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Preliminary cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
1st July – 3rd August 2023

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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 3rd in 2023 using five vessels from Norway (2), Iceland (1), Faroe Islands (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 now consists of eight years (2016-2023).

The total swept-area mackerel index in 2023 was 4.30 million tonnes in biomass and 10.67 billion in numbers, a decline by 42% for biomass and 39% for abundance compared to 2022. In 2023, the most abundant year classes were 2020, 2019, respectively. The cohort internal consistency improved compared to last year, particularly for ages 4-7 years. The catch curves showed clear year effects, and that mackerel of ages 1, 2 and to some extent also age 3, are not completely recruited to the survey. Most of the surveyed mackerel are still distributed in the Norwegian Sea. However, they were more easterly and northeasterly distributed compared to 2022. The distribution of mackerel in the Norwegian Sea retracted compared to the last decade, particularly withdrawal from the northernmost part was observed. The zero-line was reached for the whole survey area, north of latitude 60°N.

Norwegian spring-spawning herring had 4% higher abundance and 30% lower biomass in 2023 compared to 2022. The 2016 year-class (7-year-olds) dominated in the stock and contributed 45% and 28% to the total biomass and total abundance, respectively. The 2016 year-class is fully recruited to the adult stock.

The zero-line of the distribution of the mature part of NSSH was considered to be reached in all directions. The group considered the acoustic biomass estimate of herring in 2023 to be of the similar quality as in the previous survey years. The herring was mainly observed in the upper surface layer as relatively small schools.

The biomass index of blue whiting was similar in 2023 compared to 2022. Estimated stock abundance (ages 1+) was 20.8 billion in 2023 compared to 27.5 billion in 2022. Age 2 and 3 respectively, dominated the estimate in 2023 as they contributed to 41% and 23% (abundance) and 45% and 29% (biomass), respectively. The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2023 IESSNS as in the previous survey years.

Other fish species were also monitored such as lumpfish (*Cyclopterus lumpus*), capelin (*Mallotus villosus*), polar cod (*Boreogadus saida*), and Atlantic salmon (*Salmo salar*). Lumpfish were caught at 76% of surface trawl stations distributed across the surveyed area from southwestern part of Iceland, central part of North Sea to southwestern-western part of the Svalbard. Both size and abundance were greater north of latitude 72°N compared to southern areas. Capelin were caught in the surface trawl on 29 stations along the cold fronts: north of Iceland, north- and northwest of Jan Mayen, northwest of Bear Island and west of Svalbard. There were more trawl stations with catches of capelin in the west and north of Jan Mayen than previous years The polar cod were caught in larger areas in the north and northeast of Iceland compared to the time-series. A total of 62 North Atlantic salmon were caught in 24 stations both in coastal and offshore areas from 62°N to 74°N in the upper 30 m of the water column. The salmon ranged from 0.084 kg to 2.7 kg in weight, dominated by post-smolt and 1 sea-winter individuals. We caught from 1 to 12 salmon during individual surface trawl hauls. The length of the salmon ranged from 21 cm to 82 cm, with the highest fraction between 21 cm and 29 cm.

Satellite measurements of sea surface temperature (SST) in the Northeast Atlantic in July 2023 show that the northern regions of the Nordic Seas were slightly warmer than the average, while the East Greenland Current was cooler than the long-term average. The SST in the Irminger Sea and Iceland Basin were slightly warmer than the average.

The average zooplankton biomass increased in the Norwegian Sea and in Icelandic waters compared to 2022. Zooplankton showed patchy distribution throughout the area.

In the present preliminary report, no results of herring and blue whiting measurements are presented. A final survey report including these two species will be published in the fall of 2023.

2 Introduction

During approximately five weeks of survey in 2023 (1st of July to 3rd of August), five vessels; the M/V "Eros" and M/V "Vendla" from Norway, "Jákup Sverri" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland 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 major 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 and surrounding coastal and offshore waters. 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 since 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, polar cod, and Atlantic salmon. Opportunistic whale observations were also recorded from Norway and Faroe Islands. 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), Jansen et al. (2016), Bachiller et al. (2018), Olafsdottir et al. (2019), Nikolioudakis et al. (2019), dos Santos Schmidt et al. (2023).

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 international 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. Greenland did not participate in 2021 and 2023 but participated with their new research vessel R/V "Tarajoq" in 2022.

The North Sea was included in the survey area for the sixth time in 2023, following the recommendations of WGWIDE. This was done by scientists from DTU Aqua, Denmark. The commercial fishing vessels "Ceton S205" was used. 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 (see Appendix 1 for comparison with the 2018 - 2023 results).

3 Material and methods

Coordination of the IESSNS 2023 was done during the WGIPS 2023 virtual meeting in January 2023, and by correspondence in December 2022 and during spring and summer 2023. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calmer and less windy than usual for the two Norwegian vessels during the entire survey, thus providing very good survey progress as well as favourable conditions for the acoustic recordings and pelagic trawling. The Icelandic vessel, operating in Icelandic waters, experienced in general calm weather for duration of the survey with no survey delay, however three WP2-net sampling were skipped due to high winds and one surface trawl station west of Iceland was not sampled due to mechanical failure of vessel. For the Faroese vessel, the survey was not hampered by weather; however technical issues with the trawl (a repair on land was needed) reduced the survey time with approximately two days in addition to skipped trawl stations in southwestern survey area. The chartered vessel Ceton had good weather conditions throughout the survey.

Furthermore, in the western part of the Norwegian Sea (stratum 9) five surface trawl stations were added during the survey at a shorter distance than used between other stations in that strata to find the boundary of the mackerel distribution. These additional stations were excluded when calculating the age segregated abundance index which is opposite to what was done in 2022. Finally, in the northern Norwegian Sea by Bear island, one predetermined surface stations was no sampled for a unknown reason.

During the IESSNS, the special designed pelagic trawl, Multpelt 832, has 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 led 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 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 2023. The number of predetermined ("fixed") trawl stations being part of the swept-area stations for mackerel in the IESSNS are shown after the total number of trawl stations.

Vessel	Effective survey period	Length of cruise track (nmi)	Total trawl stations/ Fixed stations	CTD stations	Plankton stations
Árni Friðriksson	3-21/7	3250	43/38	38	35
Jákup Sverri	1-16/7	2825	31/27	27	27
Ceton	4-13/7	1987	36/39	36	-
Vendla	4/7-3/8	4077	66/57	57	57
Eros	4/7-3/8	3349	64/57	57	57
Total	1/7-3/8	15488	240/218	215	176

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Eros, Vendla, Árni Friðriksson and Jákup Sverri were all equipped with a SEABIRD CTD sensor and Árni Friðriksson and Jákup Sverri moreover also had a water rosette. Ceton used a Seabird SeaCat offline 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 4 vessels, excluding Ceton which operates in the North Sea. Mesh sizes were 180 µm (Eros and Vendla) and 200 µm (Árni Friðriksson and Jákup Sverri). 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. The zooplankton was sorted into three size categories (µm), > 2000, 1000–2000, 180/200–1000, on the Norwegian and Faroese vessels; and two size fractions (µm), > 1000 and 200–1000, on the Icelandic vessel. Detailed description of the zooplankton and CTD sampling is provided in the survey manual (ICES 2014a).

Three planned WP2-plankton samples were not 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 and to target blue whiting registrations identified by echograms. 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. The Norwegian vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting if catches were more than 500 kg. Sub-sample size ranged from 90 kg (if it was clean catch of either herring or mackerel) to 200 kg (if it was a mixture of herring and mackerel); however, other species were mostly sorted out of the full catch. On the Icelandic vessel, the whole catch was sorted to species for all species except mackerel and herring when the catch is large (> 1000 kg) and mostly a mix of the two before mentioned species. Then approximately 10% of the mixed herring and mackerel catch is sorted to species.

The biological sampling protocol for trawl catch varied between nations in number of specimens sampled per station (Table 3).

Results from the survey expansion southward into the North Sea are analyzed separately from the traditional survey grounds north of latitude 60°N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017). However, data collected with the IESSNS methodology from the Skagerrak and the northern and western part of the North Sea are now available for six years (2018-2023).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 1st July to 3rd August 2023. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	Árni Friðriksson	Vendla	Ceton	Jákup Sverri	Eros	Influence
Trawl producer	Ísfell new trawl in 2023	Egersund Trawl AS	Egersund Trawl AS	Vónin (2018)	Egersund Trawl AS	0
Warp in front of	Dynex-34 mm	Dynex -34 mm	Dynex	Dynex – 38 mm	Dynex-34 mm	+

doors						
Warp length during towing	350	350	270-320	350 (350-360)	350	0
Difference in warp length port/starb. (m)	16	2-10	10	0-10	5-10	0
Weight at the lower wing ends (kg)	2×400 kg	2×400	2×400	2×400	2×400	0
Setback (m)	14	6	6	6	6	+
Type of trawl door	Jupiter	Seaflex 7.5 m^2 adjustable hatches	Thybron type 15	Twister	Seaflex 7.5 m^2 adjustable hatches	0
Weight of trawl door (kg)	2200	1700	1970	1650	1700	+
Area trawl door (m^2)	6	7.5 with 25% hatches (effective 6.5)	7	4.5	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	5.1 (4.6-5.6)	4.6 (4.1-5.5)	5.1 (4.5-5.8)	4.7 (4-5.4)	4.7 (4.1-5.725)	+
Trawl height (m) mean (min-max)	31 (23-37)	25-32	30 (24-38)	32.1 (25–51)	25-32	+
Door distance (m) mean (min-max)	107 (110 - 130)	121.8 (118-126)	125 (118-133)	114 (102-122)	135 (113-140)	+
Trawl width (m)*	68.4	63.8	69.7	64.1	67.5	+
Turn radius (degrees)	5-10	5-12 SB turn	5-10	5 BB/SB turn	5-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	7-25, 7-21	6-22, 8-23	6-26, 6-26	5-17, 5-17	6-18, 8-20	+
Headline depth (m)	0	0	0	0	0	+
Float arrangements on the headline	Kite + 1 buoy on each wingtip	Kite with fender buoy +2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite with + 1 buoys and kite on each wingtip	Kite + 2 buoy on each wingtips	+
Weighing of catch	All weighed	All weighted	All weighed	All weighed	All weighted	+

* calculated from door distance (Table 6)

Table 3. Protocol of biological sampling during the IESSNS 2023. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Iceland	Norway	Denmark
Length measurements	Mackerel	200/100*	150	100	≥ 125
	Herring	200/100*	200	100	75
	Blue whiting	200/100*	100	100	75
	Lumpfish	all	all	all	all
	Salmon	All (1)	all	all	-
	Capelin	-	50	25-30	
	Other fish sp.	20-50	50	25	As appropriate
Weight, sex and maturity determination	Mackerel	15-25	50	25	***
	Herring	25-50	50	25	0
	Blue whiting	15-50	50	25	0
	Lumpfish	0-6	1^	25	0
	Salmon	All	0	25	0
	Capelin	-	50		
	Other fish sp.	0-20	0	0	0
Otoliths/scales collected	Mackerel	15-25	25	25	***
	Herring	25-50	25	25	0
	Blue whiting	15-50	50	25	0
	Lumpfish	0	1^	0	0
	Salmon	-	0	0	0
	Capelin		50		
	Other fish sp.	0	0	0	0
Fat content	Mackerel	0	10	0	0
	Herring	0	10**	0	0
	Blue whiting	0	10	0	0
Stomach sampling	Mackerel	5	10	10	0
	Herring	5	10**	10	0
	Blue whiting	5	10	10	0
	Other fish sp.	0	0	10	0
Tissue for genotyping	Mackerel	0	0	0	0
	Herring	0	0	25	0

*Length measurements / weighed individuals
**Sampled at every third station
*** Up to one fish per cm-group < 25 cm, two fish 25 – 30 cm and three fish > 30 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.

This year's survey was quite well synchronized in time and was conducted over a relatively short period (33 days) given the large spatial coverage of around 2.4 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 20th of July. The main argument for this time-period was to make the IESSNS 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.

Underwater camera observations during trawling

M/V “Eros” and M/V “Vendla” employed an underwater video camera (GoPro HD Hero 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 night-time when there was midnight sun and good underwater visibility. Video recordings were collected at 74 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 4th July and 2nd August 2023 onboard M/V “Eros” and M/V “Vendla”, and onboard Jákup Sverri (30th of June – 17th of July) opportunistic observations were done from the bridge by crew members.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V “Árni Friðriksson”, M/V “Eros”, 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 ~15-20 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 Vendla and Eros were calibrated 3rd July 2023 for 18, 38, 70, 120 and 200 kHz. Árni Friðriksson was calibrated 4th of May 2023 for frequencies 18, 38, 70, 120 and 200 kHz. Jákup Sverri was calibrated on 23rd March 2023 for 18, 38, 120, 200 and 333 kHz. Ceton did not conduct any acoustic data collection because no calibrated equipment was available, and acoustics are done in the same area and period of the year during the ICES coordinated North Sea herring acoustic survey (HERAS). 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). 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 log(L) – 71.9 dB (Foote, 1987)

Table 4. Acoustic instruments and settings for the primary frequency (38 kHz) during IESSNS 2023.

	R/V Árni Friðriksson	M/V Vendla	R/V Jákup Sverri	M/V Eros
Echo sounder	Simrad EK80	Simrad EK60	Simrad EK80	Simrad EK80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, **38**, 70, 120, 200, 333	18, 38, 70, 120, 200, 333
Primary transducer	ES38-7	ES38B	ES38-7	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	9.6	8	6-9	6
Upper integration limit (m)	15	15	12	15
Absorption coeff. (dB/km)	9.8	9.9	10.3	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	3.06	2.43
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	18	21.90	21.9	21.9
2-way beam angle (dB)	-20.30	-20.70	-20.4	-20.7
TS Transducer gain (dB)	27.02	25.22	26.94	25.22
s_A correction (dB)	0.02	-0.73	-0.13	-0.72
3 dB beam width alongship:	6.43	6.88	6.47	6.85
3 dB beam width athw. ship:	6.43	6.76	6.54	6.79
Maximum range (m)	500	500	500	500
Post processing software	LSSS v.2.14.1	LSSS 2.12.0	LSSS 2.14.1	LSSS 2.12.0

M/V Ceton: No acoustic data collection because other survey in the same area in June/July (HERAS).

Multibeam sonar

Both M/V Eros and M/V Vendla were equipped with the Simrad fisheries sonar. Medium frequency CS90 sonar (frequency range: 70-90 kHz) on M/V Eros and low frequency ST90 sonar (frequency range: 14-24 kHz) on M/V Vendla with a scientific output incorporated which allow the storing of the beam data for post-processing. Acoustic multibeam sonar data was stored continuously onboard Eros and Vendla for the entire survey.

Cruise tracks

The five 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 10 strata, of which 6 are permanent (1, 2, 3, 7, 10 and 13) and four dynamic (4, 5, 6 and 9) (Figure 2). Distance between predetermined surface trawl stations is constant within stratum but variable between strata and ranged from 40 to 70 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 2023 is shown in Figure 3. The cruising speed was between 10-11 knots if the weather permitted, otherwise the cruising speed was adapted to the weather situation.

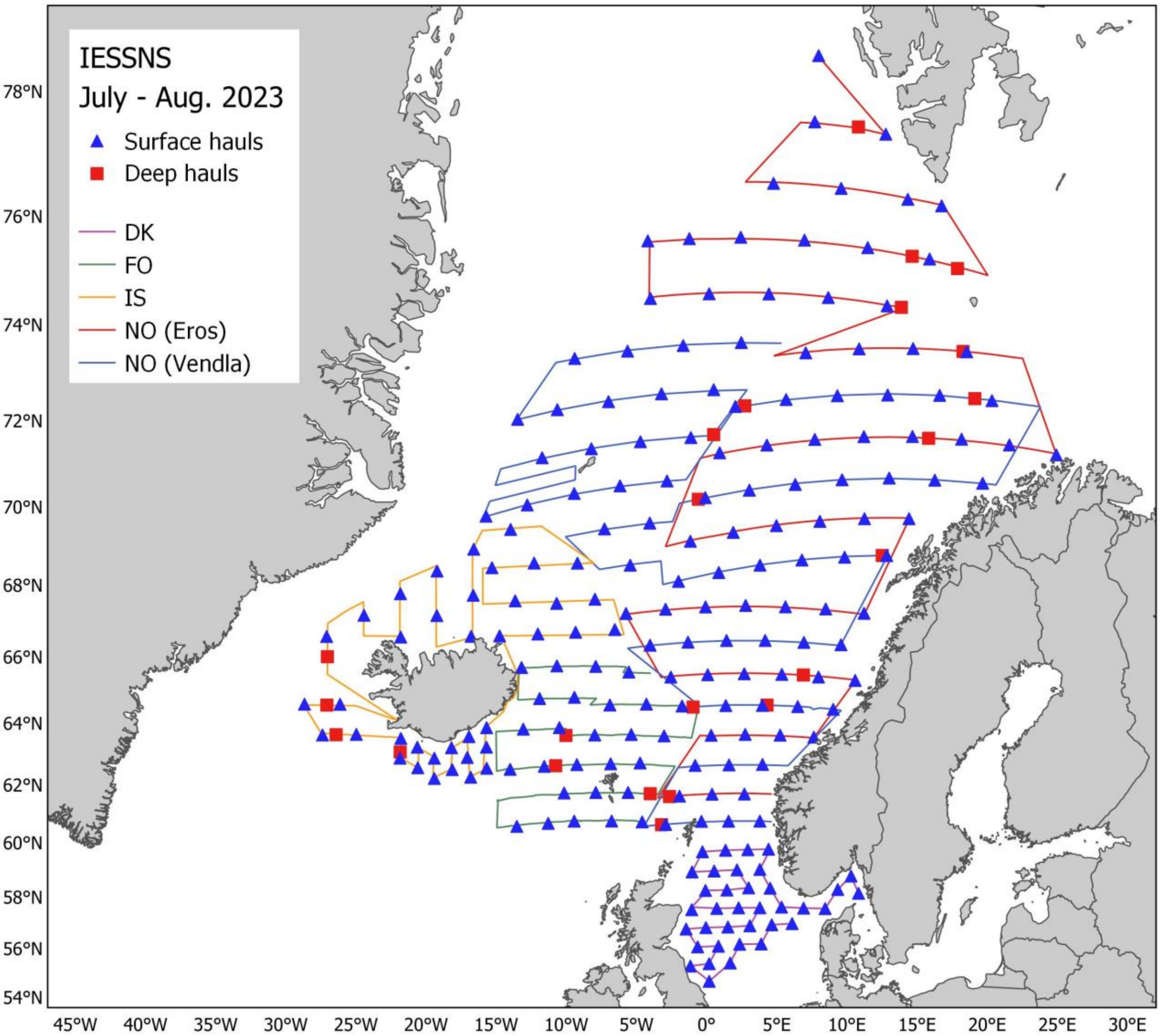


Figure 1 a. Fixed predetermined trawl stations and additional deep hauls included in the IESSNS from July 1st to August 3rd 2023. At each station a 30 min surface trawl haul was performed.

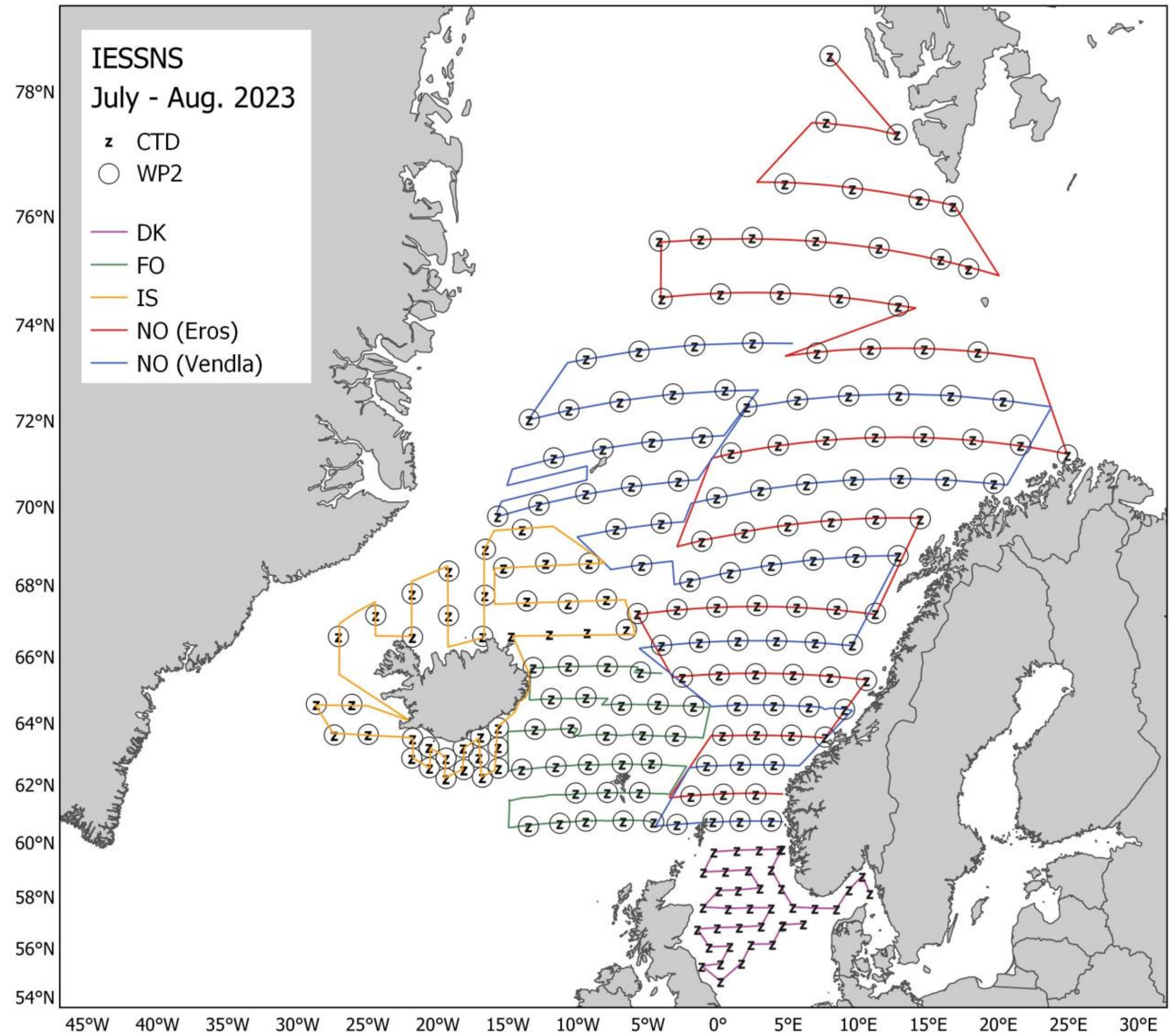


Figure 1 b. Fixed predetermined hydrographic stations (CTD and WP2) included in the IESSNS from July 1st to August 3rd 2023. CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth).

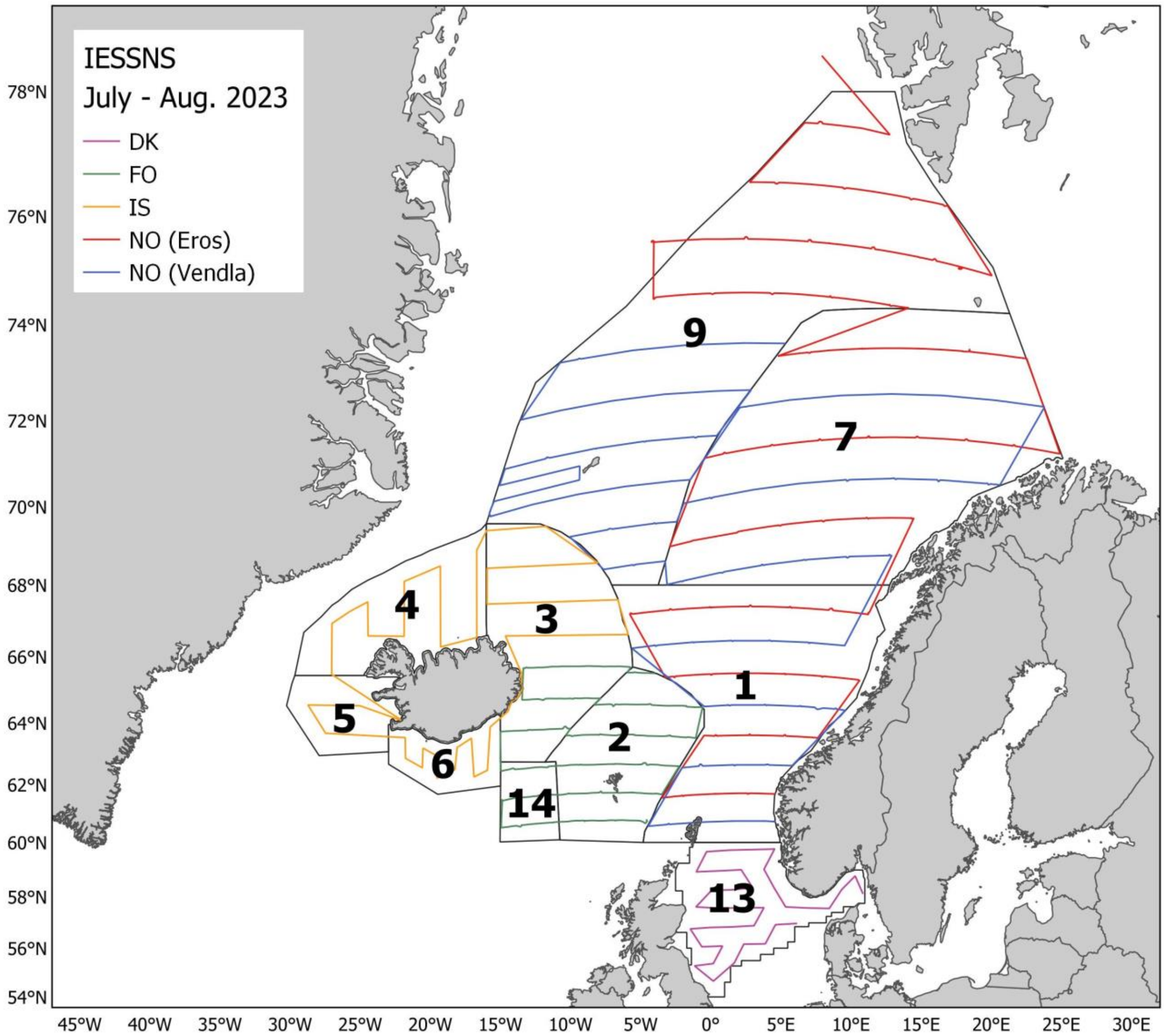


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2023. The survey area is split into 10 strata, of which 6 are permanent (1, 2, 3, 7, 10 and 13) and four dynamic (4, 5, 6 and 9). The former stratum 8 (along the Norwegian coast) was merged into adjacent strata 1 and 7. Stratum 10 (northern Greenland waters) and 11 (southern Greenland waters) were not surveyed in 2023 and are not displayed. The former stratum 12 (offshore south of Iceland) is not used any longer, since the southern boundaries of strata 5 and 6 have been converted to dynamic boundaries. For original strata boundaries see WGIPS manual (ICES 2014a). In 2023, stratum 2 was split in two strata, 2 and 14, as two predetermined surface trawl stations were not sampled on the western end of the 2nd transect from the south, see Figure 1a. Due to large variability in mackerel density within in stratum 2, the area around the skipped predetermined stations was defined as a separated stratum to reflect the mackerel density in the area. This was done to prevent inflation on mackerel abundance in the stratum 2 due to under sampling in a low-density part of stratum 2.

