Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE, No. 5)
ICES HQ, Copenhagen, Denmark, (digital meeting) 26. August – 1. September 2020

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 1st July – 4th August 2020

Leif Nøttestad, Valantine Anthonypillai, Are Salthaug, Åge Høines
Institute of Marine Research, Bergen, Norway

Anna Heiða Ólafsdóttir, James Kennedy
Marine and Freshwater Research Institute, Hafnarfjörður, Iceland

Eydna í Homrum, Leon Smith
Faroe Marine Research Institute, Tórshavn, Faroe Islands

Teunis Jansen, Søren Post
Greenland Institute of Natural Resources, Nuuk, Greenland

Kai Wieland
National Institute of Aquatic Resources, Denmark

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1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from July 1st to August 4th in 2020 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 and 2019 ICES mackerel benchmarks. 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 time series for blue whiting and NSSH have now been conducted for five years (2016-2020).

The mackerel index increased by 7.0% for biomass and 0.3% for abundance (numbers of individuals) compared to the 2019 index. In 2020, the most abundant year classes were 2010, 2016, 2011, 2013 and 2014, respectively. Overall, the cohort internal consistency continues to improve with a longer time series (2010-2020).

The survey coverage area was 2.9 million km^2 in 2020, which is similar as in previous years from 2017 to 2019. Furthermore, 0.26 million km^2 was surveyed in the North Sea in July 2020. Distribution zero boundaries were found in majority of the survey area with an exception of high mackerel abundance in the northwestern region of the Norwegian Sea into the Fram Strait west of Svalbard. The mackerel appeared less patchily distributed within the survey area and had a pronounced distribution in the central and northern Norwegian Sea in 2020 compared to previous years. This major difference in distribution consists of a substantial decline of mackerel in the west and corresponding increase in the central and northern part of the Norwegian Sea.

The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2020 was 20.3 billion and the total biomass index was 5.93 million tonnes, which is significantly higher than in 2019 (34% and 24%, respectively). The increase was due to the recruiting 2016 year-class coming strongly into the survey area. The herring stock is dominated by 4-year old herring (year class 2016) in terms of numbers (40%) and biomass (33%), but this year class is still mainly in the northeastern part of the Norwegian Sea. The 2013 year class (7 year old) is distributed in all areas with herring in the survey and it contributes 22% and 20% to the total biomass and abundance, respectively.

The total biomass of blue whiting registered during IESSNS 2020 was 1.8 million tons, which is an 11% decrease since 2019. The stock estimate in number of age groups 1+ for 2020 is 16.5 billion compared to 16.2 billion in 2019. Age group 1 is dominating the estimate in 2020 (22% and 35% of the biomass and by numbers, respectively, looking at age groups 1+). A good sign of recruiting year class (0-group) was also seen in the survey this year. Of the older age groups 6 year old blue whiting was most abundant.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred in the southern and south-western parts of the Norwegian Sea, and with the strong 2016 year class of NSSH, there was also overlap in the central and north eastern part of the Norwegian Sea. In the eastern Norwegian sea between 62-67°N, mackerel were present but herring were in low abundance, in contrast, in areas north of Iceland, herring were present while mackerel were absent. Older and younger herring were spatially segregated with larger herring distributed to the east and north of Iceland and in the southern Norwegian Sea, while young herring were found in the northeastern Norwegian Sea.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 74% 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 54 Atlantic salmon were caught in 30 stations both in coastal and offshore areas from 60°N to >77°N in the upper 30 m of the water column. The salmon ranged from 0.084 kg to 2.73 kg in weight, dominated by postsmolt weighing 100-180 grams and 1 sea-winter individuals weighing 1-2 kg.

Satellite measurements of the sea surface temperature (SST) showed that the eastern part of the Norwegian Sea and coastal waters of east Greenland in July 2020 was higher, while the western part of the Norwegian Sea, the waters south of Iceland, in the Irminger Sea and around the Faroe islands in July 2020 was broadly similar, to the average for July 1990-2009. The upper layer (10 m depth) was 1.0-2.0°C colder in 2020 compared to 2019 in most of Icelandic and Greenland waters but along the Norwegian coast, the temperature was 1.0-2.0°C warmer in 2020 compared to 2019.

Zooplankton biomass decreased from 2018-2020 in both Greenlandic and Icelandic waters. Average zooplankton biomass in the Norwegian Sea has been relatively stable over the years of the survey.

2 Introduction

During approximately five weeks of survey in 2020 (1st of July to 4th of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Tróndur í Gøtu" 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 was to collect data on abundance, distribution, migration and ecology of Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) during its summer feeding migration phase in the Nordic Seas. The resulting abundance index will be used in the stock assessment of NEA mackerel at the annual meeting of ICES working group of widely distributed stocks (WGWIDE). The IESSNS mackerel index time series goes back to 2010. Since 2016, systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) have also been conducted. This is considered as potential input for stock assessment, when the time series are sufficiently long. Furthermore, the IESSNS is a pelagic ecosystem survey collecting data on physical oceanography, plankton and other fish species such as lumpfish and Atlantic salmon. Opportunistic whale observations are also recorded. The wide geographical coverage, standardization of methods, sampling on many trophic levels and international cooperation around this survey facilitates research on the pelagic ecosystem in the Nordic Seas, see e.g. Nøttestad et al. (2016), Olafsdottir et al. (2019), Bachiller et al. (2018), Jansen et al. (2016), Nikolioudakis et al. (2019).

The methods have evolved over time since the survey was initiated by Norway in the Norwegian Sea in the beginning of the 1990s. The main elements of standardization were conducted in 2010. Smaller improvements have been implemented since 2010. Faroe Islands and Iceland have participated in the joint mackerel-ecosystem survey since 2009. Greenland since 2013 and Denmark from 2018.

The North Sea was included in the survey area for the third time in 2020, 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 35 stations (CTD and fishing with the pelagic Multpelt 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 and 2019 results).

3 Material and methods

Coordination of the IESSNS 2020 was done during the WGIPS 2020 meeting in January 2020 in Bergen, Norway, and by correspondence in spring and summer 2020. 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. However, several of the vessels experienced more wind than in previous years. The weather was fairly good and calm for the two Norwegian vessels except for a few days of fog in the northernmost part of the Norwegian Sea influencing the visual observations. The Icelandic vessel, operating in Icelandic waters, the Iceland basin and the Irminger Sea, encounter unusually many stormy days with a total of 6 days where wind conditions hampered plankton sampling and demanded reduced sailing speed for acoustic recordings. The weather was mostly calm for the Faroese vessel operating mainly in Faroese waters. The chartered vessel Ceton had excellent weather throughout the survey.

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 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 2020. 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 (* including 2 days of capelin study).

Vessel	Effective survey period	Length of cruise track (nmi)	Total trawl stations/ Fixed stations	CTD stations	Plankton stations
Árni Friðriksson	1/7-30/7	5596	65/58	60	48
Tróndur í Gøtu	2-17/7	2600	43/38	38	38
Eros	16/7-4/8	2535*	34/33	37	33
Ceton	1/7-9/7	1720	35/35	35	-
Vendla	3/7-3/8	5346	90/77	78	78
Kings Bay	3/7-3/8	5377	86/74	74	70
Total	1/7-4/8	23174	353/315	322	267

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 Seabird 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, Tróndur í Gøtu 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; ICES 2017). Sensors on the trawl doors, headrope and ground rope of the Multpelt 832 trawl recorded data, and allowed live monitoring, of effective trawl width (actually door spread) and trawl depth. 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 150 kg (if it was a mixture of herring and mackerel), however, all lumpfish were picked out from the total catch. 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 1st July to 4th August 2020. 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	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	300-350	350	340-347	0
Difference in warp length port/starb. (m)	2-10	16	2-10	10	0-15	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 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) mean (min-max)	4.72 (4.3-5.3)	5.1 (4.5-5.8)	4.89 (4.1-5.5)	4.8 (4.0-5.3)	4.9 (4.4-5.4)	4.9 (4.1-5.9)	+
Trawl height (m) mean (min-max)	28-40	36 (28-45)	28-37	31 (24-39)	45.5 (40.5-49.5)	-	+
Door distance (m) mean (min-max)	118.3 (115-120)	101.3 (90 - 113)	121.8 (118-126)	127 (115-139)	99.1 (94 – 104)	118 (113-121)	+
Trawl width (m)*	65.8	60.6	68.0	70.54	57.2	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	12-12, 4-31	6-22, 8-23	4-16	4-20, 5-19	(11.4-11)	+
Headline depth (m)	0	0	0	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 with fender buoy + 1 buoy on each wingtip	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 2020. 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	≥ 100 (separated in small and large category if appropriate)
	Herring	100	100/50*	200	100	
	Blue whiting	100	100/50*	100	100	
	Lumpfish	All	All	all	all	all
	Salmon	-	All	all	all	-
	Other fish sp.	100	25/25	50	25	As appropriate
Weight, sex and maturity determination	Mackerel	15-25	25	50	25	***
	Herring	15-25	25	50	25	0
	Blue whiting	5-50	25	50	25	0
	Lumpfish	10		1^	25	0
	Salmon	-		0	25	0
	Other fish sp.	0	0	0	0	0
Otoliths/scales collected	Mackerel	15-25	25	25	25	***
	Herring	15-25	25	50	25	0
	Blue whiting	5-50	25	50	25	0
	Lumpfish	0	0	1	0	0
	Salmon	-	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	0
	Herring	5	20	10**	10	0
	Blue whiting	5	20	10	10	0
	Other fish sp.	0	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 ≤ 25 cm and two fish > 25 cm from each station was weighed and aged.
^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 89 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 scientific personnel and crew members from the bridge between 3rd July and 2nd August 2020 onboard M/V "Kings Bay" and M/V "Vendla". Marine mammal observations were conducted, during the day (weather permitting), by a dedicated whale observer aboard R/V Árni Friðriksson from 1st until 13th July 2020. Opportunistic observations were also done from the bridge by crew members between 1st and 30th July 2020.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson", M/V "Eros", M/V "Kings Bay" and M/V "Vendla" 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 determine 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 2020 for 18, 38, 70, 120 and 200 kHz. Onboard Kings Bay there were permanent noise challenges on the multifrequency acoustics including the 38kHz transducer during the entire survey. This noise problem predominantly influenced waters deeper than 200 m and could not be solved during the survey. The noise problem was much less at low speed (<5 knots) compared to high cruising speed (10 knots). Árni Friðriksson was calibrated in early May 2020 for the frequencies 18, 38, 70, 120 and 200 kHz. On Árni, EK80 transceivers were installed recently, there were some unusual noise problems in the backscatter and intermittent technical problems which prevented acoustic recordings a few times when vessel was on transport transect causing lack of acoustic track. Tróndur í Gøtu was calibrated on 26th June 2020 for 38 kHz and due to noise problems the first week; it was again calibrated 8th July after the issue had been resolved. Because of the noise issues, data from Tróndur í Gøtu south of Faroes were only usable down to 150 m. Calibration of the acoustic equipment onboard Eros was done after the cruise on the 2nd 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, 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 2020.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu 250620	M/V Tróndur í Gøtu 080720	Eros
Echo sounder	Simrad EK80	Simrad EK 80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	38,120, 200	38,120, 200	18, 38, 70, 120, 200, 333
Primary transducer	ES38-7	ES38-7	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull	Hull
Transducer depth (m)	9	8	9	7	7	8
Upper integration limit (m)	15	15	15	Not used	Not used	15
Absorption coeff. (dB/km)	9.6	10.0	10.1	9.7	9.7	9.3
Pulse length (ms)	1.024	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	2000
Angle sensitivity (dB)	21.90	18	21.90	21.9	21.9	21.9
2-way beam angle (dB)	-20.70	-20.3	-20.70	-20.6	-20.6	-20.7
TS Transducer gain (dB)	26.33	26.9	25.46	23.44	24.09	25.50
s_A correction (dB)	-0.03	-0.02	-0.02	-0.65	-0.65	-0.6
alongship:	-0.28	6.53	0.19	7.42	7.20	6.86
athw. ship:	0.00	6.5	0.08	7.09	7.03	7.05
Maximum range (m)	500	500	500	500	500	750 for 18 and 38 kHz 500 for 70, 120 and 200 kHz
Post processing software	LSSS v.2.8.1	LSSS v.2.8	LSSS v.2.8.1	LSSS 2.8.0	LSSS 2.8.0	LSSS v.2.8

* No acoustic data collection

Multibeam sonar

Both M/V Kings Bay and M/V Vendla were 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. 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 2020 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.

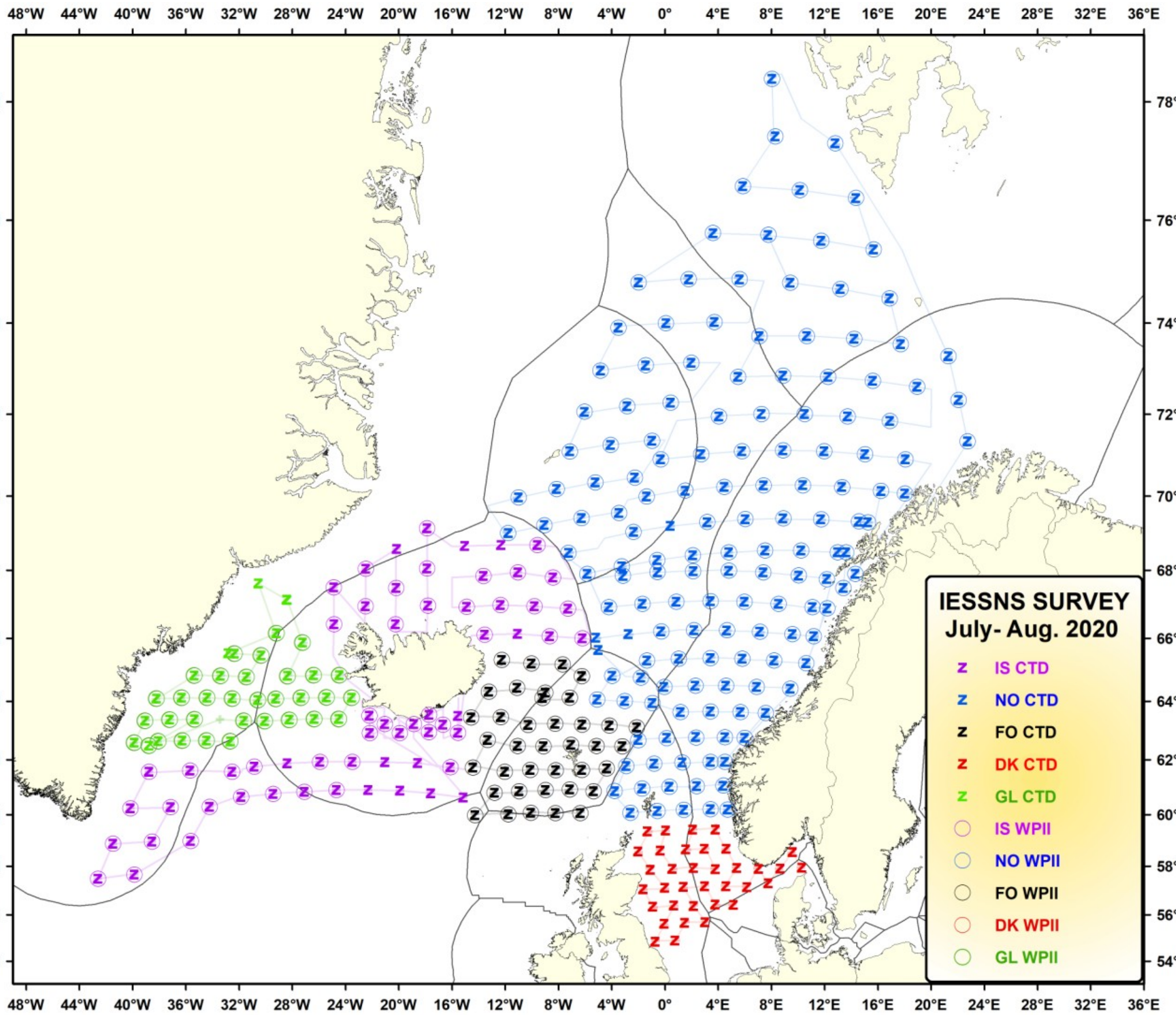

Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 1st July – 4th August 2020. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue), Eros (green) and Ceton (red).

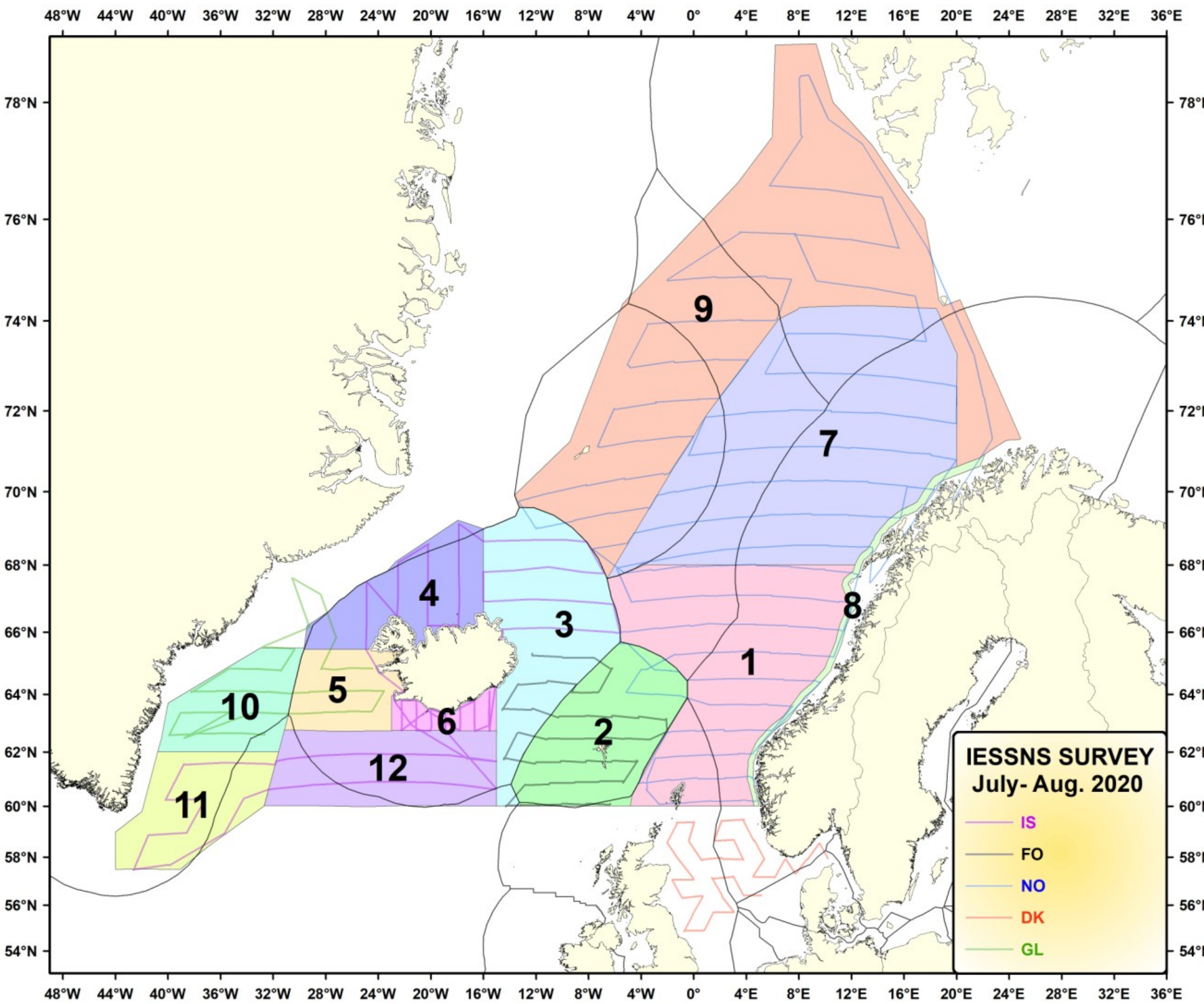

Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2020. The dynamic strata are: 4, 9 and 11.

