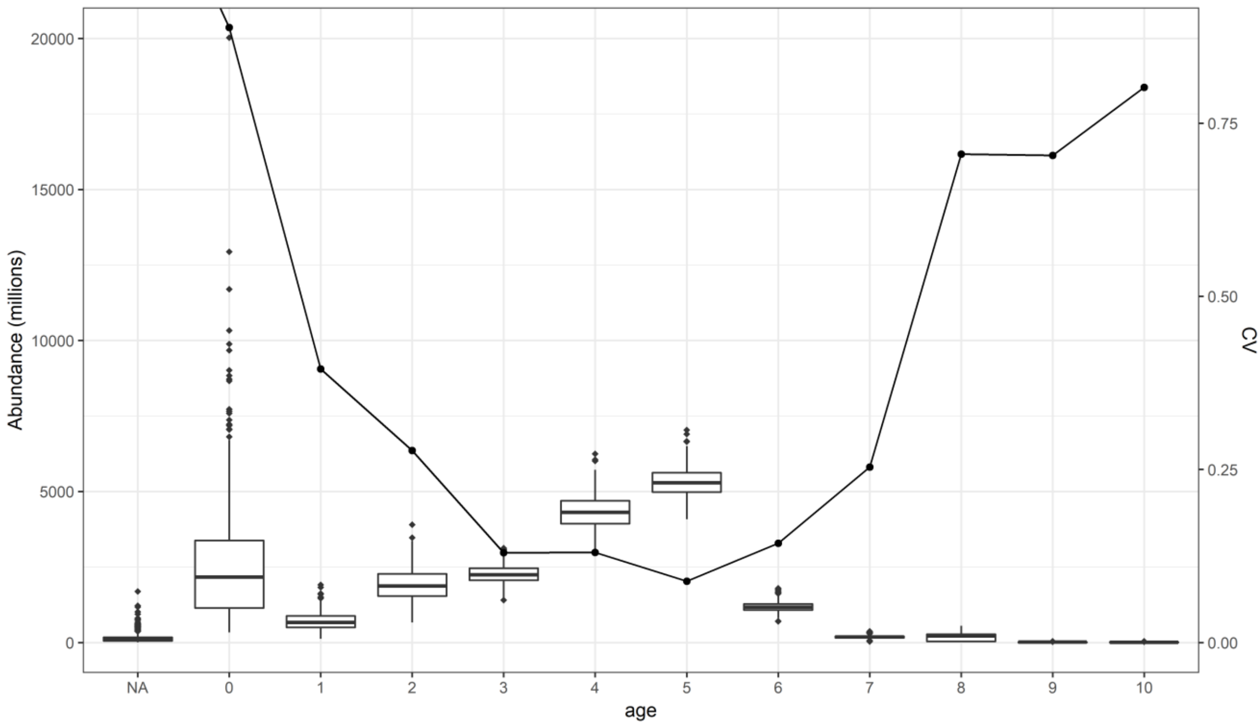


Figure 22. Number by age with uncertainty for blue whiting during IESSNS 2019. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 73% of trawl stations across the six vessels (Figure 23) and where lumpfish was caught, 98% 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 "Eros", whereas a subsample of 50 kg to 200 kg was processed onboard M/V "Finnur Fríði" in Faroese waters. Therefore, small catches (<10 kg) of lumpfish might be missing from the survey track of M/V "Finnur Fríði" (black crosses in Figure 23). 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 5 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 24). 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 472 fish (217 by R/V "Árni Friðriksson" and 255 by M/V "Eros") between 13 and 46 cm were tagged during the survey (Figure 25).