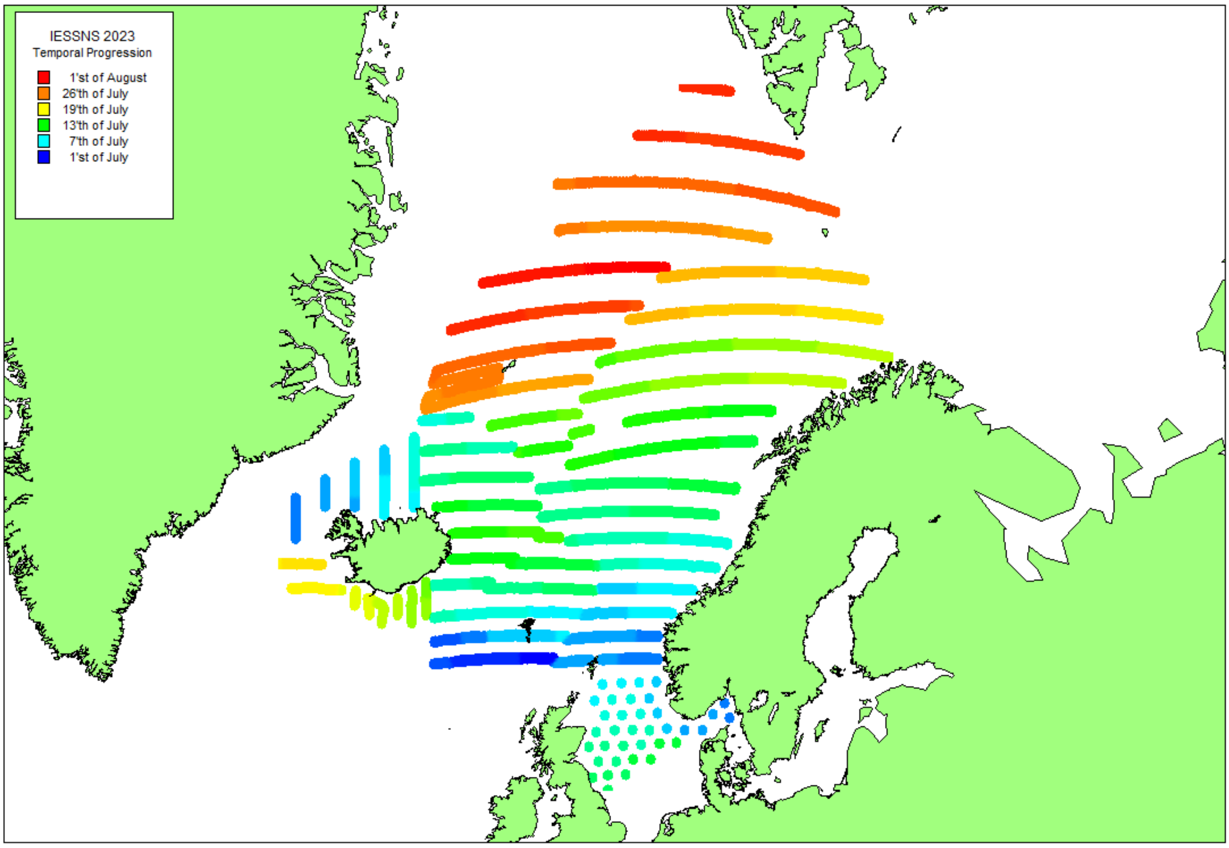


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2023: Blue represents effective survey start (1’st of July) progressing to red representing a five-week span (survey ended 3rd of August). As Ceton did not submit acoustics, they have been represented by station positions.

3.6 StoX

The recorded acoustic and biological data were analysed using the StoX software package which has been used for some years now for WGIPS coordinated surveys. A description of StoX can be found in Johnsen et al. (2019) and here: www.imr.no/forskning/prosjekter/stox. Mackerel swept-area abundance index, excluding the North Sea, was calculated using StoX version 3.6.1. The herring and blue whiting acoustic abundance indices were calculated using StoX version 3.6.2.

3.7 Swept area index and biomass estimation

This year the input data for the swept area calculations were taken from the ICES database. Up until 2020 the input data were extracted from the PGNAPES database.

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 60°N and 77°N and 40°W and 20°E in 2023. An additional run is made, including the North Sea. The density of mackerel on a trawl station 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 2023 at predetermined surface trawl stations. 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).

	Jákup Sverri	RV Árni Friðriksson	Eros	Vendla	Ceton
Trawl doors horizontal spread (m)					
Number of stations	27	29	57	57	36
Mean	113	122	122	112	125.2
max	120	130	136	120	132.7
min	102	110	115	100	117.7
st. dev.	4.2	4.6	4.8	4.0	3.8
Vertical trawl opening (m)					
Number of stations	27	36	57	57	36
Mean	32	30.8	28	29	30.4
max	49	23.2	33	32.0	37.7
min	25	37.2	25	24	23.6
st. dev.	5.9	2.9	2.9	4.3	3.2
Horizontal trawl opening (m)					
Mean	63.7	68.4	71.7	65.1	69.7
Speed (over ground, nmi)					
Number of stations	27	38	57	57	36
Mean	4.7	5.1	4.5	4.6	5.1
max	5.5	5.6	5.2	5.3	5.8
min	3.4	4.6	4.2	4.2	4.5
st. dev.	0.5	0.2	0.5	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, in 2020 the door spread was extended to 122 m and in 2022 the towing speed range was extended down to 4.3 knots and up to 5.5 knotsThe door spread was furthermore extended to 135 m in 2023. See also Appendix 4.

	Towing speed (knots)												
Door spread(m)	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	5.5
100	56.5	56.9	57.2	57.7	58.2	58.7	59.2	59.7	60.2	60.7	61.2	61.7	62.2
101	56.9	57.3	57.6	58.1	58.6	59.1	59.6	60.1	60.6	61.1	61.5	62.0	62.5
102	57.3	57.7	58.1	58.6	59.0	59.5	60.0	60.5	60.9	61.4	61.9	62.4	62.9
103	57.7	58.1	58.5	59.0	59.5	59.9	60.4	60.9	61.3	61.8	62.3	62.8	63.2
104	58.1	58.5	59.0	59.4	59.9	60.3	60.8	61.3	61.7	62.2	62.7	63.1	63.6
105	58.6	59.0	59.4	59.9	60.3	60.8	61.2	61.7	62.1	62.6	63.0	63.5	63.9
106	59.0	59.4	59.8	60.3	60.7	61.2	61.6	62.1	62.5	62.9	63.4	63.8	64.3
107	59.5	59.9	60.3	60.7	61.2	61.6	62.0	62.5	62.9	63.3	63.8	64.2	64.6
108	59.9	60.3	60.7	61.1	61.6	62.0	62.4	62.9	63.3	63.7	64.1	64.6	65.0
109	60.4	60.8	61.2	61.6	62.0	62.4	62.8	63.2	63.7	64.1	64.5	64.9	65.3
110	60.9	61.2	61.6	62.0	62.4	62.8	63.2	63.6	64.1	64.5	64.9	65.3	65.6
111	61.3	61.7	62.0	62.4	62.8	63.2	63.6	64.0	64.4	64.8	65.2	65.6	66.0
112	61.8	62.1	62.5	62.9	63.3	63.7	64.0	64.4	64.8	65.2	65.6	66.0	66.3
113	62.2	62.6	62.9	63.3	63.7	64.1	64.4	64.8	65.2	65.6	66.0	66.3	66.7
114	62.7	63.0	63.4	63.7	64.1	64.5	64.9	65.2	65.6	66.0	66.3	66.7	67.0
115	63.1	63.5	63.8	64.2	64.5	64.9	65.3	65.6	66.0	66.3	66.7	67.0	67.3
116	63.6	63.9	64.3	64.6	65.0	65.3	65.7	66.0	66.4	66.7	67.0	67.4	67.7
117	64.0	64.4	64.7	65.0	65.4	65.7	66.1	66.4	66.8	67.1	67.4	67.7	68.0
118	64.5	64.8	65.1	65.5	65.8	66.1	66.5	66.8	67.2	67.5	67.8	68.1	68.4
119	64.9	65.3	65.6	65.9	66.2	66.6	66.9	67.2	67.6	67.9	68.1	68.4	68.7
120	65.4	65.7	66.0	66.3	66.6	67.0	67.3	67.6	67.9	68.2	68.5	68.8	69.1
121	65.8	66.1	66.5	66.8	67.1	67.4	67.7	68.0	68.3	68.6	68.9	69.1	69.4
122	66.3	66.6	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0	69.2	69.5	69.8
123	66.7	67.0	67.3	67.6	67.9	68.2	68.5	68.8	69.1	69.3	69.6	69.9	70.1
124	67.2	67.5	67.8	68.0	68.3	68.6	68.9	69.2	69.5	69.7	70.0	70.2	70.4
125	67.6	67.9	68.2	68.5	68.8	69.0	69.3	69.6	69.8	70.1	70.3	70.6	70.8
126	68.1	68.4	68.7	68.9	69.2	69.5	69.7	70.0	70.2	70.5	70.7	70.9	71.1
127	68.6	68.8	69.1	69.4	69.6	69.9	70.1	70.4	70.6	70.9	71.1	71.3	71.5
128	69.0	69.3	69.5	69.8	70.0	70.3	70.5	70.8	71.0	71.2	71.4	71.6	71.8
129	69.5	69.7	70.0	70.2	70.5	70.7	71.0	71.2	71.4	71.6	71.8	72.0	72.1
130	69.9	70.2	70.4	70.7	70.9	71.1	71.4	71.6	71.8	72.0	72.2	72.3	72.5
131	70.4	70.6	70.9	71.1	71.3	71.6	71.8	72.0	72.2	72.3	72.5	72.7	72.8
132	70.8	71.1	71.3	71.5	71.8	72.0	72.2	72.4	72.5	72.7	72.9	73.0	73.1
133	71.3	71.5	71.7	72.0	72.2	72.4	72.6	72.7	72.9	73.1	73.2	73.3	73.4
134	71.7	71.9	72.2	72.4	72.6	72.8	72.9	73.1	73.3	73.4	73.5	73.6	73.7
135	72.1	72.4	72.6	72.8	73.0	73.1	73.3	73.5	73.6	73.7	73.8	73.9	74.0

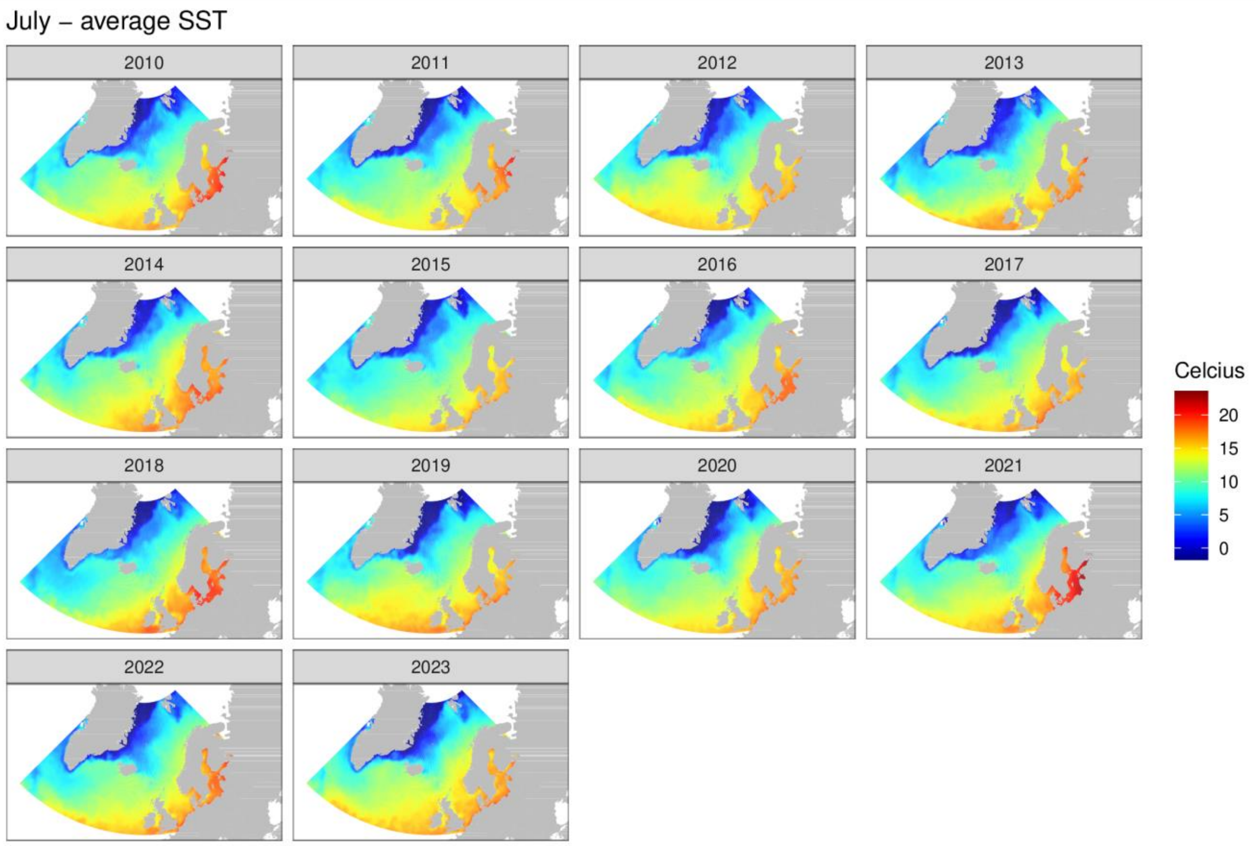
4 Results and discussion

4.1 Hydrography

Satellite measurements (NOAA OISST) of sea surface temperature (SST) in the central areas in the Northeast Atlantic in July 2023 were slightly warmer than the long-term average for July 1990-2009 based on SST plots (Figure 4a) and SST anomaly plots (Figure 4b). The northern regions of the Nordic Seas were slightly warmer than the average while the East Greenland Current was cooler than the long-term average. The SST in the Irminger Sea and Iceland Basin were slightly warmer than the average.

It should be mentioned that the NOAA SST are sensitive to the weather conditions (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 4a,b-5). However, since the anomaly is based on the average for the whole month of July, it should give representative results of the surface temperature.

The temperature distribution at 10, 50, 100 and 400 m depths is shown in Figure 5. At 10 m depth, the temperatures ranged from less than 1°C in the Greenland Sea to 16°C in the North Sea. At all depths there is a clear signal from the cold East Icelandic Current which carries cold and fresh water into the central and south-eastern part of the Norwegian Sea. Along the Norwegian Shelf and in the southernmost areas, the water masses are dominated by warmer waters of Atlantic origin. The CTD measurements at 10 m depths showed that north of Jan-Mayen the 8°C isotherm was found more easterly than last year. South of Jan-Mayen the 8°C isotherm was found more westerly than last year and was closely aligned to the Jan-Mayen Ridge.



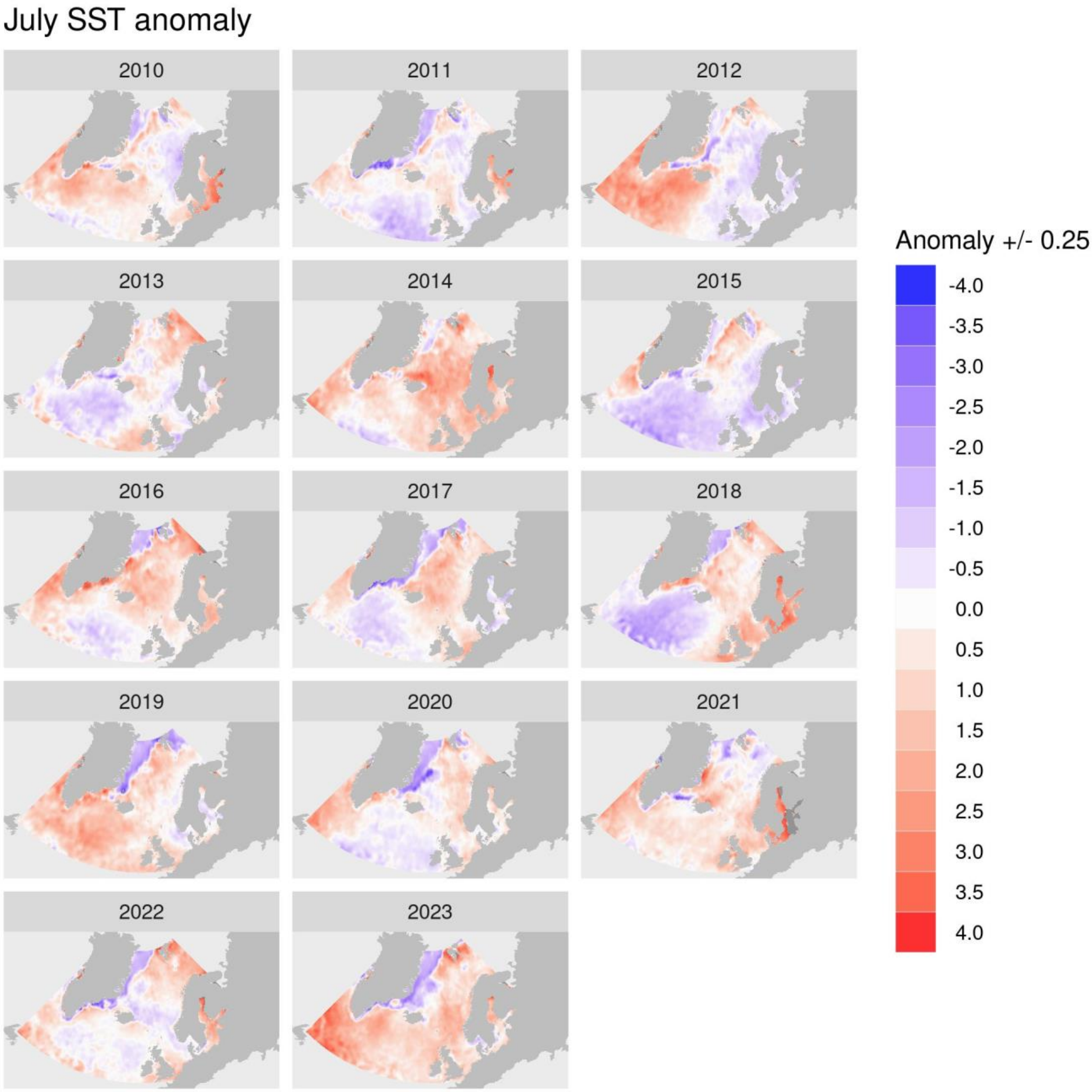


Figure 4. Annual sea surface temperature (a; top panel) and its anomaly (b; lower panel; -4 to +4°C) in Northeast Atlantic for the month of July from 2010 to 2023 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (Ver. 2.1 NOAA OISST, AVHRR-only, Banzon et al. 2016, https://www.ncei.noaa.gov/products/optimum-interpolation-sst).

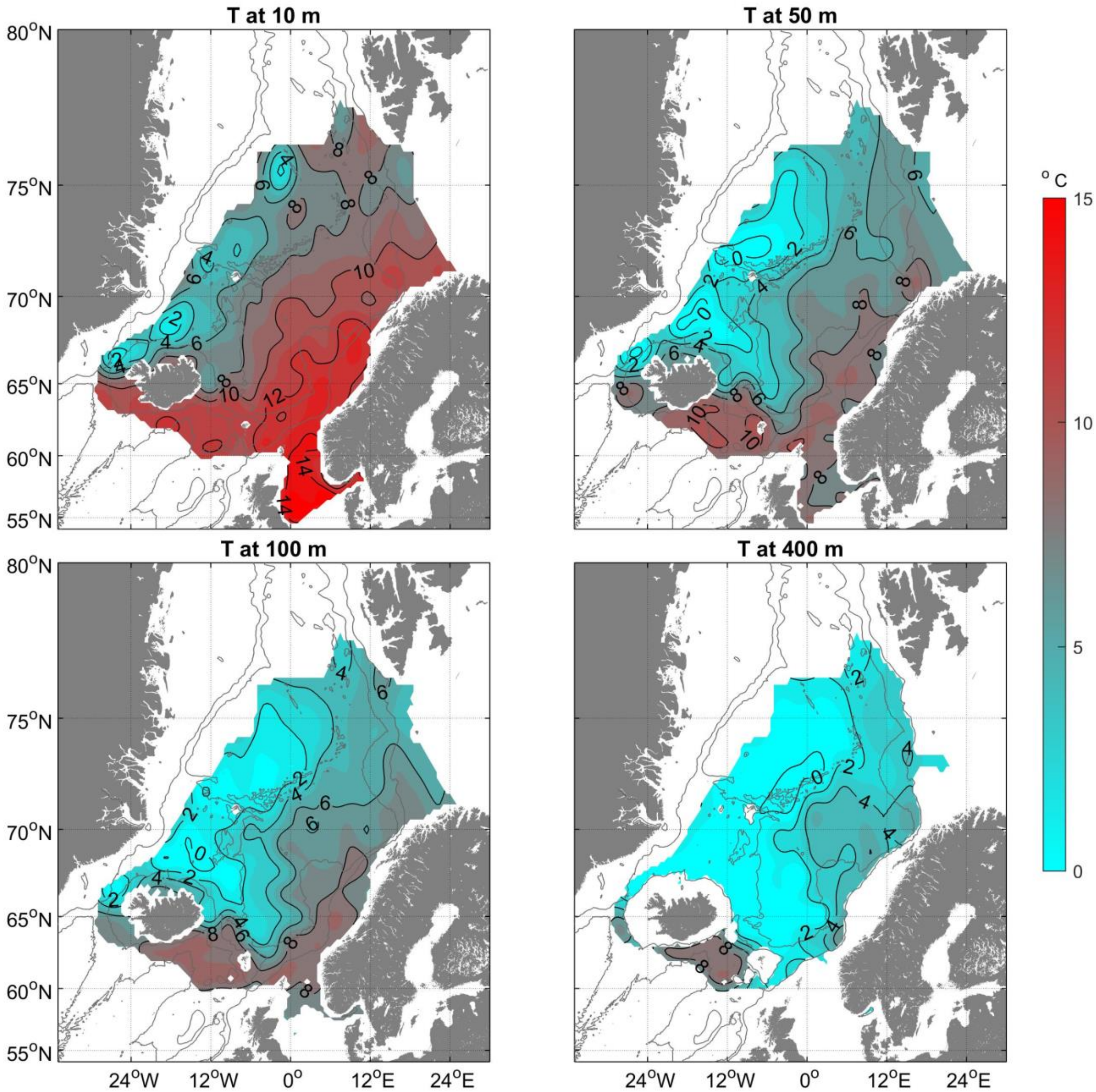


Figure 5. Interpolated temperature (°C) at 10, 50, 100 and 400 m depth in Nordic Seas and the North Sea in July-August 2023. 500 m and 2000 m depth contours are shown in light grey.

4.2 Zooplankton

The zooplankton biomass varied between areas with a patchy distribution throughout the area (Figure 6a). In the Norwegian Sea areas, the average zooplankton biomass was around 8 g/m^2, which is higher than the last two years (Figure 6b).