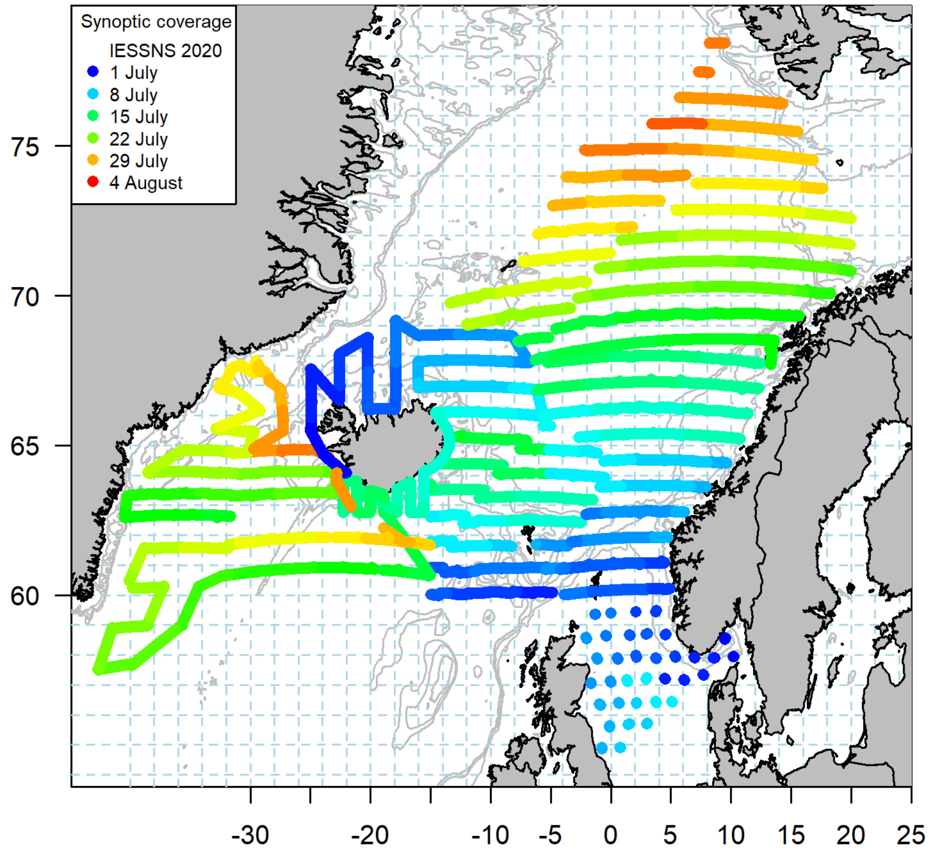

Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2020: blue represents effective survey start (1st of July) progressing to red representing a five-week span (survey ended 4th of August). As Ceton did not record acoustics, they have been represented by station positions.

3.6 StoX

Stox is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. A description of Stox can be found in Johnsen et al. (2019). 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 55°N and 79°N and 43°W and 23°E in 2020. The density of mackerel on a trawl stations is calculated by dividing the total number caught by the assumed area swept by the trawl. The area swept is calculated by multiplying the towed distance by the horizontal opening of the trawl. 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). An estimate of total number of mackerel in a stratum is obtained by taking the average density based on the trawl stations in the stratum and multiplying this with the area of the stratum.

Table 5. Descriptive statistics for trawl door spread, vertical trawl opening and tow speed for each vessel during IESSNS 2020. 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	Eros	Ceton
Trawl doors horizontal spread (m)						
Number of stations	37	58	74	78	33	35
Mean	99.1	101.3	118.3	121.8	115.2	127
max	104	113	135	129	134	139
min	94	90	110	107	100	114
st. dev.	2.2	5.1	2.84	4.6	5.2	5.7
Vertical trawl opening (m)						
Number of stations	37	58	74	78	33	35
Mean	45.5	36.4	33.6	30.3	34.9	31
max	49.5	45.0	40	40	44.8	39
min	40.5	27.5	29	25	29.2	24
st. dev.	2.0	3.8	2.9	3.0	3.2	3.9
Horizontal trawl opening (m)						
mean	57.2	60.6	65.8	68.0	67.4	70.5
Speed (over ground, nmi)						
Number of stations	38	58	74	78	33	35
mean	4.55	5.1	4.72	4.89	4.9	4.8
max	4.8	4.5	5.7	5.7	5.4	5.3
min	4.3	5.8	4.1	4.4	4.4	4.0
st. dev.	0.1	0.2	0.30	0.29	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, and in 2020 the door spread was extended to 122 m.

	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
121	66.5	66.8	67.1	67.4	67.7	68.0	68.3	68.6
122	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0

4 Results and discussion

4.1 Hydrography

Satellite measurements of sea surface temperature (SST) in the eastern part of the Norwegian Sea in July 2020 was slightly higher (0.5-1°C) compared 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 2020 was broadly similar compared to the average (Figure 4). The coastal regions of Greenland were 1-2°C warmer than the average while in the waters south of Iceland, in the Irminger Sea and around the Faroe islands, the SST was similar to the average for July 1990-2009 (Figure 4). This contrasts with the situation in 2019 when SST in the coastal areas of Greenland were 2-3°C warmer and the waters south of Iceland, in the Irminger Sea and around the Faroe islands were 1-2°C warmer than the average. The pattern of anomalies of Sea Surface Temperature in July 2020 was quite different from the other years in 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.

In situ measurements showed the upper layer (10 m depth) was 1.0-2.0°C colder in 2020 compared to 2019 in most of Icelandic and Greenland waters but 1.0-2.0°C warmer in 2020 compared to 2019 along the Norwegian coast (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 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) except around the Faroe Islands where temperature at 100 m depth was about 1°C warmer. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

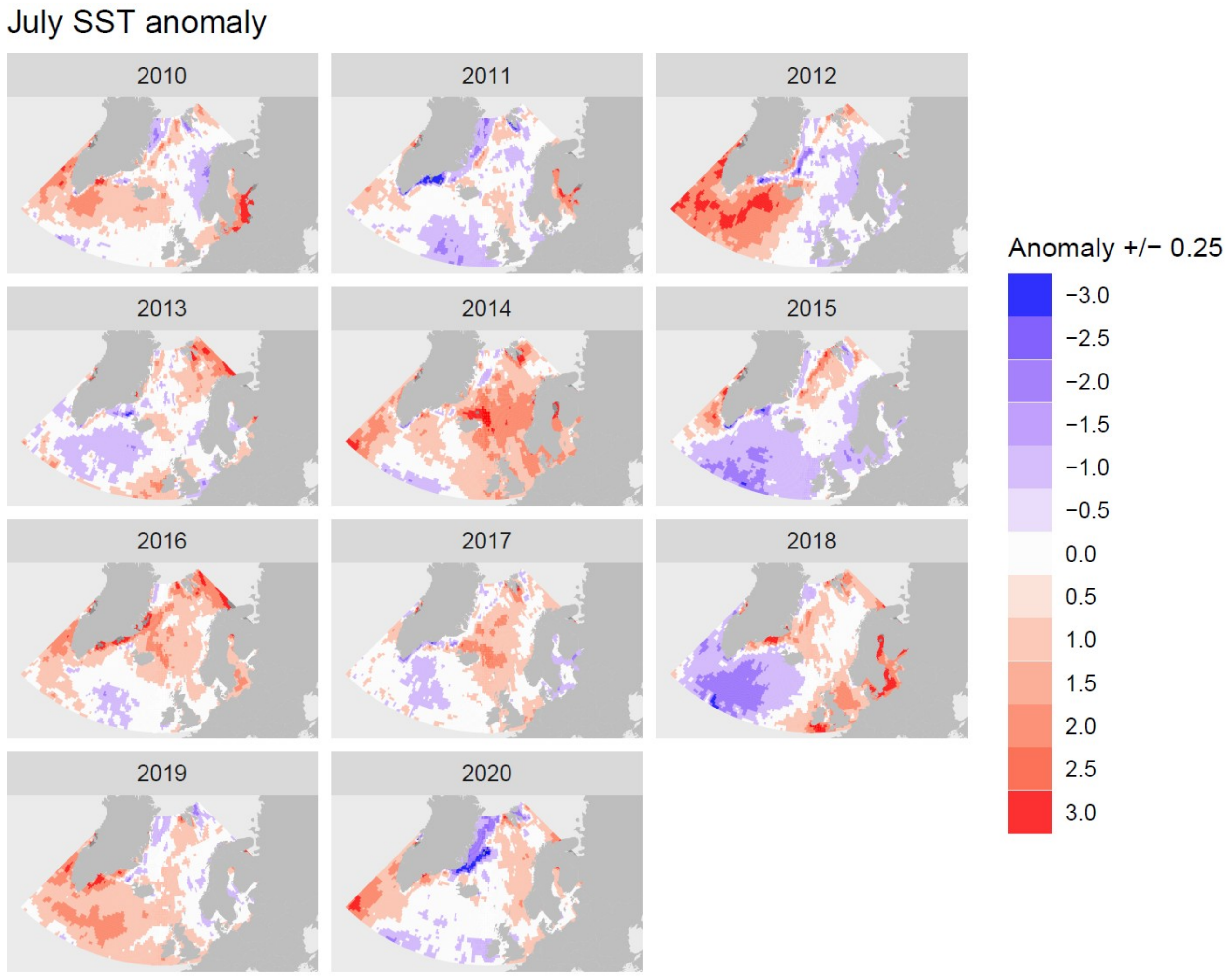

Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2020 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

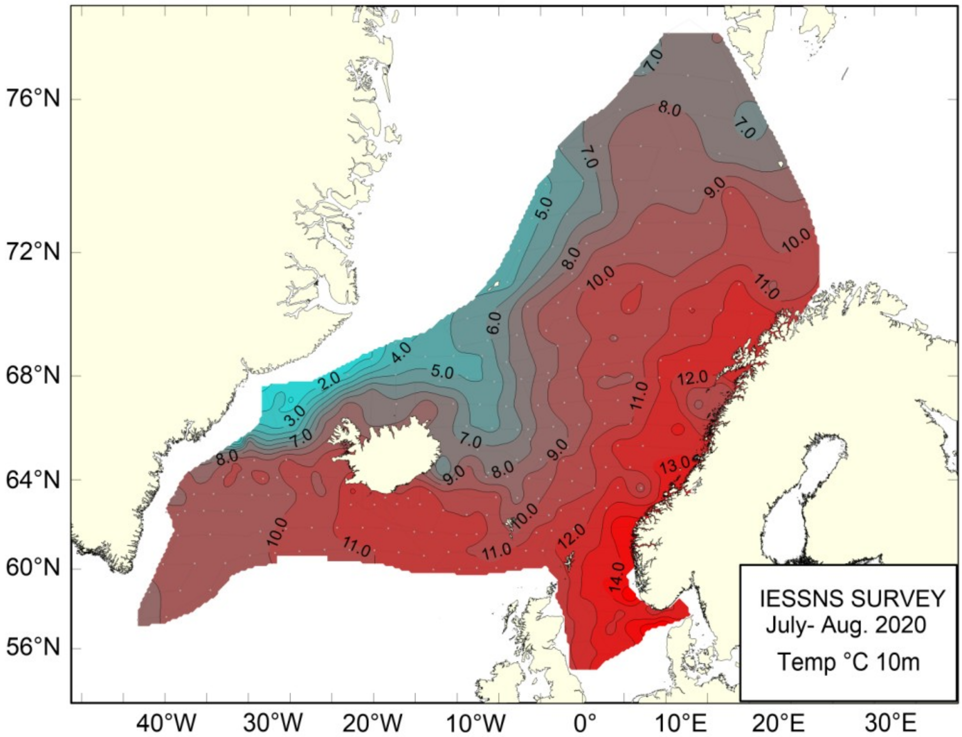

Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2020.

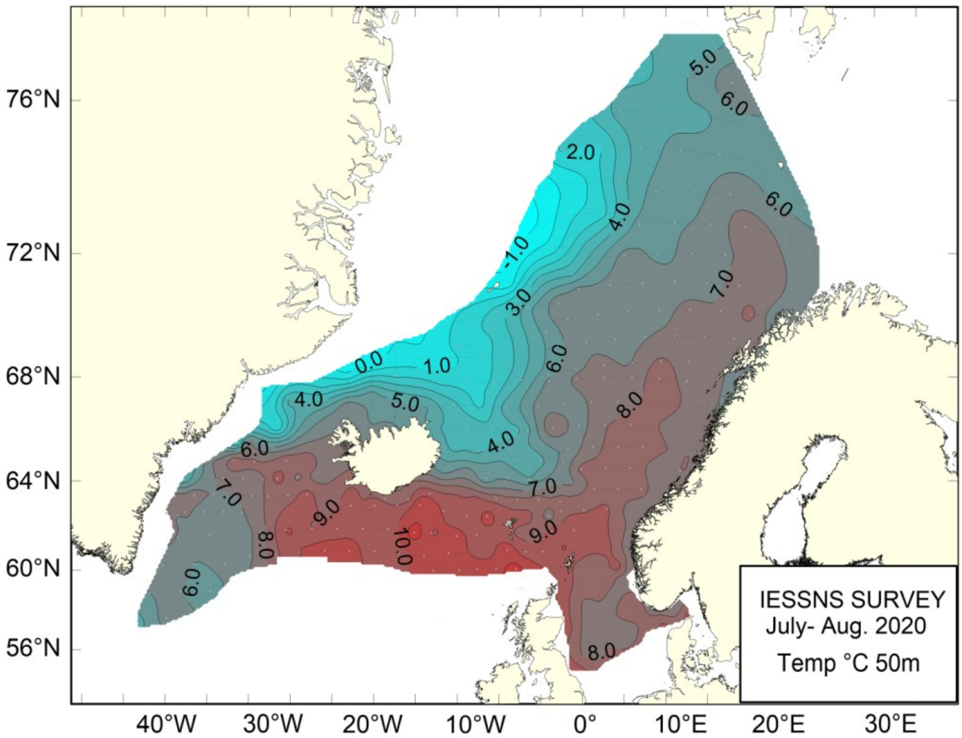

Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2020.

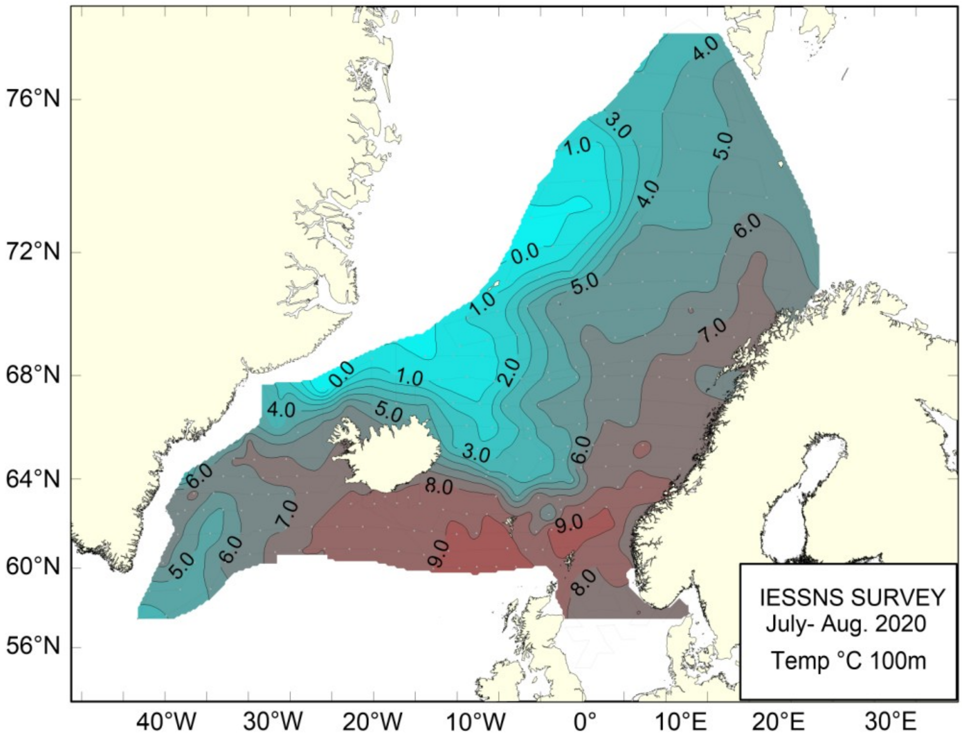

Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2020.

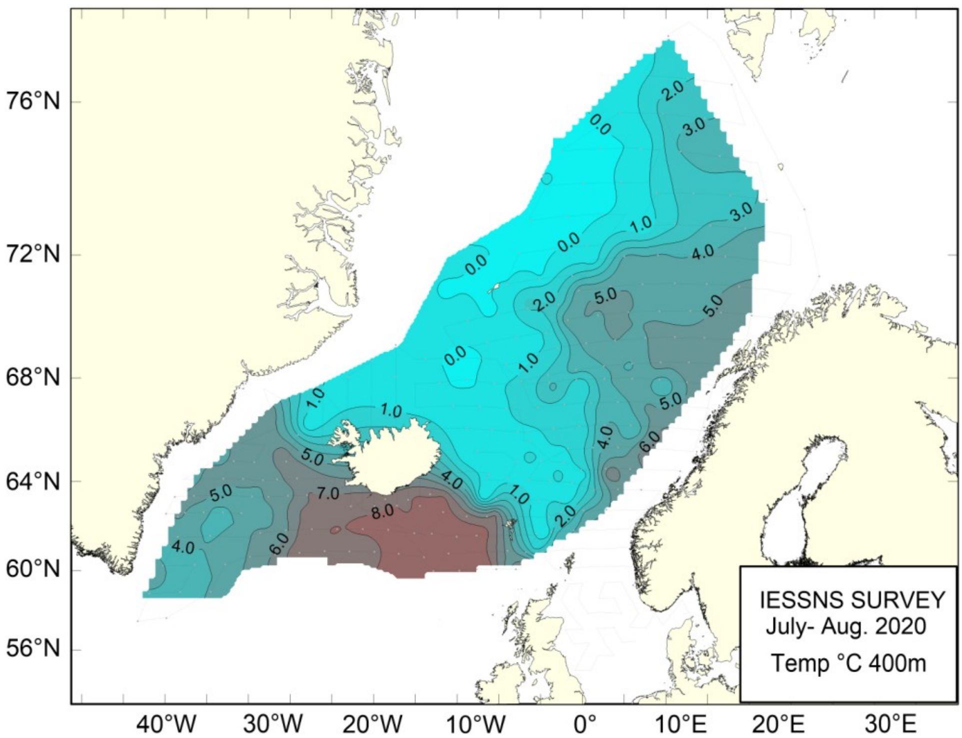

Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2020.

4.2 Zooplankton

Zooplankton biomass varied between areas and was lowest in Greenland waters, which contrasts with the previous 3 years where zooplankton biomass was the highest of the three areas (Figure 9a). In Greenland waters in 2020, the average zooplankton biomass has decreased substantially from 2018, it was 5.5 g m^{-2} in 2020 compared to 10.0 g m^{-2} in 2019 and 16.4 g m^{-2} in 2018. Average zooplankton biomass in Icelandic waters also showed a decrease from 2018 through to 2020, respectively declining from 10.8 g m^{-2} to 6.1 g m^{-2}. Through the time series from 2012-2020, the average zooplankton biomass is correlated in Icelandic and Greenlandic waters ($R^2 = 0.73$).

The average zooplankton biomass in Norwegian waters was similar to the average biomass in 2019. In this relatively short time-series, there is greater 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.

These plankton indices should be treated with some caution as it is only a snapshot of the standing stock biomass, not of the actual production in the area, which complicates spatio-temporal comparisons.