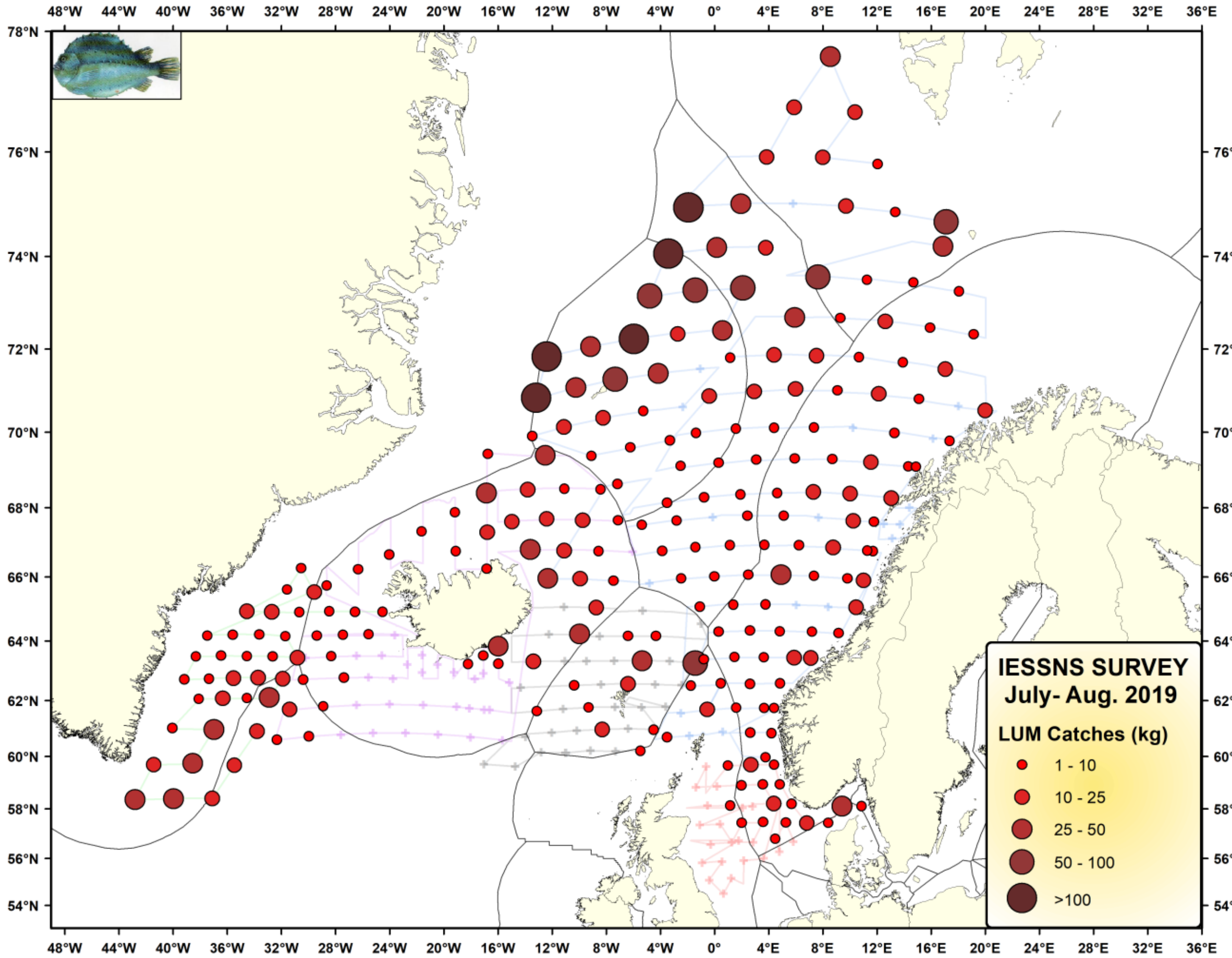


Figure 23. Lumpfish catches at surface trawl stations during IESSNS 2019.