The time-series of zooplankton biomass was averaged by three subareas: Greenland region (not covered in 2023), Iceland region, and the Norwegian Sea region is shown in Figure 6b (see definitions in legend). In the Icelandic region and the Norwegian Sea the level was higher than in 2022. The biomass index in the Norwegian Sea varied less compared to the other two indices, and in 2023 it was comparable to 2019-2020 (Figure 6b). The lower variability over time in the Norwegian Sea might in part be explained by the 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.

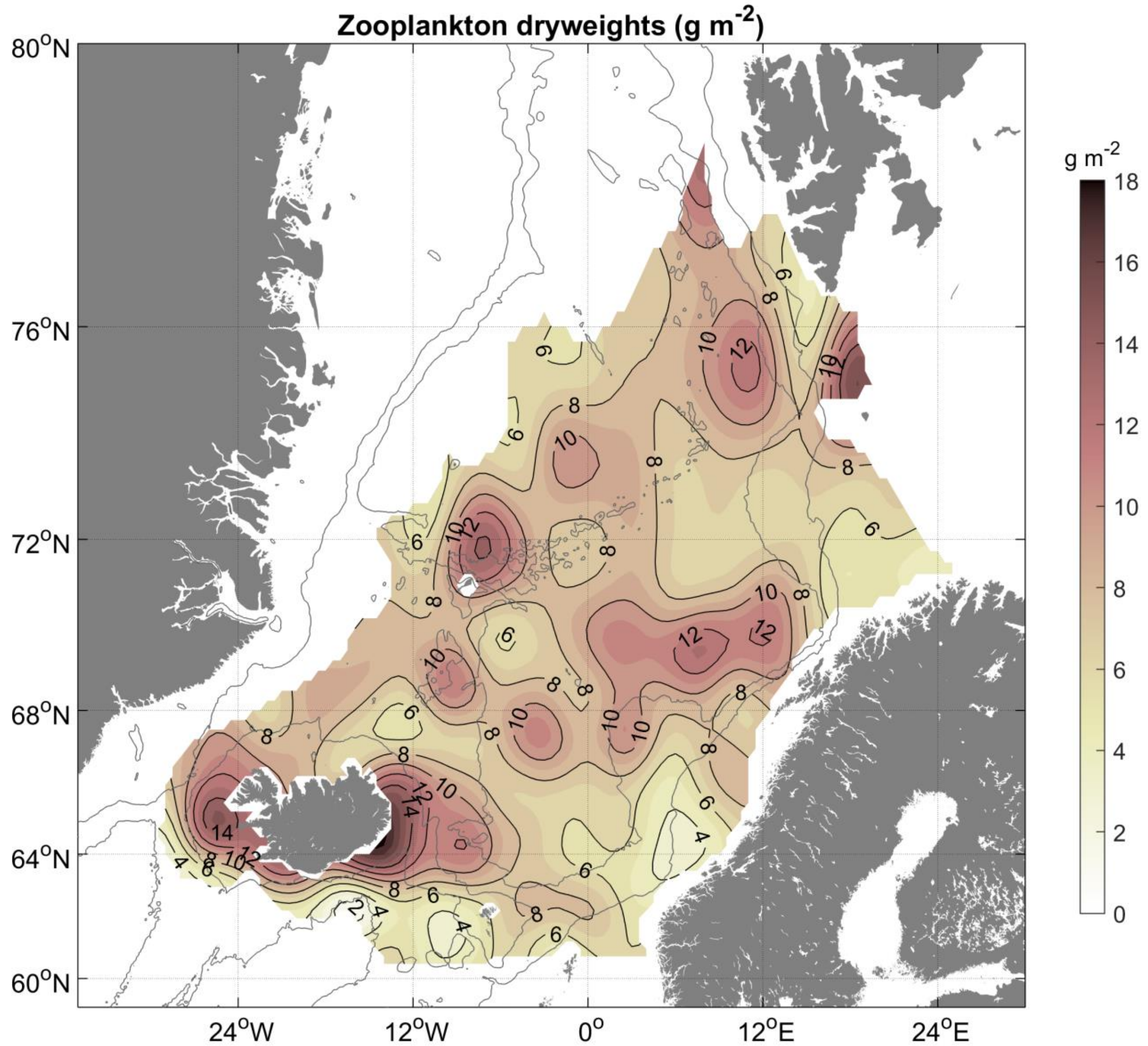


Figure 6a. Interpolated zooplankton biomass (g dw/m2, 0-200 m) in Nordic Seas in July-August 2023. 500 m and 2000 m depth contours are shown in light grey.

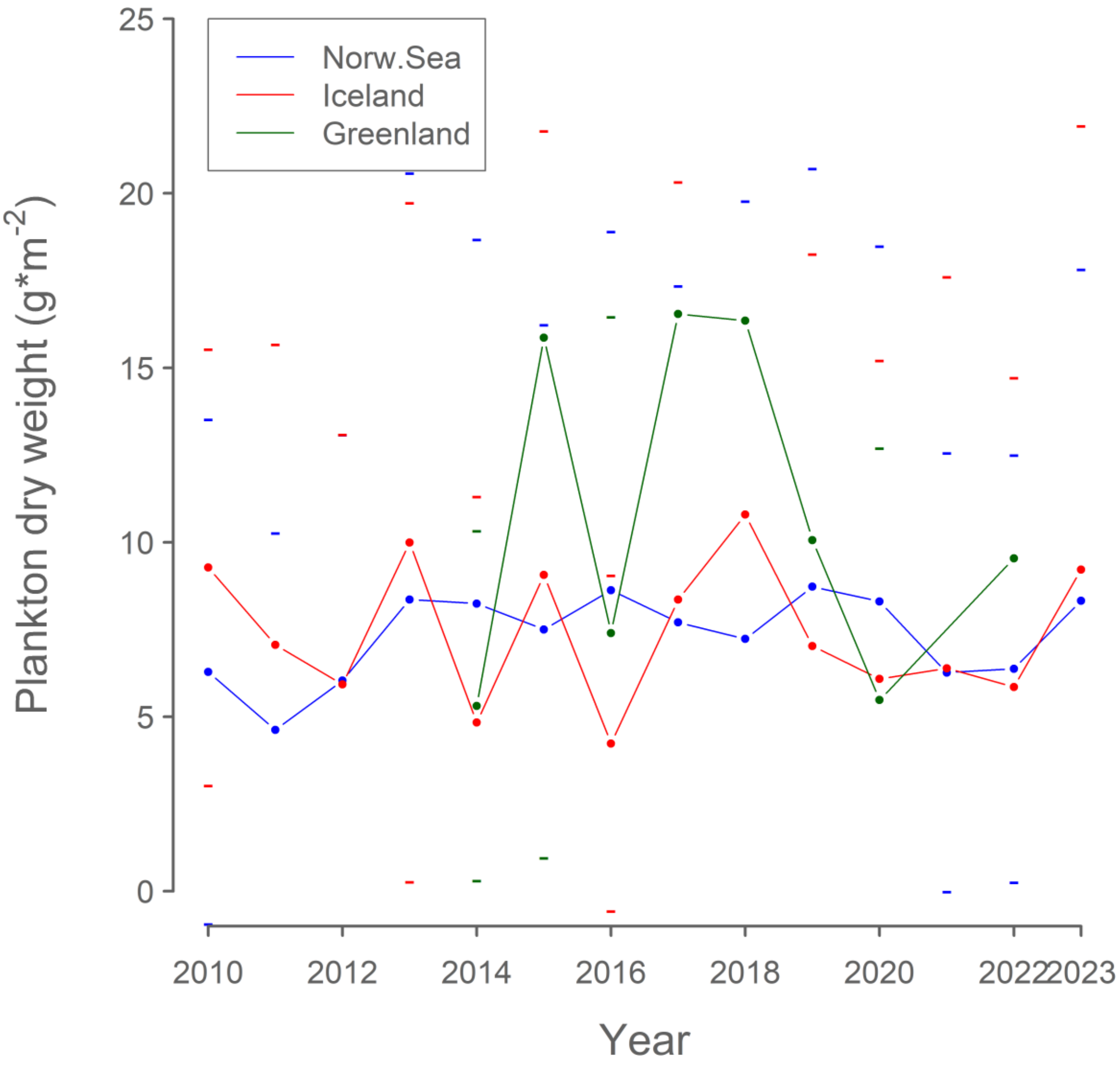


Figure 6b. Zooplankton biomass indices (g dw/m², 0-200 m). Time-series (2010-2023) of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (2014-2022, west of 30°W).

4.3 Mackerel

The total swept-area mackerel index in 2023 was 4.30 million tonnes in biomass and 10.67 billion in numbers, a decrease of 42% for biomass and 39% for abundance compared to 2022. The survey coverage area (excl. the North Sea, 0.28 million km²) was 2.36 million km² in 2023, which is 19% smaller compared to 2022. No extreme catches were taken this year, the highest catch was 5.7 tonnes. This reduces the uncertainty of the index in the biomass, CV = 0.12 in 2023 compared to CV = 0.25 in 2022.

Most of the surveyed mackerel still appears to be in the Norwegian Sea. However, they were more easterly and northeasterly distributed compared to 2022. The zero-line was reached for the whole survey area, north of latitude 60°N.

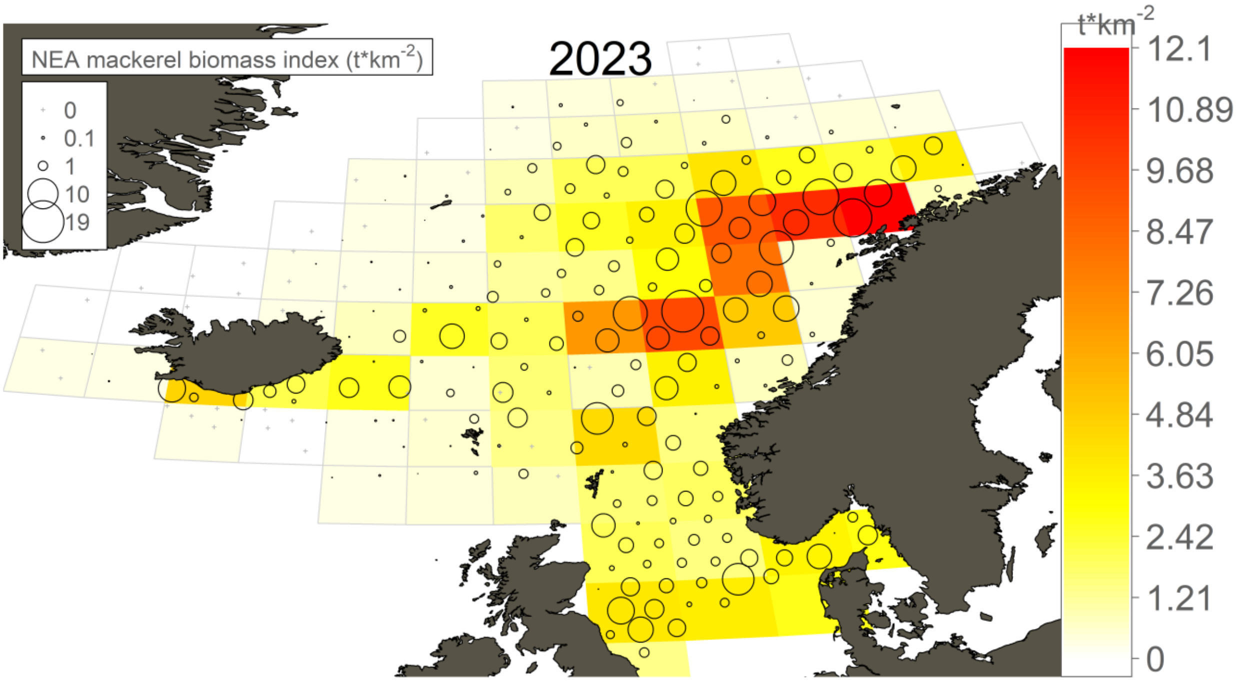


Figure 7. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.) in Nordic Seas in July-August 2023.

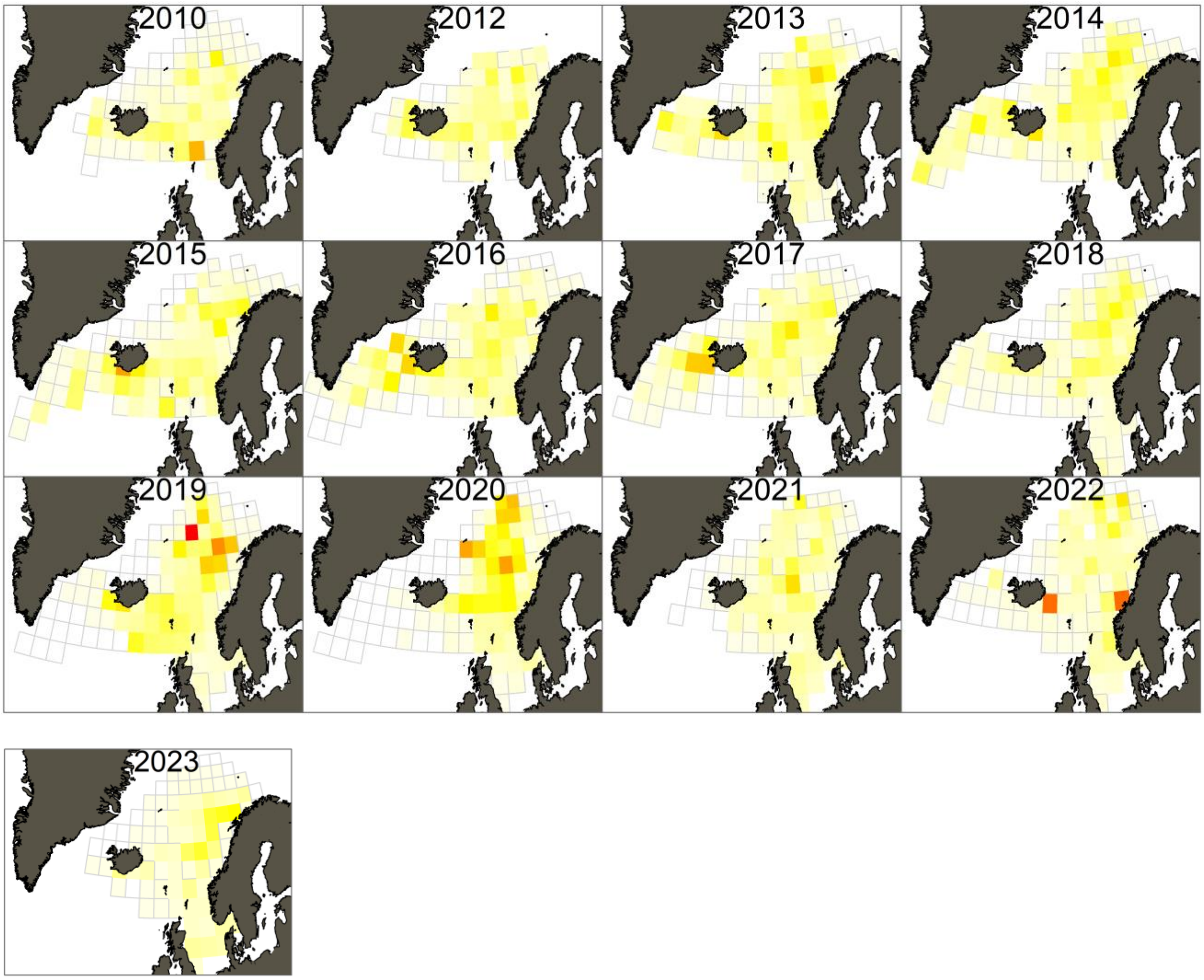


Figure 8. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations in Nordic Seas in June-August 2010-2023. Colour scale goes from white (= 0) to red (= maximum value for the highest year).

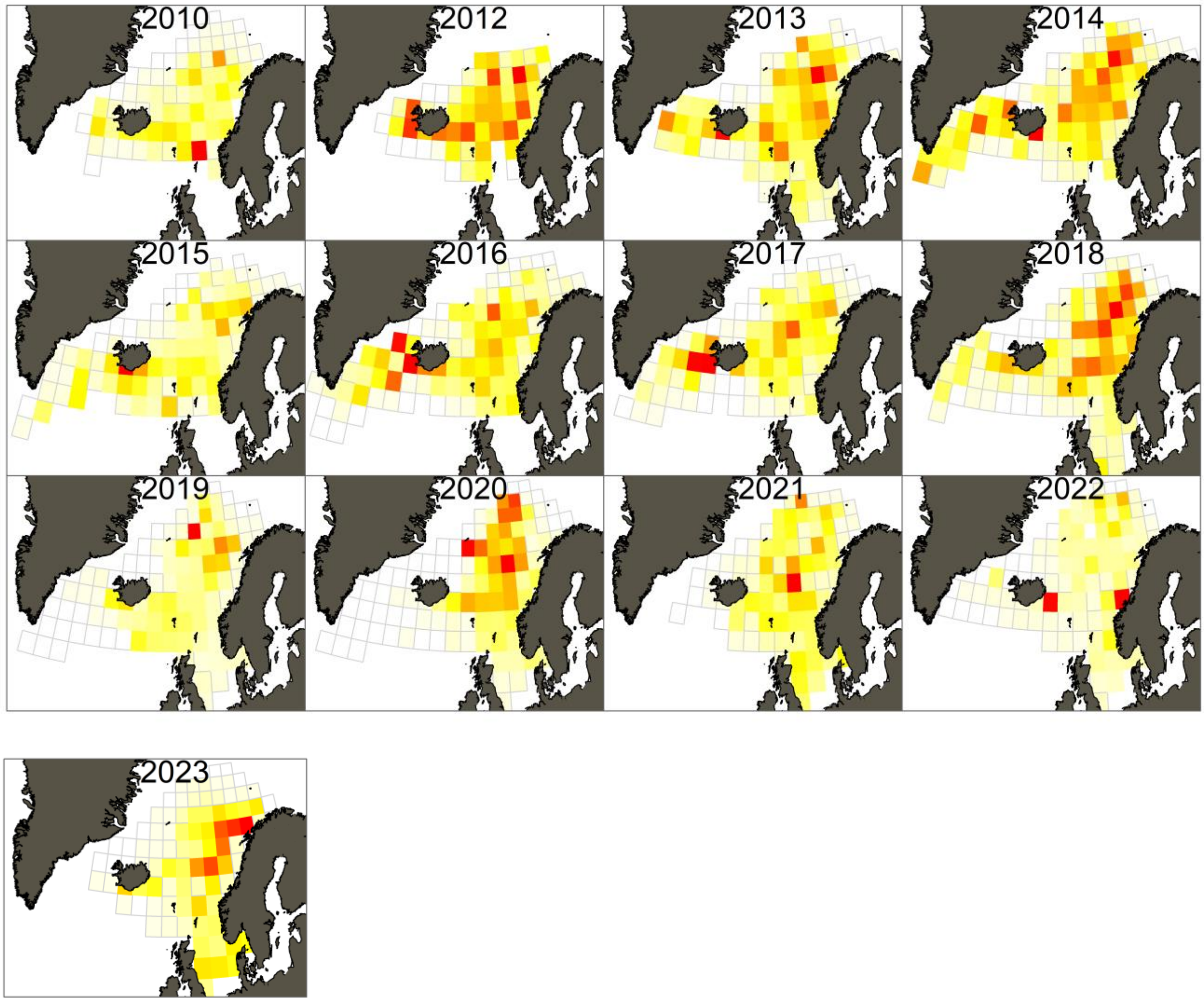


Figure 9. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations stations in Nordic Seas in June-August 2010-2023. Colour scale goes from white (= 0) to red (= maximum value for the given year).

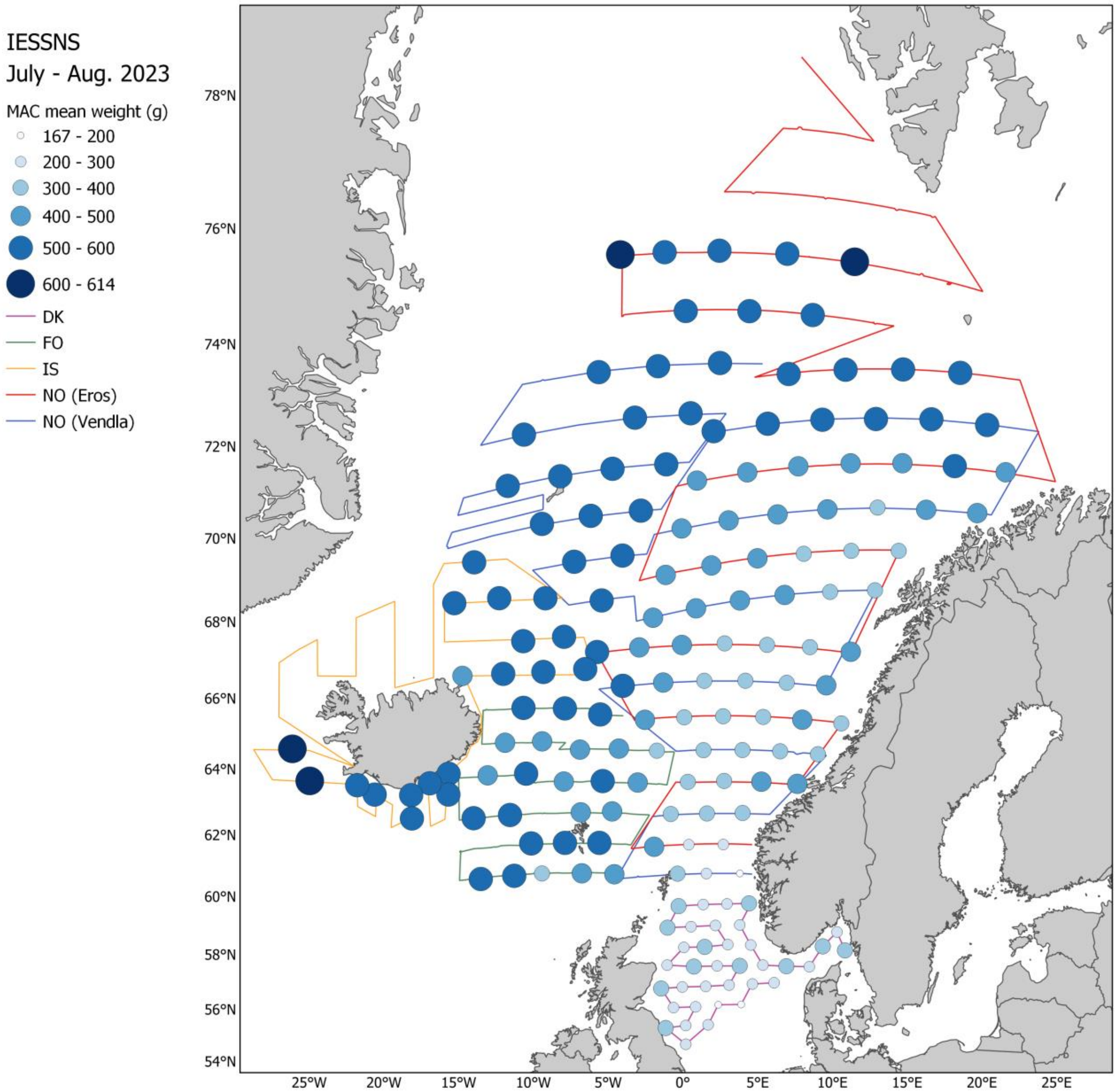


Figure 10. Average weight of mackerel at predetermined surface trawl stations during IESSNS 2023.

The mackerel weight varied between 37 to 858 g with an average of 439 g. The length of mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 17.5 to 45.5 cm, with an average of 34.2 cm. In total we measured 17464 mackerel. Mackerel length distribution followed the same overall pattern as previous years both in the Norwegian Sea, with increasing size towards the distribution boundaries in the north and the north-west, and in the western area with increasing size westward (Figure 10). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting) in 2023 according to surface trawl catches is shown in Figure 11.