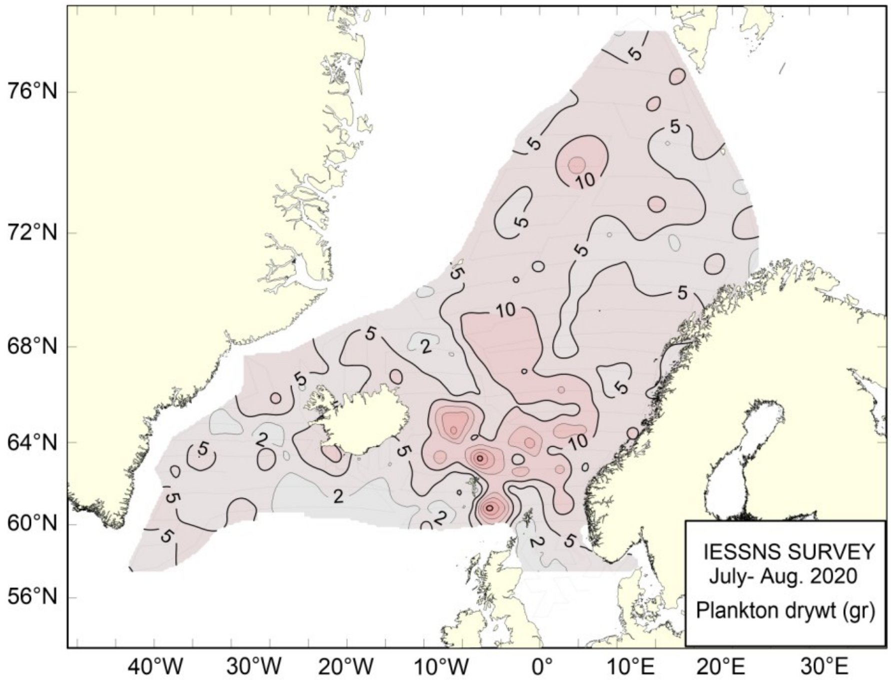

Figure 9a. Zooplankton biomass indices (g dw/m², 0-200 m) in Nordic Seas in July-August.

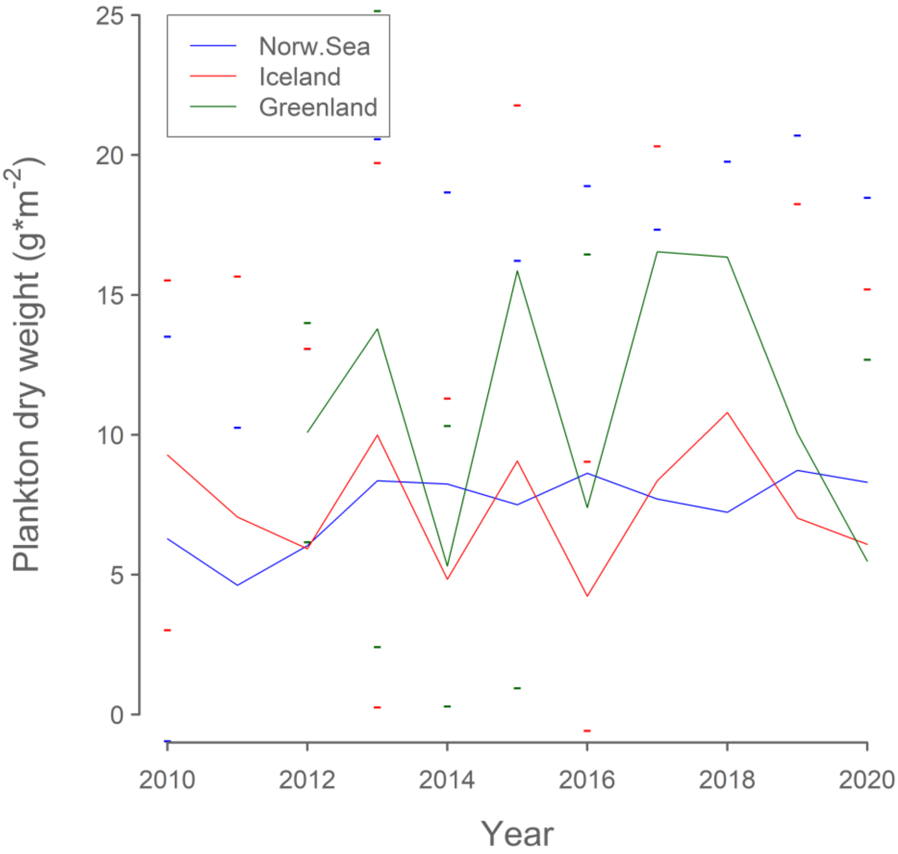

Figure 9b. Zooplankton biomass indices (g dw/m², 0-200 m). Time-series of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W).

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 2° lat. x 4° lon. rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 62 tonnes/km² (mean = 4.0). High density areas were found in the central and northern Norwegian Sea in 2020, with very small concentrations of mackerel in the western part compared to previous years (Figure 11 & 12). This was both apparent in Greenland waters with no mackerel catches taken and a large decline of mackerel catches in Icelandic waters.

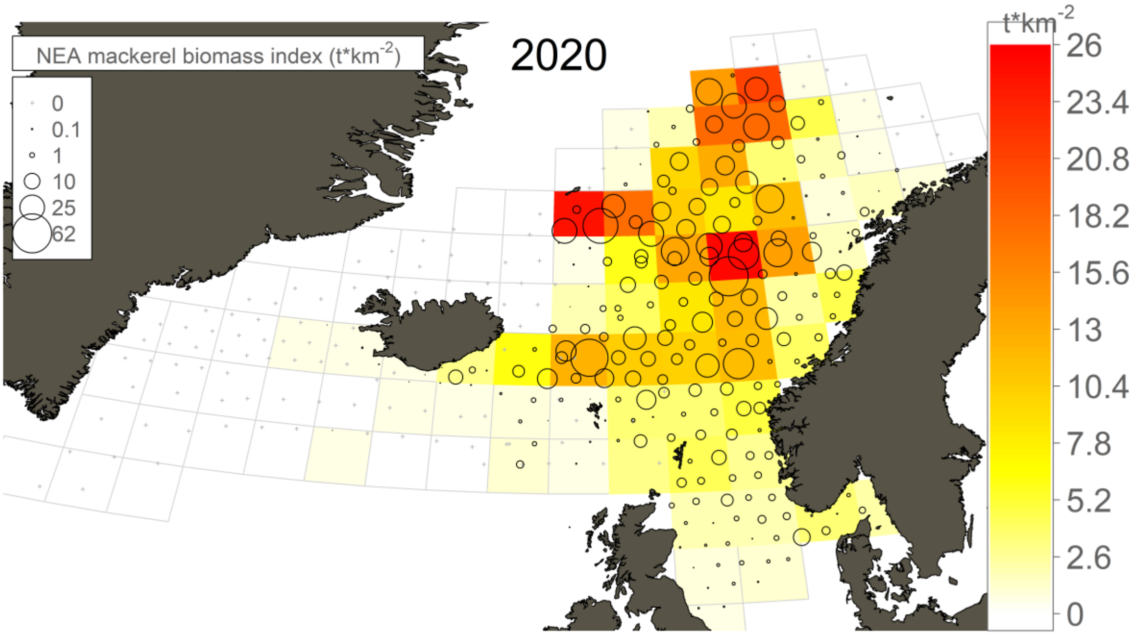

Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

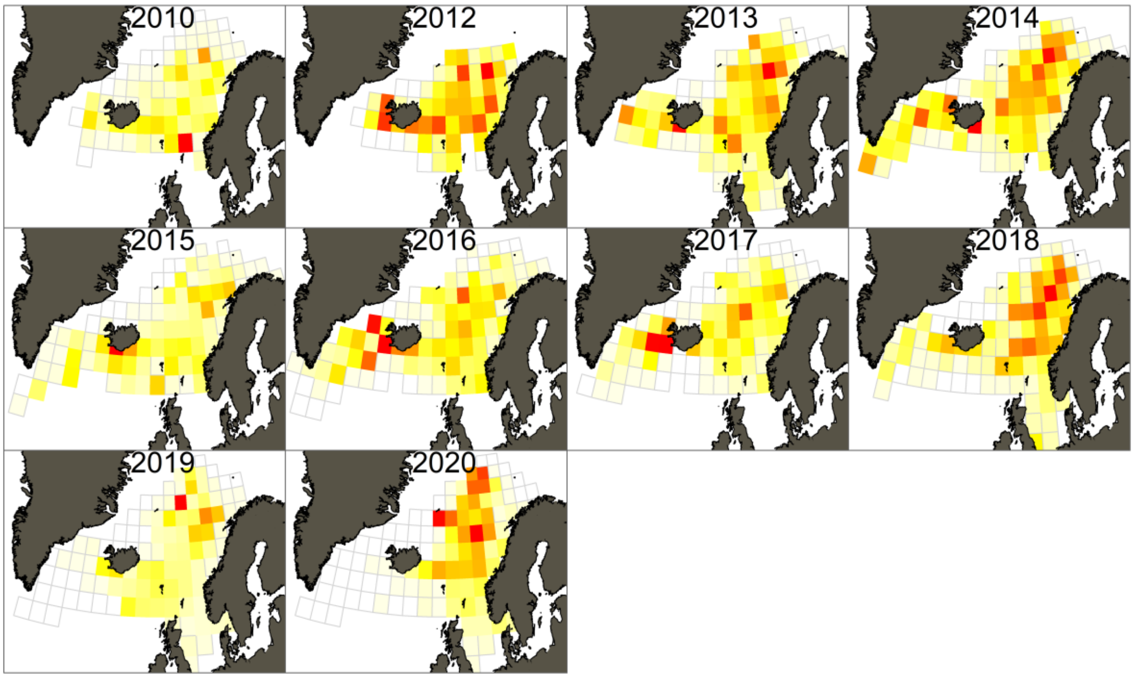

Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the highest year).

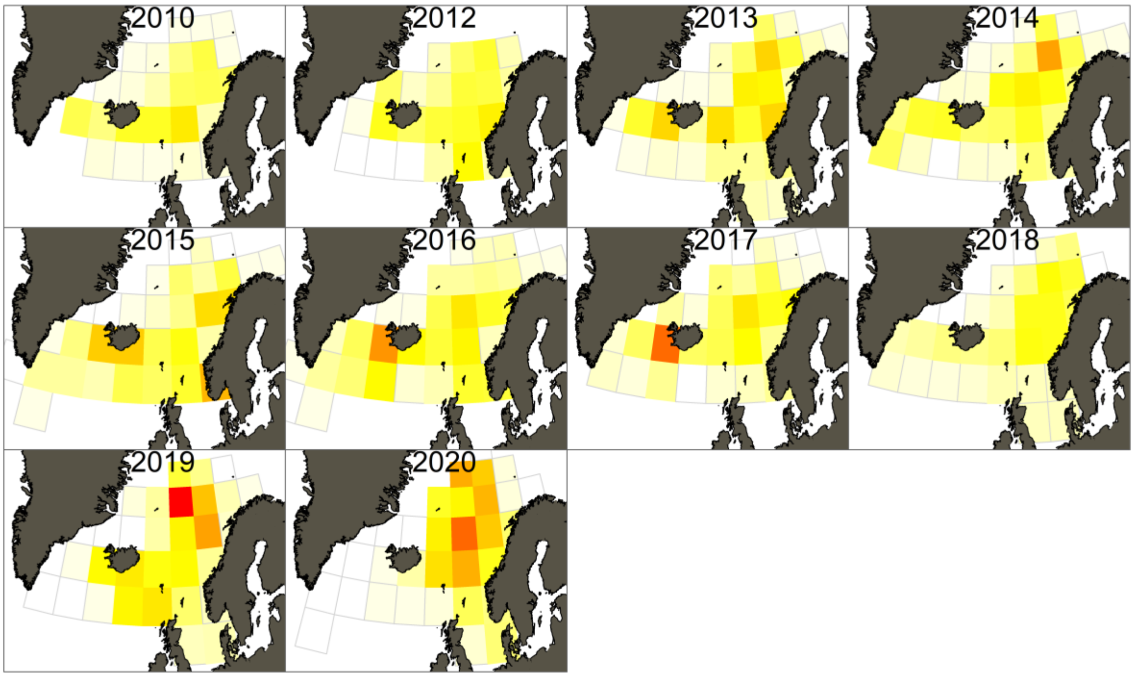

Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (4° lat. x 8° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the given year).

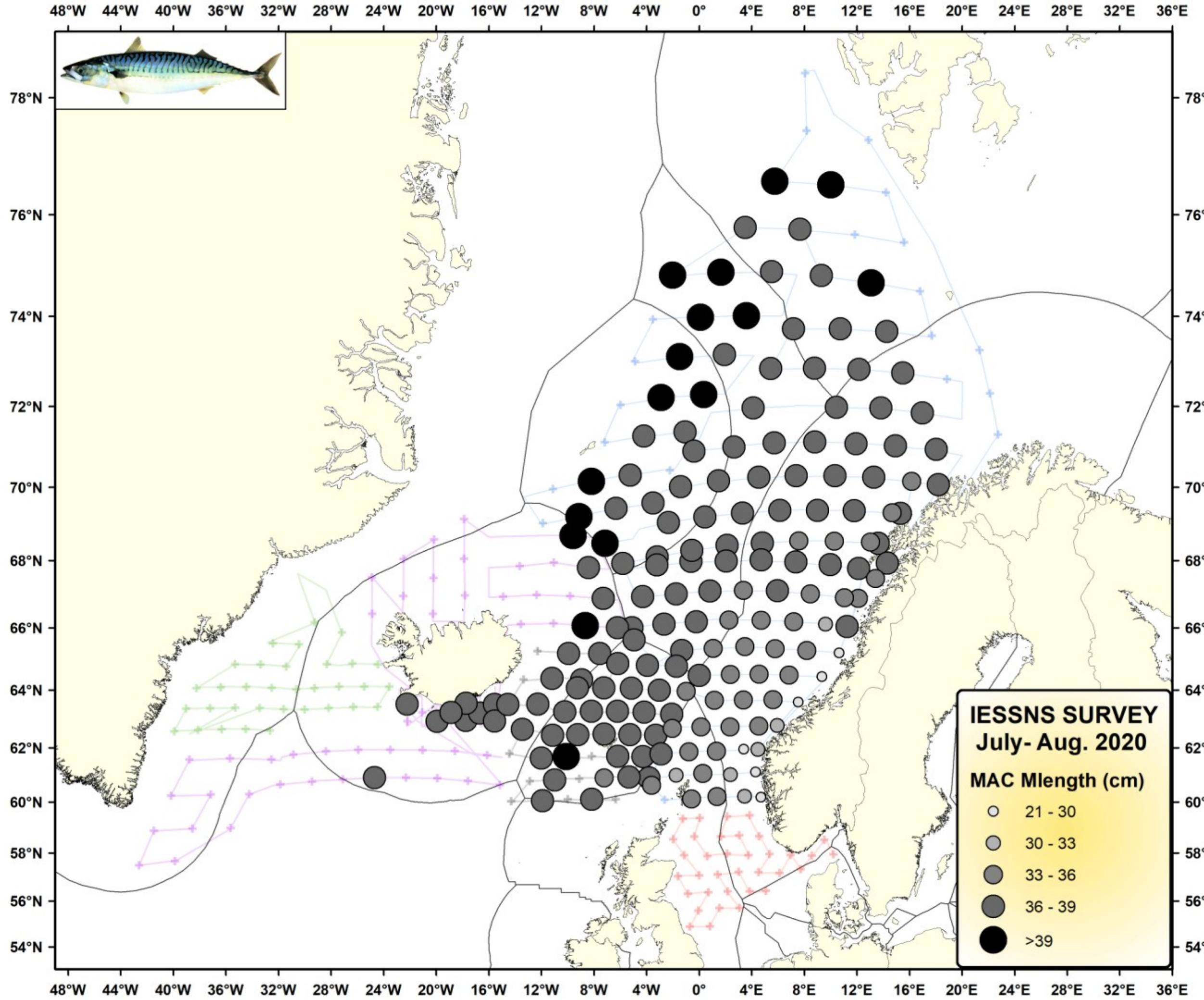

Figure 13. Average length of mackerel at predetermined surface trawl stations during IESSNS 2020.

The length of mackerel caught in the pelagic trawl hauls onboard the six vessels varied from 24.4 to 39.8 cm, with an average of 36.3 cm. Individuals in the length range 33–37 cm dominated in numbers and biomass. The mackerel weight varied between 123 to 642 g with an average of 456 g. Mackerel length distribution followed the same overall pattern as previous years in the Norwegian Sea, with increasing size towards the distribution boundaries in the north and the north-west (Figure 13). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon and lumpfish) in 2020 according to the catches are shown in Figure 14.

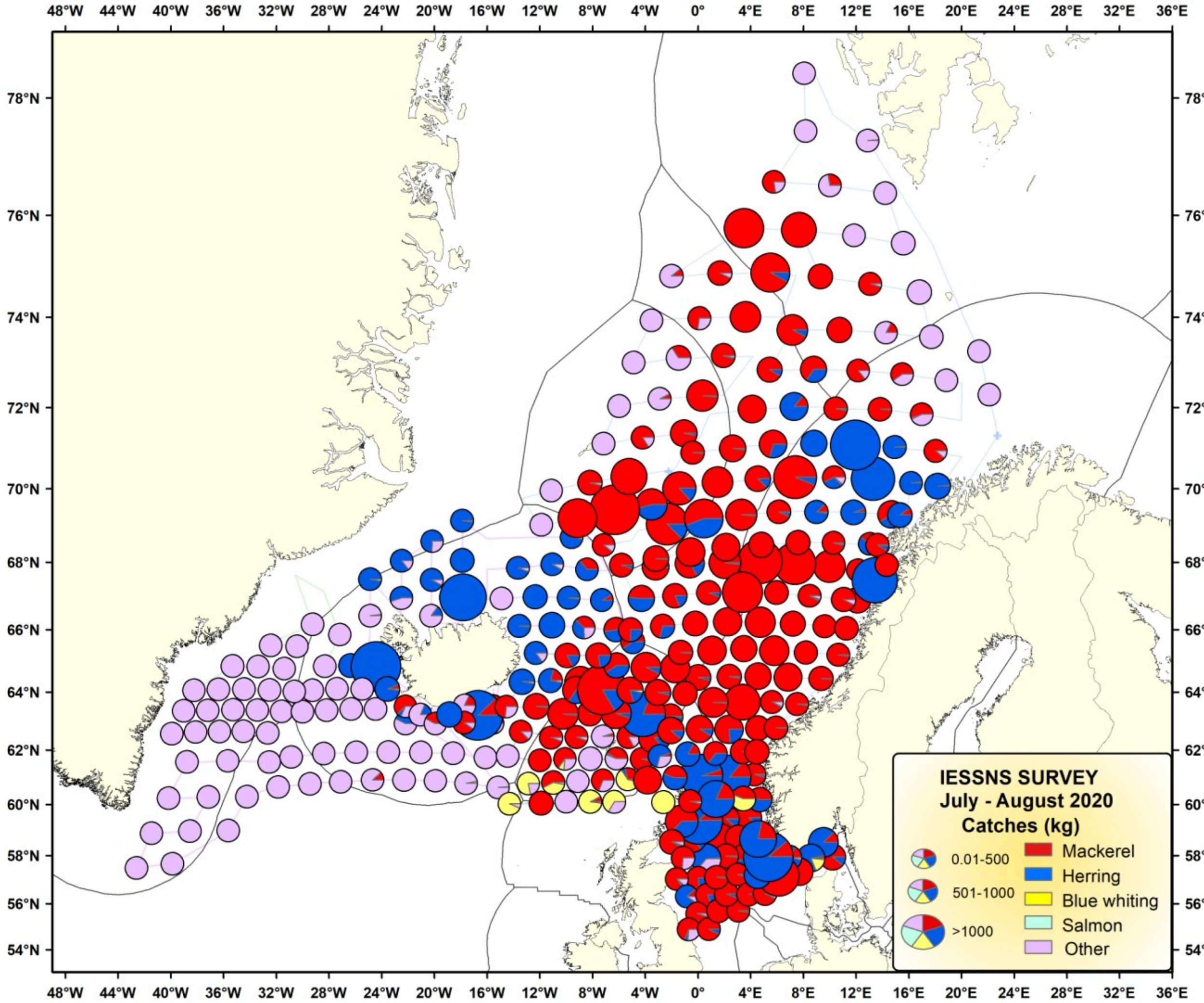

Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, and other (lumpfish)) in 2020 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2020 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX. The mackerel biomass and abundance indices in 2020 were the highest in the time series that started in 2010 (Table 7, Figure 15). Comparing the 2020 estimate to the 2019 estimate shows a 0.3% increase in abundance and 7.0% increase in biomass. The survey coverage area (excl. the North Sea, 0.27 million km^2) was 2.9 million km^2 in 2020, which is similar to the years 2017-2019. The most abundant year classes were 2010, 2016, 2011, 2013 and 2014 (Figure 16). Mackerel of age 1, 2 and to some extent also age 3 are not completely recruited to the survey (Figure 18), information on recruitment is therefore uncertain. However, the abundance of 1-3 year olds from the 2016 and 2017 year classes have consistently been high suggesting that these year classes are large. The 2018 year class appears to be closer to average. Variance in age index estimation is provided in Figure 17.