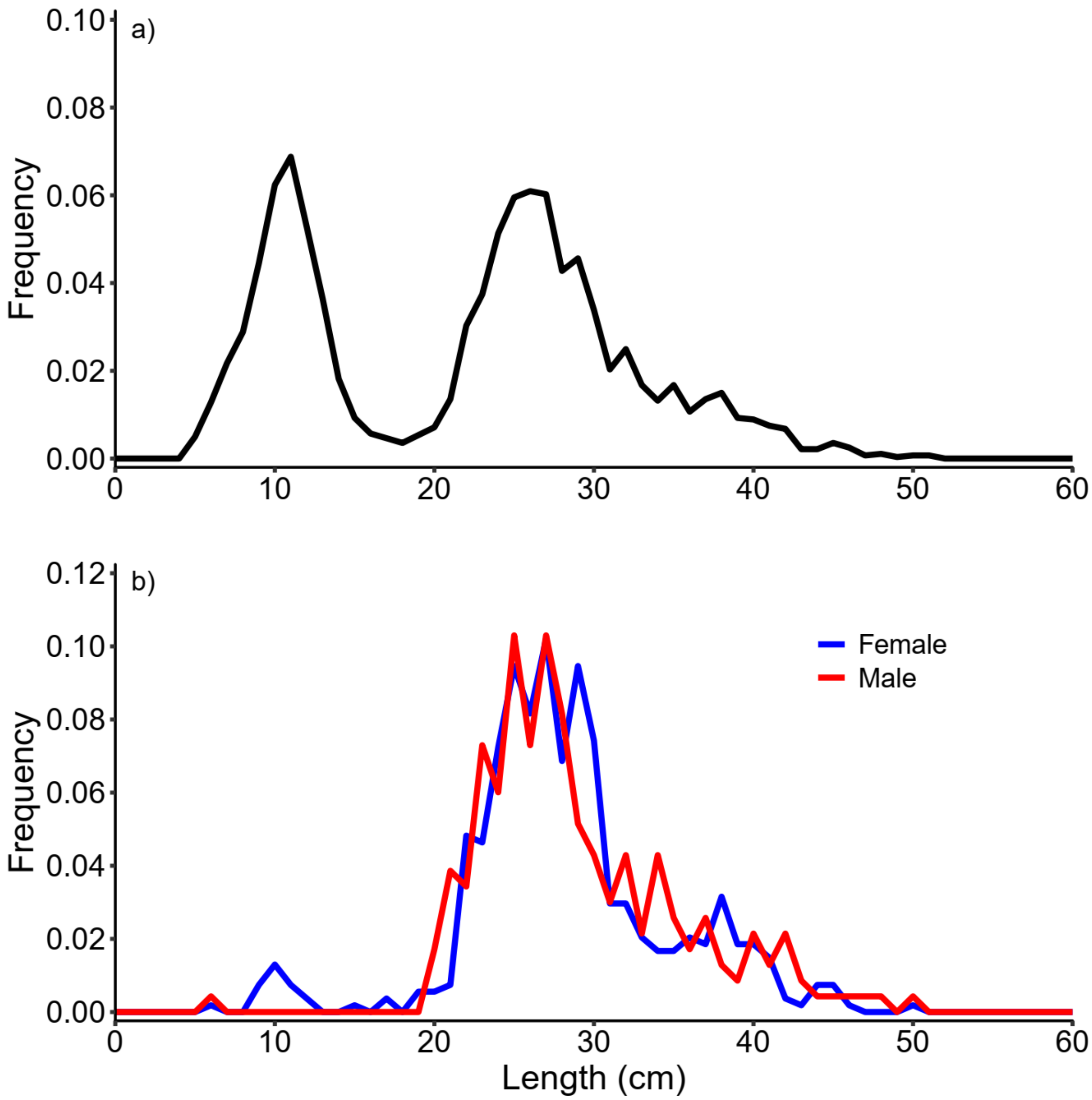


Figure 24. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

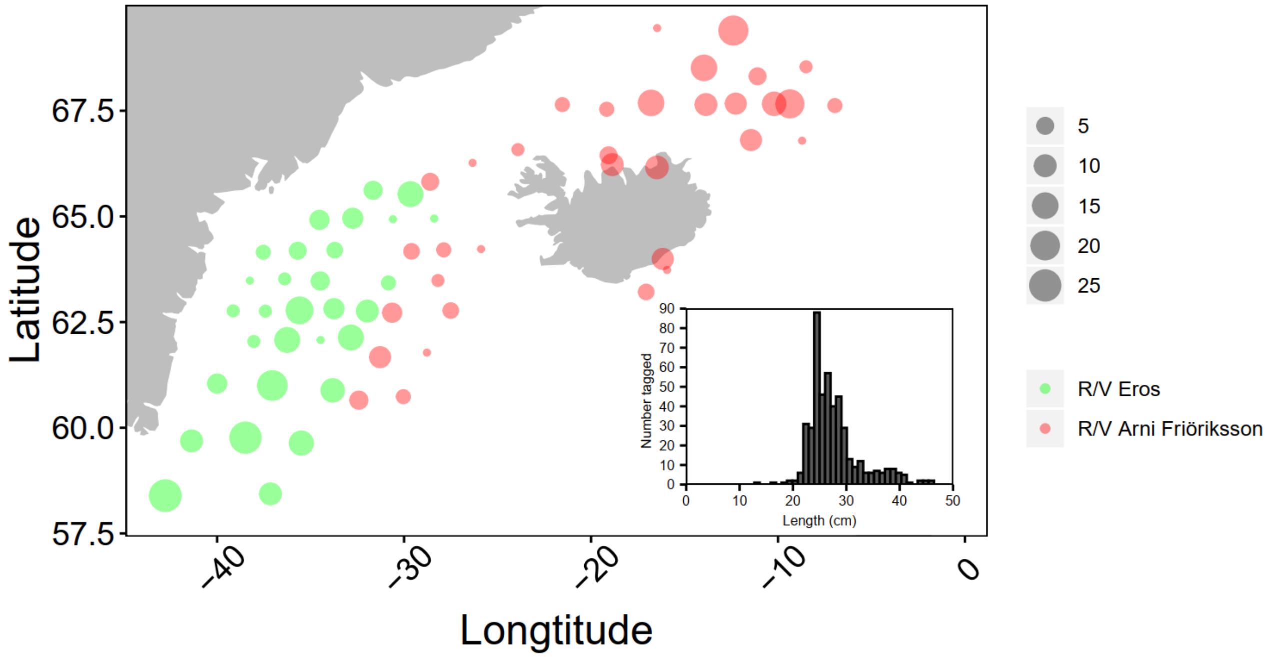


Figure 25. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 58 North Atlantic salmon were caught in 37 stations both in coastal and offshore areas from 62°N to 74°N in the upper 30 m of the water column during IESSNS 2019 (Figure 24). The salmon ranged from 0.08 kg to 2.5 kg in weight, dominated by postsmolt weighing 80-200 grams. The length of the salmon ranged from 20 cm to 62 cm, with a large majority of the salmon <30 cm in length. The general impression was that postsmolt was distributed more westerly in 2019 compared to in 2017 and 2018.