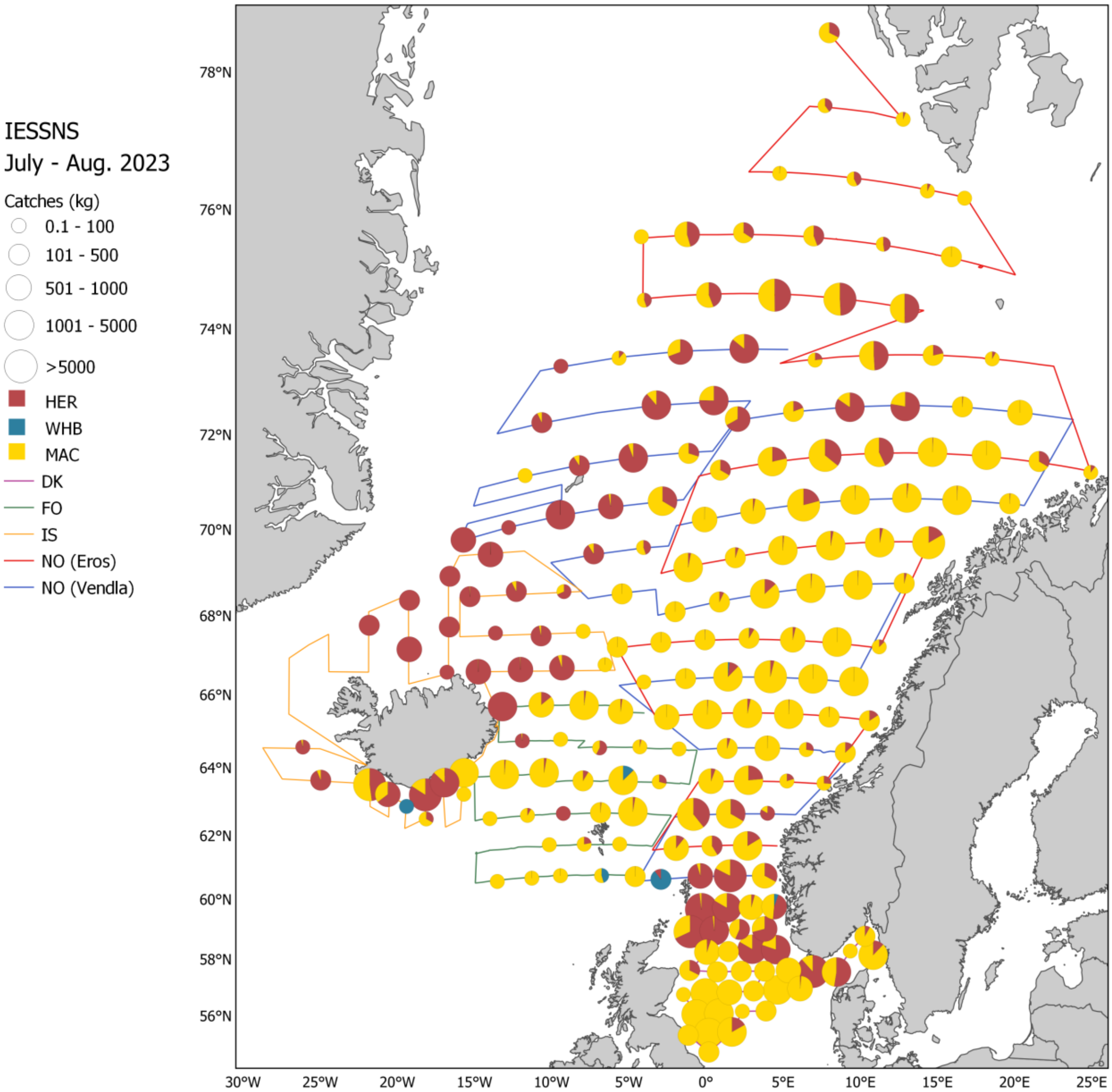


Figure 11. Distribution and spatial overlap between mackerel, herring, and blue whiting, at all surface trawl stations during IESSNS 2023. Vessel tracks are shown as continuous lines and predetermined surface trawl stations with no catch of the three species is displayed as +.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2023 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX version 3.6.1. Mackerel abundance index in 2023 was 39% lower than in 2022, and 46% lower index than the average for the last 5 years (Table 7a; Figure 12) and the biomass index was 42% lower than in 2022, and 50% lower than the average for the last 5 years (Table 7c). Mackerel estimates of abundance, biomass and mean weight by age and length are displayed in Table 7d. There is no pattern in changing size-at-age between years (Table 7b). In 2023, the two most abundant year-classes were 2020 (age 3), 2019 (age 4), respectively (Figure 13). The 2020-year class contributed with 33%, followed by 2019-year class with 16%. Mackerel of age 1, 2 and to some extent also age 3 are not completely recruited to the survey (Figure 15), because the main part of the nursery area was further south than the survey area. Therefore, information on recruitment is uncertain. Variance in age index estimation is provided in Figure 14.

The overall internal consistency improved slightly compared to last year (Figure 16). There is a good to strong internal consistency for the younger ages (1-5 years) and older ages (9-14 years) with r between 0.71 and 0.89. The internal consistency is more variable between age 5 to 9, but improved with the addition of the data from this year, confirming the relations between 5, 6 and 7, and adding a new contrasting data point to the relation between 7 and 8. More information on the relation between 7 and 8 (which have been the weakest link in the internal consistency since the beginning of the survey) is expected in IESSNS 2024 as the weak 2018 year class gets surveyed at age 8.

Mackerel index calculations from the catch in the North Sea (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).

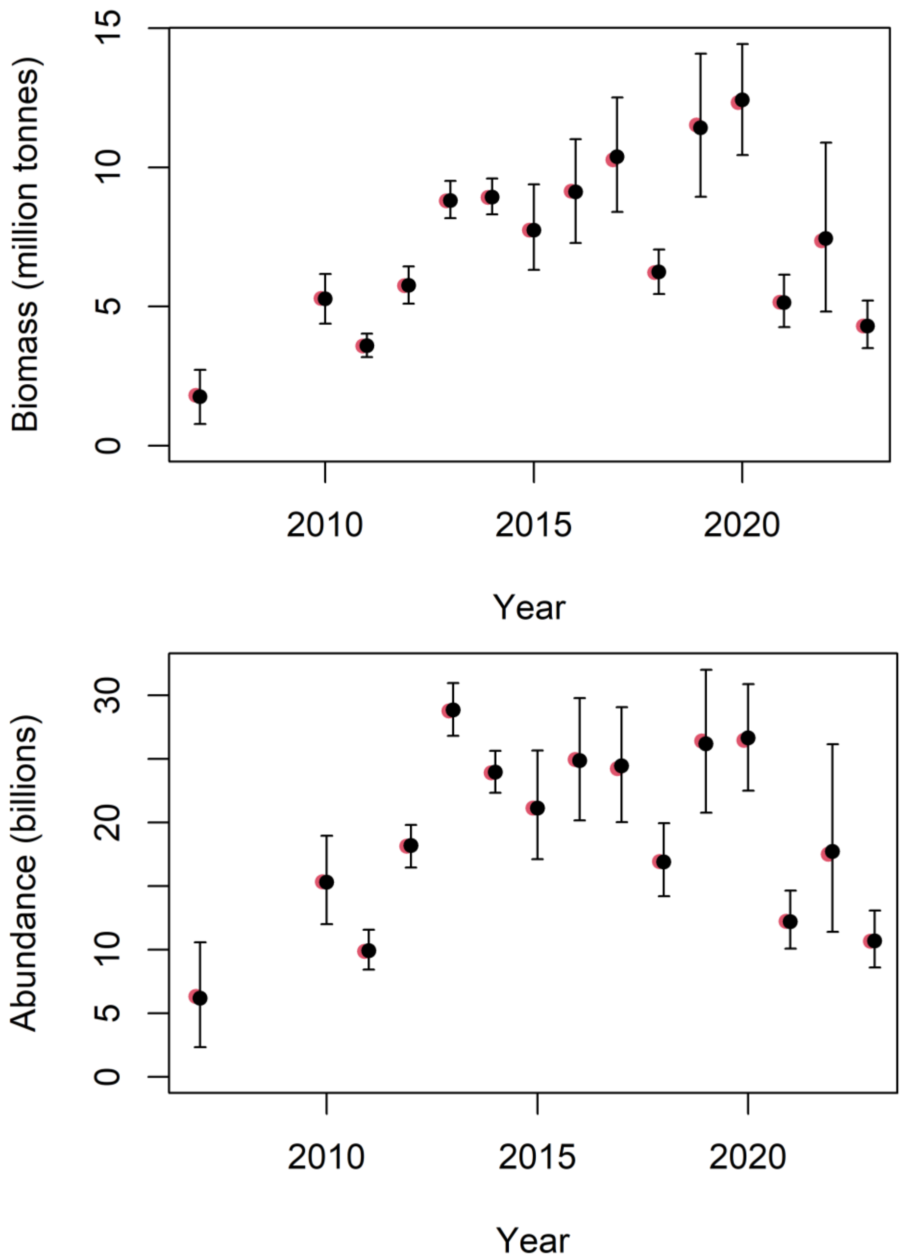


Figure 12. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX for the years 2007 and from 2010 to 2023. The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap. Note, in 2011 the northern part of the Norwegian was not surveyed, hence the index for that year is not representative of mackerel stock size. See IESSNS 2011 cruise report for details.

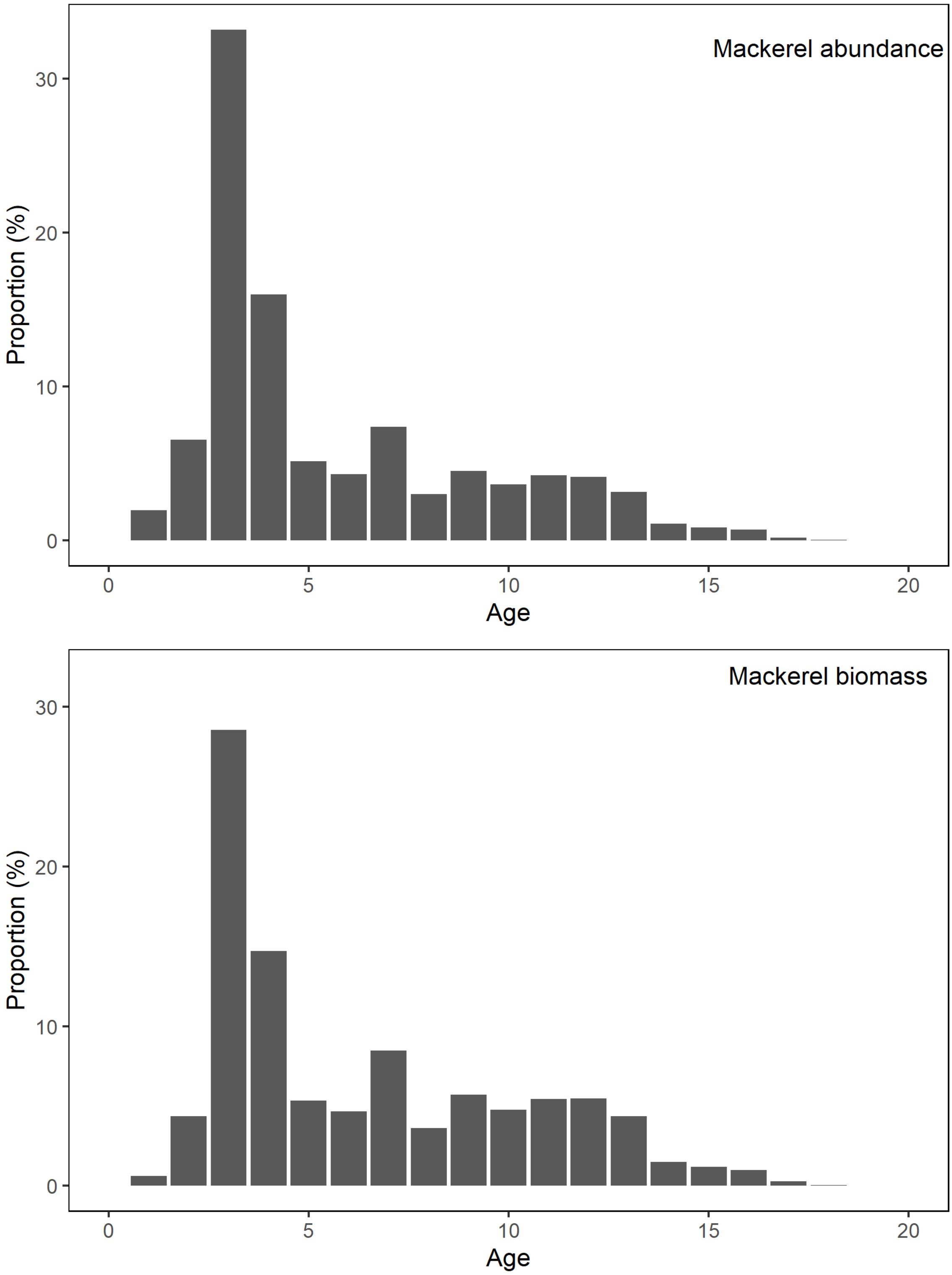


Figure 13. Mackerel age distribution in numbers (%) and in biomass (%) from IESSNS 2023.

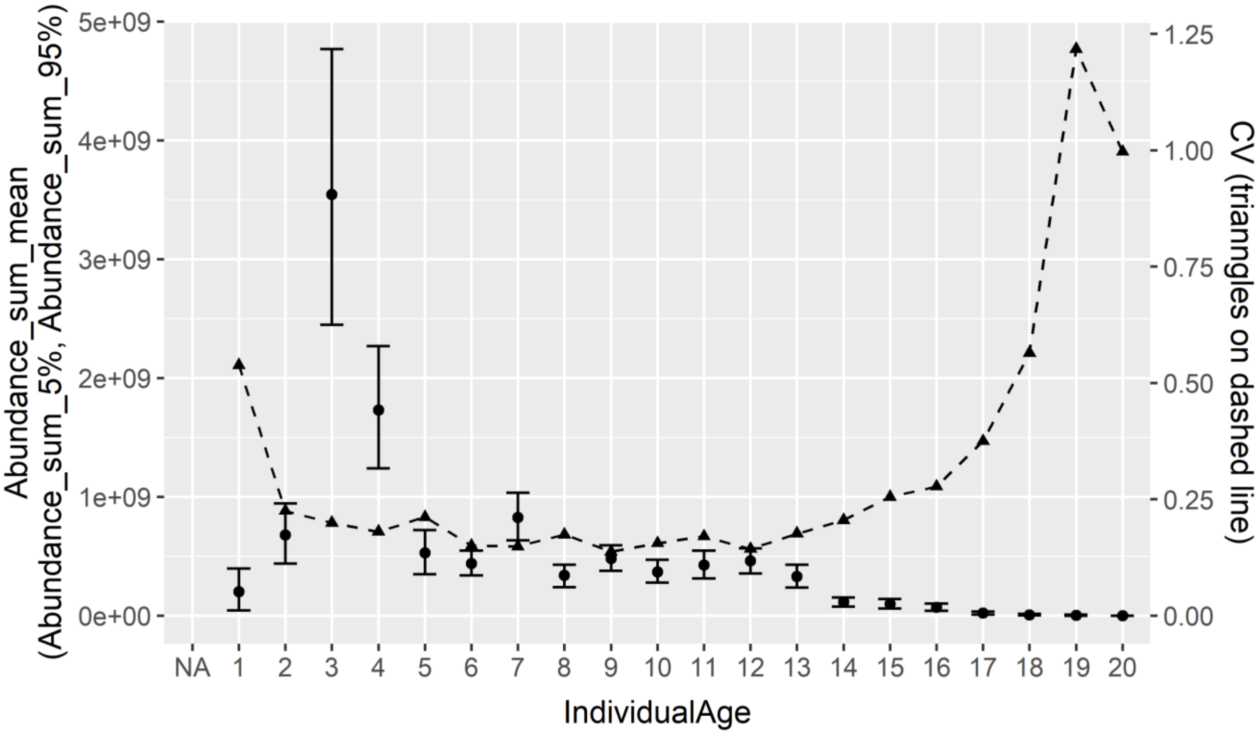


Figure 14. Number by age for mackerel in 2023. Plot of abundance (5% percentile, mean, 95% percentile) and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

Table 7. a-d) StoX baseline (point estimate) time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (grams) per age, (c) estimated biomass at age (million tonnes) in 2007 and from 2010 to 2023, and (d) estimates of abundance, biomass and mean weight by age and length.

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
2021	0.09	2.13	0.71	1.22	1.53	0.37	1.29	0.81	1.05	0.97	0.93	0.46	0.34	0.33	12.22
2022	0.02	3.91	2.36	0.94	1.31	1.04	0.60	0.96	1.00	1.86	1.61	0.90	0.56	0.45	17.51
2023	0.21	0.70	3.54	1.70	0.55	0.46	0.79	0.32	0.48	0.39	0.45	0.44	0.34	0.30	10.67

b)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13
2007	133	233	323	390	472	532	536	585	591	640	727	656	685
2010	133	212	290	353	388	438	512	527	548	580	645	683	665

2011	133	278	318	371	412	440	502	537	564	541	570	632	622
2012	112	188	286	347	397	414	437	458	488	523	514	615	509
2013	96	184	259	326	374	399	428	445	486	523	499	547	677
2014	228	275	288	335	402	433	459	477	488	533	603	544	537
2015	128	290	333	342	386	449	463	479	488	505	559	568	583
2016	95	231	324	360	371	394	440	458	479	488	494	523	511
2017	86	292	330	373	431	437	462	487	536	534	542	574	589
2018	67	229	330	390	420	449	458	477	486	515	534	543	575
2019	153	212	325	352	428	440	472	477	490	511	524	564	545
2020	99	213	315	369	394	468	483	507	520	529	539	567	575
2021	140	253	357	377	409	451	467	487	497	505	516	523	544
2022	125	263	330	408	438	431	462	508	525	519	531	531	549
2023	128	269	347	371	416	435	462	484	506	526	517	533	557

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
2021	0.01	0.54	0.25	0.46	0.62	0.17	0.60	0.39	0.52	0.49	0.48	0.24	0.18	0.19	5.15
2022	0.00	1.03	0.78	0.39	0.57	0.45	0.28	0.49	0.52	0.97	0.85	0.48	0.31	0.26	7.37
2023	0.03	0.19	1.23	0.63	0.23	0.20	0.36	0.16	0.24	0.20	0.23	0.24	0.19	0.17	4.30

*In 2011 the northern part of the Norwegian was not surveyed, hence the index for that year is not representative of mackerel stock size. See IESSNS 2011 cruise report for details.

d) Length (cm)	Age in years (year class) 1 2022	2 2021	3 2020	4 2019	5 2018	6 2017	7 2016	8 2015	9 2014	10 2013	11 2012	12 2011	13+	NA	Number (10^6)	Biomass (10^6 kg)	Mean weight (g)
17-18														<1	<1	<1	37.5
18-19														1	1	<1	47.0
19-20	3														3	<1	50.9
20-21	7														7	<1	64.1
21-22	9														9	<1	75.8
22-23	9														9	1	91.7
23-24	46														46	1	102.5
24-25	44		2												46	5	111.6
25-26	31														31	5	124.0
26-27	27														27	4	145.5
27-28	16														16	4	166.7
28-29		26													26	3	193.7
29-30	11	96													108	5	219.8
30-31		185	18												202	24	247.5
31-32		194	56												250	50	276.2
32-33	3	75	597	84											760	69	311.4
33-34		100	1307	216	19	3									1 645	237	337.9
34-35		20	1122	611	26	15	17	1							1 812	556	360.5
35-36	3	1	346	537	153	65	25		5						1 135	653	389.1
36-37			87	189	217	149	172	29	9		2	5			858	441	414.5
37-38			3	62	99	155	325	97	68	41	16	29	16		912	356	456.0
38-39			0	4	19	60	172	131	184	97	170	131	96		1 063	416	491.3
39-40			2		16	12	63	43	124	166	158	131	161		877	522	532.6
40-41		0				1	13	20	88	64	78	95	185		545	467	560.8
41-42									6	12	17	37	129		201	306	600.8
42-43										7	8	9	40		65	121	639.4
43-44												3	11		14	42	675.8
44-45													2		2	10	740.5
45-46														<1	<1	1	821.5
NA														<1	<1	<1	0.0
TSN(mill)	211.3	696.6	3 539.6	1 703.2	548.7	460.3	786.8	321.3	482.9	387.5	450.2	441.0	640.3	1.1	10 670.7	4298	
TSB(1000 t)	27.0	187.4	1 227.6	632.4	228.7	200.2	363.5	155.7	244.6	203.9	233.0	235.2	358.8	0.4	4 298		
Mean length(cm)	24.5	30.8	33.4	34.4	35.9	36.5	37.1	37.8	38.5	38.8	38.8	39.0					
Mean weight(g)	128	269	347	371	416	435	462	484	506	526	517	533					

Table 8. Bootstrap estimates from StoX (based on 1000 replicates) of mackerel in 2023. 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	45.6	192.5	395.4	200.2	107.7	0.54
2	439.9	672.8	943.7	677.5	152.4	0.22
3	2449.2	3526.3	4768.9	3544.2	706.9	0.20
4	1240.4	1715.4	2267.2	1728.9	311.6	0.18
5	350.0	521.1	721.1	529.5	112.1	0.21
6	337.7	438.1	548.6	439.8	66.1	0.15
7	633.0	818.3	1034.3	826.4	122.7	0.15
8	240.7	340.6	429.3	338.6	58.9	0.17
9	378.2	480.0	591.7	481.4	65.9	0.14
10	278.4	366.8	469.4	368.7	57.4	0.16
11	311.9	423.1	548.0	426.7	72.6	0.17
12	355.3	460.4	567.8	462.4	66.2	0.14
13	235.7	326.2	428.1	328.4	57.8	0.18
14	77.3	115.1	154.6	115.9	23.8	0.21
15	59.8	97.5	141.4	99.0	25.2	0.25
16	40.2	70.6	102.8	70.3	19.5	0.28
17	9.1	20.8	34.8	21.1	7.9	0.37
18	1.6	6.4	14.2	6.8	3.8	0.56
19	0.2	1.3	7.8	2.2	2.7	1.22
20	0.0	0.3	0.9	0.3	0.3	1.00
TSN	8590	10680	13081	10680	1344	0.13
TSB	3.50	4.28	5.21	4.30	0.51	0.12

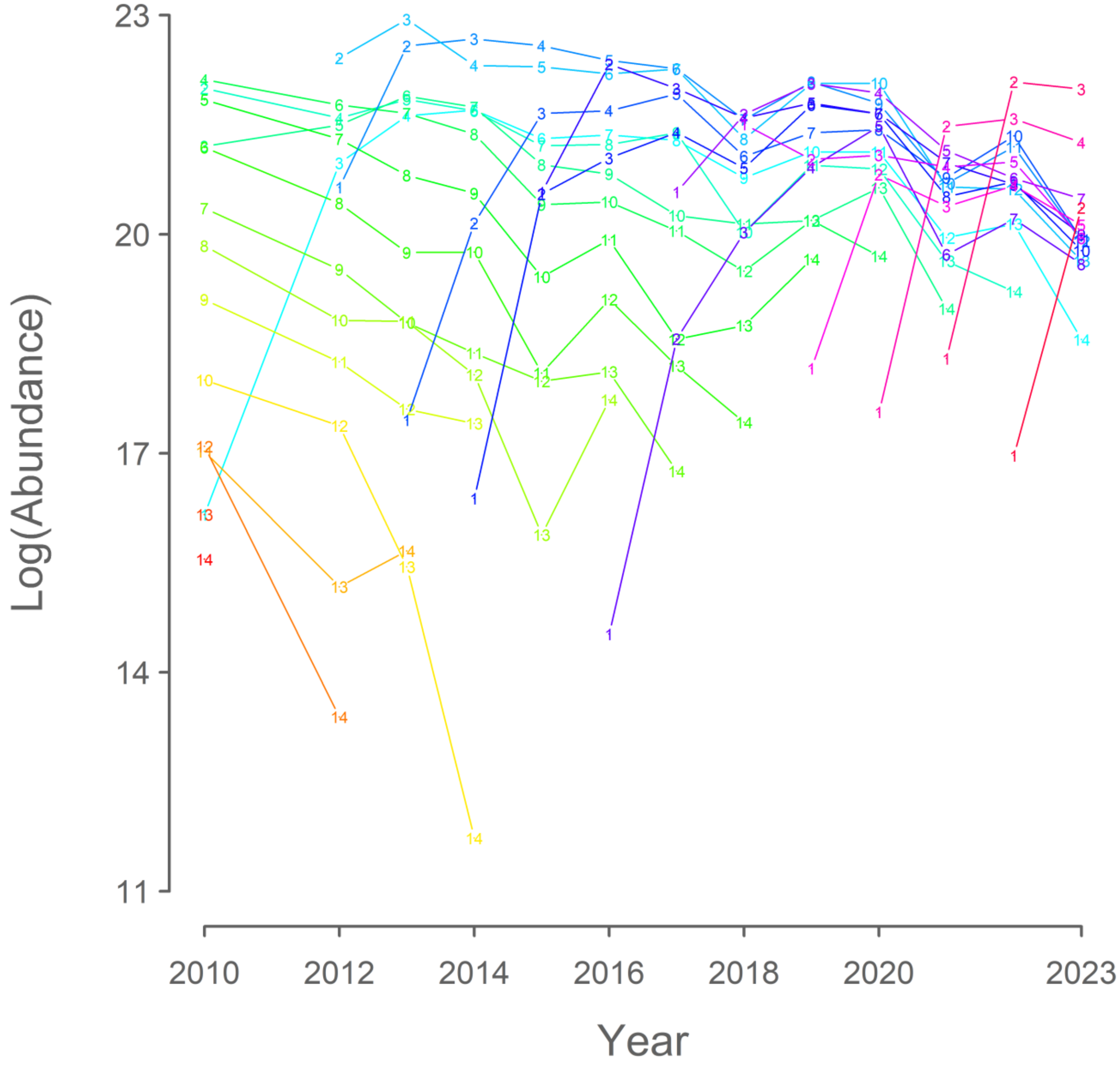


Figure 15. Catch curves for the years 2010; 2012-2023. Each cohort of mackerel is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

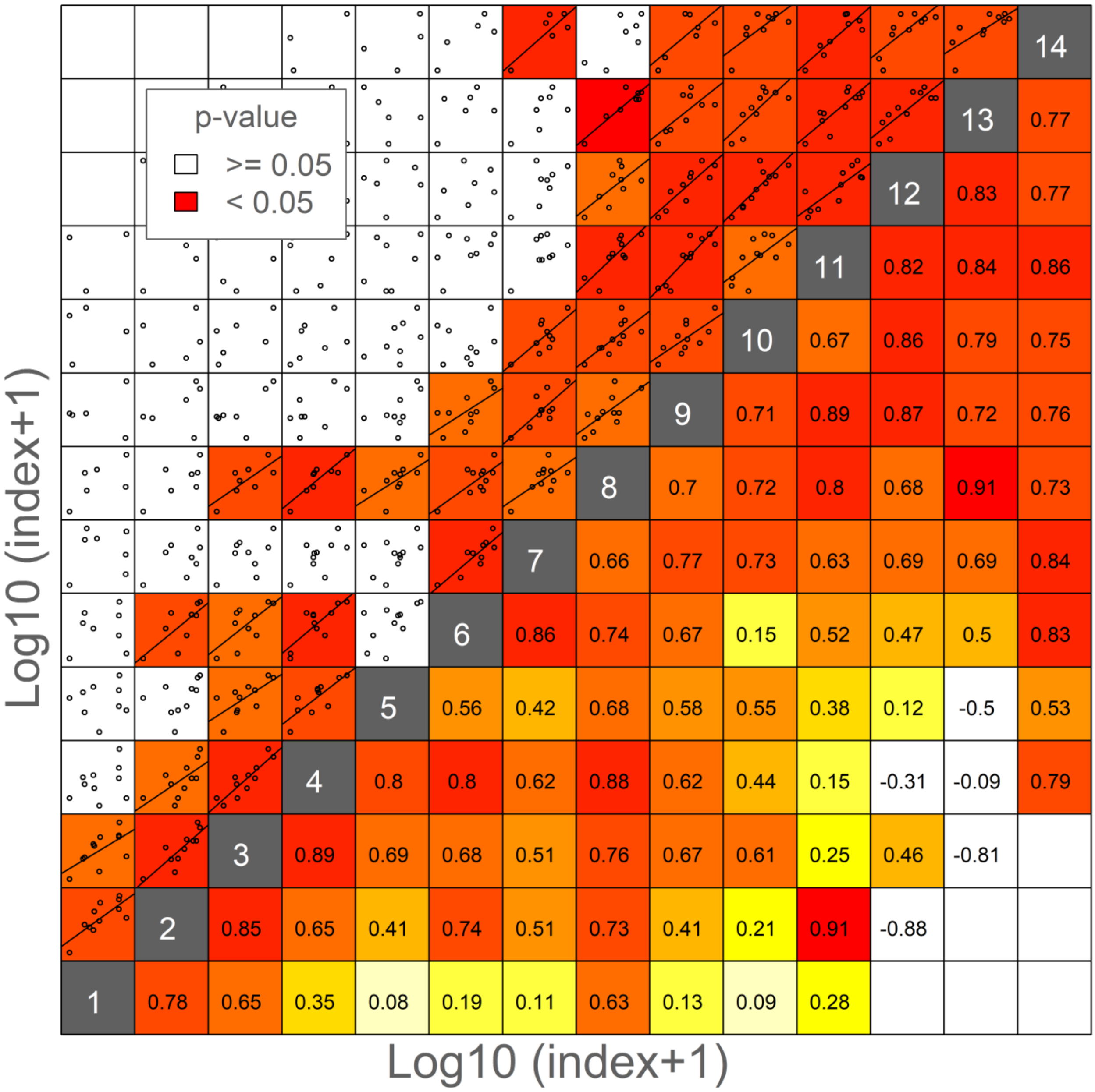


Figure 16. Internal consistency of the of mackerel density index from 2012 to 2023. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

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. mackerel may be distributed below the footrope 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, such that it covers the southwestern waters south of 60°N, e.g. UK waters.

The standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 63.7-71.7 m; 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.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring (Figure 11). This overlap occurred mostly between mackerel and Norwegian spring-spawning herring (NSSH) in the western, north-western and north-eastern part of the Norwegian Sea.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southwestern (east and north of Iceland), central and northern part of the Norwegian Sea basin (Figure 17a). The acoustic registrations in the eastern parts of the Norwegian Sea were low. Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring, while the herring to the south and west in Icelandic waters (west of 14°W south of Iceland) were allocated to Icelandic summer-spawners – these were removed from the biomass estimation of NSSH (Figure 17b).

The total number of NSSH recorded during IESSNS 2023 was 26.1 billion and the total biomass index was 5.0 million tonnes, or 6.5% higher abundance and 30% lower biomass than 2022.

The 2016 year-class (7-year-olds) dominated in the stock and contributed 45% and 28% to the total biomass and total abundance, respectively, whereas the 2020 year-class (3-year-olds) contributed 17% and 24% to the total biomass and total abundance, respectively (Figure 18 and Table 9). However, this age group is most likely overestimated due to lack of biological sampling (age samples) in the northeastern part of the survey area. This area was dominated of very small individuals and the age sampling of these were not representative. The 2016 year-class is fully recruited to the adult stock, whereas the younger fish is not recruited to the adult stock and very uncertain.

Bootstrap estimates of numbers by age are shown in Figure 18. The uncertainty (CV) around the age disaggregated abundance indices from the 2023 survey was very low, except for the dominating 7-year-olds (2016-year class) and again the high estimate of the 2020 year-class is an artifact. (Figure 18).

The internal consistency among year classes was generally very high for age classes 4 years and older, with the lowest correlation, for the youngest year classes, as expected since they are not fully recruited into the survey (Figure 19).

The zero boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. The herring was mainly observed in the upper surface layer as relatively small schools. This shallow distribution of herring might have led to an unknown portion of herring being in the "blind zone" above the transducer depth of the vessels (i.e., shallower than 10-15 m, Table 4), and therefore not being registered by the vessels. The group considered the acoustic biomass estimate of herring in 2023 to be of the similar quality as in the previous survey years.

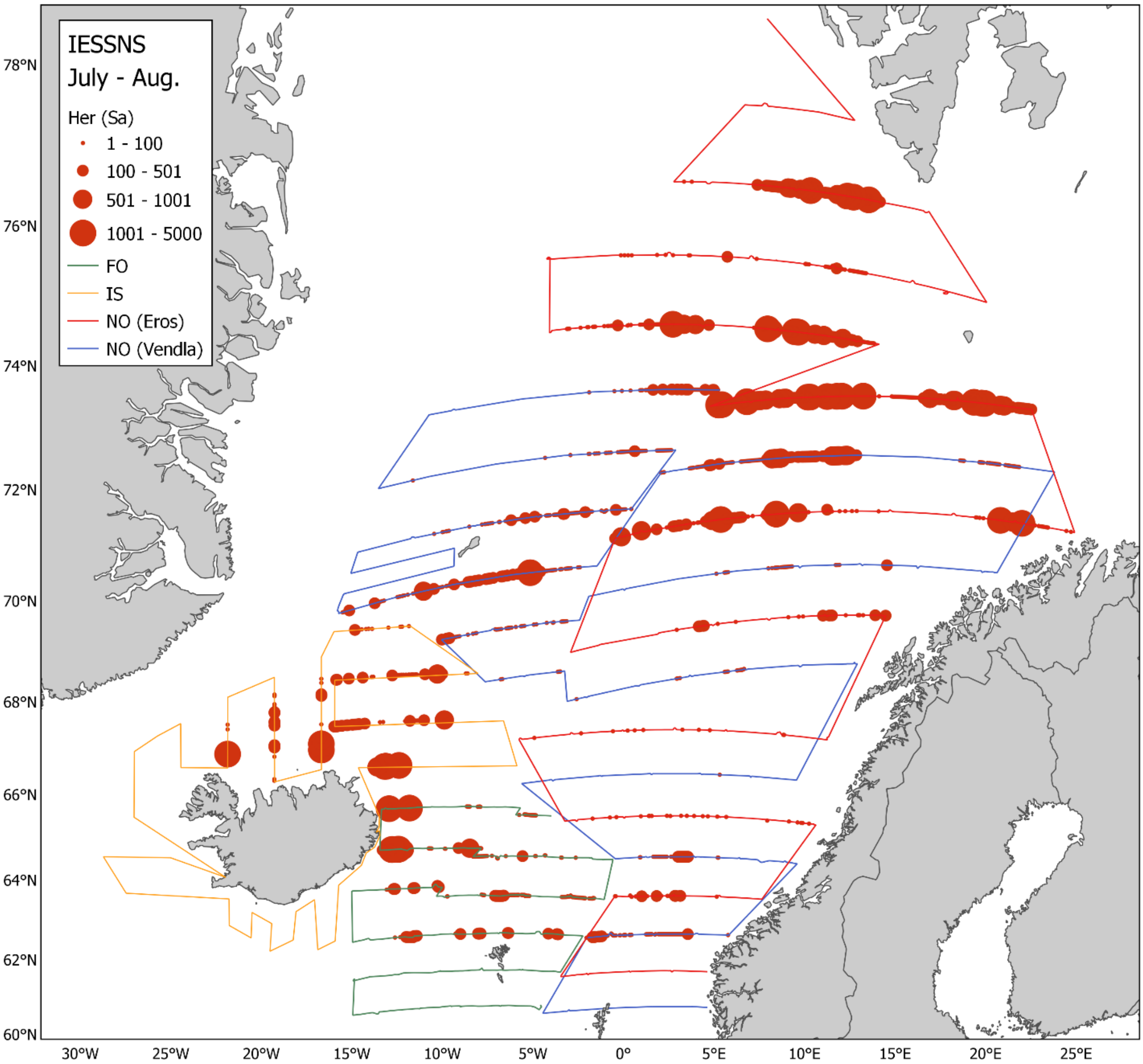


Figure 17a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2023 presented as contour lines. Values north of 62ºN, east of 14ºW to the south of Iceland, and all herring north of Iceland are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Icelandic summer spawners, Faroese autumn spawners and North Sea herring in the southeast.

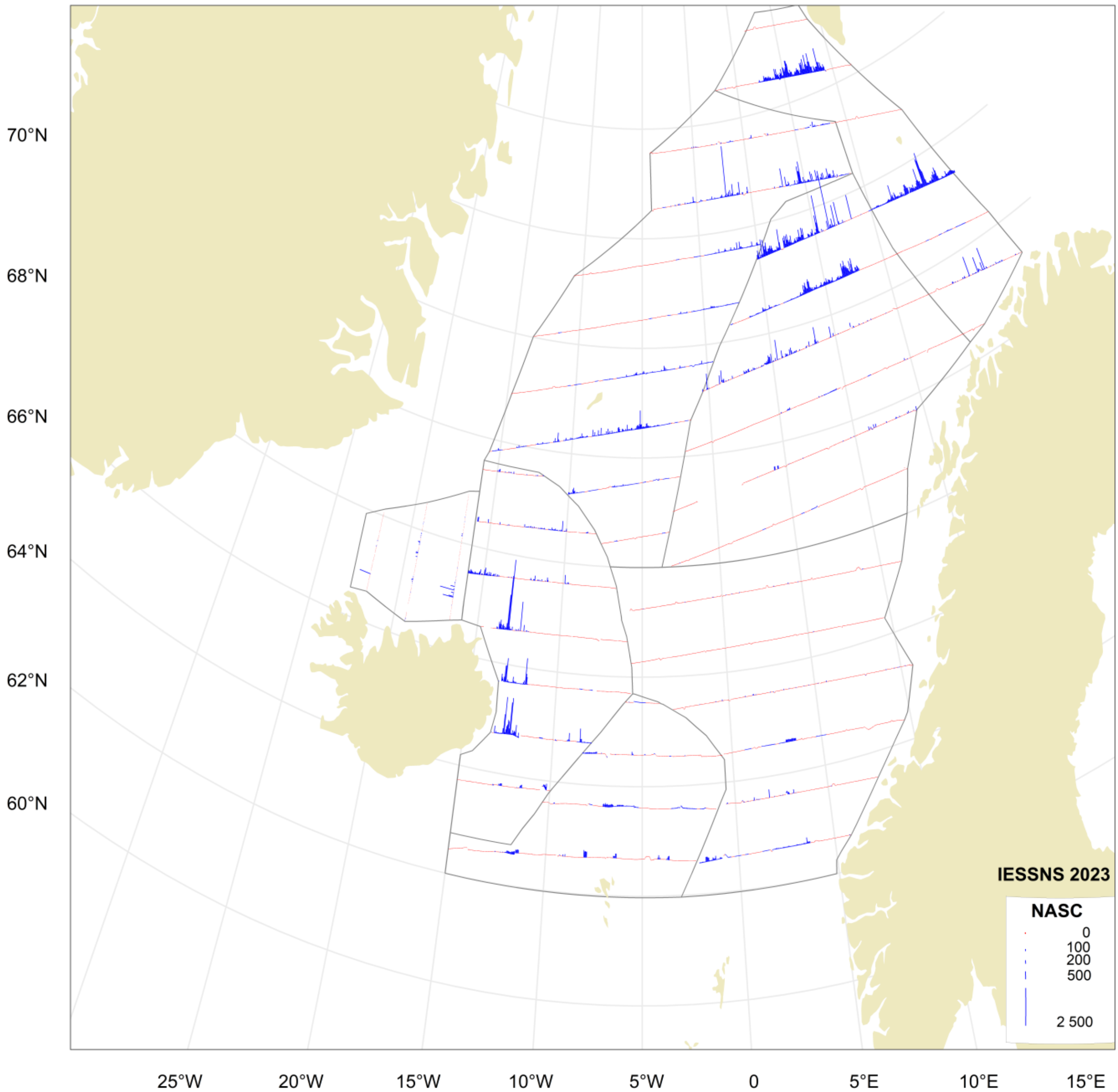


Figure 17b. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring along the cruise tracks in 2023, presented as bar plot.

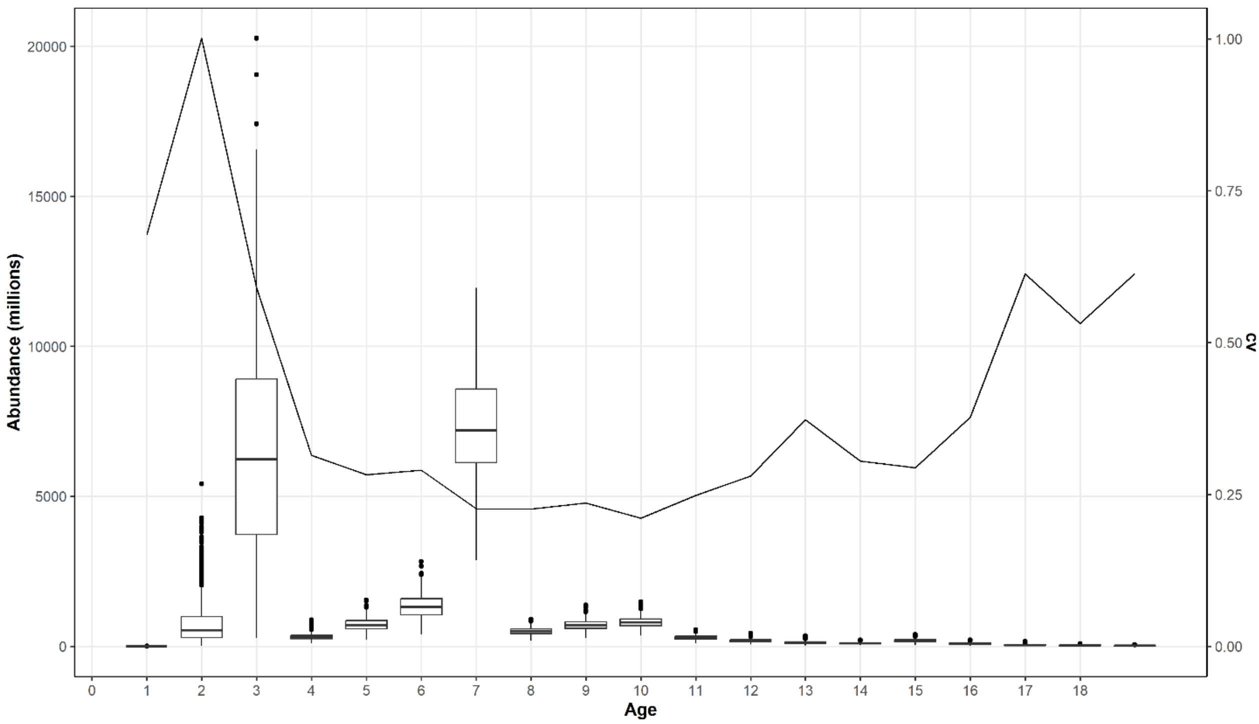


Figure 18. Abundance by age for Norwegian spring-spawning herring during IESSNS 2023. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software. The high estimate of the 3-year-olds (2020 year-class) is an artifact (see text for more information).

Table 9. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX (bootstrap) for IESSNS 2023.

Length (cm)	Age in years (year class) 1 2021	2 2020	3 2019	4 2018	5 2017	6 2016	7 2015	8 2014	9 2013	10 2012	11 2011	12 2010	13 2009	14 2008	15 2007	16 2006	17 2005	18 2004	Number (10^6)	Biomass (10^6 kg)	Mean weight (g)
9-10	1123,1																		1 123,1	5,6	5,0
10-11	1053,5																		1 053,5	7,7	7,4
11-12	1764,6																		1 764,6	17,0	9,7
12-13	1901,7																		1 901,7	23,4	12,3
13-14	191,0																		191,0	2,7	15,8
14-15																					
15-16																					
16-17		27,7																	27,7	1,4	33,4
17-18																				0,1	38,0
18-19	0,3																		0,3	0,0	47,0
19-20		3,5																	3,5	0,2	56,0
20-21		0,8	259,9																260,7	15,3	69,8
21-22																				0,2	90,0
22-23		26,8	14,7																41,6	4,5	93,6
23-24		162,9	346,2	14,1															523,2	55,8	109,4
24-25		238,8	1997,0																2 235,8	259,6	120,7
25-26		344,3	2327,7	19,9															2 691,9	345,6	135,4
26-27		12,5	493,9	26,5	2,0	2,7													537,6	80,8	163,3
27-28			336,4	31,6	29,8	5,2	4,3	2,0											409,4	70,6	184,1
28-29			282,4	33,4	27,7	17,2	7,3	8,4	1,7	1,7									379,7	74,2	208,1
29-30			167,4	41,1	62,8	19,2	15,5	1,5	5,5	6,9	2,0	3,7		1,0					326,6	75,2	230,4
30-31			120,4	60,0	149,3	48,5	13,9	6,3	5,0	21,2	3,6	1,4	1,8						431,5	108,4	249,1
31-32			29,1	47,2	198,0	127,9	243,9	29,8	6,0	14,7									696,6	187,9	268,2
32-33			2,2	34,4	135,7	530,2	1769,4	32,8	15,6	18,2		13,9	4,3						2 556,9	737,9	286,8
33-34				13,1	97,2	383,4	3330,2	28,4	128,4	28,1	8,4	6,3							4 023,6	1228,8	304,1
34-35					22,2	148,8	1682,0	218,3	185,0	170,0	23,6	10,6							2 460,5	799,5	324,1
35-36						52,1	281,4	144,8	293,8	294,3	64,1	11,1		7,4	12,0			9,5	1 170,5	405,9	346,4
36-37							4,6	14,9	56,5	166,4	161,6	24,0	52,1	44,3	43,1	29,8			597,3	217,9	365,5
37-38							7,3	16,0	13,6	71,3	22,8	108,8	47,1	31,8	40,0	30,0	21,5	27,9	437,9	173,1	397,4
38-39										11,0	4,5	8,1	14,3	17,7	78,6	19,2	14,8		168,3	70,7	422,4
39-40										3,0			3,2		6,1	15,1	5,0	10,2	42,5	17,8	429,0
40-41																		4,1	4,1	2,1	522,2
41-42																					
42-43																					
TSN(mill)	6034,3	817,4	6377,1	321,3	724,6	1335,1	7359,8	503,3	711,2	806,9	290,7	188,0	122,9	102,3	179,8	94,1	41,3	51,6	26 061,6		
cv (TSN)	1,09	1,00	0,59	0,31	0,28	0,29	0,23	0,23	0,24	0,21	0,25	0,28	0,37	0,30	0,29	0,38	0,67	0,54	0,83		
TSB(1000 t)	56,4	94,9	845,5	72,6	190,8	390,9	2 245,2	162,5	242,7	280,0	103,5	70,3	48,7	38,7	71,8	36,5	17,2	20,6	4 988,9		
cv (TSB)	1,09	1,06	0,57	0,31	0,29	0,29	0,23	0,23	0,24	0,21	0,25	0,29	0,36	0,30	0,30	0,38	0,67	0,54	0,20		
Mean length(cm)	18,0	23,1	27,5	28,9	30,5	32,2	33,0	33,5	34,2	34,8	35,3	36,0	36,6	36,5	37,4	37,4	37,6	37,8			
Mean weight(g)	47,0	111,4	193,7	226,3	256,9	288,8	303,3	313,9	336,0	344,8	353,9	377,2	403,1	385,0	405,6	390,2	424,1	401,6			

Table 10. IESSNS bootstrap time series (mean of 1000 replicates) from 2016 to 2023. StoX biomass estimates of Norwegian spring-spawning herring (millions).

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	TSB(1000 t)
2016	38	119	747	577	1 622	1 636	1 967	1 588	1 274	2 001	2 164	6 245	6 676
2017	1 232	240	1 318	4 653	1 003	1 184	795	1 716	1 004	1 115	1 657	4 040	5 821
2018	0	587	656	864	3 054	924	1 172	746	971	1 078	663	2 704	4 379
2019	0	143	1 910	616	1 101	3 487	814	751	510	780	470	4 660	4 794
2020	0	15	117	8 280	1 710	2 367	4 087	696	520	305	594	1 827	5 991
2021	1	4	184	398	12 117	1 045	1 398	2 226	502	361	393	1 641	6 103
2022	0	681	1 008	1 251	1 301	14 135	914	1 211	1 734	477	433	1 325	7 143
2023	6 034	817	6 377	321	725	1 335	7 360	503	711	807	291	780	4 989

Table 11. IESSNS baseline time series from 2016 to 2023. StoX biomass estimates of Norwegian spring-spawning herring (millions).

Year	Age 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
2021	1	3	196	388	11 988	1 109	1 342	2 292	491	365	386	1 649	6 085
2022	0	724	984	1 225	1 339	14 071	960	1 172	1 762	434	432	1 329	7 135
2023	6 030	683	7 141	293	753	1 272	7 339	520	692	855	280	811	5 056

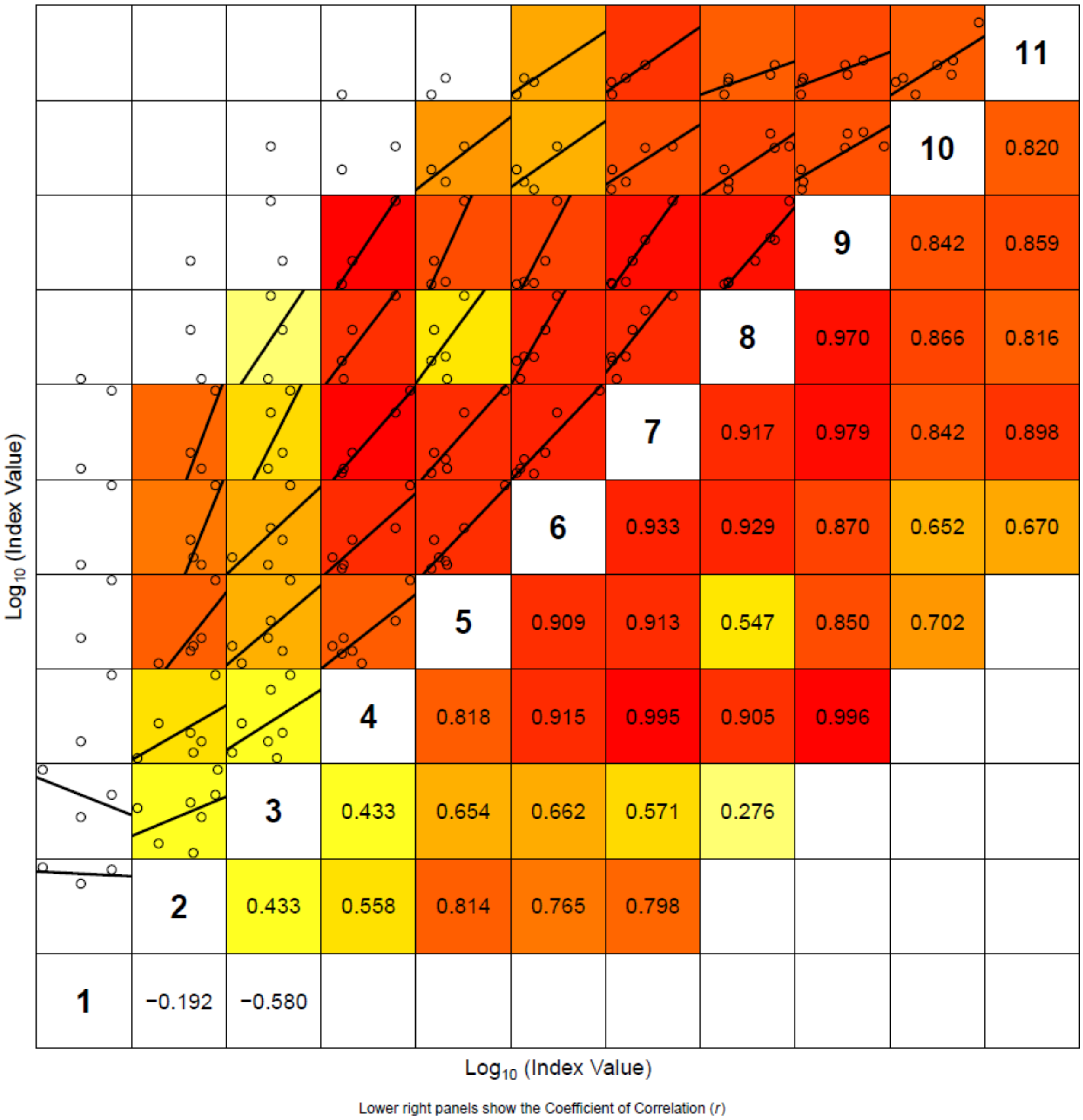


Figure 19. Internal consistency for Norwegian spring-spawning herring within the IESSNS 2023. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows 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 parts of the survey area dominated by warm Atlantic waters and had a continuous distribution from the southern boundary of the survey area (60 °N) to Spitsbergen (76 °N). High blue whiting density (sA-values) was observed in the southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands, and southeast of Iceland. Concentrations of older fish (age4+) were low, as in the previous years. Low recruitment in the years before 2020 is the main reason for this. As in previous years no blue whiting was registered in the cold East Icelandic Current, between Iceland and Jan Mayen.