The overall internal consistency plot for age-disaggregated year classes is improved compared to last year (Figure 19), especially for the ages older than 8 years. There is a good to strong internal consistency for the younger ages (1-5 years) and older ages (8-14+ years) with r between 0.73 and 0.93. However, the internal consistency is poor to moderate (0.10 < r < 0.63) between age 5 to 8 as in previous years. The reason for this poor consistency is not clear.

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 7a).

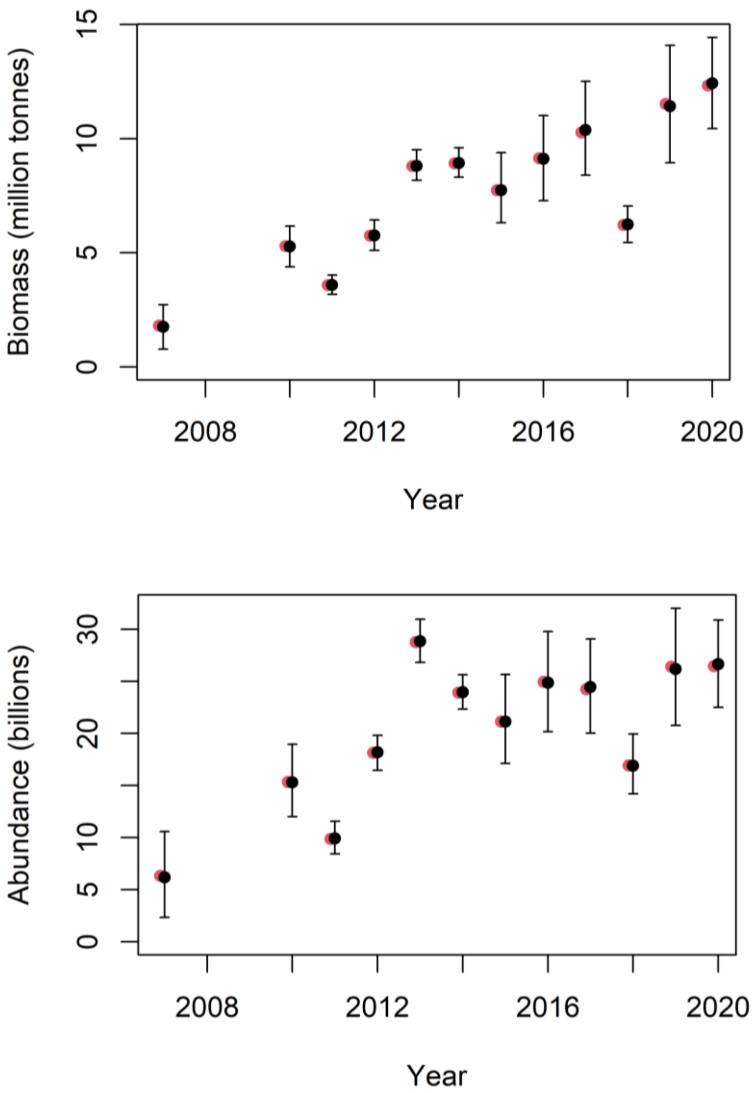

Figure 15. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX . The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap.

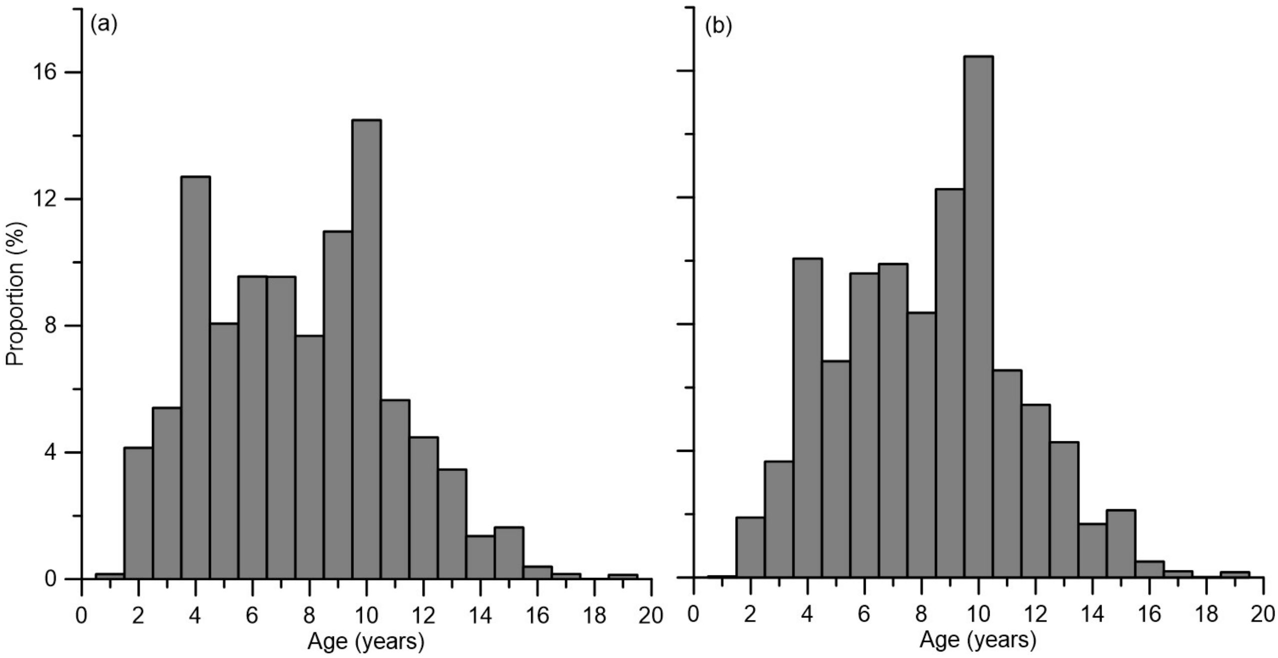

Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2020.

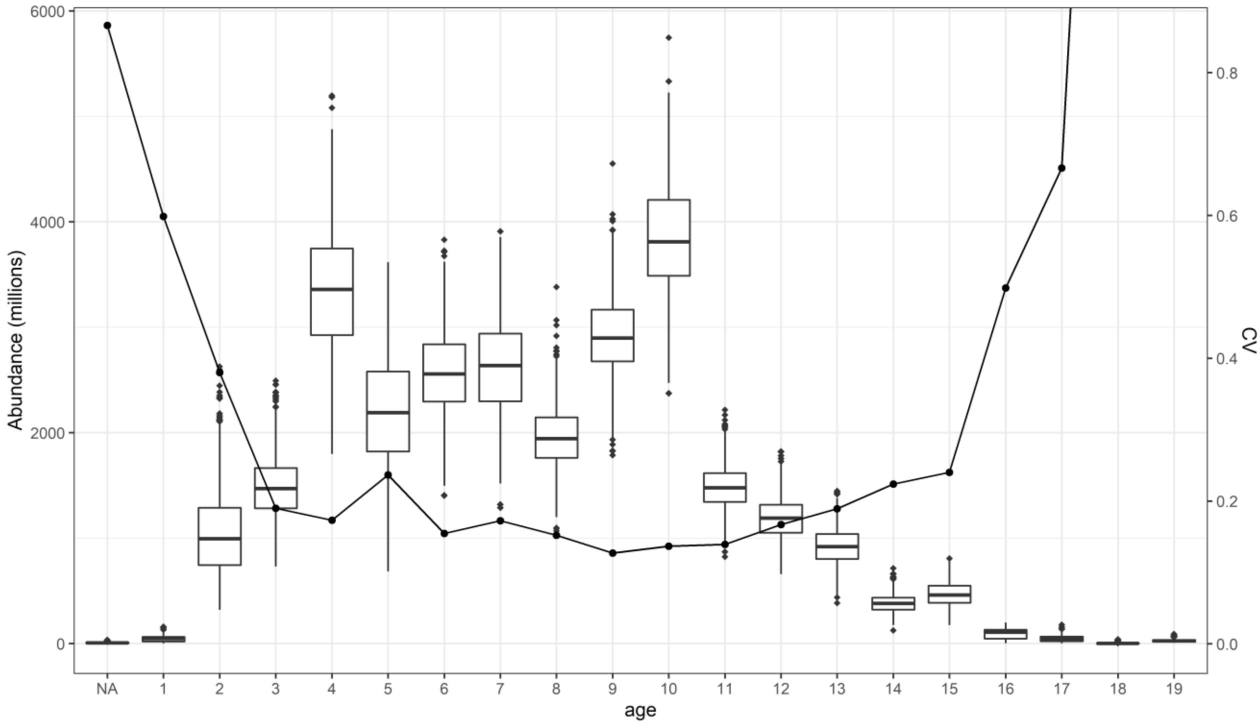

Figure 17. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-d) StoX baseline 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 2020. 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
2020	0.04	1.10	1.43	3.36	2.13	2.53	2.53	2.03	2.90	3.84	1.50	1.18	0.92	0.98	26.47

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
2020	99	213	315	369	394	468	483	507	520	529	539	567	575	593

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
2020	<0.01	0.23	0.45	1.24	0.84	1.18	1.22	1.03	1.51	2.03	0.81	0.67	0.53	0.58	12.33

Table 7d) IESSNS 2020. StoX baseline estimates of mackerel abundance, mean weight and mean length.

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

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	393	393	19.6	50.00
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	393	393	21.2	54.00
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	909	909	57.1	62.84
20-21	4052	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4052	282.8	69.81
21-22	8023	7247	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15270	1165.8	76.35
22-23	10030	22198	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32228	2962.1	91.91
23-24	7565	111117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	118681	11701.7	98.60
24-25	7310	183431	-	1008	336	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	192085	22156.8	115.35
25-26	2690	123171	11765	-	1669	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	139295	17949.6	128.86
26-27	1862	65554	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67416	9474.6	140.54
27-28	881	3699	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4580	757.6	165.41
28-29	-	17564	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17564	3501.4	199.35
29-30	-	25790	53653	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79444	17383.5	218.82
30-31	-	103227	72012	115359	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290598	74688.6	257.02
31-32	-	83435	292521	246781	1141	2324	-	-	-	-	-	-	-	-	-	-	-	-	-	-	626201	177386.6	283.27
32-33	-	215024	542203	572880	107105	-	9922	-	-	-	-	-	-	-	-	-	-	-	-	-	1447134	454841.9	314.31
33-34	-	84119	257712	724062	649131	7306	26677	-	4140	-	-	-	15167	-	-	-	-	-	-	-	1768314	609438.2	344.64
34-35	-	47238	96933	751455	505451	121005	78200	23241	-	-	-	-	-	-	-	-	-	-	-	-	1623524	616341.5	379.63
35-36	-	4399	79195	524047	472886	382463	166463	49074	51302	11993	2579	-	-	-	-	-	-	-	-	-	1744401	731706.0	419.46
36-37	-	-	3654	351209	262547	712252	696102	484937	147595	295261	42807	19532	-	3932	-	-	-	-	-	-	3019827	1386576.9	459.16
37-38	-	-	21347	54617	122176	866143	814695	573593	949691	1013723	296145	96365	10683	12836	-	-	-	-	-	-	4832014	2377172.0	491.96
38-39	-	-	-	13638	8232	398085	624742	597232	1086693	1305787	539570	261743	243535	100280	39644	17118	2952	144	-	-	5239394	2766655.1	528.05
39-40	-	-	-	141	3737	39029	53003	191022	562466	850989	375653	426225	252322	98605	85067	55565	31515	-	36000	-	3061339	1725434.6	563.62
40-41	-	-	-	6581	-	43	55389	111204	88355	291356	192351	269252	263156	63588	185140	13199	1128	-	-	-	1540743	920775.2	597.62
41-42	-	-	-	-	-	-	203	2251	13923	52584	38870	103846	77423	53161	96072	9620	5888	-	-	-	453840	292985.8	645.57
42-43	-	-	-	-	-	-	64	228	-	10518	5611	7922	18106	26678	10654	42	1571	-	-	-	81394	55052.9	676.38
43-44	-	-	-	-	-	-	-	-	73	1022	2064	-	29226	-	15338	8177	-	1898	-	-	57798	42299.0	731.84
44-45	-	-	-	-	-	-	-	-	-	2249	-	-	-	-	-	-	-	-	-	-	2249	1652.2	734.80
45-46	-	-	-	-	-	-	-	-	-	-	-	-	6013	-	-	-	-	-	-	-	6013	4875.6	810.79
46-47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48-49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1500	1500	1524.5	1016.00
TSN(1000)	42414	1097212	1430995	3361778	2134411	2528651	2525460	2032783	2904239	3835479	1495649	1184884	915631	359080	431915	103721	43054	2041	36000	3195	26468594	-	-
TSB(1000 kg)	4214.6	233291.1	451303.1	1240926.0	841504.4	1183109.7	1219891.1	1029686.5	1510848.4	2027319.3	806035.6	671778.4	526625.0	208291.0	261661.8	62120.9	24499.0	1458.5	20653.9	1622.5	-	12326840.6	-
Mean length (cm)	22.87	28.37	32.35	33.81	34.54	36.69	37.04	37.51	37.97	38.21	38.53	39.15	39.47	39.51	40.18	39.72	39.60	42.70	39.36	32.52	-	-	-
Mean weight (g)	99.37	212.62	315.38	369.13	394.26	467.88	483.04	506.54	520.22	528.57	538.92	566.96	575.15	580.07	605.82	598.92	569.03	714.50	573.71	507.79	-	-	465.72

Table 8. Bootstrap estimates from StoX (based on 1000 replicates) of mackerel. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in million tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
1	7.8	47.2	93.4	45.7	27.4	0.60
2	533.0	994.5	1835.8	1054.7	400.3	0.38
3	1068.7	1468.2	1994.3	1491.9	282.5	0.19
4	2401.5	3359.1	4298.3	3351.8	578.5	0.17
5	1358.1	2189.3	3031.9	2193.4	517.6	0.24
6	1923.0	2556.7	3194.6	2558.8	394.7	0.15
7	1837.6	2635.6	3363.3	2626.8	451.6	0.17
8	1468.6	1942.4	2434.8	1950.1	295.8	0.15
9	2337.5	2897.5	3543.4	2919.9	369.5	0.13
10	3048.3	3811.0	4752.4	3858.5	526.0	0.14
11	1175.6	1476.2	1824.7	1483.6	206.0	0.14
12	861.8	1189.3	1511.5	1187.9	198.0	0.17
13	645.9	917.4	1214.9	921.8	174.0	0.19
14	240.2	379.6	517.3	380.6	84.9	0.22
15	292.5	459.7	660.7	468.3	112.3	0.24
16	19.9	106.2	157.6	93.2	46.4	0.50
17	4.7	42.8	98.4	45.8	30.5	0.67
18	0.0	0.4	16.7	2.7	5.7	2.10
19	0.0	15.3	44.0	16.3	16.4	1.01
Unknown	0.5	4.9	19.7	6.8	5.9	0.87
TSN	22513.1	26682.4	30875.5	26658.6	2511.3	0.09
TSB	10.45	12.41	14.43	12.42	1.23	0.10

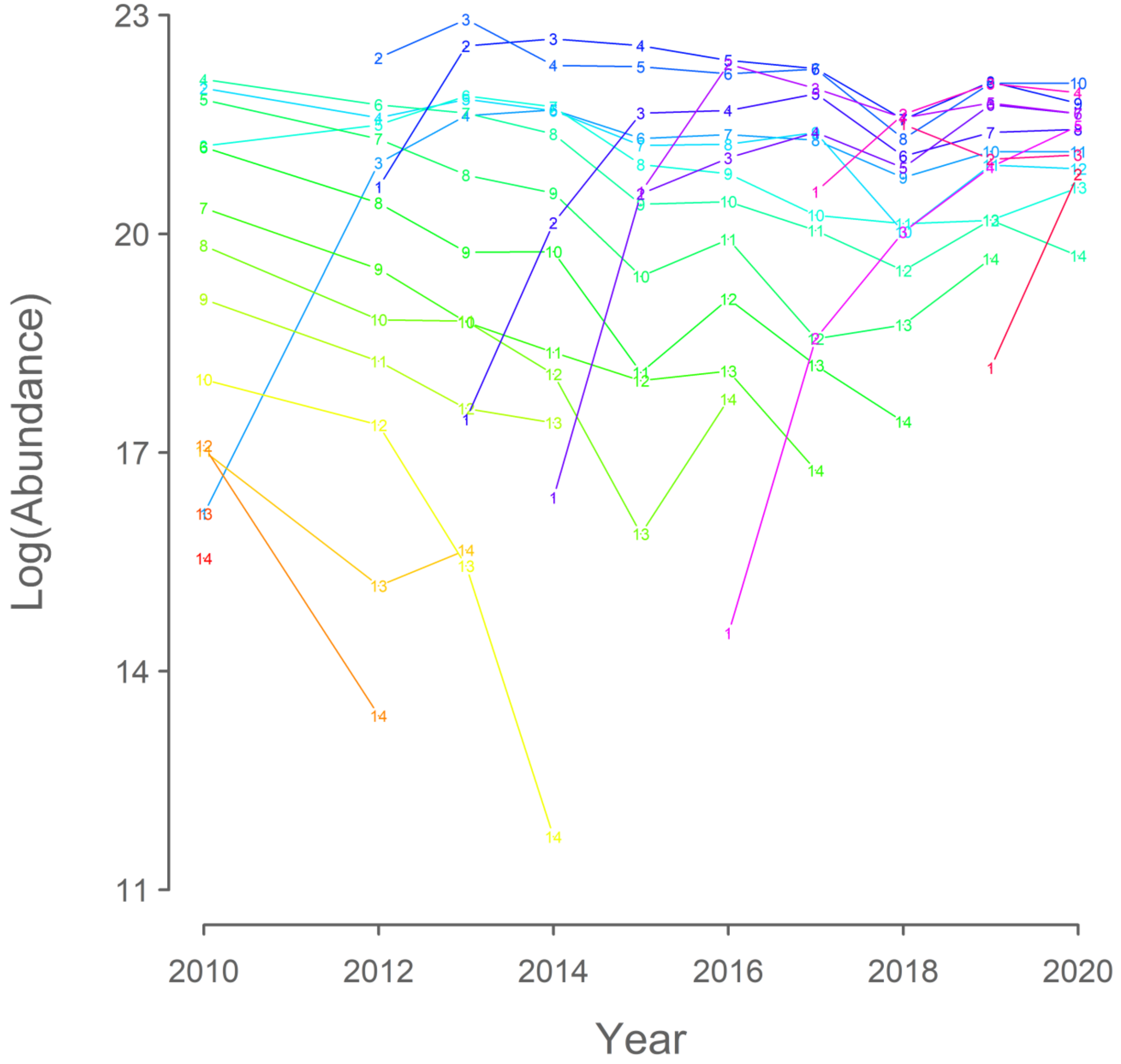

Figure 18. Catch curves. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

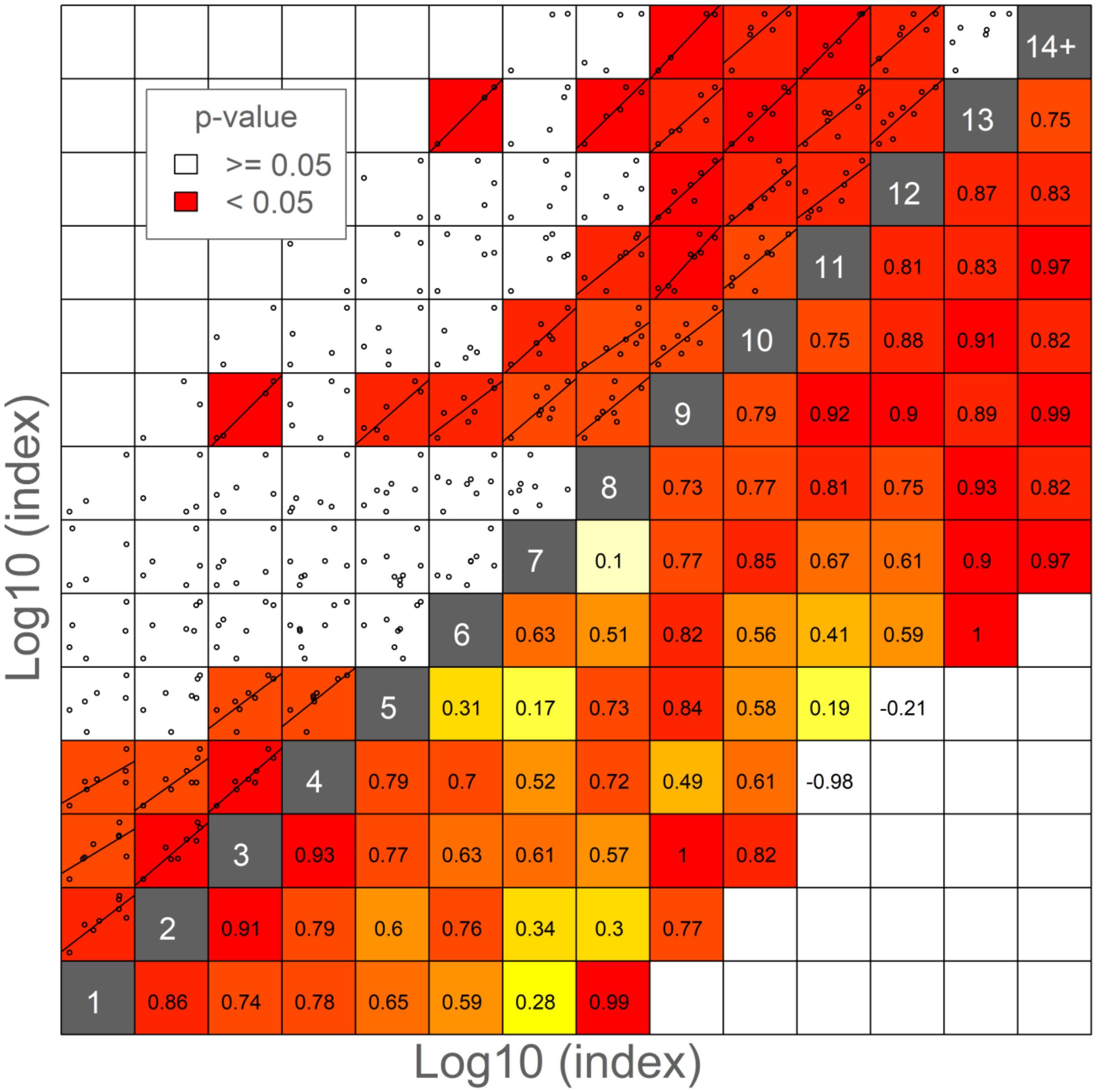

Figure 19. Internal consistency of the of mackerel density index from 2012 to 2020. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

Distribution zero boundaries were found in majority of survey area with a notable exception of high mackerel abundance in the north-western region towards the Fram Strait west of Svalbard.