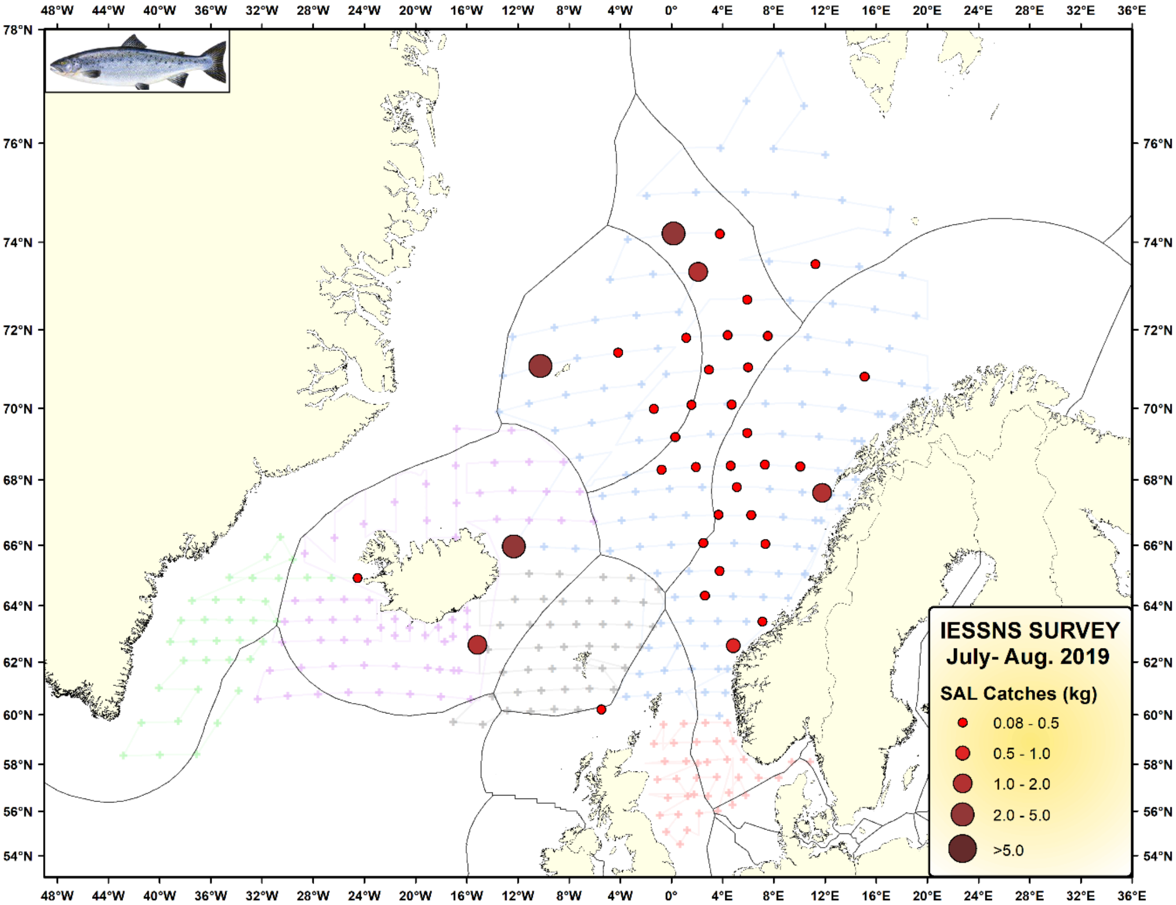


Figure 26. Catches of salmon at surface trawl stations during IESSNS 2019.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 29 stations along the cold front in SE Greenland, Denmark Strait, North of Iceland, West and North of Jan Mayen and at the entrance to the Barents Sea around Bear Island (Figure 27).