The total biomass index of blue whiting registered during IESSNS 2023 was 2.0 million tons (Table 12), which is about the same level as in 2022. Estimated stock abundance (ages 1+) was 20.8 billion compared to 27.5 billion in 2022. Age 3 and 2, respectively, dominated the estimate in 2023 as they contributed to 41% and 23% (abundance) and 45% and 29% (biomass), respectively. This year the 0-group was again significant in this survey (Table 13).

Bootstrap estimates of numbers by age, with uncertainty estimates, for blue whiting during IESSNS 2023 are shown in Figure 21. The baseline point estimates from 2016-2023 are shown in Table 13. The internal consistency among year classes is shown in Figure 22 and indicates very good internal consistency for ages 2-5, and moderate to low fit for other ages.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2023 IESSNS as in the previous survey years.

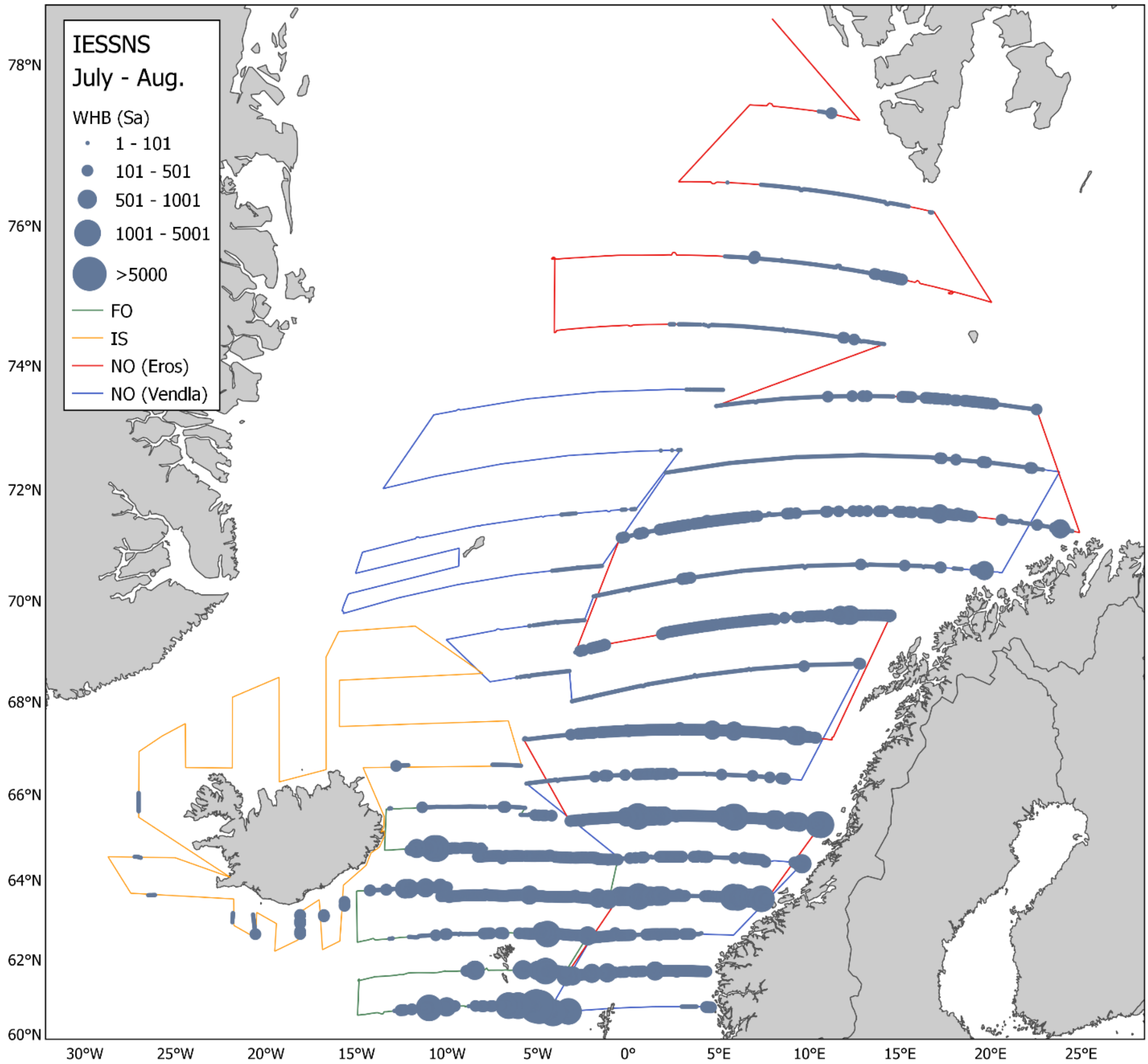


Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2023.

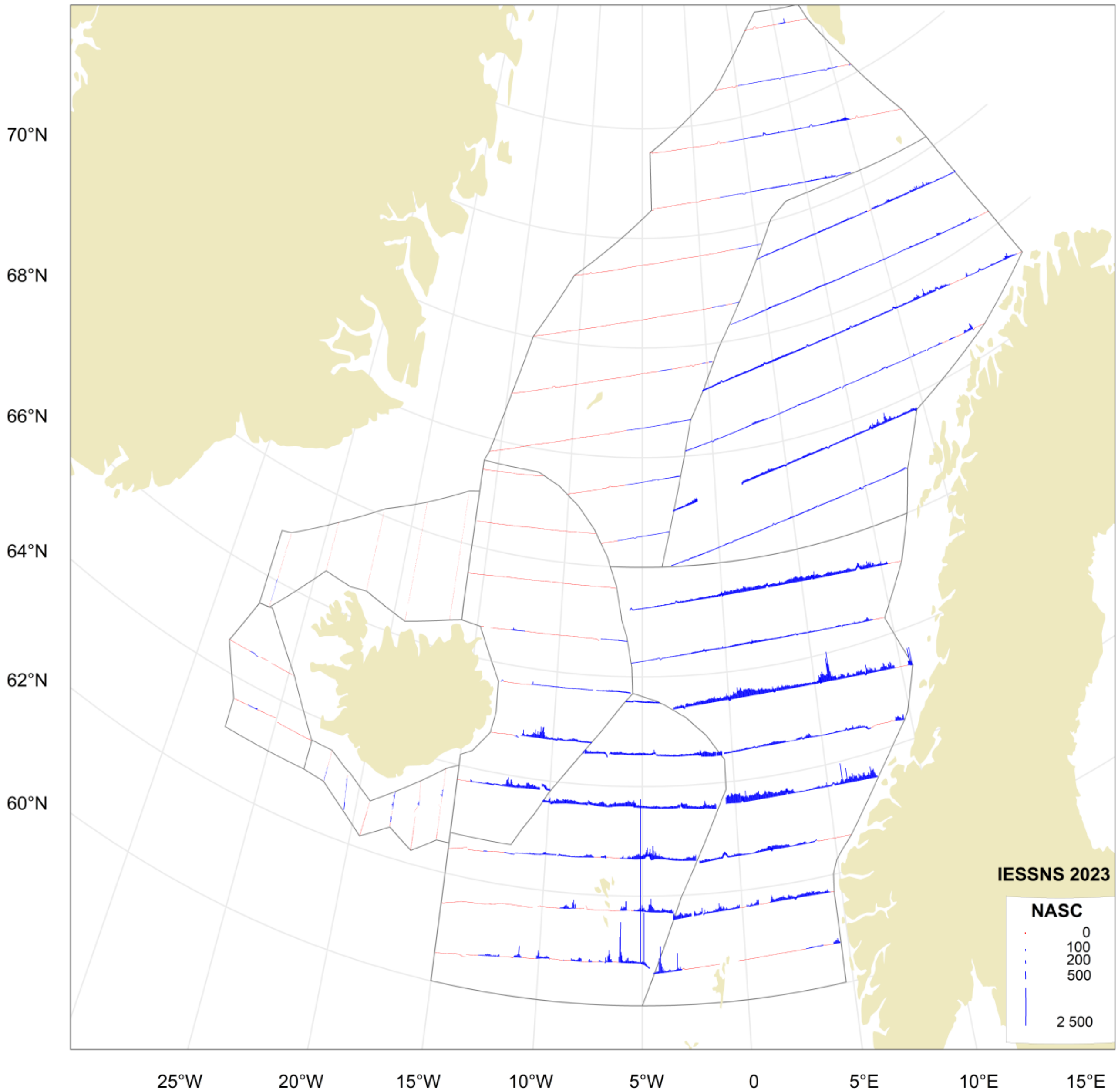


Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2023. Presented as bar plot.

Table 12. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX (bootstrap) for IESSNS 2023.

	Age in years (year class)													Number	Biomass	Mean
Length	0	1	2	3	4	5	6	7	8	9	10	11	12			weight
(cm)	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	(10^6)	(10^6 kg)	(g)
10-11	218,6													218,6	1,6	6,9
11-12	1052,6													1 052,6	8,5	8,6
12-13	1227,9													1 227,9	12,8	10,6
13-14	298,2													298,2	4,0	13,5
14-15	87,9													87,9	1,4	16,8
15-16	46,1													46,1	0,9	20,6
16-17	165,3													165,3	3,9	24,0
17-18	44,3													44,3	1,9	29,5
18-19																
19-20		149,8												149,8	5,6	35,3
20-21		226,4												226,4	11,9	50,5
21-22		1269,1	86,9											1 356,0	78,0	58,2
22-23		1076,7	227,0	59,7										1 363,4	91,0	68,1
23-24		1008,9	2131,7	45,3										3 186,0	246,2	79,2
24-25		34,2	3474,1	1093,6	18,7									4 620,7	398,2	90,2
25-26			2995,9	1745,5	124,8									4 866,1	464,5	100,1
26-27			736,4	1578,9	80,3	2,0	34,4							2 432,0	261,8	113,6
27-28			193,5	651,2	264,3	52,0								1 161,0	141,9	128,2
28-29			11,0	244,4	73,1	66,6	43,6							438,7	57,8	139,9
29-30			64,2	117,3	89,5	39,6		6,2		1,5				318,2	46,9	153,2
30-31			4,1	10,6	52,0	23,4	77,8	6,6		72,0				246,6	42,8	176,9
31-32				8,2	4,5		25,0	17,7	9,2	82,2		21,8		168,6	32,3	194,0
32-33					13,7	14,9	15,4	42,4		59,3				145,7	29,5	202,2
33-34								46,2	21,0	44,0				111,3	25,5	223,0
34-35								11,8	14,7	2,8		1,2	1,2	31,8	8,7	247,8
35-36										14,7				14,7	3,8	252,9
36-37																
37-38																
38-39																
39-40																
40-41										5,8				5,8	2,5	435,0
TSN(mill)	3141	3765	9925	5555	721	199	196	131	45	282		23	1	24 081,7		
cv (TSN)	0,71	0,37	0,18	0,17	0,24	0,39	0,46	0,47	0,72	0,64		0,89	1,15	0,17		
TSB(1000 t)	33,5	240,0	890,4	568,2	90,7	27,2	30,4	27,7	10,3	58,3		4,4	0,3	1 983,4		
cv (TSB)	0,65	0,35	0,17	0,16	0,23	0,39	0,43	0,50	0,74	0,65		0,91	1,11	0,14		
Mean length(cm)	12,8	22,0	25,1	26,0	27,7	28,6	29,4	31,7	32,1	31,7		31,9	34,0			
Mean weight(g)	14	68	104	114	138	142	164	200	216	200		204	285			

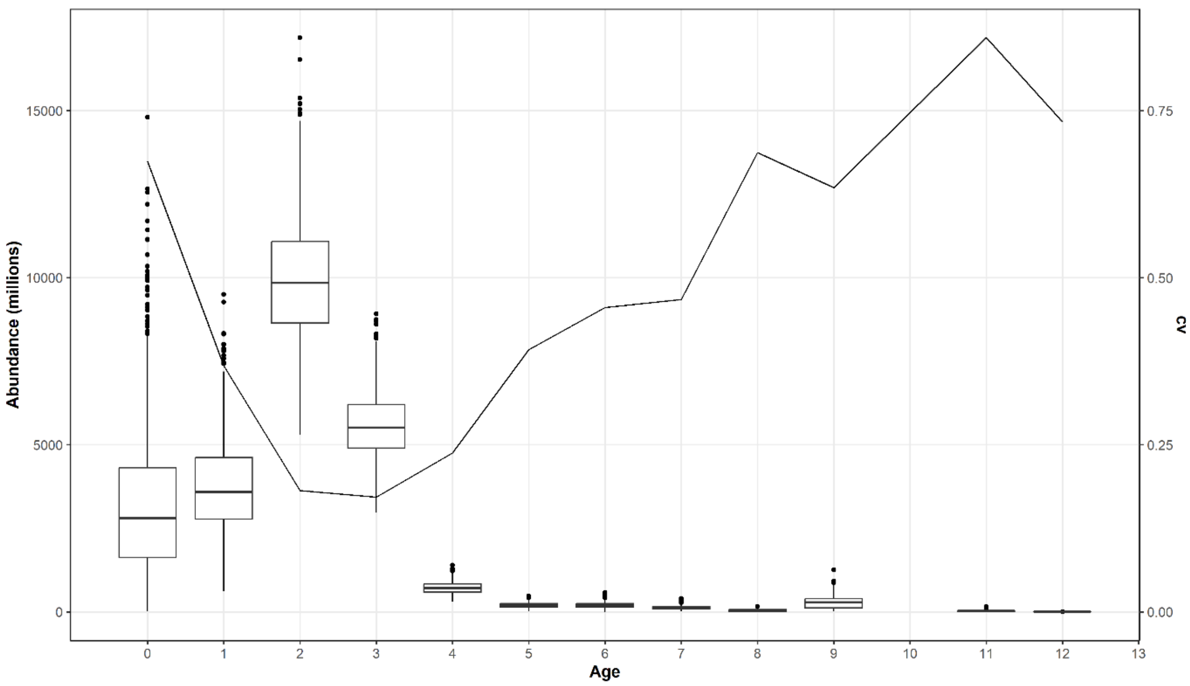


Figure 21. Number by age with uncertainty for blue whiting during IESSNS 2023. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

Table 13a. IESSNS baseline time series from 2016 to 2023. StoX biomass 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
2021	4 023	18 056	2 300	1 664	841	982	1 543	609	60	91	74	2 238
2022	978	12 454	9 773	2 279	904	314	520	303	678	177	71	2 241
2023	2 881	3 991	9 673	5 635	764	260	241	125	57	316	23	2 005

Table 13b. IESSNS bootsrap time series from 2016 to 2023. StoX biomass estimates of blue whiting (millions).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
2016	4 019	5 781	11 423	4 324	2 353	1 190	351	158	160	7	205	2 269
2017	20 547	2 423	5 901	10 066	2 172	626	238	15	29	0	17	2 618
2018	0	893	1 208	3 198	6 434	3 070	938	371	107	47	43	2 039
2019	2 471	704	1 906	2 254	4 317	5 318	1 174	181	186	9	9	2 023
2020	4 461	6 027	2 903	1 608	1 135	1 762	1 924	929	186	33	37	1 799
2021	4 470	18 484	2 372	1 494	845	851	1 493	635	71	79	84	2 237
2022	955	12 623	9 748	2 175	883	313	510	303	691	148	67	2 224
2023	3 141	3 765	9 925	5 555	721	199	196	131	45	282	24	1 983

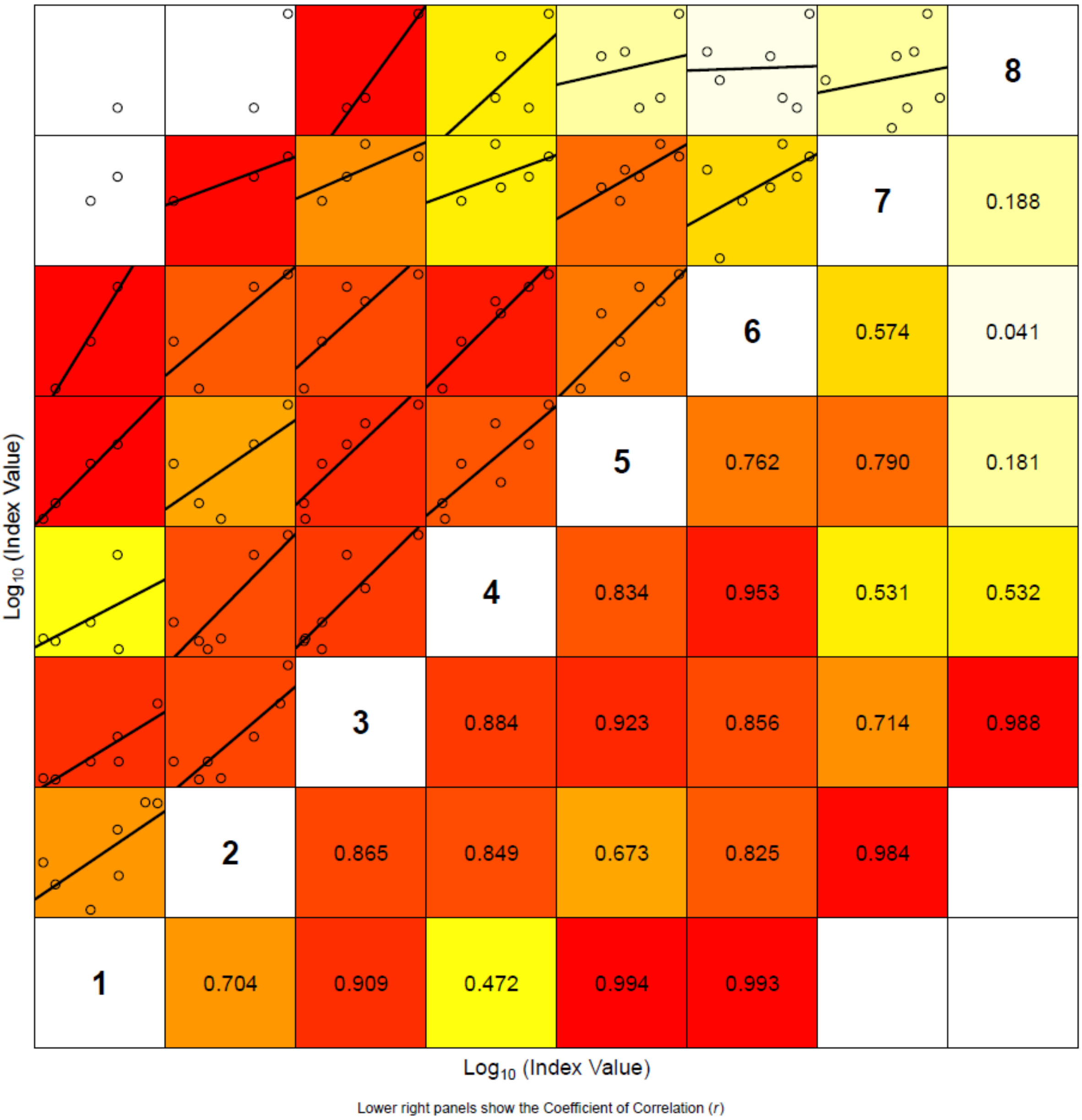


Figure 22. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (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 69% of trawl stations across the five vessels (Figure 23) and where lumpfish was caught, 70% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Iceland to the Barents Sea in the northeast, and into the North Sea in the southern part of the covered area. Abundance was greatest north of 71°N, with lower densities in the central Norwegian Sea and mostly absent directly south of Iceland, and south and southwest of the North Sea. The zero line was not hit to the northeast, northwest and west of the survey so it is likely that the distribution of lumpfish extends beyond the survey coverage.

The length of lumpfish caught varied from 4 to 51 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups (Figure 24). Only a small number of fish were sexed (115 of 1985) but for fish ≥20 cm in which sex was determined, the males (n=15) were 22-29 cm in length. The females (n=100) ranged in length from 21 to 46 cm. Generally, the mean length and mean weight of the lumpfish was highest in Faroese waters, and around Iceland and along the shelf edges of Norway and lowest in the central and northern Norwegian Sea.

A total of 374 fish (126 by R/V "Árni Friðriksson", 149 by M/V "Eros" and 99 by M/V Vendla) between 11 and 49 cm were tagged during the survey (Figure 25).

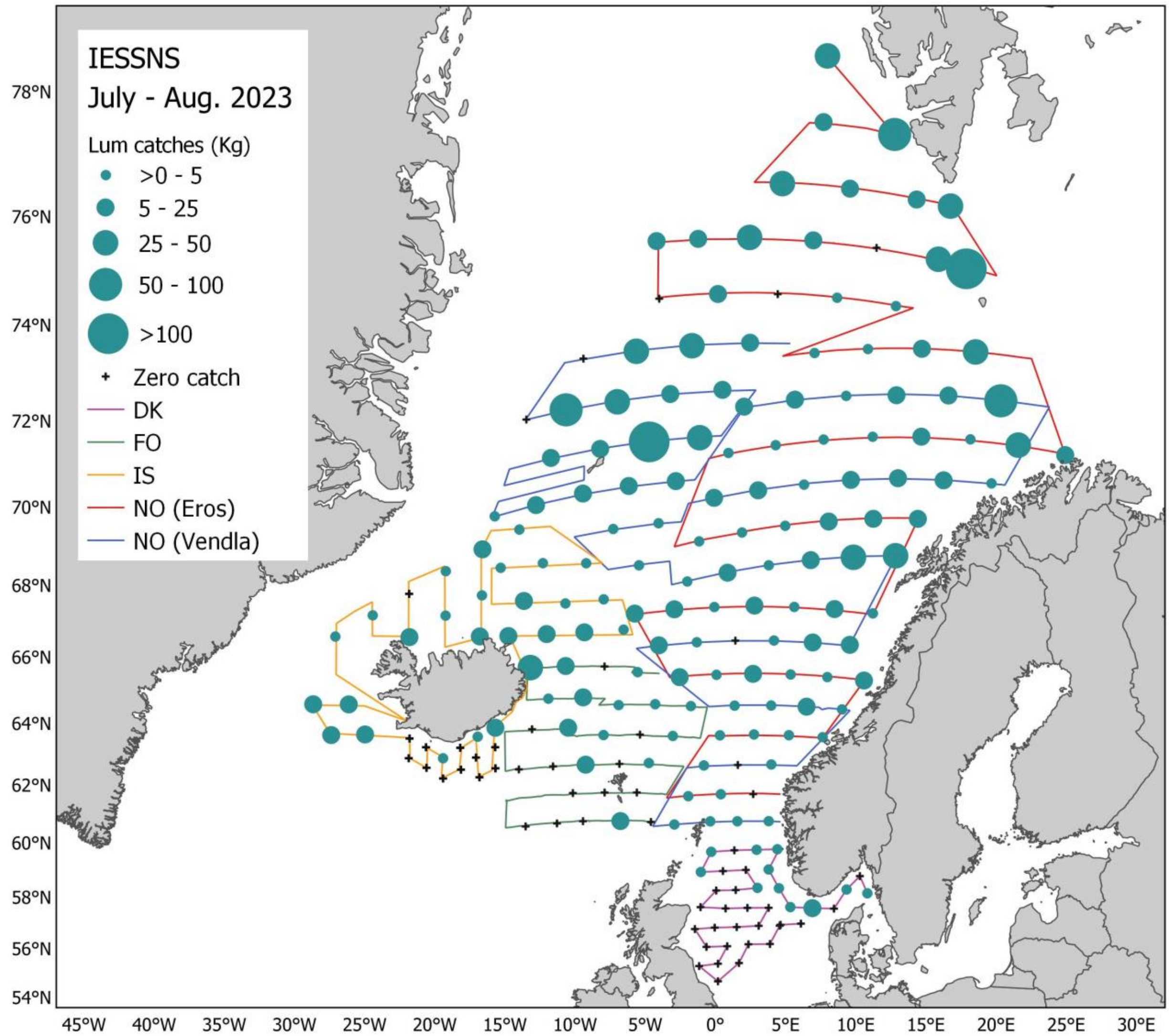


Figure 23. Lumpfish catches at surface trawl stations during IESSNS 2023.