The mackerel appeared less patchily distributed within the survey area and was distributed more in the central and northern Norwegian Sea in 2020 compared to 2018 and 2019. This difference in distribution primarily consists of a marked biomass decline in the west and an increase in the central and northern part of the Norwegian Sea. Furthermore, there was also a northerly and north-westerly shift in densities of mackerel within the Norwegian Sea.

The marked decrease since 2017 and now even disappearance of mackerel in major western areas in 2020 likely has several causes. In 2019 there were practically no mackerel in Greenland waters during the survey, and in 2020 the mackerel had disappeared altogether from Greenland waters according to our survey results. A similar pattern has also taken place in Icelandic waters, where the abundance of mackerel has declined substantially during the last few years from 2017 to 2020. Why is this happening? First of all, we measured lower mesozooplankton biomasses in both Icelandic and Greenland waters in 2020 compared to previous years, which may have reduced mackerel feeding opportunities in the western area. The temperature was 1-2°C lower in parts of Icelandic and Greenland waters in summer 2020 compared to 2019. This accounts for both the sea surface temperatures (SSTs) and in situ temperature measurements from 10 m depth. However, there should be warm enough for the mackerel to migrate to and feed in these areas. The increase of mackerel in the Norwegian Sea, particularly in the central and northern part of the Norwegian Sea, cannot be explained by improved feeding conditions, as the zooplankton biomasses in summer (at the time of IESSNS) have varied little among the recent years. Neither can it be explained by reduced abundance, as the present survey estimate is the highest on record.

The swept area method assumes that potential distribution of mackerel outside the survey area – both vertically and horizontally – is a constant percentage of the total biomass. In some years, this assumption may be violated, e.g. when mackerel may be distributed below the lower limit of the trawl or if the proportion of mackerel outside the survey coverage varies among years. In order to improve the precision of the swept-area estimate it would be beneficial to extend the survey coverage further south covering the southwestern waters south of 60°N.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred in the southern and south-western parts of the Norwegian Sea, and with the strong 2016 year class of NSSH, there was also overlap in the central and north eastern part of the Norwegian Sea. In the eastern Norwegian Sea between 62-67°N, mackerel were present but herring were in low abundance, in contrast, in areas north of Iceland, herring were present while mackerel were absent.

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 57.2.5-70.5.4m; 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, 2019 and 2020 for the northern part of the North Sea.

This year's survey was well synchronized in time and was conducted over a relatively short period (less than 5 weeks) given the large spatial coverage of around 2.9 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 northern part of the Norwegian Sea basin (Figure 20). The fish in the northeast consisted of young adults (mainly 4 year olds) while the fish further southwest are a range of age groups, although also in this southwestern area significant amounts of the 4- year old as well as 7- year old herring were present. 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) were allocated to Icelandic summer-spawners. The abundance and biomass of NSSH was distributed with slightly more than half of the biomass in the north-eastern part (mainly young herring) and slightly less than half in the south-western area. The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. However, the most abundant year class in the survey estimate, the 2016- year class (4- year olds) may not be fully covered in this survey. Some of this young year class may still not be fully recruited to the survey area.

The NSSH stock is dominated by 4 and 7-year old herring (year classes 2016 and 2013) in terms of numbers and biomass (Table 9). The 2013 year class is distributed in all areas with herring in the survey whereas the 2016 year class was mainly found in the north-eastern part. The 2013 year-class contributed 22% and 20% to the total biomass and total abundance, respectively, whereas the 2016 year-class contributed 33% and 40% to the total biomass and total abundance, respectively. The total number of herring recorded in the Norwegian Sea was 20.3 billion and the total biomass index was 5.93 million tonnes in 2020, in comparison to 15.2 billion and a total biomass index of 4.78 million tonnes in 2019. The increase was due to the recruiting 2016 year-class coming strongly into the survey area. Number by age, with uncertainty estimates, for NSSH is shown in Figure 21. The group considered the acoustic biomass estimate of herring to be of good quality in the 2020 IESSNS as in the previous survey years.

Bootstrap estimates of numbers by age of herring are shown in table 10 and the baseline point estimates from 2016-2020 are shown in table 11. The internal consistency among year classes is shown in Figure 22.

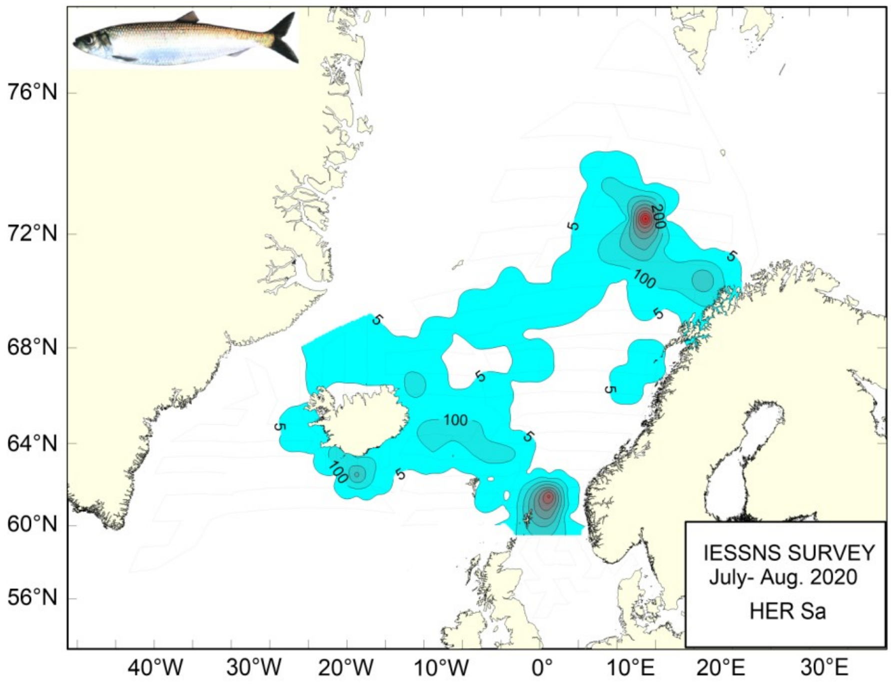

Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2020. Presented as contour lines. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

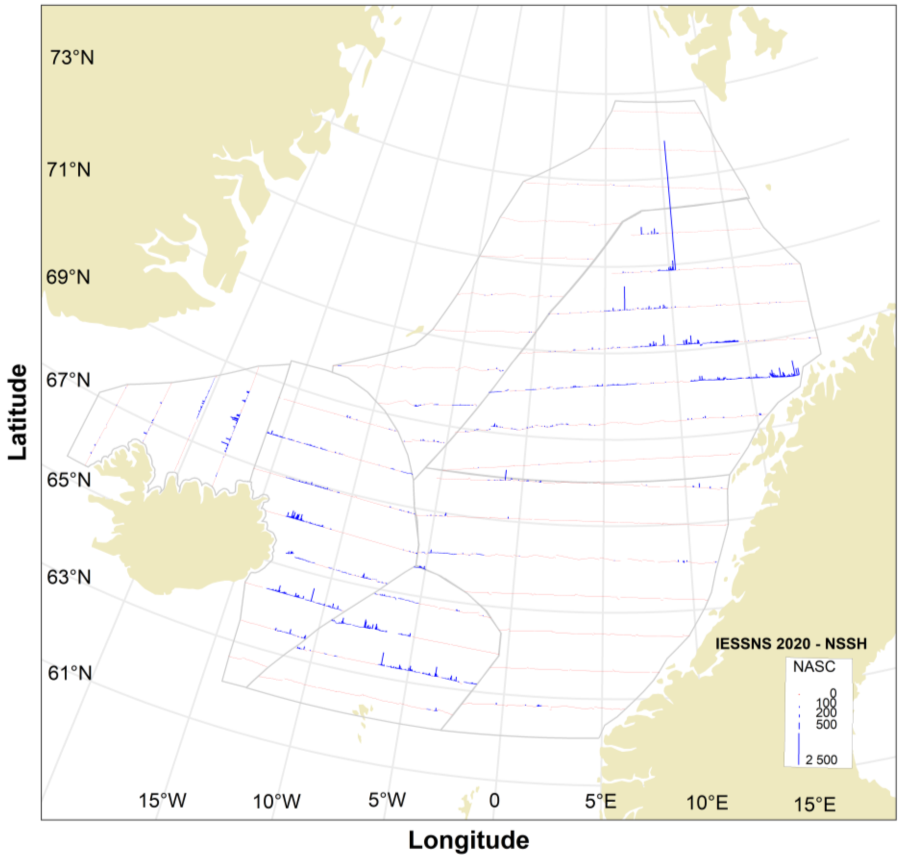

Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2020. Presented as bar plot. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

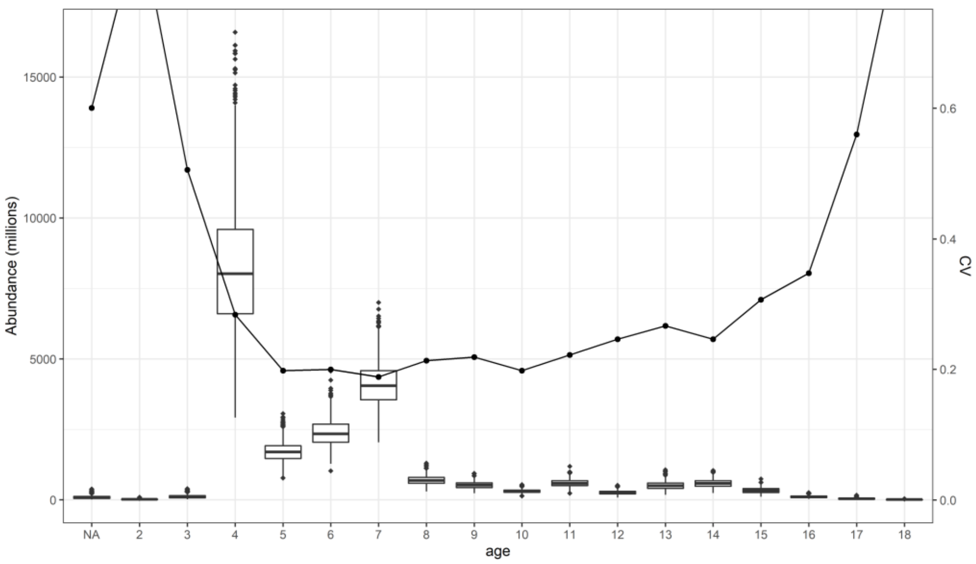

Figure 21. Number by age for Norwegian spring-spawning herring during IESSNS 2020. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 9. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2020.

LenGrp	age 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)
23-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8096	8096	1214.4	150.00
24-25	-	8096	1245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9341	1213.7	129.93
25-26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78567	78567	12099.8	154.01
26-27	3375	27307	351715	-	11208	-	-	-	-	-	-	-	-	-	-	-	-	-	393604	68895.1	175.04
27-28	-	24446	836562	99166	3492	-	-	-	-	-	-	-	-	-	-	-	-	-	963667	181071.1	187.90
28-29	3379	16894	1117284	63398	-	25315	3361	6758	7283	-	-	-	-	-	-	-	-	-	1243672	258390.6	207.76
29-30	-	27259	1659886	40066	7109	13661	5715	-	11105	-	-	-	-	-	-	-	-	-	1764802	412482.5	233.73
30-31	-	7425	2265337	210515	57260	24416	30560	3439	3595	17197	-	-	3595	-	-	-	-	-	2623338	672023.4	256.17
31-32	-	-	1490880	466629	293454	133664	19253	2627	6213	2102	2627	-	-	-	525	-	-	-	2417976	667635.7	276.11
32-33	-	-	256258	656657	1062980	820021	49599	25652	2447	9536	15645	979	1958	3789	3789	-	-	-	2909309	867854.8	298.30
33-34	-	-	51102	141466	649300	1796292	167355	22699	9237	18390	5873	-	-	-	-	-	-	-	2861712	910369.8	318.12
34-35	-	-	39963	5198	182740	1064853	186269	87278	9070	56884	10899	598	465	3859	-	-	-	-	1648074	553397.8	335.78
35-36	-	-	-	12888	59750	213889	219024	134632	37843	92581	8328	52787	20612	32823	-	11277	-	-	896432	321715.6	358.88
36-37	-	-	-	1485	7364	9469	29872	134729	126028	200909	66365	190091	201609	68316	2763	-	-	-	1039001	394231.3	379.43
37-38	-	-	11302	-	-	-	1295	65134	63493	156242	106558	182404	228486	58252	54793	2182	-	-	930141	370334.6	398.15
38-39	-	-	-	-	-	-	2049	7654	17207	35751	30464	66722	107175	100662	37800	29396	5000	-	439879	185616.9	421.97
39-40	-	-	-	-	-	-	-	-	-	-	1368	12316	28053	48916	12316	-	-	-	102969	46454.8	451.15
40-41	-	-	-	-	-	-	-	-	-	-	-	-	5170	-	4579	654	-	-	10402	5147.3	494.83
TSN(1000)	6754	111426	8081535	1697468	2334655	4101580	714352	490601	293521	589590	248127	505896	597123	316616	116565	43509	5000	86663	20340981	-	-
TSB(1000 kg)	1263.0	21354.6	1942260.4	465900.3	711503.7	1307705.0	236374.2	174051.4	108720.0	222214.0	93474.7	199884.1	234966.8	129554.8	47528.2	17760.3	2319.5	13314.2	-	5930149.1	-
Mean length (cm)	27.25	27.60	29.56	31.29	32.52	33.24	33.87	35.09	35.50	35.84	36.24	36.64	36.87	37.19	37.53	37.33	38.00	25.08	-	-	-
Mean weight (g)	187.01	191.65	240.33	274.47	304.76	318.83	330.89	354.77	370.40	376.90	376.72	395.11	393.50	409.19	407.74	408.20	463.95	153.63	-	-	291.54

Table 10. Bootstrap estimates of Norwegian spring-spawning herring in IESSNS 2020 from StoX based on 1000 replicates. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tonnes.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	0.0	11.9	42.7	15.5	13.7	0.89
3	40.7	106.5	232.6	117.2	59.3	0.51
4	4841.3	8022.4	12501.3	8280.3	2350.6	0.28
5	1182.0	1698.4	2276.3	1709.8	338.7	0.20
6	1633.7	2336.4	3144.4	2367.2	472.7	0.20
7	2938.4	4043.9	5406.8	4087.3	770.0	0.19
8	475.2	687.4	950.7	695.9	148.4	0.21
9	348.8	516.0	711.3	520.1	113.9	0.22
10	213.1	301.1	402.8	304.9	60.4	0.20
11	400.2	581.6	823.4	593.7	131.8	0.22
12	157.6	256.3	364.3	259.1	63.8	0.25
13	293.1	494.7	734.7	502.6	134.1	0.27
14	354.6	578.0	831.3	580.5	142.9	0.25
15	174.4	320.2	496.4	327.3	100.4	0.31
TSN	14655.8	20497.9	27132.4	20611.4	3829.6	0.19
TSB	4353.7	5981.3	7740.8	5990.8	1028.2	0.17

Table 11. IESSNS baseline time series from 2016 to 2020. StoX abundance estimates of Norwegian spring-spawning herring (millions).