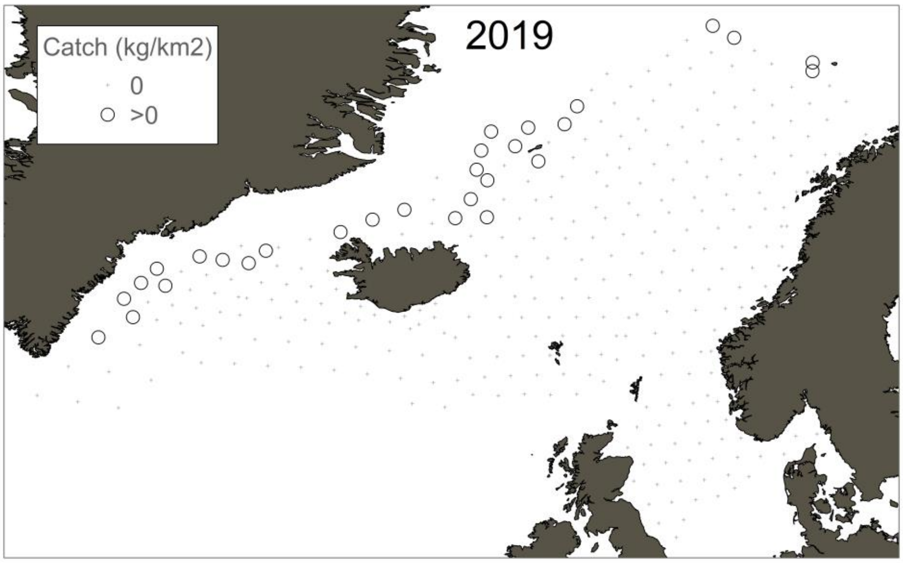


Figure 27. Presence of capelin in surface trawl stations during the IESSNS survey 2019.

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 2019 (Figure 28). Overall, 521 marine mammals of 10 different species were observed, which was a reduction from 600+ in 2018 and 700+ in 2017 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 and 2019. Kings Bay had several days with fog and very reduced visibility in the north-western region (Jan Mayen area), possibly influencing the low number of marine mammals observed on this vessel during IESSNS 2019. Vendla experienced mainly good to excellent visibility during the entire survey period except for some limited periods between Bear Island and Svalbard, 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*), sei whales (*Balaenoptera borealis*) pilot whales (*Globicephala sp.*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), white beaked dolphins (*Lagenorhynchus albirostris*) and harbour porpoise (*Phocoena phocoena*). The dominant number of marine mammal observations were along the continental shelf between the north-eastern part of the Norwegian Sea and western part of the Barents Sea. Fin whales (n=63, group size = 1-4) and humpback whales (n=73, group size = 1-10) dominated among the large whale species, and they were particularly abundant from Norwegian coast outside Finnmark stretching north/northwest via Bear Island to southwest of Svalbard. Killer whales (n=55, group size = 1-10) dominated in the southern and eastern part of the Norwegian Sea, mostly overlapping and feeding on mackerel. White beaked dolphins (n=78, group size = 1-15) were present in the northern part of the Norwegian Sea. There were more observations made of marine mammals in the central Norwegian Sea in 2019 compared to previous years.