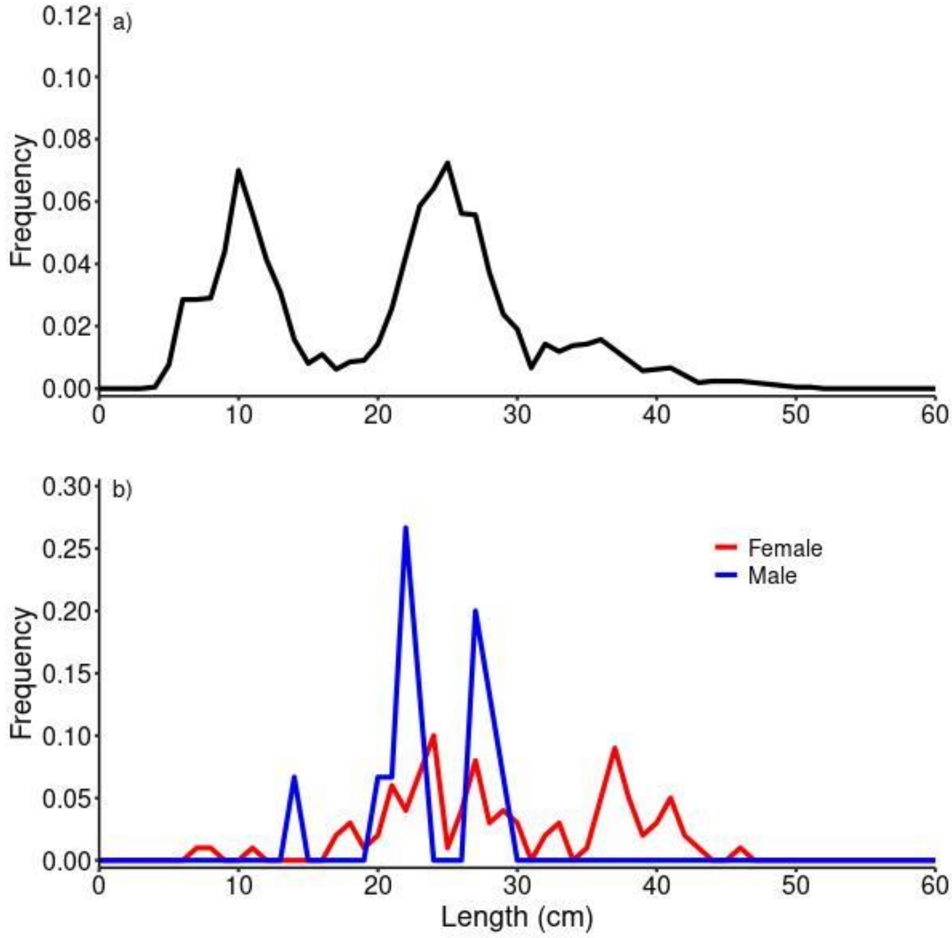


Figure 24. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

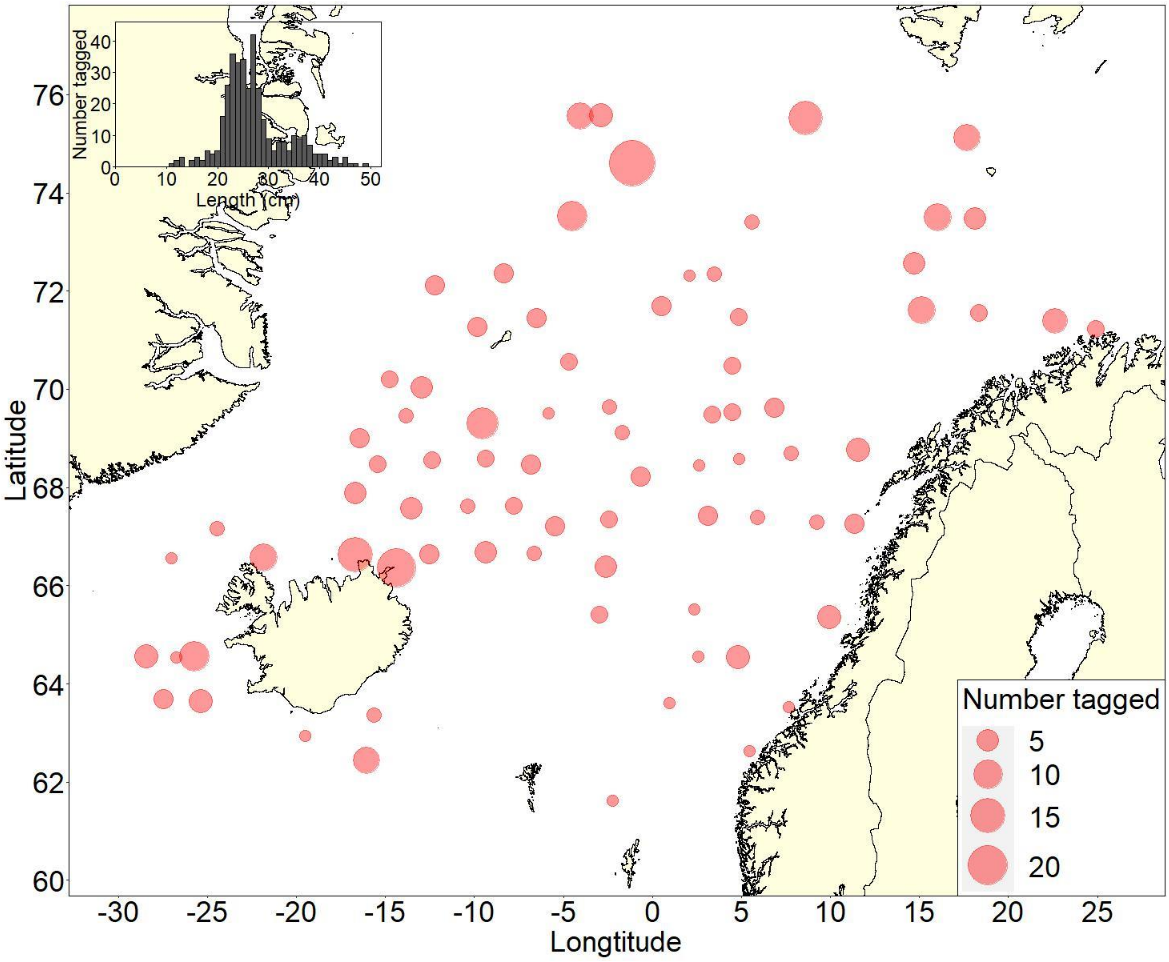


Figure 25. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 62 North Atlantic salmon were caught in 38 stations both in coastal and offshore areas from 62°N to 74°N in the upper 30 m of the water column during IESSNS 2023 (Figure 26). The salmon ranged from 0.084 kg to 2.7 kg in weight, dominated by post-smolt and 1 sea-winter individuals. We caught from 1 to 12 salmon during individual surface trawl hauls. The length of the salmon ranged from 20 cm to 82 cm, with the highest fraction between 20 cm and 29 cm.

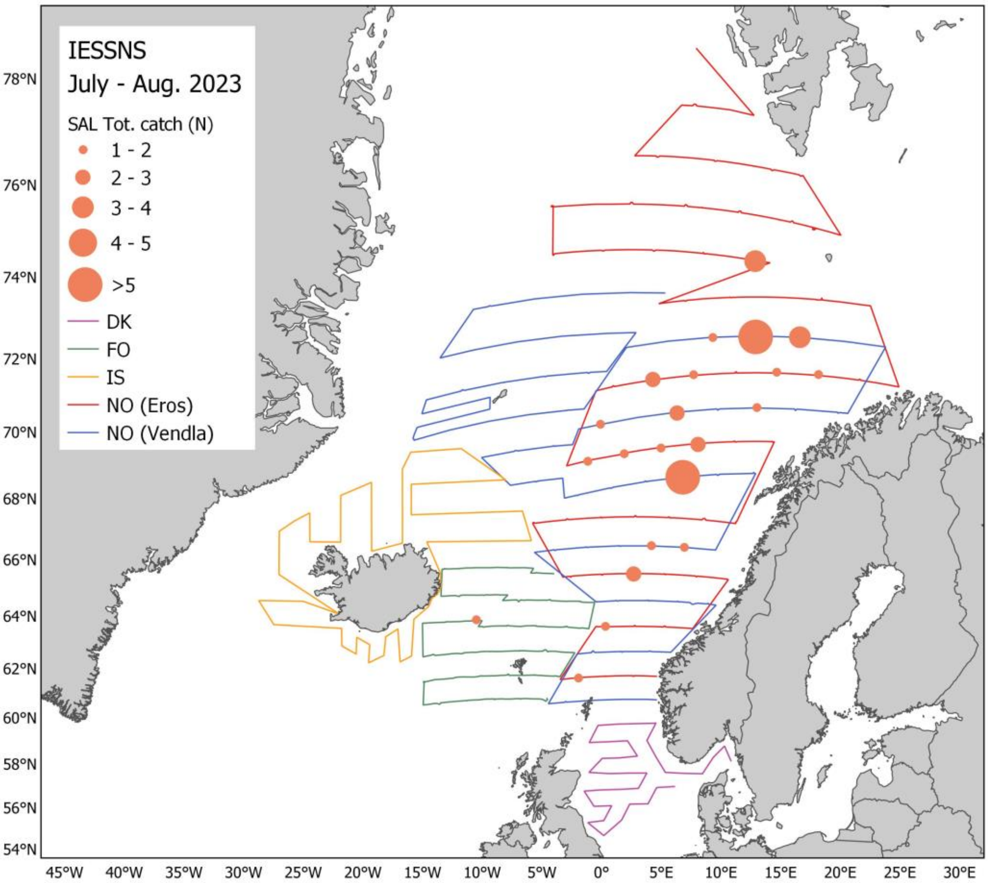


Figure 26. Catches of salmon at surface trawl stations during IESSNS 2023.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 29 stations along the cold fronts: North of Iceland, north-northwest of Jan Mayen, northwest of Bear Island and west of Svalbard (Figure 27a). Both juvenile and adult capelin were caught during the survey. The average length ranged from 6.9 to 18.8 cm and average weight ranged from 1,2 to 32.6 g in the trawl hauls. There were more pelagic trawl stations with catches of capelin in the western and northern part of the Jan Mayen.

Polar cod (*Boreogadus saida*)

Polar cod was caught in the surface trawl on 11 stations north and northeast of Iceland (Figure 27b). The catch weight per station ranged from 10 g to 5 kg. The polar cod ranged in total length from 9 cm to 20 cm and in total weight from 5 g to 36 g. Mean length was 13.2 cm (standard deviation = 1.5, n = 225) and mean weight was 15.3 g (standard deviation = 5.4, n = 224). Polar cod was caught in larger area and in greater abundance in 2023 compared to all previous years of the IESSNS survey, hence it was added to the report chapter on other species.

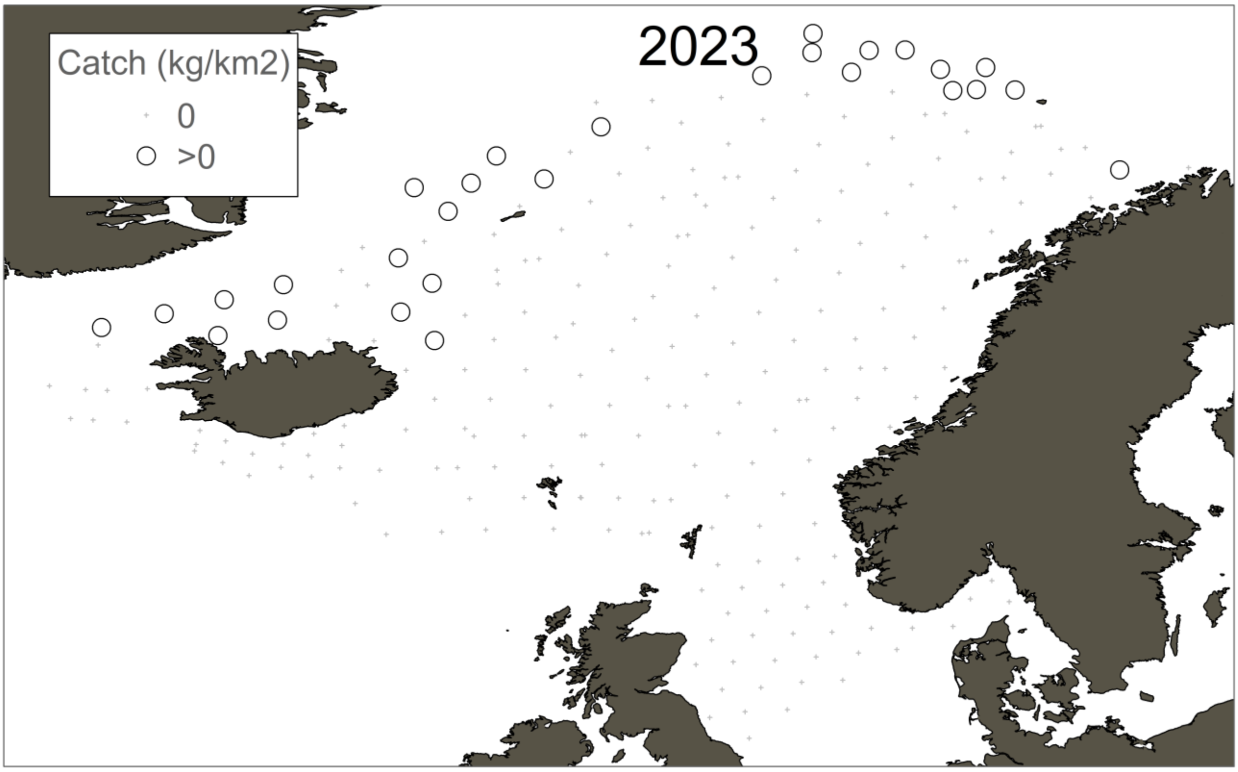


Figure 27a. Presence of capelin in surface trawl stations during IESSNS 2023.

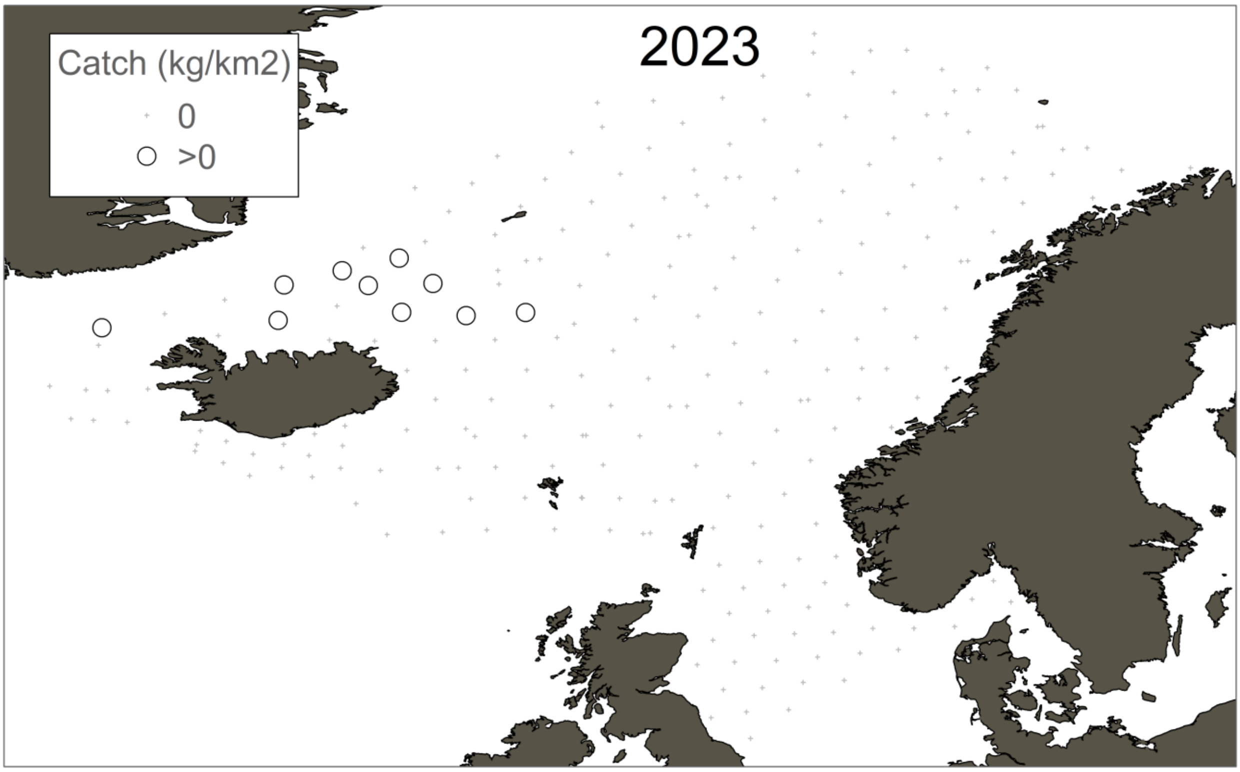


Figure 27b. Presence of polar cod in surface trawl stations during IESSNS 2023.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Eros" and M/V "Vendla" from Norway in addition to R/V "Jákup Sverri" from Faroe Islands from 1st July to 3rd August 2023 (Figure 28). Overall, 1078 marine mammals of 10 different species were observed, which was an increase from an overall 711 marine mammals observed in 2022.

The species that were observed included blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), Northern bottlenose whales (*Hyperoodon ampullatus)*, pilot whales (*Globicephala sp.*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), sei whales (*Baleanoptera borealis*), white sided dolphins (*Lagenorhynchus acutus*) white beaked dolphins (*Lagenorhynchus albirostris*). Basking sharks (*Cetorhinus maximus*) were also observed during the survey. The dominant number of marine mammal observations were found around along the continental shelf west and north of Jan Mayen and in the southwestern and western areas of Svalbard. We observed higher number of marine mammals in the central part of the Norwegian Sea in July 2023 compared with last year. Altogether eight blue whales were observed in the western and northern areas of Jan Mayen. They appeared either solitary or in groups of two individuals, and was most probably feeding on large swarms of amphipods in cold water. Fin whales (n = 82, group size = 1-20 (average group size = 2.5)) and humpback whales (n = 44, group size = 1-50 (average group size = 2.4)) dominated among the large whale species. They were distributed from 64°N to 78.30°N and from 25°E to 15°W and they had hotspot southwest and west of Svalbard as well as west and northwest of Jan Mayen. Few sperm whales (n = 8, group size = 1-2 (average group size = 1.3)) where observed. Killer whales (n = 56, group size = 1-10 (average groups size = 6.2)) dominated in the southern, north-eastern part of the Norwegian Sea, partly overlapping and presumably feeding on NEA mackerel in the upper water masses. Pilot whales (n = 112, group size = 5-100 (average groups size = 37)) where mostly observed in Faroese waters during IESSNS 2023. Five sei whale and 46 northern bottlenose whale were observed in Faroese waters, whereas three basking sharks were observed in Faroese waters and west of Lofoten. White beaked dolphins (n = 123, group size = 1-50 (average group size = 9.5)) were present in the northern part of the Norwegian Sea. Minke whales (n = 22, group size = 1-4 (average group size = 1.4)) were distributed over large areas from western coast of Norway to west of Svalbard, and from 60°N to 77°N, including overlapping and likely feeding on NSS herring in the upper 10-40 m of the water column. There is available a publication summarizing the main results on marine mammals from the IESSNS surveys from 2013 to 2018, with major focus on hot spot areas of fin whales and humpback whales from 2013 to 2018 (Løviknes et al. 2021)

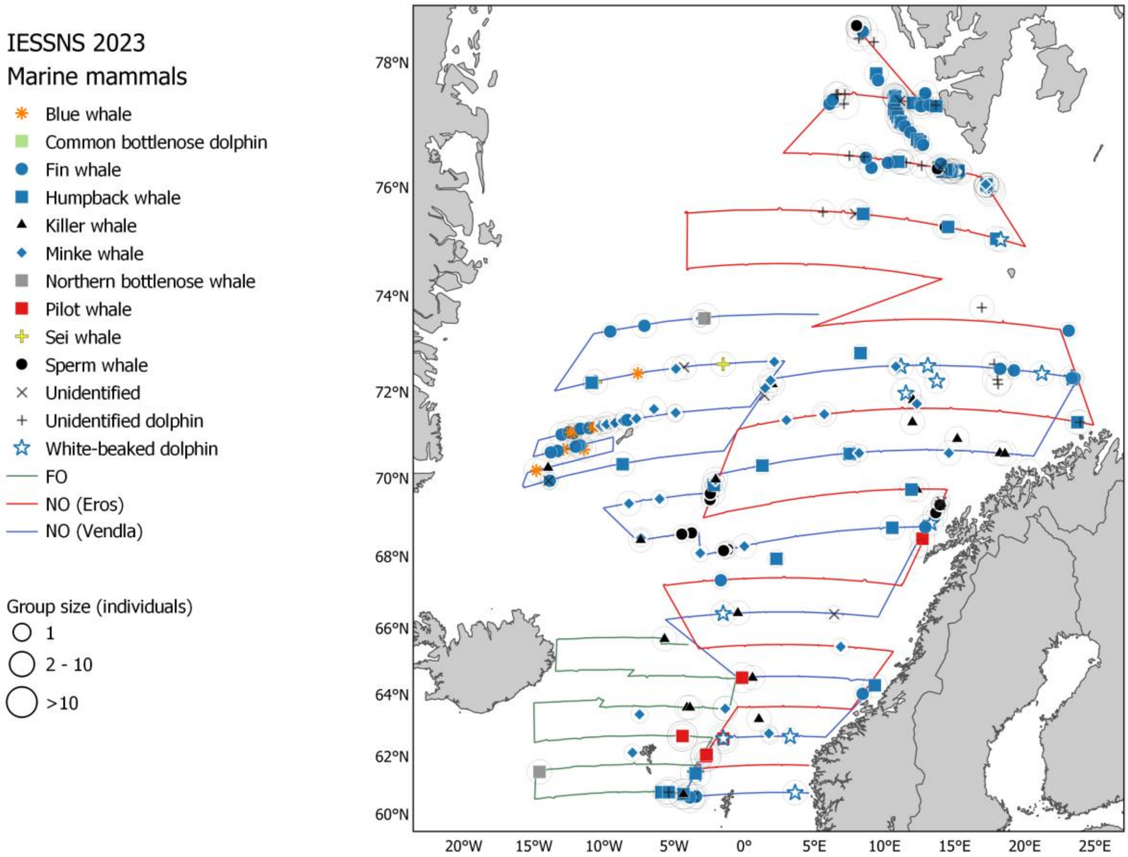


Figure 28. Overview of all marine mammals sighted during IESSNS 2023.

5 Recommendations

The group suggested the following recommendation from WGIPS	**To whom**
The surveys conducted by Denmark in 2018-2022 have clearly demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak area 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	Responsible
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 if it does not exist, but not as a zero mackerel catch station.	All
We encourage registrations of opportunistic marine mammal observations.	All
We should consider calculating the zooplankton index from annually gridded field polygons to extract area-mean time-series. WGINOR is currently working on Norwegian Sea polygons, and further work on this issue will start when their work is finalized.	All
In 2023 the IESSNS survey in the North Sea has been conducted for six consecutive years (2018-2023). It is recommended that a comprehensive report is written about the major results from the NEA mackerel time series from the IESSNS surveys in the North Sea, where an update of the internal consistency between years in the survey for selected age groups is also evaluated. This report should be made available for consideration in the next benchmark. A major aim will be to at some stage evaluate and consider the possibility to include and implement the IESSNS survey in the North Sea as an abundance index used in ICES for NEA mackerel.	DTU-Aqua (KW and co-workers)
Country representatives for the IESSNS survey should rewrite the respective sections (e.g. trawl performance, trawl station data collection) in the survey manual according to the new format by mid-September 2023.	All

7 Survey participants

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Dirk Tijssen, National Institute of Aquatic Resources, Denmark (4/7)
Kasper Schaltz, National Institute of Aquatic Resources, Denmark (5/7-13/7)
Lab team:
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10 Appendices

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. 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 June/July in this area.

Based on the experiences made in the previous years, new limits for the stratum in the North Sea were defined in 2022 (Fig. 2, stratum 13). The northern limit for the North Sea and the Skagerrak were defined as 60 °N and 59 °N, respectively. The western geographical limit in the North Sea was set to 1 ° 30′ W in the north and 2 ° 30′ W further south following the UK coastline where the Inner Moray Firth and the Firth of Forth were excluded because mackerel was not recorded there and a high abundance of 0-group gadoids, sandeel and other species makes a quantitative analysis of the catches very time consuming. The easter limit in the Skagerrak was set to 11 °E, and the southern limit in the North Sea was approximated by the 50 m isobath, which is about the shallowest depth limit for a safe setting of the Multpelt 832 trawl.

In 2023, 36 stations were taken (PT and CTD). Average mackerel catch amounted to 2362 kg/km^2, which was considerably higher than in the previous year (2022: 1689 kg/km^2) and is the second highest in the time series (2021: 2429 kg/km^{2,} 2020: 1318 kg/km^2, 2019: 1009 kg/km^2, 2018: 1743 kg/km^2) (Fig. A1-1). The length and age composition indicate a relative high amount of small (< 25 cm) individuals and the abundance of older (≥ age 3) mackerel was higher than in the previous years (Fig. A1-2).