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12+	TSB(1000 t)
2016	41	146	752	604	1 637	1 559	2 010	1 614	1 190	2 023	2 151	6 467	6 753
2017	1 216	248	1 285	4 586	1 056	1 188	816	1 794	1 022	1 131	1 653	4 119	5 885
2018	0	577	722	879	3 078	931	1 264	734	948	1 070	694	2 792	4 465
2019	0	153	1 870	590	1 067	3 475	859	702	520	700	463	4 808	4 780
2020	0	7	111	8 082	1 697	2 335	4 102	714	491	294	590	1 833	5 930

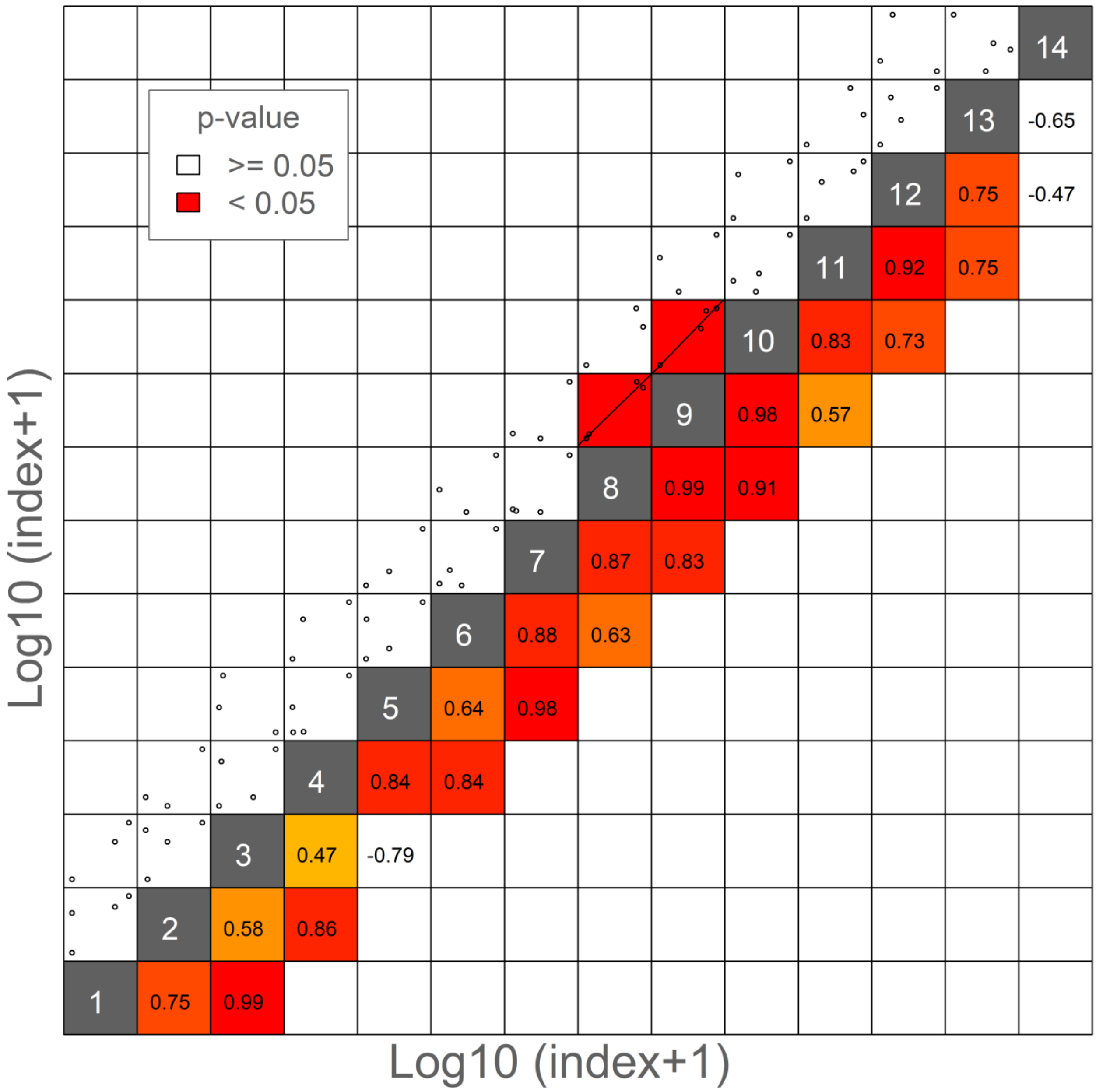

Figure 22. Internal consistency for Norwegian spring-spawning herring within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.

4.5 Blue whiting

Blue whiting was distributed in the central and eastern part of the survey area. The area around Iceland, influenced by the cold East Icelandic Current, southern Iceland and in the East Greenland area had very little blue whiting. The highest sA-values were observed in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope and around the Faroe Islands. The distribution in 2020 is somewhat changed compared to the 2019 distribution since the area to the west had less blue whiting. 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 23). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during IESSNS 2020 was 1.8 million tons (Table 12), a decrease compared to 2019 (2.0 mill tons). The stock estimate in number for 2019 is 16.5 billion compared to 16.2 billion of age groups 1+ in 2019. Age group 1 is dominating the estimate in 2020 (22% and 35% of the biomass and by numbers, respectively, looking at age groups 1+). 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 2020 is shown in Figure 24.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2020 IESSNS as in the previous survey years.

Bootstrap estimates of numbers by age of blue whiting are shown in table 13 and the baseline point estimates from 2016-2020 are shown in table 14. The internal consistency among year classes is shown in Figure 25.

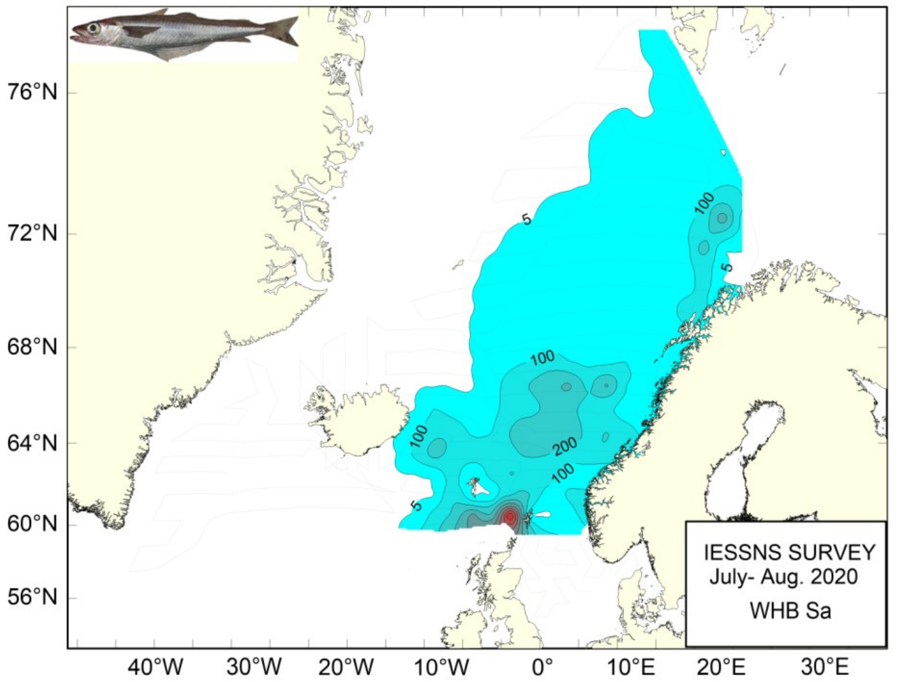

Figure 23a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2020. Presented as contour lines.

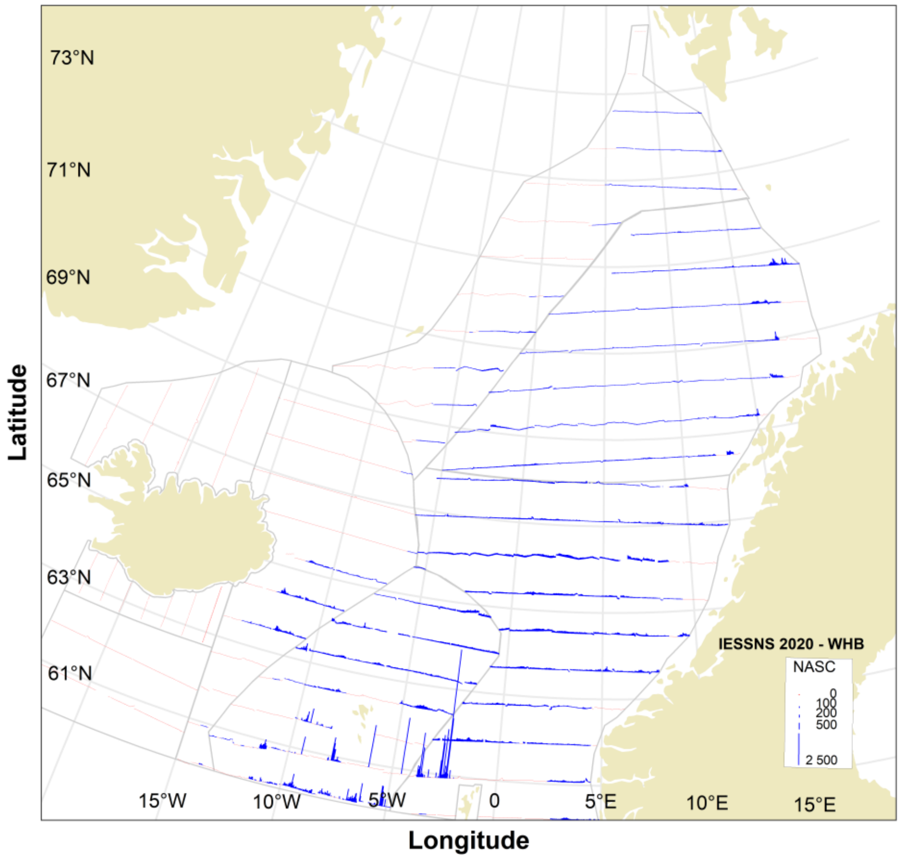

Figure 23b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2020. Presented as bar plot.

Table 12. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2020.

	age															
LenGrp	0	1	2	3	4	5	6	7	8	9	10	11	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
5-6	-	-	-	-	-	-	-	-	-	-	-	-	475244	475244	712.9	1.50
6-7	-	-	-	-	-	-	-	-	-	-	-	-	143824	143824	287.6	2.00
7-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-11	-	-	-	-	-	-	-	-	-	-	-	-	8818	8818	-	-
11-12	563743	-	-	-	-	-	-	-	-	-	-	-	-	563743	5035.3	8.93
12-13	1397043	-	-	-	-	-	-	-	-	-	-	-	-	1397043	14951.9	10.70
13-14	1144766	-	-	-	-	-	-	-	-	-	-	-	-	1144766	15260.0	13.33
14-15	708720	-	-	-	-	-	-	-	-	-	-	-	-	708720	12718.3	17.95
15-16	204667	-	-	-	-	-	-	-	-	-	-	-	-	204667	4388.4	21.44
16-17	47482	-	-	-	-	-	-	-	-	-	-	-	-	47482	1288.3	27.13
17-18	-	3418	-	-	-	-	-	-	-	-	-	-	-	3418	88.9	26.00
18-19	-	64303	-	-	-	-	-	-	-	-	-	-	-	64303	1888.1	29.36
19-20	-	284101	-	-	-	-	-	-	-	-	-	-	-	284101	9739.1	34.28
20-21	-	587975	-	-	-	-	-	-	-	-	-	-	-	587975	24124.0	41.03
21-22	-	545134	47261	-	-	-	-	-	-	-	-	-	-	592395	32192.9	54.34
22-23	-	1398559	107462	37309	-	-	-	-	-	-	-	-	-	1543330	100316.9	65.00
23-24	-	1711675	308186	38983	-	-	-	-	-	-	-	-	-	2058844	153721.1	74.66
24-25	-	940084	647953	10125	10125	-	-	-	-	-	-	-	-	1608287	137805.7	85.68
25-26	-	236626	976587	187545	13539	-	-	-	-	-	-	-	-	1414296	139747.6	98.81
26-27	-	25266	630904	542256	117736	6493	12986	12986	-	-	-	-	-	1348629	144673.9	107.27
27-28	-	-	225161	499183	242781	286923	227906	82001	35726	-	-	-	-	1599680	184243.3	115.18
28-29	-	6671	29683	146062	307749	407455	442685	242832	46698	-	-	-	-	1629835	202332.8	124.14
29-30	-	-	3603	103964	357715	325435	424059	123417	17867	7132	-	-	-	1363192	185760.3	136.27
30-31	-	-	19072	-	35630	319960	432661	241792	51531	-	-	-	-	1100647	172701.0	156.91
31-32	-	-	-	42429	109970	230538	173418	61271	18805	-	7979	-	-	644410	115474.0	179.19
32-33	-	-	-	21413	10255	84793	163006	52500	5510	-	-	-	-	337476	66983.8	198.48
33-34	-	-	-	-	-	53440	76612	45387	-	3143	-	-	-	178582	37721.3	211.23
34-35	-	-	-	-	-	3265	17964	73978	4902	4902	-	3265	-	108277	24233.5	223.81
35-36	-	-	-	-	-	-	15450	2572	11583	6000	2572	-	-	38177	9852.7	258.08
36-37	-	-	-	-	-	-	3428	-	8719	-	-	15899	-	28047	7717.8	275.17
TSN(1000)	4066422	5803812	2995873	1629269	1205499	1718303	1990176	938736	201341	21177	10551	19165	627886	21228210	-	-
TSB(1000 kg)	53642.3	389957.9	286417.5	187223.1	156139.2	250393.4	297906.6	141121.8	30522.9	4034.1	2102.3	5499.9	1000.5	-	1805961.5	-
Mean length (cm)	12.93	22.54	25.10	26.86	28.42	29.36	29.60	29.92	29.86	32.51	32.35	36.07	5.55	-	-	-
Mean weight (g)	13.19	67.19	95.60	114.91	129.52	145.72	149.69	150.33	151.60	190.49	199.25	286.98	1.62	-	-	85.11

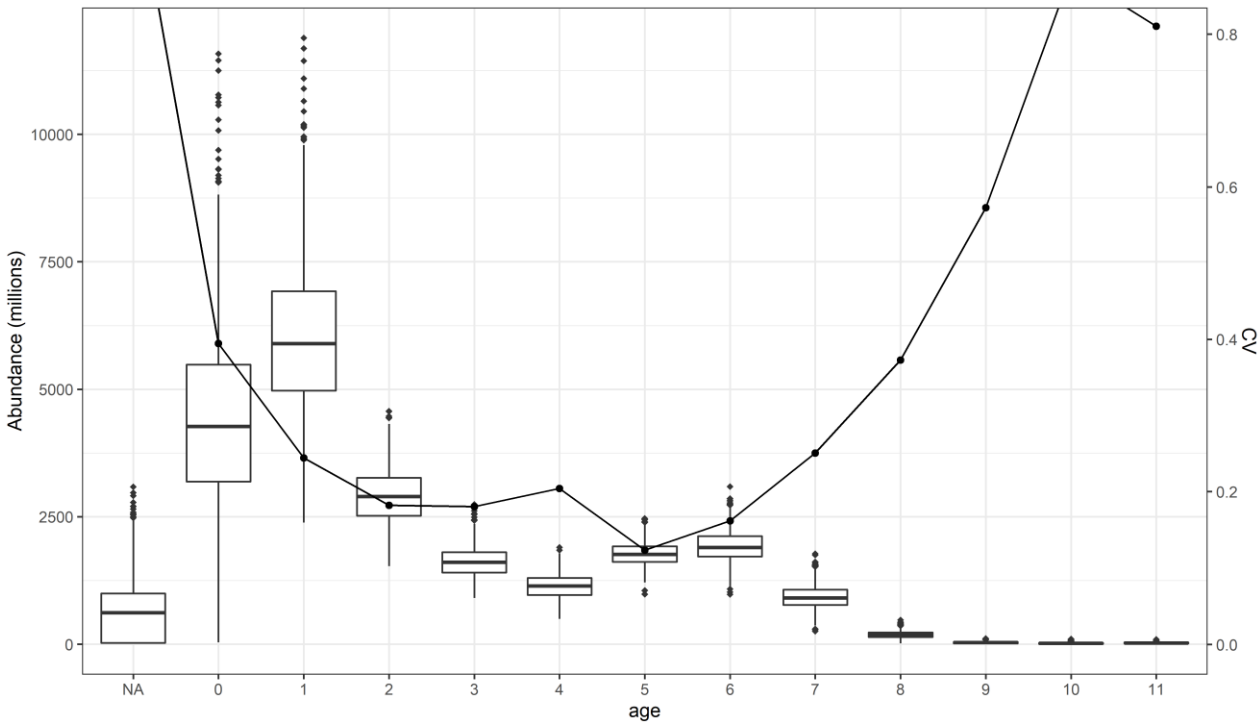

Figure 24. Number by age with uncertainty for blue whiting during IESSNS 2020. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 13. Bootstrap estimates of blue whiting in IESSNS 2020 from StoX based on 1000 replicates. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tonnes.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
0	2022.3	4267.3	7716.5	4460.7	1760.1	0.39
1	3897.4	5891.6	8780.3	6027.3	1473.2	0.24
2	2083.9	2896.4	3787.5	2903.3	529.4	0.18
3	1138.0	1602.8	2081.1	1607.7	290.3	0.18
4	755.5	1140.6	1502.4	1134.9	231.8	0.20
5	1411.6	1761.9	2114.7	1762.2	217.3	0.12
6	1431.1	1894.8	2453.9	1923.9	311.4	0.16
7	563.8	907.5	1350.8	928.6	232.9	0.25
8	73.5	184.5	305.9	186.0	69.3	0.37
9	9.1	30.9	68.8	33.4	19.2	0.57
10	0.0	14.9	42.1	16.3	14.4	0.88
TSN	17416.6	21333.9	26740.9	21611.2	2850.5	0.13
TSB	1524.4	1787.7	2102.1	1798.8	177.9	0.10

Table 14. IESSNS baseline time series from 2016 to 2020. StoX abundance estimates of blue whiting (millions).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
2016	3 869	5 609	11 367	4 373	2 554	1 132	323	178	177	8	233	2 283
2017	23 137	2 558	5 764	10 303	2 301	573	250	18	25	0	25	2 704
2018	0	915	1 165	3 252	6 350	3 151	900	385	100	52	41	2 039
2019	2 153	640	1 933	2 179	4 348	5 434	1 151	209	229	5	8	2 028
2020	4 066	5 804	2 996	1 629	1 205	1 718	1 990	939	201	21	30	1 806

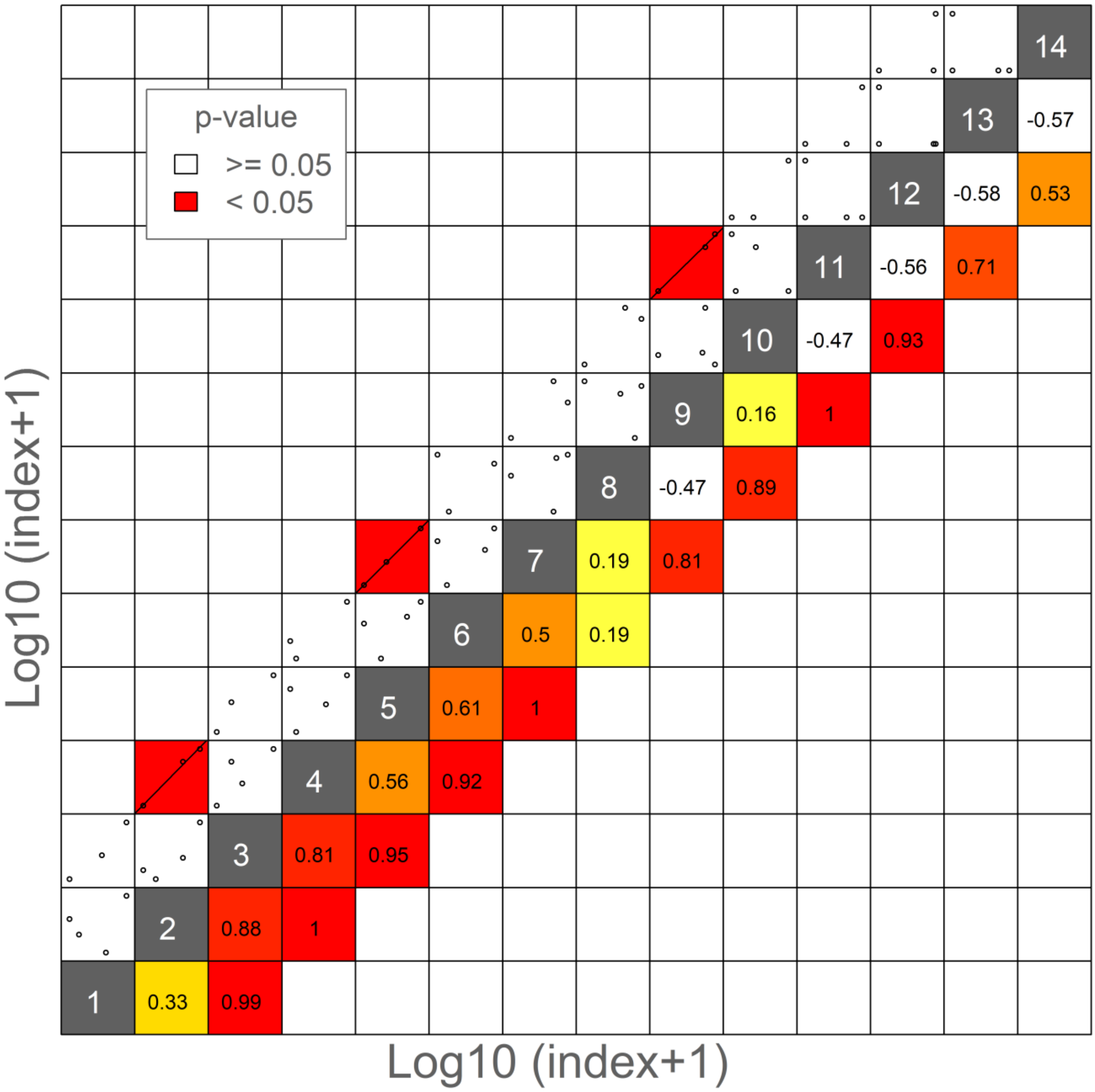

Figure 25. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 74% of trawl stations across the six vessels (Figure 26) and where lumpfish was caught, 72% 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, in previous years aboard the Faroese vessel, a subsample of 50 kg to 200 kg of the total catch was processed. Therefore, small catches (<10 kg) of lumpfish may have been missed, however in 2020, all lumpfish were sorted from the catch and weighed.