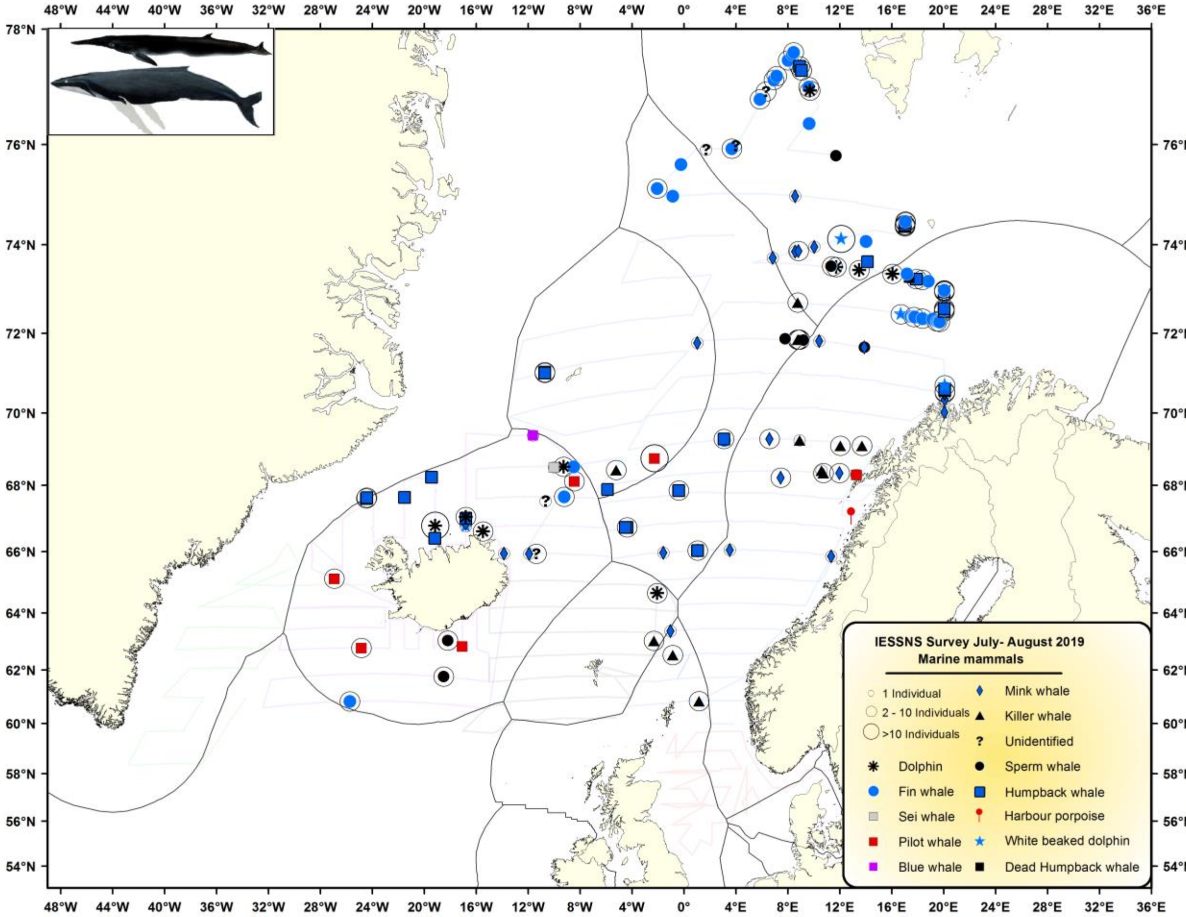


Figure 28. Overview of all marine mammals sighted during IESSNS 2019.

5 Recommendations

Recommendation	To whom
WGIPS recommends that the IESSNS extension to the North Sea should continue for establishing a time series suitable for assessing the part of the NE Atlantic Mackerel stock in the North Sea. The surveys conducted by Denmark in 2018 and 2019 have demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak for the area is deeper than 50 m. The survey provides essential fishery-independent information on the stock during its feeding migration in summer and WGIPS recommends that the Danish survey should continue as a regular annual survey.	WGWIDE, RCG NANSEA

6 Action points for survey participants

Action points
The guidelines for trawl performance should be revised to reflect realistic manoeuvring of the Multpelt832 trawl.
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.
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.
Tagging of lumpfish should be initiated or continue on all vessels.
We recommend that observers collect sighting information of marine mammals and birds on all vessels.

7 Survey participants

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M/V "Ceton"
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Per Christensen, National Institute of Aquatic Resources, Denmark
Søren Eskildsen, National Institute of Aquatic Resources, Denmark

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We greatly appreciate and thank skippers and crew members onboard M/V "Kings Bay", M/V "Vendla", M/V "Eros", M/V "Finnur Fríði", R/V "Árni Friðriksson" and M/V "Ceton" for outstanding collaboration and practical assistance during the joint mackerel-ecosystem IESSNS cruise in the Nordic Seas from 28th of June to 5th of August 2019.

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1 Appendix 1:

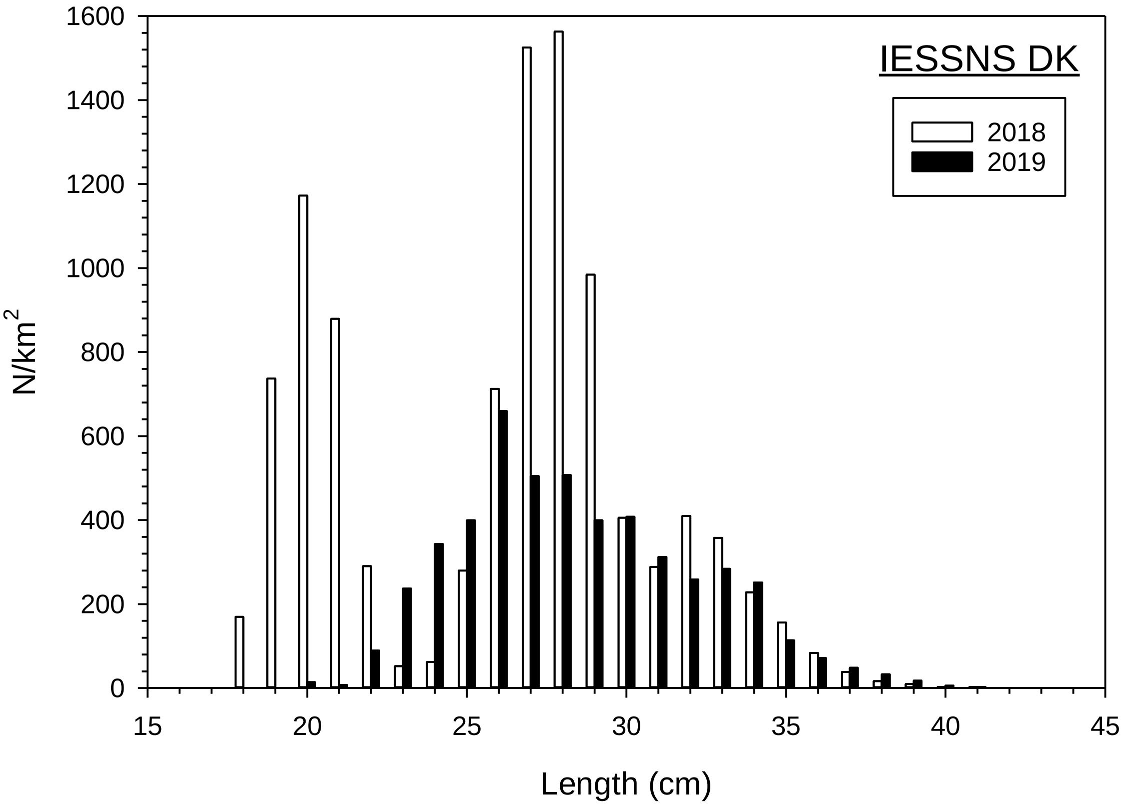
Denmark joined the IESSNS in 2018 for the first time extending the original survey area into the North Sea. The commercial fishing vessels “Ceton S205” was used, and in total 39 stations (CTD and fishing with the pelagic Multipelt 832 trawl) had successfully been conducted. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths larger 50 m and no plankton samples were taken.