The StoX (version 3.6.1) baseline estimates of mackerel biomass and abundance in the North Sea for 2023 were 650 371 tonnes and 3.3 billion individuals (Table A1-1) which is a 27 % higher biomass and a 40 % higher abundance than last year. The biomass and abundance estimates are based on the stratum limits as shown in Fig. 2 (stratum 13). The area of this polygon is 285 781 km^2.

Catches curves indicate that all ages including age 1 and 2 are well represented in the survey data, and the 2022-year class is the highest at age 1 in the time series (Fig. A1-3).

The internal consistency plots (Fig. A1-4), however, do not show any significant correlations. This is likely due to the low number of observations which are so far available. Furthermore, interannual variations in the migration of the cohorts in and out of the North Sea may have an effect as well.

Table A1-1. StoX (version 3.6.1) baseline estimates of age segregated and length segregated mackerel indices for the North Sea in 2023.

	Age in years / Year class													Number	Biomass	Mean
Length	1	2	3	4	5	6	7	8	9	10	11	12	13			weight
(cm)	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	(10^6)	(ton)	(g)
17-18																
18-19																
19-20																
20-21	10.7													10.7	800	75
21-22	151.2													151.2	12122	80
22-23	605.8													605.8	55116	91
23-24	572.8													572.8	56187	98
24-25	258.9													258.9	29431	114
25-26	77.8													77.8	9934	128
26-27	50.3													50.3	7418	148
27-28	33.3	4.6												38.0	6594	174
28-29	58.8	34.0												92.8	18114	195
29-30	71.8	49.7												121.5	26646	219
30-31	55.9	93.6	0.4											149.9	36760	245
31-32	18.5	195.4	18.3	0.7										232.9	61810	265
32-33		256.6	93.9	4.7	3.0									358.2	107294	299
33-34		75.9	159.1	53.6										288.5	92445	320
34-35		0.6	69.5	53.6	25.5	2.7								151.9	52262	344
35-36			7.2	13.2	19.4	18.2	13.6	1.4						73.1	26473	362
36-37			0.8	1.5	19.7	21.2	4.3	2.1						49.6	19162	386
37-38					2.5	10.8	6.7	6.2	1.3	0.1				27.6	11670	423
38-39					1.6	0.4	6.5	12.7	0.7	0.7	0.2	0.2		23.0	10843	472
39-40					0.8		0.8	3.1	3.8	0.3	0.3	0.1		9.1	4421	485
40-41							0.8	1.4		0.1	0.7	0.3	0.3	3.6	2015	560
41-42									0.1	0.1	0.6			0.8	486	573
42-43														0.0	0	
43-44									1.1					1.1	915	858
44-45																
TSN (mill)	1965.8	710.3	349.1	127.4	72.5	53.3	32.6	26.9	7.0	1.4	1.7	0.5	0.3	3,349	648919	
TSB (ton)	222558	194721	110530	42839	26509	20636	13029	12420	3690	658	911	265	153			
Mean length (cm)	23.5	31.1	32.9	33.6	35.0	35.8	36.4	37.7	39.2	38.6	40.0	39.2	40.0			
Mean weight (g)	113	274	317	336	366	387	399	462	530	476	522	494	476			

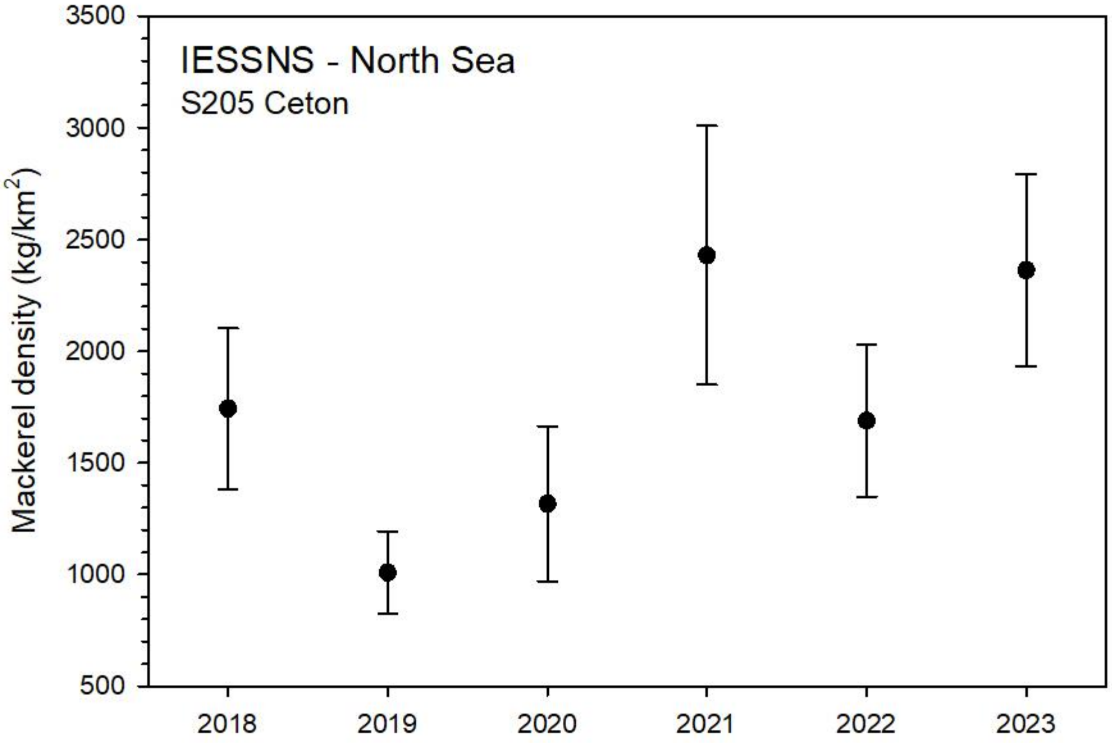


Fig. A1-1. Biomass density (mean and standard error) of mackerel in the North Sea 2018 to 2023.

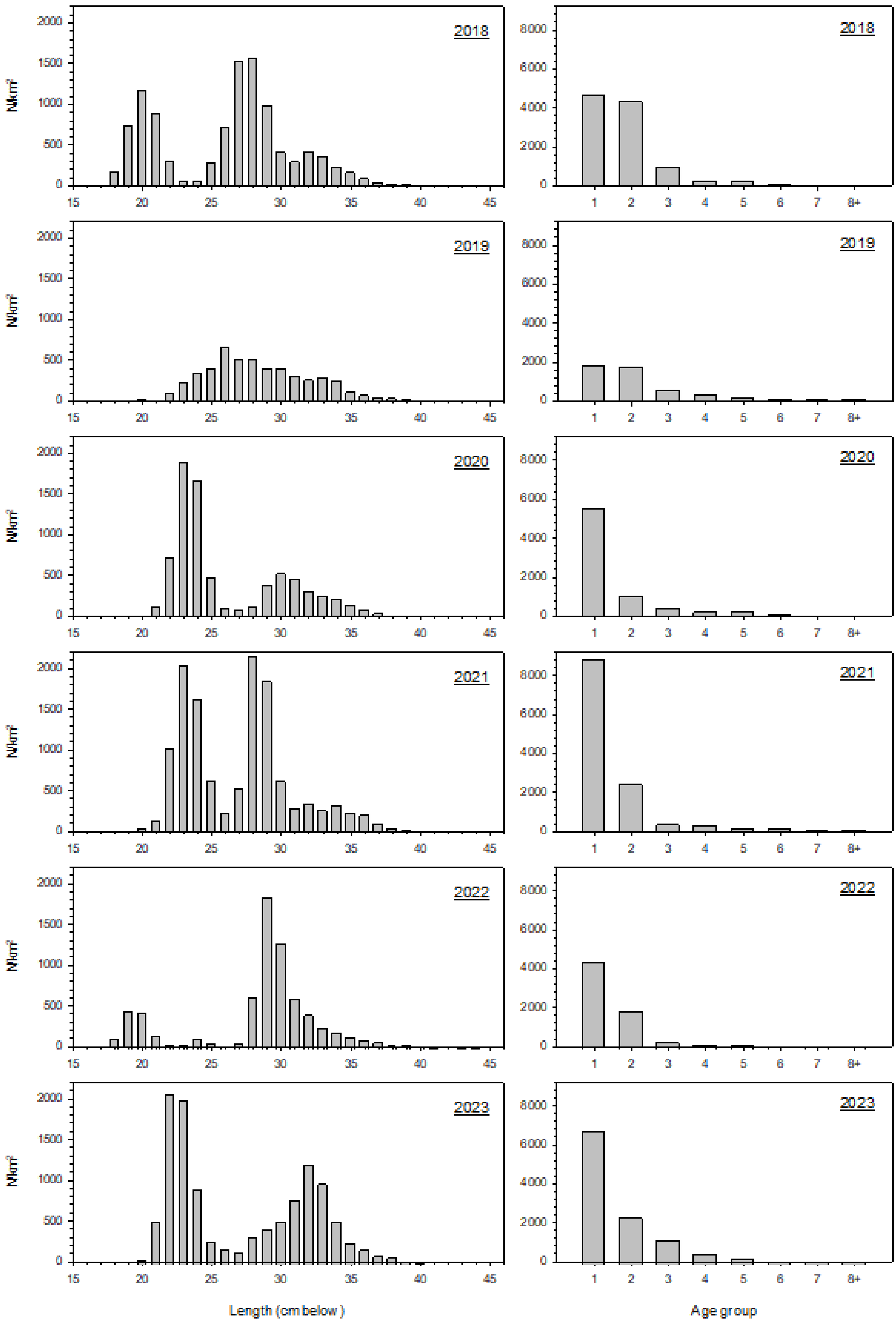
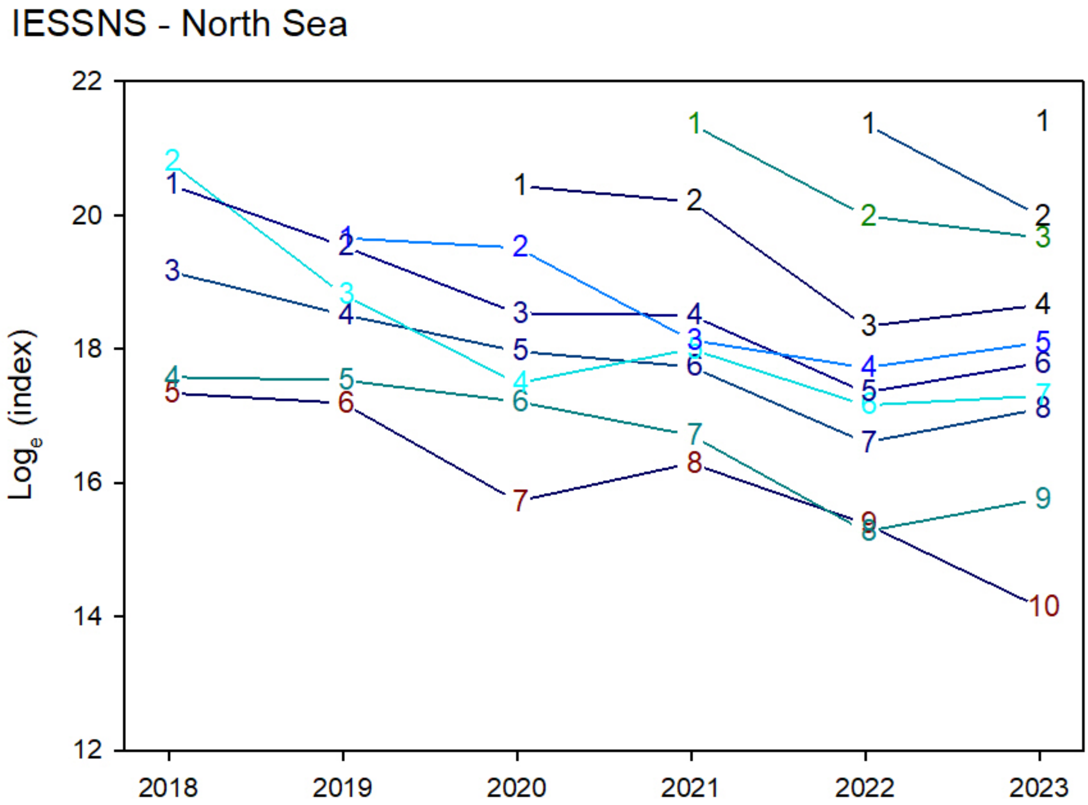
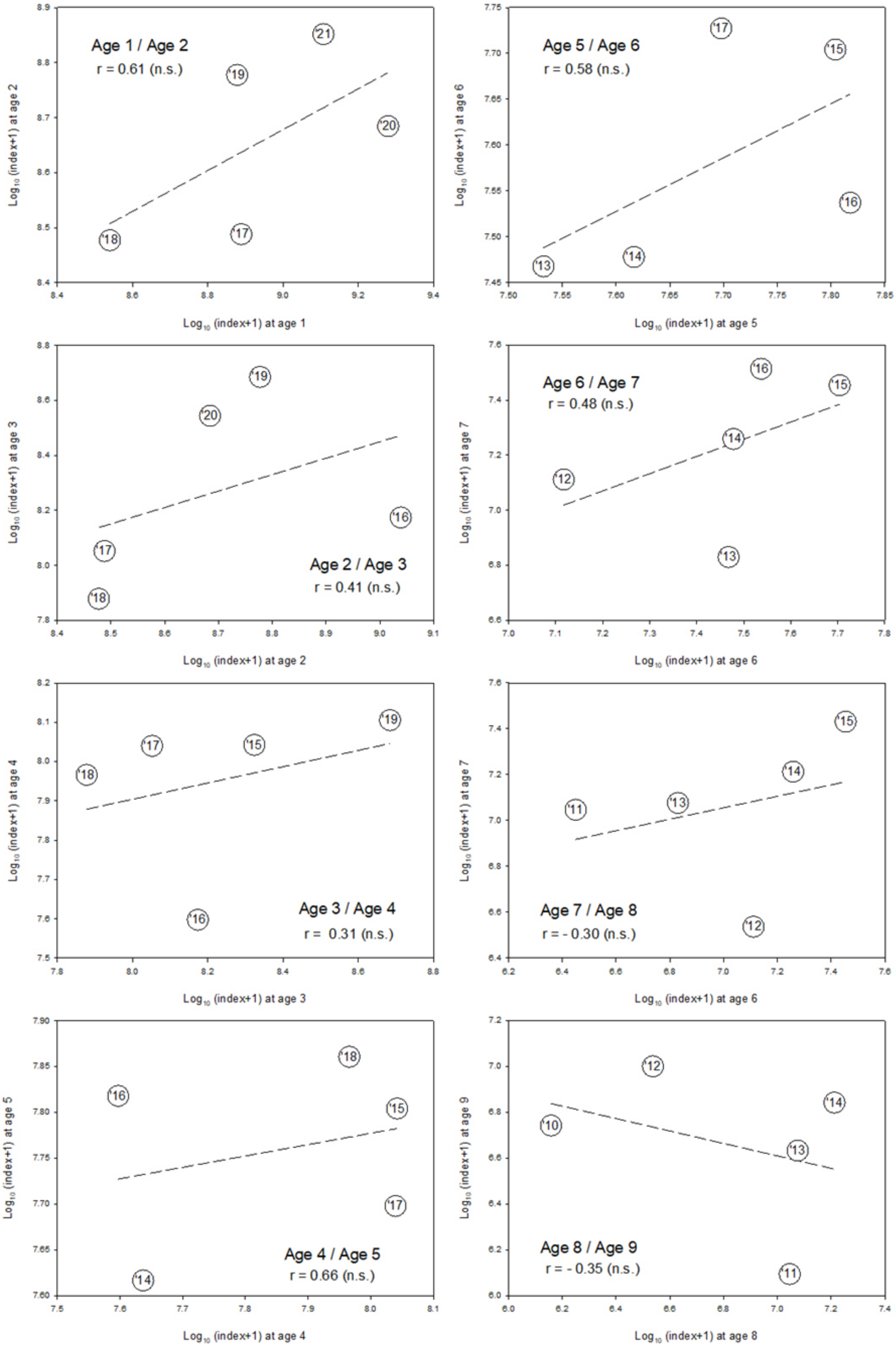


Fig. A1-2. Comparison of length and age distribution of mackerel in the North Sea 2018 to 2023.



cohorts,
numbers denote ages).


Age 1 / Age 2
r = 0.61 (n.s.)
Log10 (index+1) at age 1
Log10 (index+1) at age 2
Age 5 / Age 6
r = 0.58 (n.s.)
Log10 (index+1) at age 5
Log10 (index+1) at age 6
Age 2 / Age 3
r = 0.41 (n.s.)
Log10 (index+1) at age 2
Log10 (index+1) at age 3
Age 6 / Age 7
r = 0.48 (n.s.)
Log10 (index+1) at age 6
Log10 (index+1) at age 7
Age 3 / Age 4
r = 0.31 (n.s.)
Log10 (index+1) at age 3
Log10 (index+1) at age 4
Age 7 / Age 8
r = - 0.30 (n.s.)
Log10 (index+1) at age 6
Log10 (index+1) at age 7
Age 4 / Age 5
r = 0.66 (n.s.)
Log10 (index+1) at age 4
Log10 (index+1) at age 5
Age 8 / Age 9
r = - 0.35 (n.s.)
Log10 (index+1) at age 8
Log10 (index+1) at age 9

to 2023

Appendix 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 2023.

Vessel	Country	Horizontal trawl opening (m)	Exclusion list	
			Cruise	Stations
Vendla	Norway	65.1	2023203003	53, 59, 69, 76, 77, 80, 89, 94, 100, 105, 110
Eros	Norway	71.7	202204002	12, 19, 42, 47, 51, 57, 58, 62, 64, 65, 70, 72
R/V Árni Friðriksson	Iceland	68.4	A8-2023	280, 281, 315, 318, 321
R/V Jákup Sverri	Faroe Islands	64.1	2334	21, 28, 37, 45*
Ceton	Denmark	69.7	IESSNS2023	9,30

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceded by 2230 (e.g. '22300005')

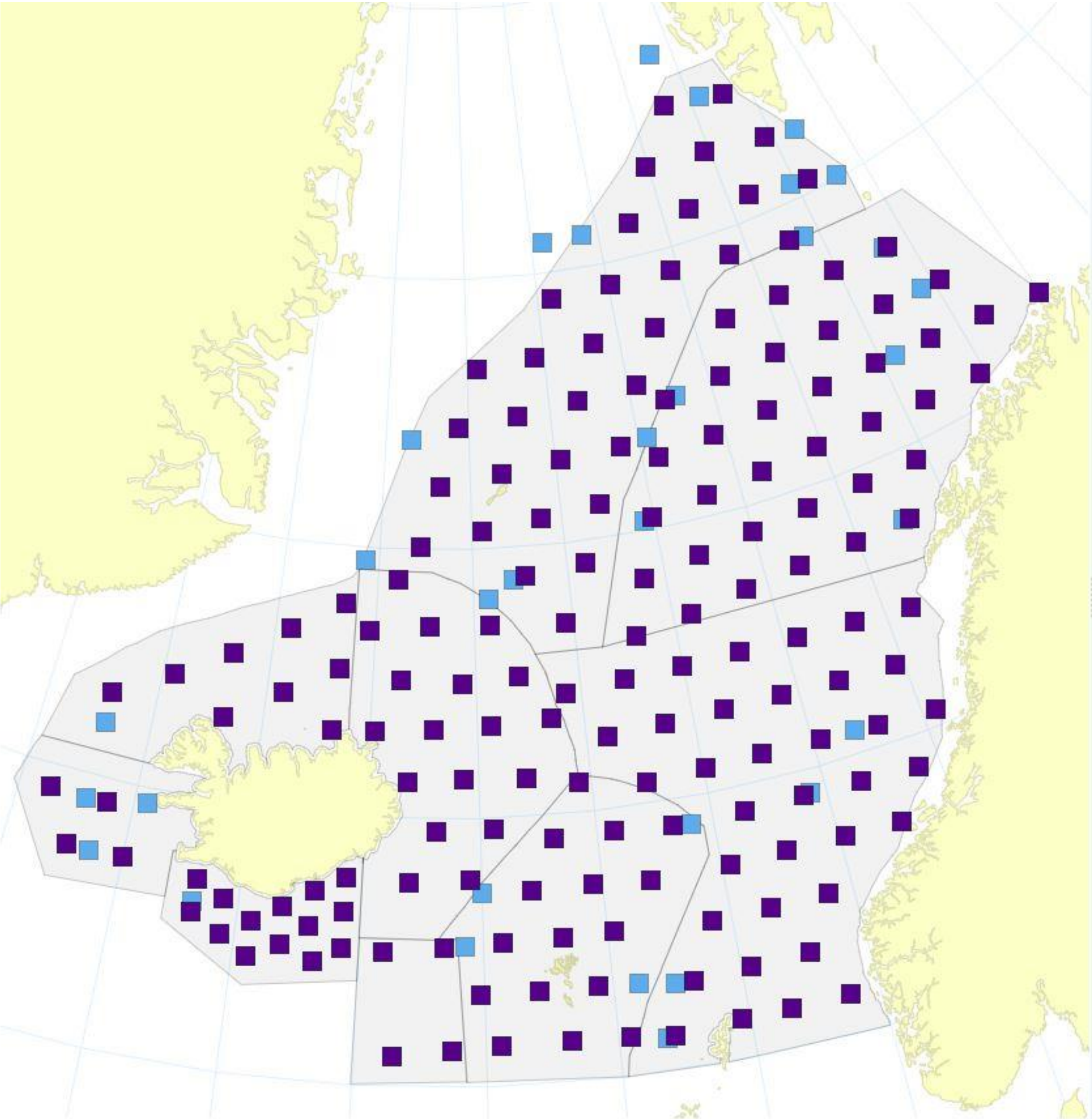


Figure A2-1. IESSNS 2023. Surface trawl stations included (filled dark blue rectangle) and excluded (filled light blue rectangle) in calculations of mackerel age segregated index used in the assessment. Strata boundary also displayed (grey solid lines).

Appendix 3

Horizontal trawl opening of the Multpelt 832 trawl is a function of trawl door spread and tow speed (Table 6 in the 2022 report). The estimates in table 6 are originally based on flume tank simulations in 2013 (Hirtshals, Denmark) where two formulas were empirically derived 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

In 2017, the towing speed range was increased to 5.2 knots, i.e. an extrapolation of the trawl opening as a function of door spread and speed was performed. In 2022 the towing speed range was further extended down to 4.3 knots and up to 5.5 knots, using a kriging gridding method, see figure A4-1. In 2023, the trawl opening was extended to 135m (Table 6).

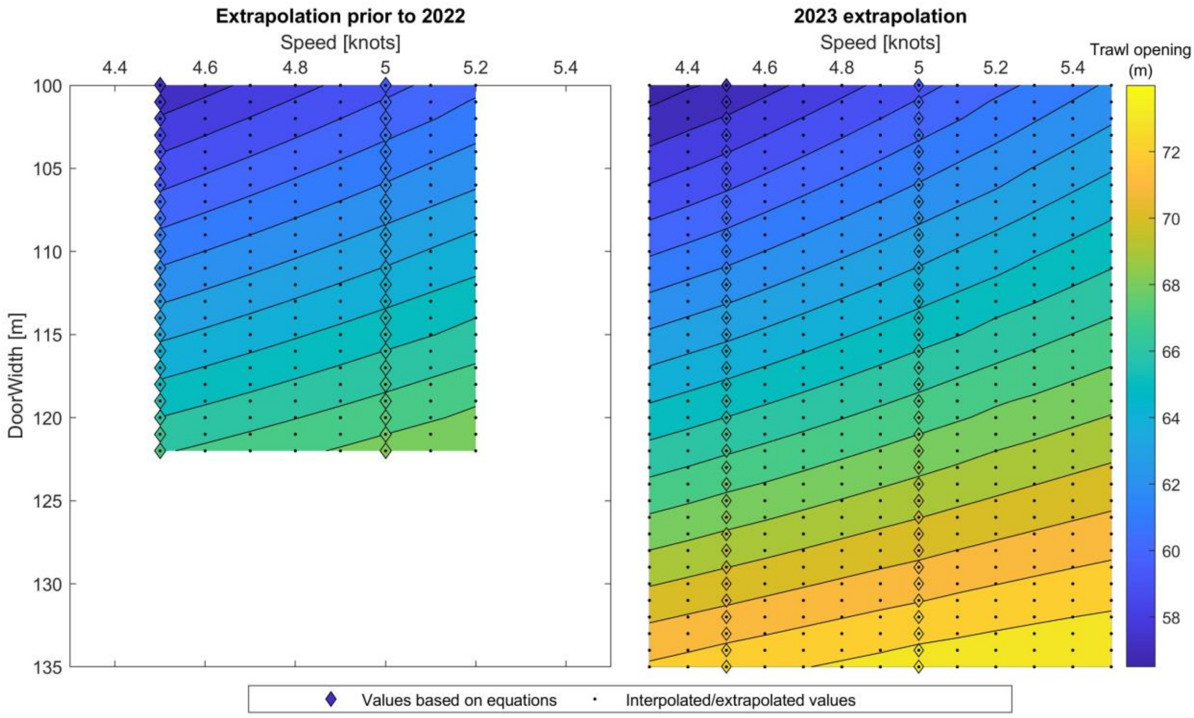


Figure A3-1. Table 6 in the report shown as a plot.