Abundance was greatest north of 66°N, and lowest directly south of Iceland, and western side of the North Sea. 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 2 to 50 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 27). 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, of the fish which were sexed, the ratio of females to males was approximately 4.4:1. Generally, the mean length and mean weight of the lumpfish was highest in Faroese waters and the coastal waters and along the shelf edges of Norway and lowest in the central and northern Norwegian Sea.

A total of 715 fish (370 by R/V "Árni Friðriksson", 159 by M/V "Eros", 93 by M/V Vendla and 95 by M/V King's Bay) between 10 and 48 cm were tagged during the survey (Figure 28).

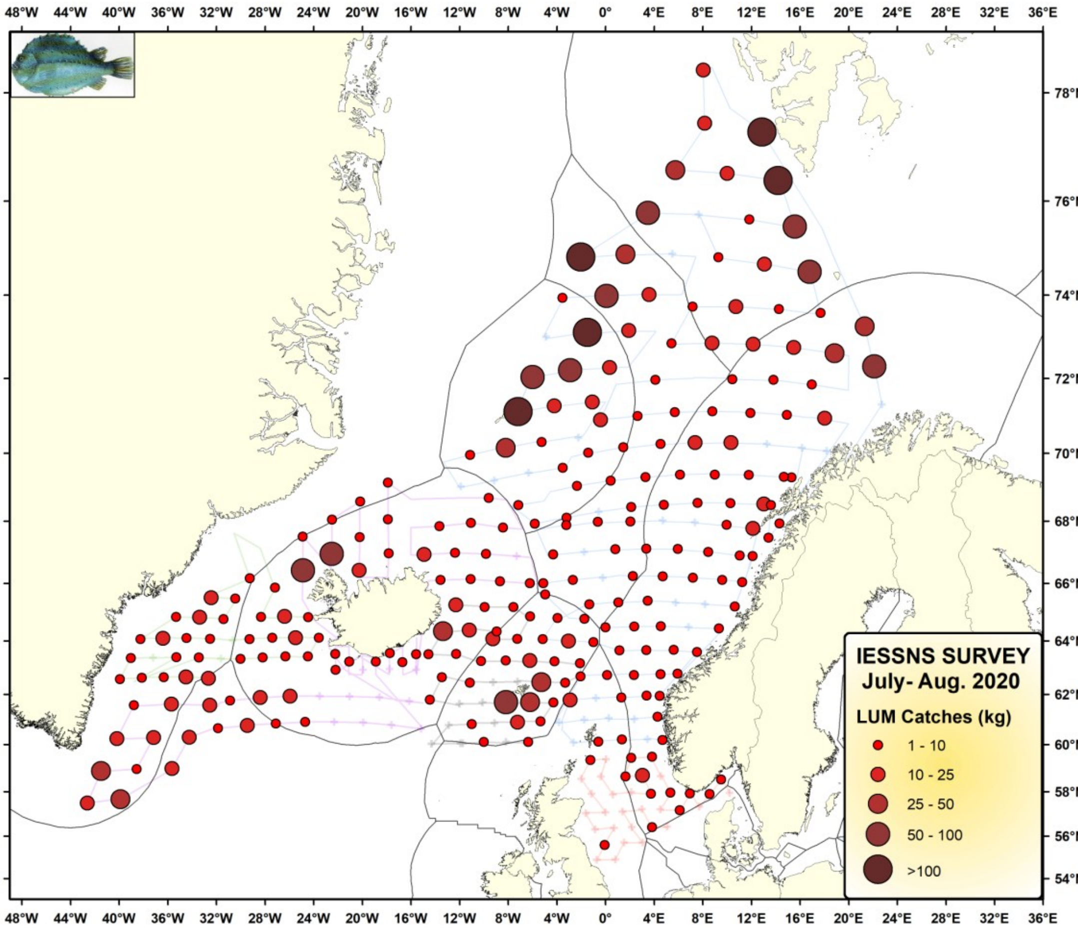

Figure 26. Lumpfish catches at surface trawl stations during IESSNS 2020.

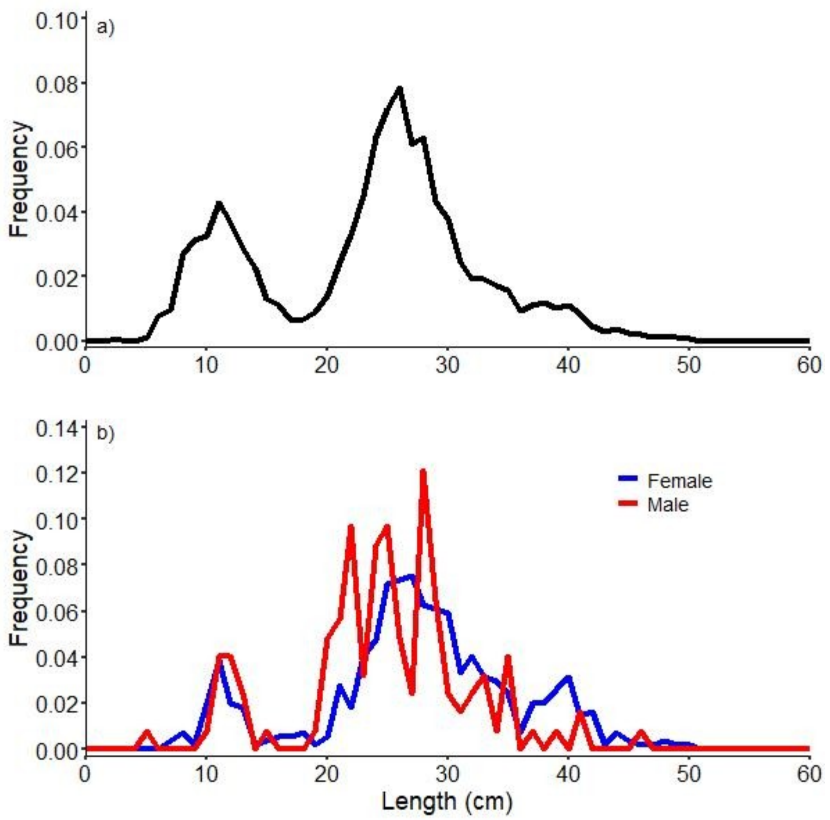

Figure 27. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

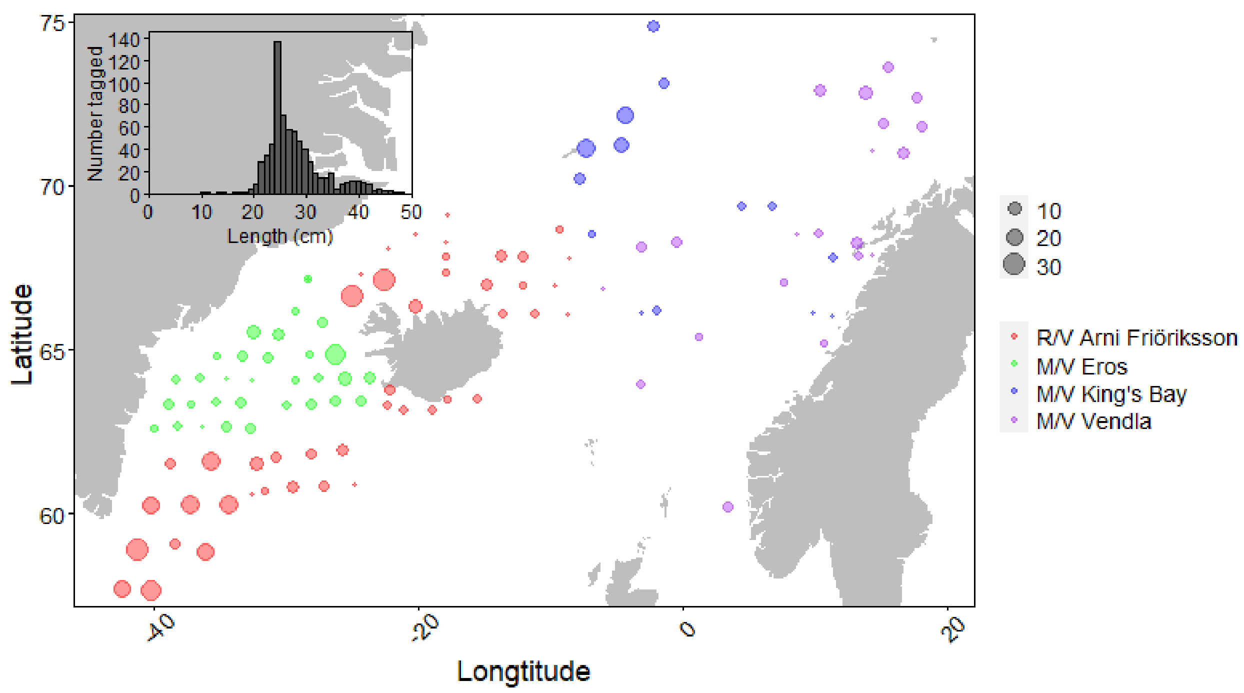

Figure 28. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish. Location of fish tagged aboard King's Bay was not available at time of writing.

Salmon (*Salmo salar*)

A total of 54 North Atlantic salmon were caught in 30 stations both in coastal and offshore areas from 60°N to >77°N in the upper 30 m of the water column during IESSNS 2020 (Figure 29). The salmon ranged from 0.084 kg to 2.73 kg in weight, dominated by postsmolt weighing 100-180 grams and individuals weighing 1-2 kg. We caught from 1 to 8 salmon (small shoals) during individual surface trawl hauls. The length of the salmon ranged from 20.5 cm to 61 cm, with a pronounced bimodal distribution of <30 cm and >45 cm long salmon.

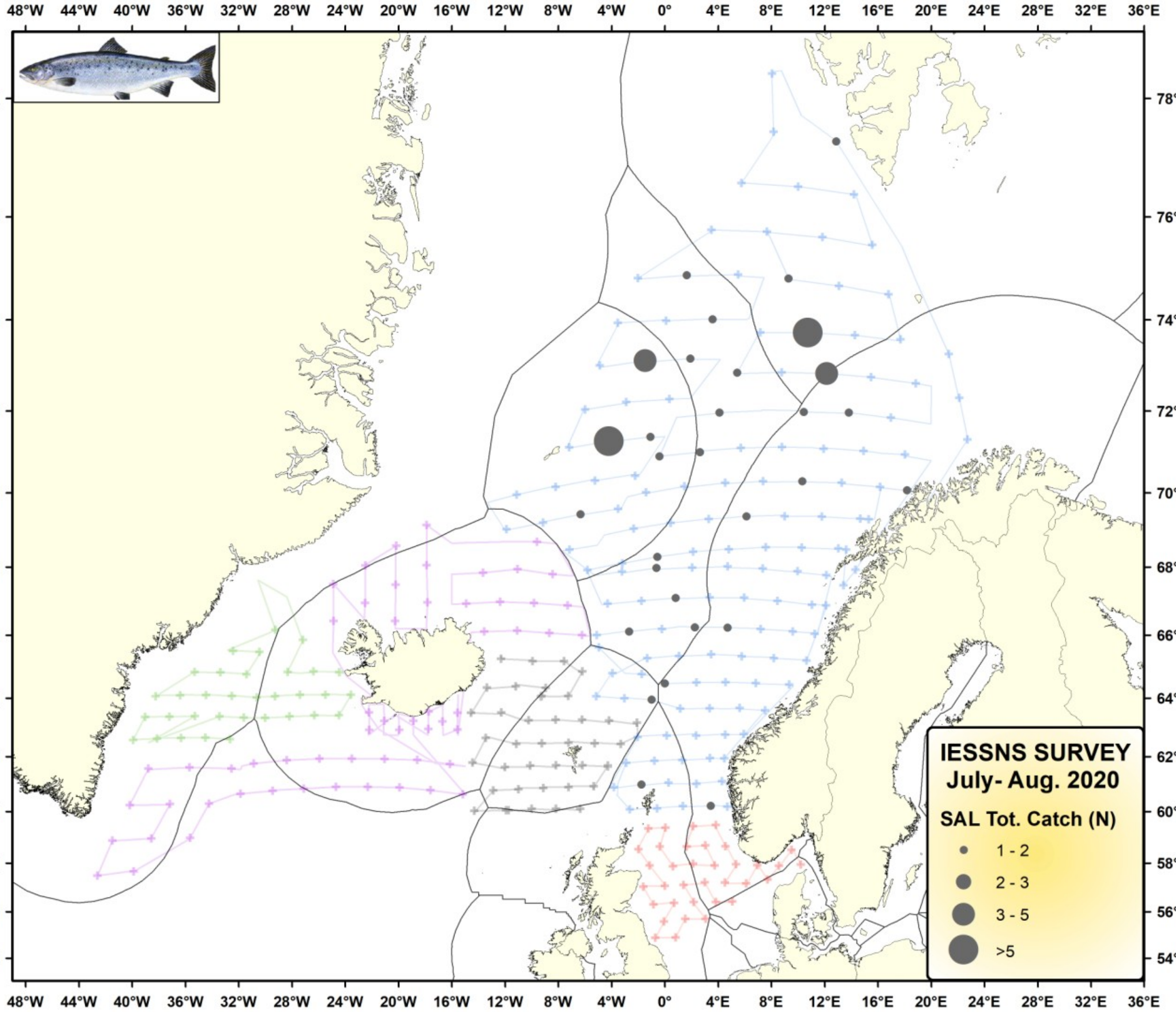

Figure 29. Catches of salmon at surface trawl stations during IESSNS 2020.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 42 stations primarily along the cold fronts: In East Greenland from Cape Farewell to Ittoqqertoormiit, Denmark Strait, North of Iceland, North-East of Jan Mayen and at the entrance to the Barents Sea (Figure 30).

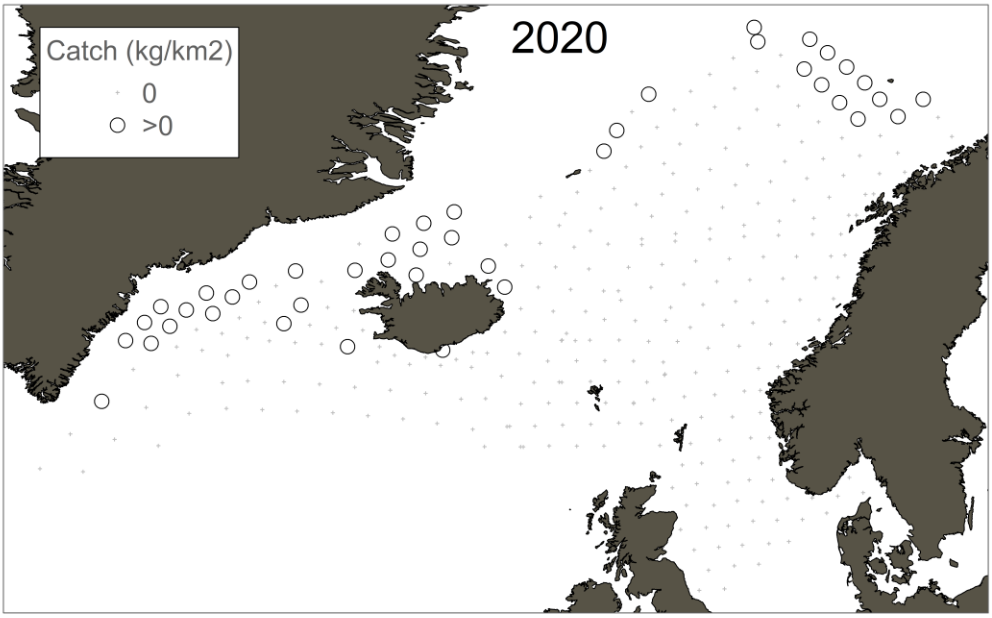

Figure 30. Presence of capelin in surface trawl stations.

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 2020 (Figure 31). Overall, 802 marine mammals of 10 different species were observed, which was an increase from 521 marine mammals in 2019, 600+ in 2018 and 700+ in 2017 observed individuals. R/V "Árni Friðriksson" dedicated whale observers were onboard in 2017 and for the 1st leg in 2020, which was not the case from 2018-2019 and the 2nd leg in 2020. Kings Bay and Vendla conducted only opportunistic whale observations for all years including the years 2017-2020. The increase in number of marine mammals came even though both Kings Bay and Vendla had several days with fog and very reduced visibility in the north-western region (Jan Mayen area) and northernmost areas between Bear Island and Svalbard. This has possibly influenced the low number of marine mammals observed on these two vessels in the normally abundant marine mammal habitats within the northernmost parts of our surveyed areas during IESSNS 2020. R/V "Árni Friðriksson" had also occasional periods with fog north of Iceland.

The species that were observed included; blue whales (*Balaenoptera musculus),* fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), bottlenose whales (*Hyperoodon ampullatus)*, 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 found around Iceland, along the continental shelf between the north-eastern part of the Norwegian Sea and in a line between Finnmark to southwest of Svalbard. Fin whales (n = 117, group size = 1-20 (average groups size = 4.7)) and humpback whales (n = 89, group size = 1-60 (average groups size = 5.1)) dominated among the large whale species, and they were particularly abundant northwest of Iceland and from Norwegian coast outside Finnmark stretching north/northwest via Bear Island to southwest of Svalbard. Fin whales also appeared to be present in the northeastern part of the Norwegian Sea feeding on NSS herring. Killer whales (n = 71, group size = 1-12 (average groups size = 5.1)) dominated in the southern, northern and north-eastern part of the Norwegian Sea, mostly overlapping and feeding on NES mackerel in the upper water masses. Dolphins (n = 134, group size = 3-20 (average groups size = 8.9)) were present in the northern part of the Norwegian Sea. Minke whales (n = 37, group size = 1-4 (average groups size = 1.4)) dominated in the north-eastern part of the Norwegian Sea, primarily overlapping and feeding on NSS herring in the upper 40 m of the water column. Altogether 3 individual observations of blue whale were done north and northwest of Iceland, whereas 2 northern bottlenose whales were observed south of Iceland. There were generally low numbers of marine mammal observations made of marine mammals in the southern and central parts of the Norwegian Sea in 2020 compared to previous years.