Denmark joined the IESSNS again in 2019 using the same vessel. 38 station were taken (PT and CTD, no plankton and no appropriate acoustic equipment available). The locations of stations differed slightly from the previous year focussing on the area north and west of Doggerbank and extended into the eastern Skagerrak.

Average mackerel catch in 20019 was lower than in 2018 (1009 compared to 1743 kg/km2). The length and age composition indicate a relative low amount of small (< 25 cm) individuals (Tab. A.1) whereas the abundance of older (≥ age 6) mackerel was higher in 2019 than in 2018 (Fig. A.1.), and the mean individual weight increased from 204 in 2018 to 220 g in 2019.

Table A1. StoX estimate of age segregated and length segregated mackerel index for the North Sea in 2019. Also provided is average length and weight per age class.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20-21	2314	-	-	-	-	-	-	-	-	-	-	-	2314	149.0	64.36
21-22	1469	-	-	-	-	-	-	-	-	-	-	-	1469	111.8	76.09
22-23	13171	-	-	-	-	-	-	-	-	-	-	-	13171	1133.7	86.08
23-24	33414	745	-	-	-	-	-	-	-	-	-	-	34159	3096.2	90.64
24-25	50228	-	-	-	-	-	-	-	-	-	-	-	50228	5557.8	110.65
25-26	62325	209	-	-	-	-	-	-	-	-	-	-	62534	8172.5	130.69
26-27	88071	17616	-	-	-	-	-	-	-	-	-	-	105686	14967.0	141.62
27-28	66712	24203	674	-	-	-	-	-	-	-	-	-	91588	15526.3	169.52
28-29	24663	81243	-	-	-	-	-	-	-	-	-	-	105906	20070.9	189.52
29-30	3405	90274	2644	-	-	-	-	-	-	-	-	-	96323	19671.7	204.23
30-31	759	54156	45081	346	-	-	-	-	-	-	-	-	100342	24027.1	239.45
31-32	-	27383	25019	27464	-	-	-	-	-	-	-	-	79865	21511.4	269.35
32-33	-	4929	42869	16616	400	-	-	-	-	-	-	-	64814	17876.5	275.81
33-34	-	6714	22531	34224	7627	-	-	-	-	-	-	-	71097	21182.0	297.93
34-35	-	-	9371	22922	15351	15109	-	113	-	-	-	-	62866	20863.7	331.88
35-36	-	-	965	7597	11034	5520	3715	1054	-	-	-	-	29885	10414.4	348.48
36-37	-	-	-	978	6236	3733	3227	2409	1527	-	-	-	18110	6920.1	382.11
37-38	-	-	-	-	713	4068	3654	2651	1369	-	-	-	12455	5191.8	416.85
38-39	-	-	-	-	-	658	2329	2498	1012	1166	-	-	7662	3461.5	451.77
39-40	-	-	-	-	-	261	-	1463	1082	725	-	466	3996	1957.4	489.81
40-41	-	-	-	-	-	-	-	442	404	462	10	19	1337	696.8	521.08
41-42	-	-	-	-	-	-	-	490	129	97	13	13	742	458.7	618.09
42-43	-	-	-	-	-	-	-	-	-	-	64	-	64	42.8	672.00
43-44	-	-	-	-	-	-	-	-	-	80	-	-	80	51.2	638.00
TSN(1000)	346531	307470	149154	110147	41361	29349	12925	11119	5522	2530	87	499	1016695	-	-
TSB(1000 kg)	46889.3	63754.6	40510.5	33331.5	14102.1	10336.8	5369.5	4753.4	2485.9	1270.9	55.9	251.9	-	223112.3	-
Mean length (cm)	25.40	28.88	31.45	32.72	34.43	34.99	36.36	37.35	37.63	38.93	41.61	39.09	-	-	-
Mean weight (g)	135.31	207.35	271.60	302.61	340.95	352.20	415.44	427.52	450.16	502.30	639.96	505.26	-	-	219.45



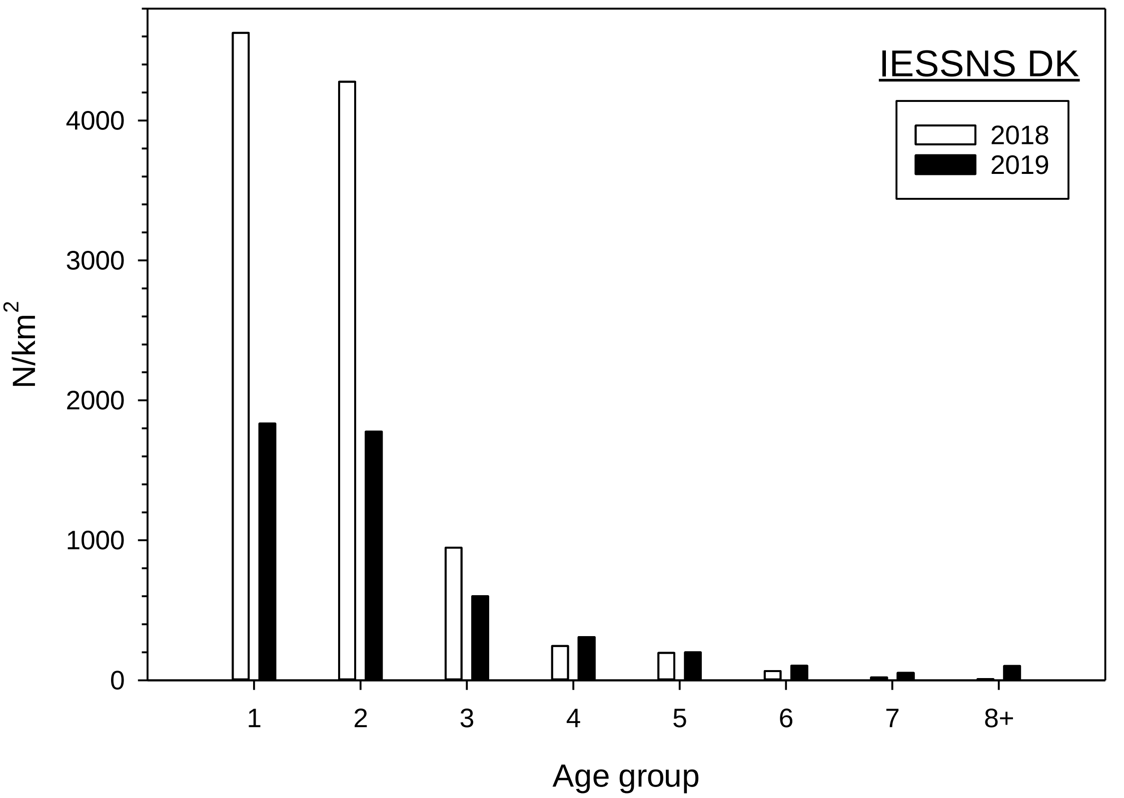


Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018 and 2019.

2 Annex 2:

The mackerel index is calculated on all valid surface stations. That means, that invalid and potential extra surface stations and deeper stations need to be excluded. Below is the exclusion list used when calculating the mackerel abundance index for IESSNS 2019.

Table A2-1: Trawl station exclusion list for IESSNS 2019 for calculating the mackerel abundance index.

Vessel	Country	Exclusion list	
		Cruise	Stations
Kings Bay	Norway	2019837	29,38,47,52,55,70,74,77,79,81,82,86,92,98
Vendla	Norway	2019838	37,41,49,52,57,64,67,70,73,76,77,78,83,86,88,89,90,91,93,97,100,104,109,112,113
Árni Friðriksson	Iceland	A8-2019	342,344,347,361,365,366,375,383
Finnur Fríði	Faroe Islands	1952	9, 33,50,73,82,1081,1084 *
Eros	Greenland	CH-2019-01	87
Ceton	EU (Denmark)		North Sea data were not used in the combined index in IESSNS 2019

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceeded by 1952 (e.g. ‘19520009’)