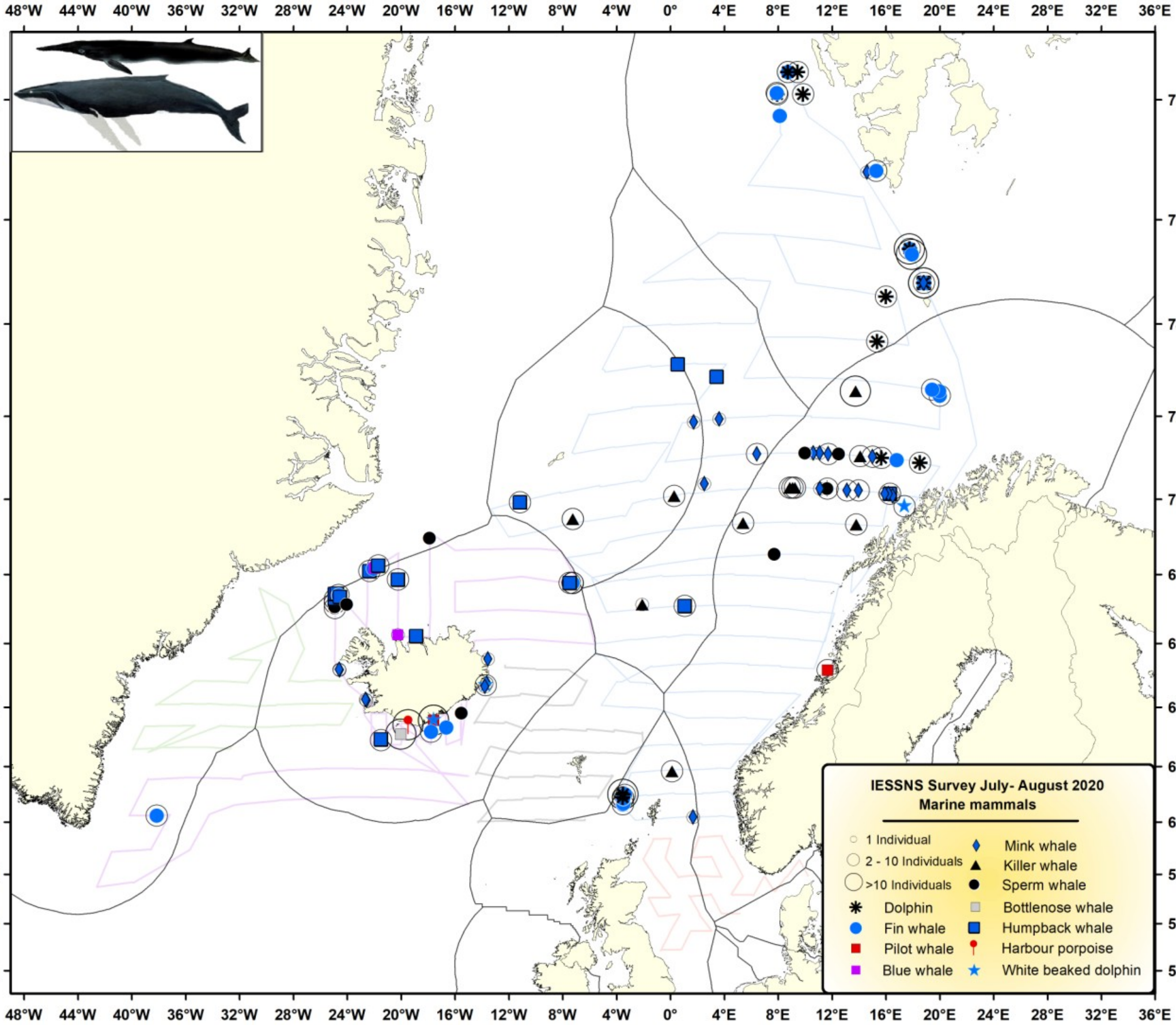

Figure 31. Overview of all marine mammals sighted during IESSNS 2020.

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, 2019 and 2020 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 that 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. For 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 weighed. 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 on all vessels.
Table 3 – biological sampling - needs to be changed to reflect what is sampled on the different vessels.
We should consider calculating the zooplankton index from annually gridded field polygons to extract area-mean time-series.
For next year's survey, the group should consider having the strata Greenland South and Iceland south offshore (Strata numbers 11 and 12) as dynamic Strata given the absence of mackerel in these strata the last two years.
For next year's survey, the group should consider distributing transects differently among vessels, such that synoptic coverage becomes better than this year and survey time is optimally used.

7 Survey participants

M/V "Vendla":
Arne Johannes Holmin (cruise leader), Institute of Marine Research, Bergen, Norway
Åge Høines (cruise leader), Institute of Marine Research, Bergen, Norway
Lage Drivenes, Institute of Marine Research, Bergen, Norway
Benjamin Marum, Institute of Marine Research, Bergen, Norway
Valantine Anthonypillai, Institute of Marine Research, Bergen, Norway
Thassya Christina dos Santos Schmidt, Institute of Marine Research, Bergen, Norway
Vilde Regine Bjørdal, Institute of Marine Research, Bergen, Norway
Lea Marie Hellenbrecht, , Institute of Marine Research, Bergen, Norway
Frøydis Tousgaard Rist Bogetveit, Institute of Marine Research, Bergen, Norway
Susanne Tonheim, Institute of Marine Research, Bergen, Norway

M/V "Kings Bay":
Leif Nøttestad (International coordinator and cruise leader), Institute of Marine Research, Bergen, Norway
Are Salthaug (cruise leader), Institute of Marine Research, Bergen, Norway
Jarle Kristiansen, Institute of Marine Research, Bergen, Norway
Olav j. Sørås, Institute of Marine Research, Bergen, Norway
Guosong Zhang, Institute of Marine Research, Bergen, Norway
Eilert Hermansen, Institute of Marine Research, Bergen, Norway
Ørjan Sørensen, Institute of Marine Research, Bergen, Norway
Erling Boge, Institute of Marine Research, Bergen, Norway
Astrid Fuglseth Rasmussen, Institute of Marine Research, Bergen, Norway
Herdis Langøy Mørk, Institute of Marine Research, Bergen, Norway
Inger Henriksen, Institute of Marine Research, Bergen, Norway
Adam Custer, Institute of Marine Research, Bergen, Norway
Christine Djønne, Institute of Marine Research, Bergen, Norway

R/V "Árni Friðriksson":
Anna Heiða Ólafsdóttir (cruise leader and coordinator), Marine and Freshwater Research Institute, Reykjavík, Iceland
Arnþór B. Kristjánsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Ása Hilmarsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Ástþór Gíslason, Marine and Freshwater Research Institute, Reykjavík, Iceland
Birkir Bárðarson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Enrique G. A. Garcia, DTU Aqua, Denmark
Freyr Arnaldsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Georg Haney, Marine and Freshwater Research Institute, Reykjavík, Iceland
Guðrún Finnbogadóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Halldór Tyrfingsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Jacek Sliwinski, Marine and Freshwater Research Institute, Reykjavík, Iceland
James Kennedy (cruise leader), Marine and Freshwater Research Institute, Reykjavík, Iceland
Klara Jakobsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Martina Blumel, Geomar, Germany
Ragnhildur Ólafsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Sigurlína Gunnarsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Sólrún Sigurgeirsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland

Svanhildur Egilsdóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Sverrir Daníel Halldórsson, Marine and Freshwater Research Institute, Reykjavík, Iceland
Teresa S. G. Silva, Marine and Freshwater Research Institute, Reykjavík, Iceland

M/V "Tróndur í Gøtu":
Eydna í Homrum, Faroe Marine Research Institute, Torshavn, Faroe
Ebba Mortensen, Faroe Marine Research Institute, Torshavn, Faroe
Poul Vestergaard, Faroe Marine Research Institute, Torshavn, Faroe
Ragnar Karlsson, Faroe Marine Research Institute, Torshavn, Faroe

M/V "Eros":
On-board cruise leader: Søren L. Post, Greenland Institute of Natural Resources, Nuuk, Greenland
Jørgen Sethsen, Greenland Institute of Natural Resources, Nuuk, Greenland
Alexander Damkjær, Greenland Institute of Natural Resources, Nuuk, Greenland
Frederik Fuda Bjare, Greenland Institute of Natural Resources, Nuuk, Greenland
Svandís Eva Aradóttir, Marine and Freshwater Research Institute, Reykjavík, Iceland
Land based coordinator: Teunis Jansen, Greenland Institute of Natural Resources, Nuuk, Greenland

M/V "Ceton"
At sea:
Kai Wieland (cruise leader), National Institute of Aquatic Resources, Denmark
Per Christensen, National Institute of Aquatic Resources, Denmark
Dirk Tijssen, National Institute of Aquatic Resources, Denmark
Lab team:
Jesper Knudsen, National Institute of Aquatic Resources, Denmark
Søren Eskildsen, National Institute of Aquatic Resources, Denmark
Gert Holst, National Institute of Aquatic Resources, Denmark
Maria Jarnum, National Institute of Aquatic Resources, Denmark

8 Acknowledgements

We greatly appreciate and thank skippers and crew members onboard M/V "Kings Bay", M/V "Vendla", M/V "Eros", M/V "Tróndur í Gøtu", 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 1st of July to 4th of August 2020.

9 References

Bachiller E, Utne KR, Jansen T, Huse G. 2018. Bioenergetics modeling of the annual consumption of zooplankton by pelagic fish feeding in the Northeast Atlantic. PLOS ONE 13(1): e0190345. https://doi.org/10.1371/journal.pone.0190345

Banzon, V., Smith, T. M., Chin, T. M., Liu, C., and Hankins, W., 2016. A long-term record of blended satellite and in situ sea-surface temperature for climate monitoring, modelling and environmental studies. Earth System Science Data. 8, 165–176, doi:10.5194/essd-8-165-2016.

Foote, K. G., 1987. Fish target strengths for use in echo integrator surveys. Journal of the Acoustical Society of America. 82: 981-987.

ICES. 2012. Report of the International Bottom Trawl Survey Working Group (IBTSWG), 27–30 March 2012, Lorient, France. ICES CM 2012/SSGESST:03. 323 pp.

ICES 2013a. Report of the Workshop on Northeast Atlantic Mackerel monitoring and methodologies including science and industry involvement (WKNAMMM), 25–28 February 2013, ICES Headquarters, Copenhagen and Hirtshals, Denmark. ICES CM 2013/SSGESST:18. 33 pp.

ICES. 2013b. Report of the Working Group on Improving Use of Survey Data for Assessment and Advice (WGISDAA), 19-21 March 2013, Marine Institute, Dublin, Ireland. ICES CM 2013/SSGESST:07.22 pp.

ICES 2014a. Manual for international pelagic surveys (IPS). Working document of Working Group of International Surveys (WGIPS), Version 1.02 [available at ICES WGIPS sharepoint] 98 pp.

ICES 2014b. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA), 17–21 February 2014, Copenhagen, Denmark. ICES CM 2014/ACOM: 43. 341 pp

ICES. 2017. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January-3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

Jansen, T., Post, S., Kristiansen, T., Oskarsson, G.J., Boje, J., MacKenzie, B.R., Broberg, M., Siegstad, H., 2016. Ocean warming expands habitat of a rich natural resource and benefits a national economy. Ecol. Appl. 26: 2021–2032. doi:10.1002/eap.1384

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A.J., Dingsør, G.E., Fuglebakk, E., Handegard, N.O. 2019. StoX: An open source software for marine survey analyses. Methods Ecol Evol. 2019; 10:1523–1528.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquaculture Science. 47: 1282-1291.

Nikolioudakis, N., Skaug, H. J., Olafsdottir, A. H., Jansen, T., Jacobsen, J. A., and Enberg, K. 2019. Drivers of the summer-distribution of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2011 to 2017; a Bayesian hierarchical modelling approach. ICES Journal of Marine Science. 76(2): 530-548. doi:10.1093/icesjms/fsy085

Nøttestad, L., Utne, K.R., Óskarsson, G. J., Jónsson, S. Þ., Jacobsen, J. A., Tangen, Ø., Anthonypillai, V., Aanes, S., Vølstad, J.H., Bernasconi, M., Debes, H., Smith, L., Sveinbjörnsson, S., Holst, J.C., Jansen, T. and Slotte, A. 2016. Quantifying changes in abundance, biomass and spatial distribution of Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) in the Nordic Seas from 2007 to 2014. ICES Journal of Marine Science. 73(2): 359-373. doi:10.1093/icesjms/fsv218.

Ólafsdóttir, A., Utne, K.R., Jansen, T., Jacobsen, J.A., Nøttestad, L., Óskarsson, G.J., Slotte, A., Melle, W. 2019. Geographical expansion of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2007 - 2014 was primarily driven by stock size and constrained by temperature. Deep-Sea Research Part II. 159, 152-168.

Salthaug, A., Aanes, S., Johnsen, E., Utne, K. R., Nøttestad, L., and Slotte, A. 2017. Estimating Northeast Atlantic mackerel abundance from IESSNS with StoX. Working Document (WD) for WGIPS 2017 and WKWIDE 2017. 103 pp.

Valdemarsen, J.W., J.A. Jacobsen, G.J. Óskarsson, K.R. Utne, H.A. Einarsson, S. Sveinbjörnsson, L. Smith, K. Zachariassen and L. Nøttestad 2014. Swept area estimation of the North East Atlantic mackerel stock using a standardized surface trawling technique. Working Document (WD) to ICES WKPELA. 14 pp.

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. No plankton samples were taken and no acoustic data were recorded because this is covered by the HERAS survey in this area.

Denmark joined the IESSNS again in 2020 using the same vessel. 35 stations 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 2020 was higher than in 2019 (1318 kg/km² compared to 1009 kg/km² in 2019 and 1743 kg/km² in 2018). The length and age composition indicate a relative high amount of small (< 25 cm) individuals (Tab. A.1) whereas the abundance of older (≥ age 6) mackerel was similar to the two previous years (Fig. A.1.).

StoX baseline estimate of mackerel abundance in the North Sea was 257 079 tonnes (Table A1-1.)

Table A1-1. StoX baseline estimate of age segregated and length segregated mackerel index for the North Sea in 2020. Also provided is average length and weight per age class.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290	16.2	56.00
20-21	658	-	-	-	-	-	-	-	-	-	-	-	-	-	-	658	46.0	69.86
21-22	14362	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14362	1095.1	76.25
22-23	89711	-	-	-	-	-	-	-	-	-	-	-	-	-	-	89711	7814.2	87.10
23-24	243191	-	-	-	-	-	-	-	-	-	-	-	-	-	-	243191	24255.8	99.74
24-25	221620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	221620	24426.8	110.22
25-26	70558	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70558	8987.5	127.38
26-27	20143	30	-	-	-	-	-	-	-	-	-	-	-	-	-	20173	3056.0	151.49
27-28	14250	755	-	-	-	-	-	-	-	-	-	-	-	-	-	15005	2587.2	172.43
28-29	16512	10895	30	-	-	-	-	-	-	-	-	-	-	-	-	27438	5589.7	203.72
29-30	41904	45292	-	118	-	-	-	-	-	-	-	-	-	-	-	87314	20048.0	229.61
30-31	12433	105414	10511	149	-	-	-	-	-	-	-	-	-	-	-	128506	32163.8	250.29
31-32	9337	87232	18023	8	56	-	-	-	-	-	-	-	-	-	-	114656	30945.2	269.90
32-33	-	44072	29681	2938	273	-	33	33	-	-	-	-	-	-	-	77031	23036.7	299.06
33-34	-	6172	33006	24828	3610	17	-	33	-	-	-	-	-	-	-	67667	21906.0	323.73
34-35	-	104	18866	8811	27909	2740	10	-	-	-	-	-	-	-	-	58440	19251.6	329.43
35-36	-	-	2525	2680	24833	8721	-	-	-	71	-	-	-	-	-	38830	14652.9	377.36
36-37	-	-	-	8	6446	14148	1943	271	-	-	-	-	-	-	-	22816	9291.2	407.22
37-38	-	-	-	-	420	4214	3603	1294	31	765	61	-	-	-	-	10388	4638.9	446.57
38-39	-	-	-	-	138	215	273	982	403	16	-	-	-	-	-	2026	966.3	476.93
39-40	-	-	-	-	-	-	891	194	800	-	-	-	-	-	-	1885	956.1	507.11
40-41	-	-	-	-	-	-	-	635	8	246	689	125	-	157	-	1860	963.2	517.87
41-42	-	-	-	-	-	-	-	-	-	48	224	-	-	-	-	272	170.5	626.65
42-43	-	-	-	-	-	-	-	-	-	212	-	-	18	-	61	291	207.7	714.65
43-44	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	8	6.3	807.00
44-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46-47	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TSN(1000)	754967	299966	112643	39540	63685	30054	6754	3442	1242	1366	974	125	18	157	61	1314994	-	-
TSB(1000 kg)	91063.5	76959.2	34212.6	13320.1	22366.7	12552.2	2985.1	1575.9	592.4	711.0	542.8	68.5	11.4	81.0	36.4	-	257078.9	-
Mean length (cm)	24.13	30.42	32.35	33.26	34.55	35.68	36.99	37.79	38.63	38.40	40.04	40.00	42.00	40.00	42.00	-	-	-
Mean weight (g)	120.62	256.56	303.73	336.88	351.21	417.66	441.98	457.84	476.86	520.68	557.39	550.00	649.00	516.00	596.00	-	-	195.50

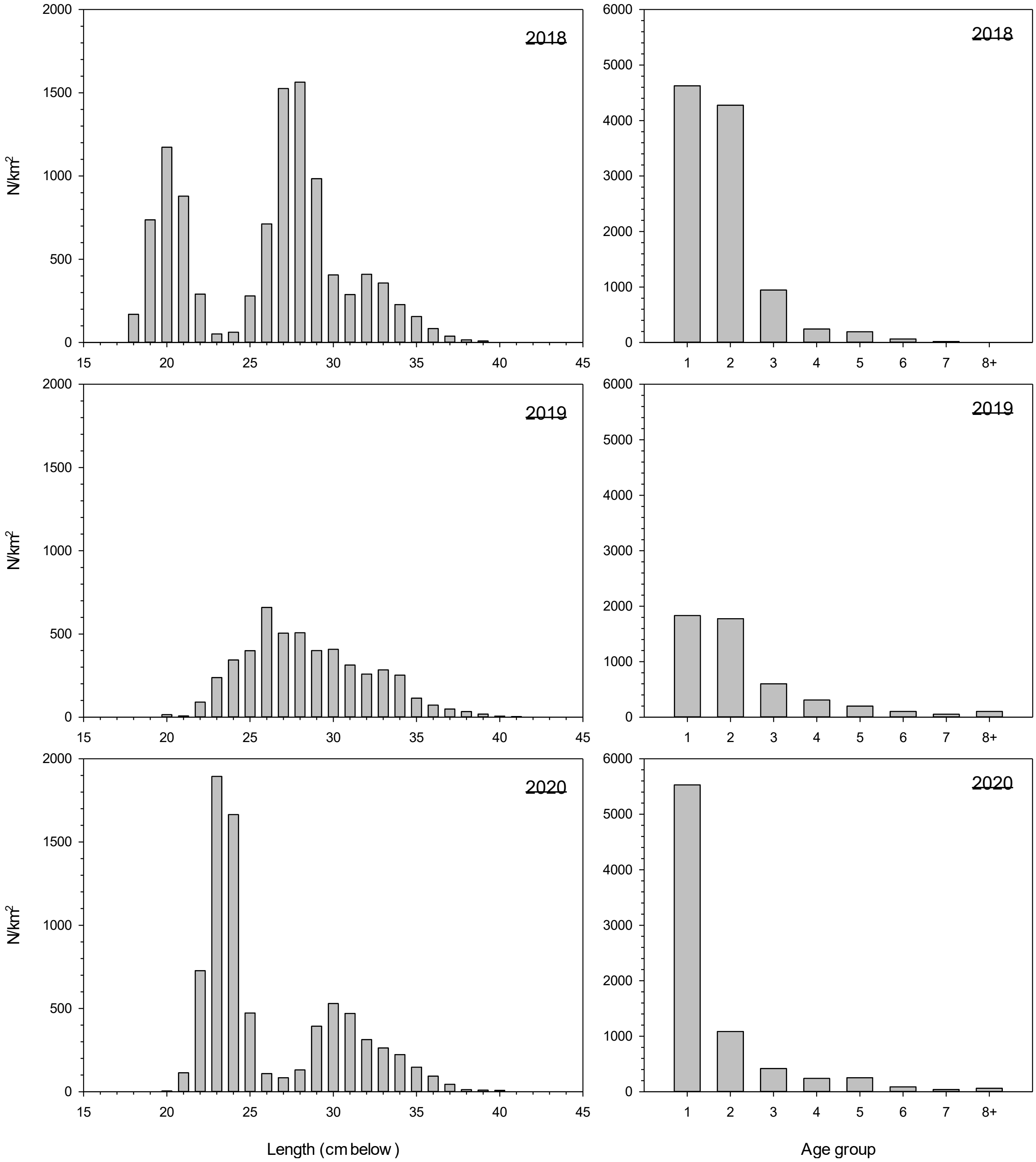

Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018, 2019 and 2020.

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 2020.

Table A2-1: Trawl station exclusion list for IESSNS 2020 for calculating the mackerel abundance index.

Vessel	Country	Exclusion list	
		Cruise	Stations
Kings Bay	Norway	2020814	15,21,28,33,38,46,50,57,61,64,69,81,94
Vendla	Norway	2020813	41,46,54,61,71,77,85,88,89,91,96,99,101,104,125
Árni Friðriksson	Iceland	A7-2020	393,401,414,417,424,427,433
Tróndur í Gøtu	Faroe Islands	2052	7,14,25,42,49,70,73 *
Eros	Greenland	CH-2020-01	122,128
Ceton	EU (Denmark)	IESSNS2020	none

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceded by 2052 (e.g. ‘20520025’)